# Is it Safe?

Norwegian People's Aid

## A Framework for Assessing and Addressing the Ongoing Humanitarian and Environmental Consequences of Nuclear Testing

A Study by Norwegian People's Aid and Partners

Oslo, November 2025

**Cover photograph:**
Alijan Imanbaev at home in Semey, Kazakhstan. Alijan has epilepsy and learning difficulties linked to nuclear testing at the Semipalatinsk Test Site. His mother has become his full-time carer, spending all her time at home with him. Photograph © Phillip Hatcher-Moore.


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The project was managed by Ove Helfredsen Sparre-Enger and overseen by Grethe Lauglo Østern.

**Acknowledgments**
This report was made possible thanks to the generous funding from the Government of Norway.

Norwegian People's Aid (NPA) would like to thank Lilly Adams and Stephen Schwartz for comments on the chapter on the United States. We would like to thank Giff Johnson for comments on the chapter on the Marshall Islands; Heinui Le Caill for comments on the chapter on Mā'ohi Nui (French Polynesia); Henrik Stålhane Hiim for comments on the chapter on China; and Alimzhan Akhmetov for comments on the chapter on Kazakhstan. We would also like to thank Jenny Reeves for comments on the chapter on victim assistance; Bonnie Docherty, Kjølv Egeland, and Svein Mykkeltveit for comments on the draft report as a whole, and Dimity Hawkins, Elizabeth Minor, and Alicia Sanders-Zakre for their support to the project.





ISBN 978-82-7766-091-2

Design by Molberger

# Explanatory Note: The Definition of a ‘Nuclear Test’

In keeping with common practice in research on nuclear testing, this report uses the term ‘nuclear test’ broadly, referring not only to nuclear explosions as prohibited under the 1996 Comprehensive Nuclear-Test-Ban Treaty (CTBT) but also to certain zero-yield tests listed in the cited historical records of nuclear tests.

Although it is not yet in force, the CTBT prohibits each State Party from undertaking ‘any nuclear weapon test explosion or any other nuclear explosion’. The Treaty does not define ‘nuclear test’ or ‘nuclear explosion’, but a nuclear explosion is understood to mean any detonation of a nuclear explosive device characterized by the instantaneous release of energy from self-sustaining nuclear fission and/or fusion. The CTBT is also understood not to prohibit tests with zero nuclear yield, which could be either subcritical tests (detonations involving fissile material in insufficient quantities to sustain a nuclear chain reaction) or hydrodynamic tests (where the fissile material in the explosive device is replaced by non-fissile material).[1]

In the historical records cited in this report, nuclear-armed States have varied in their reporting practices. For completeness and transparency, some have included certain ‘zero yield’ tests in nuclear test counts, such as failed or interrupted detonations or those that involved the dispersal of nuclear material, often with significant environmental and humanitarian consequences, but where no fission was intended (e.g. plutonium dispersal tests). Others have not.

Recent (October and November 2025) statements on nuclear testing have prompted a discussion on hydronuclear experiments. Such experiments involve a brief, supercritical chain reaction and a very small nuclear yield, and are thus non-zero and prohibited by the CTBT. Allegations are made that such experiments are ongoing in defiance of the CTBT, a matter outside the scope of this report.

1 O. Dahlman, J. Mackby, S. Mykkeltveit, and H. Haak, *Detect and Deter: Can Countries Verify the Nuclear Test Ban?*, Springer, 2011, pp. 30-32.

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# Foreword

This multidisciplinary framework study represents the best available knowledge on the impacts of nuclear testing and the efforts undertaken or needed to address those impacts. The scientific community has amassed a tremendous amount of knowledge about the humanitarian and environmental consequences of nuclear-weapon testing. Much, however, has remained fragmented and many key stakeholders—as well as the general public—are unaware of the profound, deep-rooted, and persistent effects of decades of nuclear testing. Crucially, theoretical knowledge has never been systematically combined with analysis of the ongoing humanitarian and environmental remediation needs in affected areas worldwide. This framework study takes an important first step towards filling that gap by amassing and consolidating the best available evidence into a single detailed, action-oriented resource.

The study looks at the range of consequences—physical, psychological, social, economic, and environmental—engendered by nuclear testing in the most affected countries.[1] Drawing on world-leading scholars and experts from affected States, it proposes a framework for how affected communities can best be supported to ensure safety, promote development, and further justice and accountability. It also identifies how the nuclear-testing States can meet their responsibilities to the populations affected by their testing, as well as to the environment more broadly.

The study begins by summarizing the main conclusions and recommendations arising from the research. Part I of the report then synthesizes the history of nuclear tests and the state of knowledge on which areas have been impacted, outlining the litany of inaction that has left the populations most exposed to harm largely unsupported. The term 'nuclear colonialism' has entered the English language to denote how Indigenous communities were considered sacrificial pawns in the development of nuclear weapons. The lack of an adequate response to the needs for victim assistance and environmental remediation continues to this day. 'Is it safe?' is a question that still reverberates. The need for action, howsoever belated, is the rationale for this study.

To assist more actors—from affected communities to national authorities, the humanitarian and development sectors, and potential donors—in understanding the nature and parameters of the ongoing need for action, Part II of the report provides an overview of the scientific knowledge pertaining to both the immediate and long-term effects of the detonation of nuclear explosive devices. It describes the environmental consequences of nuclear detonations and the impact of climate change on nuclear risks along with the human effects of ionizing radiation. The psychological, social, economic, political, and cultural impacts of nuclear weapon testing are also considered.

1 Thus, the report does not consider needs resulting from other nuclear-weapon activities such as the mining, milling, storage, and transportation of uranium for nuclear-weapons production, or accidents arising from the development, production, transportation, storage, and deployment of nuclear weapons and/or their key components.

Part III of the report outlines the state of knowledge on intervention measures. This covers the framework of shared responsibility among all States, where affected States take the lead and other States provide international cooperation and assistance to map radioactive contamination, undertake environmental remediation, and provide victim assistance.[2] It also considers the significant challenges faced in seeking to secure legal remedies for the harm past and present that has been inflicted on so many.

Part IV of the report comprises nine case studies, which cover all the States and territories where atmospheric testing (and in some cases also underground testing) has occurred. These are: Algeria, Australia, China, Mā'ohi Nui (French Polynesia), Kazakhstan, Kiribati, the Marshall Islands, Novaya Zemlya in Russia, and the continental United States. Each case study summarizes the history of testing in the particular context and then considers the direct human effects, the transgenerational consequences, societal effects, victim assistance interventions and needs, environmental contamination and remediation efforts and challenges, and legal duties and reparation.

The end of the story of nuclear testing has not yet been written, for the prospect of new testing looms large.[3] For those dying of cancer today and in the future from radionuclides emitted from nuclear detonations that occurred decades ago, the end of their story is already foretold. They just do not know it.

On behalf of Norwegian People's Aid and the contributors to this report, I hope that this framework study will serve as a helpful resource for all those seeking to better understand the ongoing legacies of nuclear testing and to contribute meaningfully to assist the victims and remediate the environment. Whether by informing policy and further research, guiding intervention efforts, or deepening public understanding, we trust that the evidence and analysis presented here will support renewed and coordinated action – towards justice for affected communities and the protection of our shared environment. May it also serve as a reminder of the enduring human and environmental costs of nuclear weapons, and strengthen the resolve that they must never be tested or used again.

**Raymond Johansen**

Secretary General
Norwegian People's Aid

2 For the purpose of this report, and reflecting the notion of a victim under international human rights law, we have elaborated and used the following definition of a victim of nuclear testing: A person, family, or community whose fundamental human rights have been directly and adversely affected by nuclear weapon testing programmes, detonations, and/or fallout.

3 See, e.g., R. Gramer, 'North Korea's Next Nuclear Test Is A Matter of "When", Not "If"', *Foreign Policy*, 23 November 2022, at: https://bit.ly/3v1iY1V; S. Sonner, 'US moves closer to underground testing of nuclear weapons stockpile without any actual explosions', *Associated Press*, 5 October 2023, at: https://bit.ly/4cmPrRd; C. Chiappa, 'Putin officially opens door to new nuke testing', Politico, 2 November 2023, at: https://bit.ly/43eG6Xs; Y. Kobayashi, 'Signs of China's Resumption of Nuclear Tests: Strong Determination to Bolster Nuclear Force and the Crisis of Nuclear Proliferation', *SPF China Observer*, No. 42, Sasakawa Peace Foundation, 4 April 2023, at: https://bit.ly/43hJl0g.


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# Study Conclusions and Recommendations

This section of the report summarizes the key insights from the analysis in the study, including by emphasizing new as well as established findings from scientific scholarship. It makes recommendations as to how affected communities can best be supported – by the States that tested nuclear weapons, by international donors, by the national authorities of the affected States, and by the humanitarian and development sectors. It is not too late for the international community to make a difference, by repairing some of the harm that has been inflicted on civilians in the many nuclear testing grounds to serve the strategic interests of nuclear-armed States and their allies.

**The Demand for Accountability:** French President Emmanuel Macron in conversation with a victim of French nuclear testing who took part in a demonstration upon the president's arrival in Moorea island, French Polynesia (Mā'ohi Nui), on 27 July 2021. Photograph © Jacques Witt/SIPA/Shutterstock/NTB.

# Conclusions

**Between 1945 and 2017, at least eight States—and most probably nine—conducted an estimated total of 2,069 nuclear tests involving 2,425 devices worldwide: China, France, India, Israel,[4] North Korea, Pakistan, the Soviet Union, the United Kingdom, and the United States.**
One quarter of the 2,069 tests were atmospheric, meaning they were conducted on or above ground, in space, or under or over water. The remaining three quarters of tests were conducted underground. The combined explosive yield of all nuclear tests, together with the atomic bombings of Hiroshima and Nagasaki, has been estimated to amount to 530 megatons (Mt), the explosive equivalent of more than 35,000 Hiroshima bombs. Atmospheric nuclear tests, which are generally associated with the greatest environmental and humanitarian consequences, accounted for 440 Mt (more than 80 per cent) of this total yield, and underground tests for 90 Mt. Underground nuclear testing, while typically less devastating than atmospheric tests, still poses potential risks such as groundwater contamination and radioactive gas release.

**Excluding seven tests that were conducted in or over international waters, all nuclear tests were conducted in territories that today fall within the internationally recognized borders of a total of fifteen different States, which are thus considered directly impacted by nuclear testing.**
Of the fifteen States, nine are directly impacted by atmospheric nuclear testing (and in some cases also by underground nuclear testing): Algeria, Australia, China, France (not on metropolitan territory but in French Polynesia – Mā'ohi Nui), Kazakhstan, Kiribati, the Marshall Islands, Russia (in particular in Novaya Zemlya above the Arctic Circle), and the United States (including Alaska and the Johnston Atoll). The remaining six are directly impacted by underground nuclear testing only: North Korea, India, Pakistan, Turkmenistan, Ukraine, and Uzbekistan.

**Nuclear testing caused widespread and enduring harm to human health, societies, and ecosystems.**
Particularly among populations closest to the test sites, nuclear testing is estimated to have caused countless cases of illness, congenital anomalies, and premature death; psychological trauma; displacement; socio-economic, cultural, and political harm; and radioactive and chemical contamination of the environment—rendering some areas uninhabitable.

**Past nuclear tests continue to kill today: the environmental and humanitarian consequences of past nuclear testing are ongoing.**
In some instances, formerly inhabited areas remain contaminated decades after the nuclear explosions. Many affected communities and survivors also continue to live with health impacts resulting from nuclear testing, including intergenerational effects. People who witnessed nuclear tests or were potentially exposed to ionizing radiation may suffer from chronic stress, anxiety, and depression, and display

4 It is believed that Israel conducted one nuclear test in 1979, but this has never been confirmed. The test may have been conducted jointly with the apartheid regime of South Africa.

symptoms of trauma, including from worries about the potential health effects on themselves, their children, and grandchildren. Continued displacement, loss of livelihoods, and cultural disruption also continues to this day.

**Importantly, the impact from atmospheric nuclear testing is global: everyone on Earth has been exposed—and continues to be exposed—to radioactive fallout from atmospheric nuclear testing.** Atmospheric nuclear tests, which were conducted between 1945 and 1980, released significant quantities of radioactive fallout that crossed national borders (so-called transboundary fallout) and spread around the world, exposing every State and every person on Earth to some level of contamination. Nuclear test explosions are the largest ever human source of radioactive contamination and exposure. While many test workers and people living near and downwind of nuclear tests received high radiation doses, most of the global population received small doses. But although the individual risk from such low doses is small, because of the huge number of people exposed to the collective radiation dose, the aggregate health burden is actually the largest among all those who received low doses.

**Over time, total excess deaths from cancer as a result of past atmospheric testing are likely to amount to at least two million.** One quarter of these deaths have already occurred, the result of the ionizing radiation emitted by the nuclear test detonations. This is, however, a low estimate – one that, most probably, greatly understates the true long-term toll of nuclear test explosions. Moreover, given that around half of almost all cancers are fatal, a comparable additional number of non-fatal cancer cases can be expected. Added to that must be a similar number of cardiovascular deaths – all the result of radiation from past nuclear testing. Moreover, all these estimates take no account of past or future leakage of radioisotopes into the biosphere from underground nuclear test sites.

**The harm caused by nuclear testing is under-estimated, under-communicated, and under-addressed, leaving most affected communities—especially Indigenous Peoples—without adequate support.** The ongoing inaction perpetuates the historical injustice. In most cases, the necessary assessment has not yet been conducted of whether contamination remains that requires environmental remediation and of whether populations are presently in need of victim assistance or even still exposed to risk. Where such assessments have been conducted, the quality has been varying and they are often disputed. Importantly, assessments of consequences of nuclear weapons testing have also often been narrowly confined to the dramatic medical impacts, while ignoring the wider range of psychological, socio-economic, and cultural harm that affected populations are experiencing, such as the cases in which nuclear weapons testing has driven Indigenous Peoples away from ancestral lands without due compensation or the opportunity to return.

**The harm from nuclear testing has fallen disproportionately on colonized and Indigenous Peoples.** In each of the nine above-mentioned States that are directly impacted by atmospheric nuclear testing, the affected territories include unceded territories (i.e. those traditionally owned by Indigenous Peoples but taken without their consent). The term nuclear colonialism has come to describe how nuclear technologies—such as uranium mining, weapons testing, and waste disposal—have been used as tools of ongoing colonial oppression, particularly against Indigenous Peoples, who were treated as expendable.

**Most communities affected by nuclear testing struggle to access appropriate healthcare, and the limited services that do exist are grossly inadequate.** Oncological services are often expensive and rarely available in the economically marginalized zones where nuclear testing occurred. For example, individuals with cancer in the Marshall Islands must travel to Hawaii, the Philippines, or Taiwan to get treatment. Unless they have supplemental insurance or other resources, they can bring only one support person with them and there is a cost cap on their care. This removes them from family and community sources of support and means they do not receive care in the Marshallese language. Given the marginalization of many communities affected by nuclear testing, resources for psychological support are often insufficient.

**In many cases, even basic measures like risk education do not exist.**
Affected populations often do not have access to knowledge about the level of threat, how to protect themselves, which areas not to access, and which food types to avoid. Where populations are in fact no longer exposed to ongoing risk, they may nevertheless suffer unnecessary psychological stress because of a lack of certainty and ongoing suspicion.

**The nuclear testing States have almost invariably minimized or obscured the harm their testing has caused.**
Sometimes omissions or understatements have been deliberate; in other instances, underestimates of risks and damage have been only negligent or as a result of scientific ignorance. On many occasions, they have failed to collect relevant evidence and even ignored evidence of radiation-related health impacts. The suffering of affected communities is exacerbated by the lack of respect and recognition for the harm that has been caused to them.

**Where testing States have acknowledged harm, they have tended to address it through compensation schemes that function more to limit liability than to help victims in good faith.**
While direct payments of compensation have been important tools for assisting victims, they often limit eligibility through arbitrary geographic, temporal, dosage, and/or diagnosis thresholds. Claimants face significant difficulties in proving their presence in the areas and on the dates determined, as well as their medical records. One example is the French compensation scheme established by the 2010 Morin Law for its nuclear tests in Algeria and Mā'ohi Nui, which allows compensation for a list of cancers, but which has been described as an 'unscalable wall' for many victims. Because of bureaucratic, linguistic, and evidentiary hurdles only 2 of 1,026 successful claims have been Algerian.

**There has been a culture of secrecy in the nuclear testing States that persists to this day, hindering contemporary research efforts aimed at generating more detailed knowledge about the enduring impacts of nuclear testing and potential strategies for their mitigation.**
This has left affected communities struggling for recognition, medical care, and remediation. In Kiribati, for example, the United Kingdom and the United States conducted scientific studies on the medical and environmental impacts of their tests that to this day remain classified and restricted to the public, including to the victims themselves and their families. Algeria still does not know exactly where nuclear waste, including plutonium, was buried after the French nuclear tests on its territory. Some successes have, though, been achieved on this issue. In 2013, a set of declassified documents from the French Ministry of Defence were made public after a long legal battle between French and Mā'ohi victims' rights organizations and the government. The archive consists of 233 documents totalling approximately 2,000 pages, covering broadly the period of 1966–74 during which France conducted 41 atmospheric tests in Mā'ohi Nui. The documents revealed new information on radioactive fallout that struck the local populations without their knowledge.

**Despite decades of radioactive contamination and health damage, no nuclear-armed State has formally apologized for the harm caused by the tests they conducted.**
When testing States acknowledge nuclear legacies, they usually recognize them as legitimate sacrifices in the interests of national security, rather than harm caused by their wrongdoing.

**In addition to the absence of adequate environmental remediation and victim assistance from the States responsible for the nuclear tests, international responses, too, have been minimal.**

Unlike victims of landmines and explosive remnants of war, who benefit from robust international humanitarian mechanisms, nuclear survivors have been treated as an 'internal matter' of sovereign States, resulting in very little international support from other States, international organizations, and non-governmental organizations. This has left affected populations without essential support. The methods and expertise exist. Funding, access, and political will are the real constraints.

**A mandate gap exists: no international body has the mandate to assist affected States in tackling the long-term consequences of nuclear testing.**

Existing international institutions, such as the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) and the International Atomic Energy Agency (IAEA), lack the mandates, independence, or capacity needed to comprehensively strengthen the capacities of national authorities in affected States, who are often confronted with almost overwhelming challenges of assessing the ongoing needs for environmental remediation and victim assistance and for planning and implementing the requisite interventions. UNSCEAR has compiled technical research on the sources and effects of ionizing radiation, but has no capacity to assist affected States and communities. The IAEA has conducted technical assessments of radiological conditions in former test sites in some countries, but likewise is not mandated or equipped to respond to the needs.

**In the absence of international assistance, civil society and survivors' groups—from veterans' associations to grassroots Indigenous movements—have built networks of solidarity, advocacy, and self-support.**

They have created awareness of the harms of nuclear testing, exposed hidden information, pressed for recognition, and linked their struggles to broader movements for disarmament, decolonization, and human rights.

**Scientific knowledge of the harmful health effects of ionizing radiation has emerged over a long period of time.**

Despite efforts by vested interests to obscure these dangers, strong scientific evidence links radiation exposure to DNA damage and cancer, even at low doses. There is no dose of radiation that is 'safe', in the sense that it is free of health risk. Ionizing radiation also increases the risk of occurrence and death from non-cancer diseases such as cardiovascular and respiratory disease. Intergenerational impacts, including genetic damage and congenital anomalies, have also been recorded.

**Radiation risk is not uniform across a population: it is highest in very young children and declines gradually with age.**

According to data on survivors of the atomic bombings of Hiroshima and Nagasaki, infants are, overall, about four times as sensitive to radiation's cancer-inducing effects as are middle-aged adults. The greater vulnerability of children than adults to radiation damage is substantial: for boys, exposures in infancy (below one year of age) are 3.7 times more likely to lead to cancer than the same exposure for a 30-year-old man; for infant girls compared with 30-year-old women, that risk is 4.5 times greater. These differences relate to both increased sensitivity of the young and the usually longer remaining years of life during which effects can become manifest.

**Girls and women are more susceptible to harm from radiation than are boys and men.**

It is astonishing that it took sixty years of tracking cancer among the victims of the atomic bombs dropped on Hiroshima and Nagasaki before it was finally acknowledged by the US National Academy of Sciences in 2006 that ionizing radiation is more harmful to female bodies than to males. The primarily male workforce of the Manhattan Project and then in the United States during the Cold War explains the use of 'Reference Man' for the purposes of calculating radiation exposure and harm and for modelling compliance with regulation. But the adult male is the most radiation-resistant category of human being, and so using it as a sole reference point results in systematic underestimation of radiological danger and harm for children and for females of all ages. The data from Hiroshima and Nagasaki show that females – especially those exposed as children – suffer significantly higher lifetime cancer rates than males. Regulatory frameworks have been slow to adapt to this fact.

**Climate change is expected to worsen the risks from former nuclear test sites to people and ecosystems.**

When temperatures, rainfall, and sea levels are affected, the pathways and behaviour of radionuclides and other contaminants may change. Climate shift can even create large-scale shifts in community and ecosystem composition, which may further increase vulnerability to contamination. So far, only the Marshall Islands has integrated the legacy of nuclear testing into its national climate adaptation strategy.

**Despite occasional successes in domestic courts (very much the exception), a successful claim for a remedy for past nuclear harm has still to be achieved in a regional human rights court.**

Aside from the challenge of proving causation, the problems are primarily jurisdictional in nature. Most of the atmospheric tests were conducted in the 1950s and 1960s prior to the elaboration of the two United Nations human rights covenants, and did not even necessarily contravene applicable international human rights law at the time. While the moral case for State responsibility for nuclear harm cannot be contested, the four key jurisdictional bases of international human rights law—geographical, material, personal, and temporal—continue to constitute weighty obstacles to formal accountability under international law.

**Since 2010, recognition of the humanitarian and environmental consequences of the use and testing of nuclear weapons has grown at the United Nations.**

This momentum has particularly been created through the Treaty on the Prohibition of Nuclear Weapons (TPNW), which entered into force in 2021 and is the first treaty to require victim assistance and environmental remediation after use and testing of nuclear weapons. Successive United Nations (UN) General Assembly resolutions since 2022 have further encouraged States to provide international support to communities affected by nuclear testing. However, unless these declarations and this increased attention to the ongoing needs for environmental remediation and victim assistance are translated into action on the ground that makes a demonstrable positive difference in affected people's lives, they will fall short of addressing the legacy of nuclear testing.

# Recommendations

**RECOMMENDATION 1: The historic harm caused by nuclear testing must be acknowledged, confronted, and apologized for.**

Acknowledging the profound and lasting harm that nuclear testing has inflicted on human health and the environment—and confronting these past wrongs—is both a matter of justice and global solidarity. It is also essential to preventing any future testing or use of nuclear weapons. Nuclear testing States should recognize, and publicly apologize for, the enduring harm their nuclear tests have brought on affected populations and territories, including Indigenous Peoples and their lands. The phenomenon of 'nuclear colonialism' demands attention, reflection, and collective action. Initiatives such as research, truth-seeking, education, memorialization, prosecution, and other forms of reparation must be pursued to deliver the recognition and accountability that victims deserve. At the same time, this knowledge must be used to strengthen global awareness about the environmental and humanitarian consequences any new nuclear explosion, particularly in the atmosphere, would cause.

**RECOMMENDATION 2: Testing States should be far more transparent.**

Those States that have conducted nuclear tests should release testing data that is not or no longer militarily sensitive publicly, wherever this can facilitate needs assessments, environmental remediation, and victim assistance. After decades of secrets and lies, release of these data is long overdue in order to alleviate the unacceptable harm their tests have caused and which they continue to cause.

**RECOMMENDATION 3: Action must be taken now to assess needs, remediate environments, and assist victims.**

Political will and decisive steps are now urgently required in a situation which, for far too long, has not received the necessary attention, to save lives, alleviate suffering, and protect human dignity and ecosystems. For affected communities, it is crucial that ongoing support needs are identified. It is equally important to provide clear assurance to both communities and governments when thorough and transparent assessment can establish that no continued impact exists. Further efforts are therefore needed to conduct a comprehensive, field-based global assessment of the ongoing needs for environmental remediation and victim assistance resulting from nuclear testing. Yet such an overview is not a prerequisite for action. It is already evident which territories and peoples bear the heaviest burdens. Accordingly, it is also clear where the international community must urgently focus its support – and where nuclear-testing States have responsibilities that must be acknowledged and fulfilled. While the scale of the impact from nuclear testing may appear overwhelming, effective prioritization is both essential and possible.

**RECOMMENDATION 4: International support must urgently be provided to four States and one other territory directly impacted by atmospheric nuclear testing.**

Addressing the consequences of past nuclear testing requires shared responsibility. The affected States themselves should take the lead, with support from other States. This report calls for urgent international financial, material, and technical support to the following four post-colonial States and one Non-Self-Governing Territory, to enhance their capacity to assess ongoing needs and to plan and implement adequate environmental remediation and victim assistance:

- Algeria (French atmospheric and underground nuclear tests)
- Kazakhstan (Soviet atmospheric and underground nuclear tests)
- Kiribati (United Kingdom and United States atmospheric nuclear tests)
- Marshall Islands (United States atmospheric nuclear tests)
- Mā'ohi Nui (French Polynesia) (French atmospheric and underground nuclear tests)

International support to these five should be a priority because they remain among the most impacted by atmospheric nuclear testing and least resourced in addressing the long-term consequences. The continued suffering resulting from nuclear tests is well-documented, and the affected populations, including Indigenous Peoples, have limited access to appropriate healthcare and human rights protections. The four responsible testing States—France, Russia, the United Kingdom, and the United States—bear a primary and unequivocal responsibility to finally and meaningfully provide the required international support to other countries harmed by their nuclear tests. This harm, however, has also been ignored for far too long by the military allies of nuclear-armed States—and indeed by the international community as a whole—and all States in a position to do so should contribute to this endeavour. Considering that only four directly impacted States and one territory require international support and cooperation, the necessary collective action is entirely achievable.

**RECOMMENDATION 5: Four nuclear-armed States and one settler State directly impacted by atmospheric nuclear testing must scale up their domestic efforts to tackle the humanitarian and environmental consequences.**

China, France (in its overseas collectivity of Mā'ohi Nui), Russia, and the United States should substantially scale up their domestic efforts to assess and address ongoing victim assistance and environmental remediation needs arising from the atmospheric and underground nuclear tests they conducted on territories within their current internationally recognized borders, including on unceded territories of Indigenous Peoples. Likewise, Australia, as a settler State, should reinforce its national initiatives to assess and meet ongoing needs after the harm caused by the atmospheric nuclear tests conducted there by the United Kingdom on unceded territories of Indigenous Peoples. The United Kingdom, in turn, must support these efforts.

**RECOMMENDATION 6: Six States directly impacted by only underground nuclear testing must implement or update radiation risk assessments.**

India, North Korea, and Pakistan should conduct radiation risk assessments involving competent international bodies, ensuring a transparent evaluation of whether environmental remediation and victim assistance are presently needed following the underground nuclear tests they conducted within their internationally recognized borders. Similarly, with the support of competent international bodies, Turkmenistan, Ukraine, and Uzbekistan—where the Soviet Union detonated a small number of underground nuclear explosive devices—should provide updated assessments of the conditions at the relevant sites.

**RECOMMENDATION 7: Further research on the extent and impact of transboundary fallout from past atmospheric nuclear tests is needed.**

Coordinated international efforts should be launched to further assess the extent of fallout from atmospheric nuclear testing that crossed national borders and its impacts on indirectly affected States. To do so, new atmospheric modelling methodology can be employed to reconstruct the fallout from individual nuclear tests, enabling scientists to determine which neighbouring countries were reached and which radiation levels they suffered. Such research will depend on active cooperation and data transparency from the five States that had atmospheric testing programmes – China, France, Russia, the United Kingdom, and the United States. In particular, better data are needed regarding the spread of fallout from Soviet nuclear tests.

**RECOMMENDATION 8: Intergovernmental organizations should be empowered and mandated to respond to humanitarian and environmental needs resulting from nuclear detonations.**
The mandate gap that has left affected States largely struggling alone to tackle the harmful legacies of nuclear testing must be filled. Existing intergovernmental organizations need to be given the mandate to support and capacity-build national authorities in affected States to conduct national needs assessments, environmental remediation, and victim assistance. Alternatively, a new, dedicated international body needs to be established and resourced adequately for that purpose.

**RECOMMENDATION 9: A new humanitarian and development stream should be created.**
A dedicated stream of donor-supported humanitarian and development assistance should be established to address in a systematic and comprehensive way ongoing harm from nuclear testing and related activities. This should be similar to, for instance, the sector that supports the national authorities of States affected by landmines and explosive remnants of war in assisting impacted communities. The broader humanitarian and development sectors should also seek to enhance their knowledge about the impacts, vulnerabilities, and needs generated by nuclear tests and incorporate this knowledge in their programming in the relevant affected areas, to prevent continued neglect. International and non-governmental organizations have a responsibility to advocate for support to affected populations and in supporting national implementation measures.

**RECOMMENDATION 10: The assistance needed by the survivors of nuclear testing should be understood in broad terms.**
Those working to build norms on victim assistance to the survivors of nuclear testing should consider ways to make it more open and accessible to those who need it the most, on a presumptive and precautionary basis – rather than on a liability-limiting basis or by relying on finding specific, self-identifying victims. Needs assessment should thus not only list people identified as victims but also map the risks to people who do not know they may be victims. To ensure their right to health, access to general, high-quality health services and cancer care should be significantly improved for communities located in the vicinity of nuclear test sites and/or in areas of concentrated fallout. This should include psychosocial support and screening for cancer, heart disease, and other conditions associated with exposure to radiation. Screening should be conducted alongside clear, detailed, and culturally-specific risk education tailored to the particular context to help people understand the risks. The combination of risk education and screening encourages early intervention to address health problems and can also help manage psychological anxieties associated with radiation exposure.

**RECOMMENDATION 11: Environmental remediation measures must be implemented to reduce radiation exposure.**
Environmental remediation after nuclear testing may seem like a daunting task and returning a test site to its pre-detonation state is rarely, if ever, feasible. Nevertheless, undertaking remediation can have important environmental and humanitarian benefits, serving to disrupt the pathways through which people are exposed to radiation and addressing the contamination itself. A range of steps can and should be taken, even if the contamination from nuclear testing dates back decades. Importantly, simple environmental remediation measures like risk education programmes and marking and fencing of contaminated sites are also important tools to reduce exposure to radiation.

**RECOMMENDATION 12: Programme design and implementation should be principled and community-based.**
All efforts to address the impacts of nuclear testing must adhere to humanitarian principles and human rights standards. They must, in particular, uphold at least four guiding principles:

1. Every stage of the process must be inclusive, meaning, inter alia, that affected communities must be actively involved in needs assessments and in the design, implementation, and monitoring and evaluation of environmental remediation and victim assistance interventions.
2. The principle of non-discrimination should be upheld in the design and implementation of all intervention measures, meaning that they should not discriminate among victims or against victims based on their sex, age, race, ability, or other status.
3. All environmental remediation and victim assistance activities must be transparent, making information about the process available to all stakeholders to encourage the exchange of lessons learned, facilitate monitoring, and promote accountability.
4. All programmes must be accessible, so that affected communities can receive the benefits to which they are entitled.

**RECOMMENDATION 13: The meaningful participation of Indigenous and other affected peoples in policy-making on nuclear test legacies must be ensured.**
In particular, specific and official mechanisms should be established at local, national, and international levels to facilitate meaningful participation of marginalized communities, Indigenous, and Non-Self-Governing Peoples in policy-making on how to address the ongoing consequences of nuclear testing, recognizing their rights to self-determination and many contributions to restoration of good relations with contaminated lands and waters.

**RECOMMENDATION 14: Access to national compensation mechanisms should be created or expanded.**
In light of available information that clearly shows that thousands of claimants have been disadvantaged, nuclear-testing States should expand the eligibility criteria for their national compensation mechanisms to cover all the victims of their nuclear tests (or else, they should establish such mechanisms if they do not yet exist).

**RECOMMENDATION 15: Climate change must be taken into account when assessing and addressing risks resulting from nuclear testing.**
Urgent updates are needed to international guidance on the assessment of environmental radiological contamination to incorporate the effects of climate change. Risk assessments must consider the different exposure scenarios (underground as well as atmospheric tests) as well as the risk of the release or transportation of radionuclides and other contaminants due to physical landform changes or changes in climatic conditions. Risk assessments should consider actual or expected climate change, its effect on contamination sources, exposure pathways, and receptors, and the durability and resilience of remediation or management options. The legacy of nuclear testing should also be incorporated into affected States' national climate adaptation strategies.

**RECOMMENDATION 16: All States should refrain from ever detonating a nuclear explosive device and should adhere to the Comprehensive Nuclear-Test-Ban Treaty and other instruments that make such testing or use unlawful.**
The potential consequences of further nuclear detonations are so severe—as this report evidences—that treaty prohibitions on atmospheric and underground testing need urgently to be reflected in customary norms. A customary prohibition on testing would be a global good, complementing the existing duty of nuclear disarmament identified by the International Court of Justice in its 1986 Advisory Opinion.


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# Part I

# Nuclear Testing History and Geography

**The Last Test?** At the time of writing, the world's last nuclear test was conducted in North Korea on 3 September 2017, but it is not certain that it will be the final one. In the photo from the day of the test, a man at the main railway station in Seoul watches a TV news programme after South Korean officials said they had detected an artificial 5.6 magnitude quake in North Korea. The signs read: 'The presidential Blue House analysing whether North Korea has conducted its sixth nuclear test'. Photograph © Ahn Young-joon, AP Photo/NTB.

Chapter 1:

# Eight Decades and Counting of Nuclear Testing

Stuart Casey-Maslen

This chapter explores the history of nuclear weapons testing, emphasizing that much remains unknown about the full scope and impact of these detonations. While it is clear that nuclear tests have caused and continued to cause widespread illness, death, displacement, and environmental devastation—especially for communities living near test sites—nuclear-armed States have often understated or obscured the extent of harm.

There is much that we still do not know about nuclear testing. We do not know precisely how many nuclear explosive devices have been detonated. We do not know exactly how many States have conducted nuclear tests. But most importantly, as this study confirms, we still have much to learn about how individuals positioned or living closest to test sites or other hot spots have been—and continue to be—affected by the radionuclides emitted by the detonation of nuclear explosive devices.

What we do know is that nuclear tests have caused widespread illness and premature death. In certain instances, they have displaced entire populations and prevented their return to their homes, inflicting enduring psychological trauma and socio-economic, cultural, political, and environmental harm. We also know that everyone on the planet is still living with the risks that result from past atmospheric testing. Hundreds of thousands of people around the globe are believed to have died from cancers and other illnesses as a result of past nuclear testing and more will die in the future – even if we will not know their identities.

While underlining the fact that underground testing is not risk-free, we know that above ground—atmospheric—testing is generally the more dangerous to health. Hard evidence has demonstrated that also many so-called 'safety tests' and other experiments involving fissile material in nuclear weapons development programmes, released radioactive and chemical contamination that caused significant humanitarian and environmental harm. Where information is available, these activities are covered in this report's country case studies, offering a more comprehensive account of the footprint of nuclear testing. Finally, we have learned that the nuclear powers have almost invariably understated the harm their nuclear testing has caused. Sometimes omissions or understatements have been deliberate; in other instances, underestimates of risks and damage have been only negligent, or as a result of scientific ignorance.

The first nuclear test detonation occurred more than 80 years ago, on 16 July 1945, in the New Mexico desert in the United States (US). At the time of writing, the most recent test detonation was conducted in the Democratic People's Republic of Korea (North Korea) on 3 September 2017 as the photograph above recalls. The explosive yield from the Trinity test in 1945, the first ever nuclear detonation, which was conducted by the United States, was estimated to equate to 21 kilotons (kt) of TNT.[1] The explosive yield of the North Korean test in 2017, its sixth, is estimated to have been somewhere between 50 and 100 kt.[2]

In between these two nuclear events, more than 2,400 other nuclear explosive devices were detonated worldwide, along with the nuclear bombings of Hiroshima and Nagasaki in August 1945. The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) has estimated the combined explosive yield of all nuclear explosions as amounting to 530 megatons (Mt), the explosive equivalent of more than 35,000 Hiroshima bombs. Atmospheric nuclear tests accounted for 440 Mt (more than 80 per cent) of the total yield.[3]

The largest ever nuclear detonation was an act of the Soviet Union. The so-called 'Tsar Bomba' test in 1961 was of a 50 Mt bomb that was detonated over Severny Island in Novaya Zemlya, above the Arctic Circle.[4] The explosive energy it generated—more than 1,500 times that of the Hiroshima and Nagasaki bombs combined—

1 Nuclear Threat Initiative (NTI), '"Downwind" of Trinity: Remembering the First Victims of the Atomic Bomb', Atomic Pulse, 15 July 2021, at: https://bit.ly/48InXSJ.

2 'Under-Secretary-General Jeffrey Feltman's Remarks to the Security Council on the Nuclear Test Announced by the Democratic People's Republic of Korea', United Nations, New York, 4 September 2017, at: https://bit.ly/3Tu5WTS.

3 UNSCEAR, 'Sources and Effects of Ionizing Radiation', Report, Vienna, 2000, Annex C: Exposures to the public from man-made sources of radiation, pp. 160 and 177 and Table 22 (p. 233).

4 The bomb had become known by a myriad of neutral technical designations – Project 27000, Product Code 202, RDS-220, and Kuzinka Mat (Kuzka's Mother). S. Dowling, 'The monster atomic bomb that was too big to use', *BBC*, 16 August 2017, at: https://bit.ly/48Huq0t.

caused a seismic wave to travel around the globe three times. Windows shattered as far away as Finland and Norway due to atmospheric focusing of the shock wave.[5] The Soviet Union was also responsible for the next four greatest test detonations by yield size (all four of which occurred in 1962), equating to 24 Mt in one test to around 20 Mt for each of the other three.[6]

The sixth largest nuclear detonation in history (the biggest in yield at the time) was a US test in 1954 in the Marshall Islands – Castle Bravo. The 15 Mt explosion caused far higher levels of fallout and damage than scientists had predicted. The effects it caused were, depending on what one believes, either an accident due to unexpected weather conditions and other factors or a deliberate act of environmental destruction. Whatever the reason, the explosion released large quantities of radioactive debris into the atmosphere that fell over an area extending across 10,000 square kilometres, contaminating the inhabitants of nearby atolls, US service members, and the crew of a Japanese fishing trawler. This was the worst radiological disaster in US history.[7]

The precise number of nuclear test detonations is unknown; however, Figure 1 and Table 1 overleaf offer the best available, updated, global estimate of nuclear tests. This estimate has been elaborated by the research team for this report, identifying a total of 2,069 tests involving 2,425 devices. Of the total number of tests, 541 were atmospheric[8] while the remaining 1,528 were conducted underground. The table includes so-called peaceful nuclear explosions and known safety tests. While the most commonly cited figure is 2,056 nuclear tests—based on official State data—Table 1 includes 13 additional tests: one Israeli atmospheric test and twelve UK safety tests in Australia.

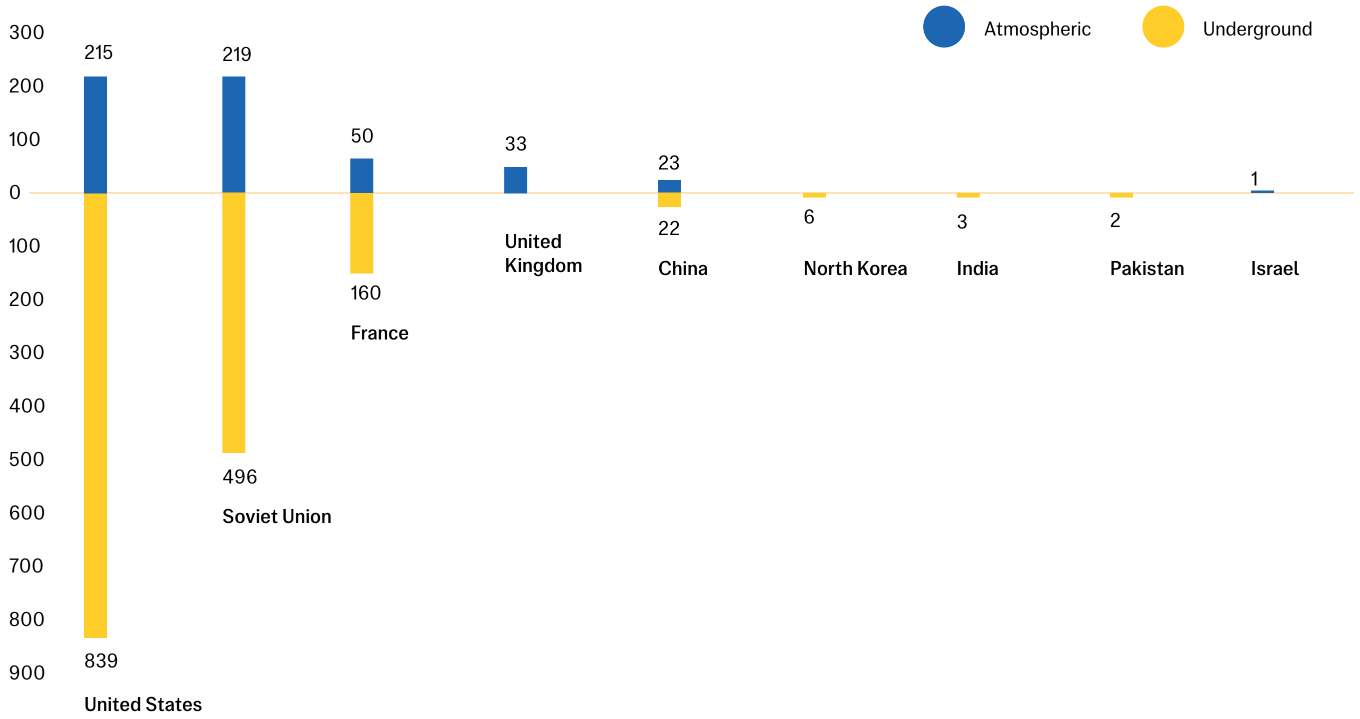
Attaining clarity on the total number of tests and their architects is hampered by a series of factors. First and foremost, of course, is secrecy by the testing powers. To this day, many facts remain classified top secret even when the occurrence of the test is undeniable. It is not subject to question that China, France, India, North Korea, Pakistan, the Soviet Union, the United Kingdom, and the United States have all test-detonated nuclear weapons. In addition, the 'Vela Incident' on 22 September 1979 is strongly believed to be an instance of a US satellite recording a nuclear test detonation (a likelihood rated at more than 90 per cent by the US Central Intelligence Agency but disputed by other sources).[9] The device, seemingly belonging to Israel,[10] was exploded in the sub-Antarctic Indian Ocean, near the Prince Edward Islands, which are administered by South Africa. The detonation may have been a joint Israeli-South African test.[11]

There are also differences in recording tests. A single test may in fact involve the detonation of multiple nuclear explosive devices.[12] Detonations may be recorded as 'peaceful nuclear explosions' rather than nuclear-weapon

5 Atomic Heritage Foundation, 'Tsar Bomba', 8 August 2014, at: https://bit.ly/3It1bni.
6 M. Belan, 'The Top 10 Largest Nuclear Explosions, Visualized', Visual Capitalist, 13 May 2022, at: https://bit.ly/43hJTDd.
7 Atomic Heritage Foundation, 'Castle Bravo', 1 March 2017, at: https://bit.ly/3wN95W6.
8 Unless otherwise specified, this report follows the approach taken by the Stockholm International Peace Research Institute (SIPRI) in defining all tests banned by the 1963 Partial Test Ban Treaty as 'atmospheric nuclear tests', whether they are conducted on or above ground, on or under water, or in outer space.
9 Cited in a memorandum by Jerry Oplinger, National Security Council/Science and Technology Staff, to Ambassador Henry Owen, 'South Atlantic Event', 25 January 1980, Excised copy, available at: https://bit.ly/3wMS0vl.
10 W. Burr, A. Cohen, L.-E. De Geer, V. Gilinsky, S. Polakow-Suransky, H. Sokolski, L. Weiss, and C. Wright, 'Blast From the Past', *Foreign Policy,* 22 September 2019, at: https://bit.ly/43cm4wC.
11 See, e.g., A. Cohen and W. Burr, 'Revisiting the 1979 VELA Mystery: A Report on a Critical Oral History Conference', 31 August 2020, at: https://bit.ly/3IzOV4g; C. Sublette, 'Report on the 1979 Vela Incident', Last revised 1 September 2001, Nuclear Weapon Archive, at: https://bit.ly/3IVhqgi.
12 A test was defined in the context of the Threshold Test Ban Treaty as either a single underground nuclear explosion (detonation) conducted at a test site, or two or more underground nuclear explosions (detonations) conducted within an area delineated by a circle having a diameter of two kilometres and conducted within a total period of time not to exceed 0.1 seconds. Protocol to the Treaty Between The United States of America and The Union of Soviet Socialist Republics on the Limitation of Underground Nuclear Weapon Tests; adopted at Washington, DC, 1 June 1990; entered into force, 11 December 1990, S. 1, Definition 2.

tests.[13] In addition, there is a lack of consensus on the definition of so-called 'safety tests',[14] and practice varies on their inclusion in official nuclear test records. While the United States, the Soviet Union, and (to some extent) France, have—regardless of whether they produced a nuclear yield or not—included safety tests in their official nuclear test counts, the United Kingdom has not. As discussed below and in the Australia case study, this report adds twelve UK safety tests that have often been omitted from global nuclear test counts. Their inclusion in this report's total follows established practice in several concerned States as described above and also the precedent set by UNSCEAR's authoritative 2000 report.

**Figure 1:** **Atmospheric and underground nuclear tests by State**




In terms of data on US testing, the US Department of Energy reports 1,054 US nuclear tests in total, of which 945 were on the continental United States.[15] The total yield equates to at least 200 Mt. The United States also detonated nuclear explosive devices over the Marshall Islands and Kiribati as well as over the southern Atlantic Ocean and the Pacific Ocean. The United States ceased nuclear testing in 1992 but in 2018 formally reduced its nuclear testing readiness—the time it would need to prepare for an explosive nuclear test—from between 24 and 36 months to between 6 and 10 months.[16] A persistent minority of commentators have opposed the US nuclear testing moratorium since it was endorsed by Congress in 1992.[17] In late October 2025, US President Donald Trump instructed the Pentagon to immediately start matching other nuclear powers in their testing of nuclear weapons. It was unclear what kind of testing this referred to.[18]

13 Nuclear tests are deemed in this study and the cited historical records to encompass all peaceful nuclear explosions as well as tests that are reported as such. So-called peaceful nuclear explosions were carried out by a State for non-military purposes, such as civil engineering, resource extraction, or scientific research.
14 Safety tests were typically conducted to evaluate whether a nuclear explosion would occur in accident scenarios, but sometimes also to study the distribution of radioactive particles from an inadvertent non-nuclear detonation of a nuclear weapon in various environments. Some safety tests produced a nuclear yield, while others did not. Regardless, the result was the dispersal of significant amounts of radioactive materials.
15 DoE, 'United States Nuclear Tests, July 1945 Through September 1992'.
16 D. G. Kimball, 'The Looming Threat of Renewed U.S. Nuclear Testing', Arms Control Today, July 2024, at: https://bit.ly/4eRjgtV.
17 J. Knox, 'We Need to Prevent a New Era of Nuclear Weapons Testing', Blog post, The Equation blog, Union of Concerned Scientists, 20 November 2024, at: https://bit.ly/4fKVQqv.
18 See, e.g., A. Clayton, P. Sauer, and H. Davidson, 'Trump directs Pentagon to match Russia and China in nuclear weapons testing', The Guardian, 30 October 2025, at: http://bit.ly/3LdbLn8.

## Table 1: Best Estimate of Nuclear Tests Worldwide, 1945 to 2017[19]

| Testing State | Number of tests | | | Number of detonations[20] | | |
|---|---|---|---|---|---|---|
| | Atmospheric | Underground | Totals | Atmospheric | Underground | Totals |
| United States[21] | 215 (incl. 18 safety tests) | 839 (incl. 70 safety tests) | 1,054 (incl. 88 safety tests) | 215 | 934 | 1,149 |
| Soviet Union[22] | 219 (incl. 11 safety tests) | 496 (incl. 14 safety tests) | 715 (incl. 25 safety tests) | 219 | 750 | 969 |
| France[23] | 50 (incl. 5 safety tests) | 160 (incl. 10 safety tests) | 210 (incl. 15 safety tests) | 50 | 160 | 210 |
| United Kingdom[24, 25] | 33 (incl. 12 safety tests) | 0 | 33 (incl. 12 safety tests) | 33 | 0 | 33 |
| China[26] | 23 | 22 | 45 | 23 | 22 | 45 |
| India[27] | 0 | 3 | 3 | 0 | 6 | 6 |
| Pakistan[28] | 0 | 2 | 2 | 0 | 6 | 6 |
| North Korea[29] | 0 | 6 | 6 | 0 | 6 | 6 |
| Israel[30] | 1 | | 1 | 1 | | 1 |
| **Totals** | **541** | **1,528** | **2,069** | **541** | **1,884** | **2,425** |

19 In addition to the specific sources cited for each testing State, the information in the table draws from the following sources: V. Fedchenko, XI. Nuclear explosions, 1945–2017, in SIPRI Yearbook 2018; UNSCEAR, 'Exposures to the public from man-made sources of radiation', in 'Sources and Effects of Ionizing Radiation', Report, United Nations, New York, 2000; Arms Control Association, 'Nuclear Testing Tally', Fact sheet, January 2024; F. Warner and R. J. C. Kirchmann (eds.), *SCOPE 59. Nuclear Test Explosions: Environmental and Human Impacts*, Scientific Committee on Problems of the Environment (SCOPE) of the International Council for Science, John Wiley & Sons, New York, 1999.

20 Multiple devices may be detonated in a single test, which explains the difference between the number of tests and the number of detonations.

21 See below the case studies on Kiribati, the Marshall Islands, and the United States; and United States Department of Energy (DoE), 'United States Nuclear Tests, July 1945 Through September 1992', Report, US doc. DOE/NV--209-REV 16, Nevada Operations Office, December 2015.

22 See below the case studies on Kazakhstan and Novaya Zemlya; R. S. Norris and T. B. Cochran, 'Nuclear Weapons Tests and Peaceful Nuclear Explosions by the Soviet Union, August 29, 1949 to October 24, 1990', Draft, Natural Resource Defense Council, Washington, DC, 1996; and P. Podvig (ed.), *Russian Strategic Nuclear Forces*, MIT Press, Boston, MA, 2001.

23 Most official records cite a total of 210 French nuclear tests, including five safety tests. However, the actual number of safety tests included in this number is fifteen; five atmospheric and ten underground, all conducted in Mā'ohi Nui (French Polynesia). As discussed in the relevant case study in this report, certain so-called 'complementary experiments' conducted by France in Algeria meet the characteristics of safety tests but are not included as such in official records. See this report's case studies on Mā'ohi Nui and Algeria. Regarding Mā'ohi Nui, see also French Commissariat à l'Énergie Atomique et aux énergies Alternatives (CEA), 'Les essais nucléaires en Polynésie française: Pourquoi, Comment, et Avec Quelles Conséquences?', Report, September 2022, at: https://bit.ly/3xf2Pqo, pp. 50–59; International Atomic Energy Agency (IAEA), 'The Radiological Situation at the Atolls of Mururoa and Fangataufa', Main Report, Vienna, 1998, at: https://bit.ly/3uvGdRo, pp. 26–30. Regarding Algeria, see IAEA, 'Radiological Conditions at the Former French Nuclear Test Sites in Algeria: Preliminary Assessment and Recommendations', Radiological Assessment Report Series, 2005, at: https://bit.ly/3UPyhVR.

24 See below the case studies on Australia and Kiribati. Based on national authority data only, most nuclear test records cite 21 atmospheric nuclear tests conducted by the United Kingdom – nine in Kiribati and twelve in Australia. However, consistent with the 2000 UNSCEAR report and the 1999 SCOPE 59 report, this report classifies the 12 Vixen B tests carried out in Australia—in other sources generally listed as so-called minor trials—as safety tests, thereby increasing the total number of UK atmospheric nuclear tests to 33. See UNSCEAR, 'Exposures to the public from man-made sources of radiation', Annex C, Table 22; Warner and Kirchmann (eds.), SCOPE 59, pp. 30–31. The report of the Royal Commission into British Nuclear Tests in Australia also described the Vixen B trials as 'safety experiments', stating that they 'involved the release of fission energy'. See: Justice J. McClelland, *Royal Commission into British nuclear tests in Australia*, Vol. 2, 1985, pp. 397–98.

25 The United Kingdom conducted a further 28 tests jointly with the United States in Nevada, of which 24 were underground nuclear tests and 4 (Operation Roller Coaster) were atmospheric zero yield tests listed as storage-transportation and plutonium dispersal tests. The total of 28 joint US-UK tests is included in the tests conducted by the United States and is not repeated here.

26 See below the case study on China. See also J. Wilson Lewis and X. Litai, *China Builds the Bomb*, Stanford University Press, Stanford, CA, 1988, 202–03.

27 See O. Dahlman, S. Mykkeltveit, and H. Haak, *Nuclear Test Ban, Converting Political Visions to Reality*, Springer, 2009, 2.

28 Ibid.

29 CTBTO Preparatory Commission, 'Detecting Nuclear Tests', at: https://bit.ly/3v2d14O.

30 This test, which is generally ascribed to Israel, may have been conducted jointly with the apartheid regime of South Africa. W. Burr, A. Cohen, L.-E. De Geer, V. Gilinsky, S. Polakow-Suransky, H. Sokolski, L. Weiss, and C. Wright, 'Blast From the Past', *Foreign Policy*, 22 September 2019, at: https://bit.ly/43cm4wC.

The Soviet Union conducted an estimated 715 nuclear tests, which involved the detonation of an (again estimated) total of 969 nuclear devices rendering a total yield of approximately 285 Mt, equivalent to around 19,000 Hiroshima bombs and representing more than half of the total global yield produced in all nuclear tests.[31] Tests took place mainly in the Arctic and in Kazakhstan, along with a total of five in Turkmenistan, Ukraine, and Uzbekistan. The number of Soviet tests remains an estimate because some data are still classified top secret or are unavailable due to lack of reliable record-keeping. Many Soviet tests also involved multiple nuclear devices detonated within milliseconds to seconds ('salvo explosions'), resulting in a higher count of nuclear detonations compared to the number of tests. In September 2023, analysts reported an expansion of Russia's nuclear test site in Novaya Zemlya in the Arctic Ocean archipelago,[32] and in November, Russia withdrew its ratification of the 1996 Comprehensive Nuclear-Test-Ban Treaty (CTBT).[33] In September 2024, it was suggested that Vladimir Putin's options to retaliate if the West let Ukraine use its long-range missiles to strike Russia could include conducting a nuclear test.[34] If that were to happen, this would be its first test since the collapse of the Soviet Union, whose nuclear testing ended in 1990.

France conducted a total of 210 nuclear tests in Algeria and Mā'ohi Nui (French Polynesia) combined, but none on metropolitan French territory. Between February 1960 and February 1966, France conducted 17 nuclear tests in the vicinity of the towns of In Ekker and Reggane in the Algerian Sahara. The first atmospheric test is reported by the International Atomic Energy Agency (IAEA) to have had a yield of between 40 and 80 kt.[35] A total of 40 other experiments using fissile material were also conducted at the Adrar Tikertine site near the Taourirt Tan Ataram mountain range (Operation Pollen) and in Hammoudia (Operation Augias).[36] Between 1966 and 1996, France carried out 193 nuclear tests in Moruroa and Fangataufa atolls in Mā'ohi Nui, of which 46 were atmospheric. The largest yield was of 2.6 Mt in a test (part of Operation Canopus) in 1968, which made France the fifth nation to test a thermonuclear device after the United States, the Soviet Union, the United Kingdom, and China.[37]

The United Kingdom test-detonated weapons in three other States: Australia, Kiribati, and the United States. Over the course of six years in the 1950s, 12 atmospheric nuclear test detonations were conducted in Australia with explosive yields ranging between 0.9 and 60 kt.[38] As mentioned above, the United Kingdom also conducted 12 safety tests in Australia (the highly polluting 'Vixen B' series) and around 600 other so-called 'minor trials' that caused the dispersion of plutonium and other radioactive and chemical material. There was a high degree of secrecy by the UK authorities about the nature of the Vixen B trials and the contamination they produced was not disclosed. Data from the trials have still not been made public by the United Kingdom.[39] The United Kingdom then conducted nine atmospheric nuclear tests in 1957 and 1958 over Kiritimati (Christmas Island) and Malden Island in the central Pacific Ocean (Kiribati became a sovereign nation in 1979).[40] A total of 24 underground tests were conducted jointly with the United States at its Nevada Test Site, a 1,350 square-mile

31 R. S. Norris and T. B. Cochran, 'Nuclear Weapons Tests and Peaceful Nuclear Explosions by the Soviet Union, August 29, 1949 to October 24, 1990', Draft, Natural Resource Defense Council, Washington, DC, 1996, at: https://bit.ly/4devtHi, p. 2.

32 E. Cheung, B. Lendon and I. Watson, 'Exclusive: Satellite images show increased activity at nuclear test sites in Russia, China and US', CNN, 23 September 2023, at: https://bit.ly/3ucftoL.

33 Comprehensive Nuclear-Test-Ban Treaty; adopted at New York, 10 September 1996; not yet in force. See also B. Vitkine, 'Russia withdraws from two arms treaties and tests a ballistic missile', *Le Monde*, 9 November 2023, at: https://bit.ly/4bfsHSs.

34 A. Osborn and M. Trevelyan, 'Putin's options for Ukraine missiles response include nuclear test, experts say', *Reuters*, 15 September 2024, at: https://bit.ly/4gzSyas.

35 IAEA, 'Radiological Conditions at the Former French Nuclear Test Sites in Algeria: Preliminary Assessment and Recommendations', Radiological Assessment Report Series, 2005, at: https://bit.ly/3UPyhVR, p. 7.

36 See below the case study on Algeria. See also A. Mansouri, 'French nuclear explosions in the Algerian desert: A heavy colonial legacy', *Maçadir Review* (an Arabic-language journal), Vol. 7, No. 1 (2019), 9–45.

37 IAEA, 'The Radiological Situation at the Atolls of Mururoa and Fangataufa', Main Report, Vienna, 1998, at: https://bit.ly/3uvGdRo.

38 UK government, 'UK atmospheric nuclear weapons tests', Factsheet 5: UK programme, at: https://bit.ly/3QkXHa3, 4. Some claim that the nuclear explosive device with the largest yield was in fact equivalent to 98 kt. See E. Tynan, *Atomic Thunder: British Nuclear Testing in Australia*, Pen & Sword Military, United Kingdom, 2018, 87 and 158.

39 Tynan, *Atomic Thunder: British Nuclear Testing in Australia*, 119, 122.

40 UK government, 'UK atmospheric nuclear weapons tests', Factsheet 5: UK programme, at: https://bit.ly/4l5dxTp, p. 6.

area about 65 miles north-west of Las Vegas.[41] A further four atmospheric tests were undertaken jointly by the United Kingdom and the United States, all in 1963. These were storage-transportation tests conducted on the Nevada Test and Training Range with a view to measuring plutonium dispersal risk. Tests began in 1958 and continued through to 1991, just a year before all US nuclear testing ended. The largest yield in the joint tests is believed to be of 140 kt, from a test detonation in April 1980.[42]

Between 1964 and 1996, China conducted at least 45 nuclear tests (a small number of reports claim the total was 47), all at its Lop Nur test site in the north-west of the country, with yields ranging from 1 kt to 4 Mt. The yields of several tests are only estimates. In December 1966, China detonated its first hydrogen bomb. Twenty-three tests were atmospheric, including a number in the megaton range.[43] China was the last State to test-detonate a hydrogen bomb above the ground – in 1980. New construction was reported in 2023 and 2024 at China's Lop Nur nuclear test site.[44]

India test-detonated its first nuclear explosive device in May 1974, becoming the sixth nuclear-armed State.[45] Officially known as Pokhran I, the test is better known as 'Smiling Buddha'. Announced at the time by the government as a peaceful nuclear explosion, the head of India's nuclear programme later admitted that the Pokhran test was in reality 'a bomb'.[46] In May 1998, Operation Shakti—also known as Pokhran II—saw India conduct two tests with a total of five nuclear devices.[47] Two weeks after India's nuclear tests, Pakistan tested five bombs in a single day and a sixth two days later.[48] India and Pakistan are believed to have considerably exaggerated the yields of their respective nuclear tests in May 1998 for political purposes.[49]

North Korea has conducted six nuclear tests to date, with the first in October 2006 and the last in September 2017.[50] The UN Security Council condemned its first test as a threat to international peace and security.[51] Its reaction to the sixth test on 2 September 2017 was to condemn it 'in the strongest terms' and to reaffirm its decisions that North Korea 'shall not conduct any further launches that use ballistic missile technology, nuclear tests, or any other provocation'.[52] Pyongyang announced a moratorium on nuclear testing in April 2018, but declared that the moratorium was no longer in place the following year.[53] IAEA has stated that North Korea's test site at Punggye-ri remains prepared to support a nuclear test, and that it has continued to see indications of activity there.[54]

The CTBT prohibits all nuclear test detonations, for both civilian and military purposes, in all environments. The treaty is supported by a global verification regime designed to detect any nuclear explosion conducted anywhere, including a network of seismic, hydroacoustic, infrasound, and radionuclide monitoring stations.[55]

41 US Department of Energy, 'United States Nuclear Tests July 1945 through September 1992', Doc. DOE/NV--209-REV 16, Nevada Operations Office, September 2015, at: https://bit.ly/3HGXo5o.
42 Ibid.; and see R. S. Norris, A. S. Burrows, and R. W. Fieldhouse, *Nuclear Weapons Databook, Vol. 5: British, French, and Chinese Nuclear Weapons*, Westview Press, Boulder, CO, 1994, 402–04.
43 Atomic Archive, 'China's Nuclear Tests', undated but accessed 1 March 2024 at: https://bit.ly/43afDdk.
44 W. J. Broad, C. Buckley, and J. Corum, 'China Quietly Rebuilds Secretive Base for Nuclear Tests', *The New York Times*, Last updated 9 January 2024, at: https://bit.ly/3Vcj5S6.
45 Center for Arms Control and Non-proliferation, 'India's Nuclear Capabilities', Fact Sheet, 29 August 2019, at: http://bit.ly/3cEINFv.
46 Atomic Heritage Foundation, 'Indian Nuclear Program', 23 August 2018, at http://bit.ly/3dFIZWw.
47 O. Dahlman, S. Mykkeltveit, and H. Haak, *Nuclear Test Ban, Converting Political Visions to Reality,* Springer, 2009, 2; and F. Ringdal, S. Mykkeltveit, and T. Kværna, 'NORSAR and the Nuclear Test Ban', Stiftelsen NORSAR, 2022, at: https://bit.ly/48flyjX, pp. 134–40.
48 Ibid.; and S. Casey-Maslen, *Nuclear Weapons: Law, Policy, and Practice*, Cambridge University Press, Cambridge, 2021, 44.
49 F. Ringdal, S. Mykkeltveit, and T. Kværna, 'NORSAR and the Nuclear Test Ban', Stiftelsen NORSAR, 2022, at: https://bit.ly/48flyjX, p. 140.
50 CTBTO Preparatory Commission, 'Detecting Nuclear Tests', at: https://bit.ly/3v2d14O.
51 UN Security Council Resolution 1718, adopted by unanimous vote in favour on 14 October 2006, operative para. 1.
52 UN Security Council Resolution 2375, adopted by unanimous vote in favour on 11 September 2017, operative paras. 1 and 2.
53 K. Davenport and J. Masterson, 'North Korea Reiterates End to Test Moratorium', Arms Control Association, 30 January 2020, at: https://bit.ly/3EWmha6.
54 'IAEA Director General's Introductory Statement to the Board of Governors', IAEA, 6 March 2023, at: https://bit.ly/3Vj9FU4.
55 CTBTO, 'Verification Regime' at: https://bit.ly/4llr8a3.

Although it has been signed by 187 States and ratified by 178 of these (as of 1 October 2025), the treaty has not yet entered into force because nine 'Annex 2' States—China, Egypt, Iran, Israel, India, North Korea, Pakistan, Russia, and the United States—have not ratified it. All nuclear explosions are also prohibited under Article 1(1)(a) of the Treaty on the Prohibition of Nuclear Weapons (TPNW), which entered into force in 2021. No nuclear-armed State is yet party to the TPNW.

Table 2 summarizes the status under multilateral nuclear-weapons related treaties of all testing States and affected States covered in this report. Any new nuclear test detonation by any State would contravene the wording in the CTBT, as well as, arguably, contravening customary international law. It would also be incompatible with the prohibition on testing in the TPNW.

**Table 2: Status of treaty adherence by all States covered in this report**

| | CTBT | PTBT[56] | NPT | TPNW | NWFZ treaty[57] |
|---|---|---|---|---|---|
| **Non-nuclear-armed States** | | | | | |
| Algeria | Ratified (Annex 2 State) | Signed 1963 | State Party | Signed 2017 | State Party (Pelindaba) |
| Australia | Ratified (Annex 2 State) | State Party | State Party | | State Party (Rarotonga) |
| Kazakhstan | Ratified | | State Party | State Party | State Party (Semipalatinsk) |
| Kiribati | Ratified | | State Party | State Party | State Party (Rarotonga) |
| Marshall Islands | Ratified | | State Party | | Signed 2025 (Rarotonga) |
| Turkmenistan | Ratified | | State Party | | State Party (Semipalatinsk) |
| Ukraine | Ratified (Annex 2 State) | State Party | State Party | | |
| Uzbekistan | Ratified | | State Party | | State Party (Semipalatinsk) |
| **Nuclear-testing States** | | | | | |
| China | Signed 1996 (Annex 2 State) | | State Party | | |
| North Korea | | | Withdrew 2003 | | |
| France | State Party (Annex 2 State) | | State Party | | |
| India | | State Party | | | |
| Israel | Signed 1996 (Annex 2 State) | State Party | | | |
| Pakistan | | State Party | | | |
| Russia | Signed 1996, withdrew ratification 2023 (Annex 2 State) | State Party | State Party | | |
| United States | Signed 1996 (Annex 2 State) | State Party | State Party | | |
| United Kingdom | Ratified (Annex 2 State) | State Party | State Party | | |

56 1963 Treaty Banning Nuclear Weapon Tests in the Atmosphere, in Outer Space and Under Water, also called the Partial Test-Ban Treaty (PTBT).

57 The nuclear-weapon-free zone (NWFZ) treaties are: Treaty of Tlatelolco (1967 Treaty for the Prohibition of Nuclear Weapons in Latin America and the Caribbean); Treaty of Rarotonga (1985 South Pacific Nuclear Free Zone Treaty); Treaty of Bangkok (1995 Treaty on the Southeast Asia Nuclear Weapon-Free Zone); Treaty of Pelindaba (1996 African Nuclear-Weapon-Free Zone Treaty); and Treaty of Semipalatinsk (2006 Treaty on a Nuclear-Weapon-Free Zone in Central Asia). China, France, Russia, the United Kingdom, and the United States have signed, and in some cases ratified, protocols to the NWFZ treaties. The table does not provide information on the status of these protocols.

Chapter 2:

# The State of Knowledge on Impacted Territories

Grethe Lauglo Østern and
Matthew Breay Bolton

No country or person on Earth has been spared from exposure to radioactive fallout from nuclear testing. However, some regions and populations, particularly Indigenous communities and post-colonial States, have experienced disproportionate harm. Urgent, targeted action is needed to address the humanitarian and environmental damage caused by nuclear testing. While a full global impact assessment is still lacking, there is already clear evidence of where the most severe harm has occurred and where resources and responsibility should be focused.

Impact from the nuclear tests conducted between 1945 and 2017 continues to be global. There is not a country or a person on earth that has not been exposed to some level of radioactive fallout from past atmospheric nuclear tests.[1] Of course, some areas have been far more exposed to harm as a result of nuclear testing than others. The long-overdue task of addressing this harm calls for available operational and financial resources to be prioritised where they are needed the most.

Further work is required to produce a comprehensive, field-based global assessment of the ongoing needs for environmental remediation and victim assistance in the aftermath of nuclear testing. It is not necessary, however, to have a full global overview of impact and needs before action is taken. For it is already clear which countries and peoples are suffering the most from nuclear testing. Accordingly, it is also clear where the international community must urgently focus its support – and where nuclear-testing States have responsibilities that must be acknowledged and fulfilled.

Table 1 summarizes where the global count of 2,069 nuclear tests occurred and identifies the States responsible for those tests. Excluding the seven tests conducted in international waters, all other nuclear tests were conducted in territories that today fall within the internationally recognized borders of a total of 15 different States, including in unceded territories (i.e. those traditionally owned by Indigenous Peoples but taken without their consent).

**Table 1: Nuclear tests by location and testing State**

| | Testing State | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Test location | US | USSR | UK | France | India | Pakistan | Israel | China | North Korea | Totals |
| Algeria | | | | 17 | | | | | | 17 |
| Australia | | | 24 | | | | | | | 24 |
| China | | | | | | | | 45 | | 45 |
| Continental US | 945 | | | | | | | | | 945 |
| Mā'ohi Nui (France) | | | | 193 | | | | | | 193 |
| India | | | | | 3 | | | | | 3 |
| Johnston Atoll (US) | 12 | | | | | | | | | 12 |
| Kazakhstan | | 489 | | | | | | | | 489 |
| Kiribati | 24 | | 9 | | | | | | | 33 |
| Marshall Islands | 67[2] | | | | | | | | | 67 |
| North Korea | | | | | | | | | 6 | 6 |
| Novaya Zemlya (Russia) | | 130 | | | | | | | | 130 |
| Other sites in Russia | | 91 | | | | | | | | 91 |
| Pakistan | | | | | | 2 | | | | 2 |
| Turkmenistan | | 1 | | | | | | | | 1 |
| Ukraine | | 2 | | | | | | | | 2 |
| Uzbekistan | | 2 | | | | | | | | 2 |
| Indian Ocean | | | | | | | 1 | | | 1 |
| Pacific Ocean | 3[3] | | | | | | | | | 3 |
| South Atlantic Ocean | 3 | | | | | | | | | 3 |
| Totals | 1,054 | 715 | 33 | 210 | 3 | 2 | 1 | 45 | 6 | 2,069 |

1 Further information is provided in Chapter 6.

2 The United States officially lists 66 nuclear tests as having been conducted in the Marshall Islands, whereas the Nuclear Claims Tribunal cites 67. The research for this report's case study on the Marshall Islands identified that the discrepancy arises from a test code-named Yucca, which was detonated on a balloon above the ocean. The United States recorded the location of the test as the Pacific Ocean, though it was in fact conducted within the area now designated as the Exclusive Economic Zone (EEZ) of the Marshall Islands.

3 The United States officially lists the location of four nuclear tests as over the Pacific Ocean. As just noted, one of these tests was in fact conducted within the area now designated as the Marshall Islands' EEZ.

While the scale of the impact from nuclear testing may appear overwhelming, effective prioritization is both essential and possible. At country level, detailed national risk and needs assessments will enable the most affected locations and populations to be identified. To assist with prioritization at the global level, four initial actions are proposed below, each addressing a particular geographical aspect of the nuclear-testing legacy.

The parallel priorities for action are based on a simple analytical framework. First, it distinguishes between two categories of affected States: those directly impacted—where tests were physically conducted—and those indirectly impacted, through transboundary fallout. Second, it classifies directly impacted States based on the type of testing conducted—atmospheric or underground—recognizing that atmospheric tests are generally associated with greater risks. Third, it differentiates between nuclear-armed States that today are directly impacted by tests they themselves conducted on territories within their current internationally recognized borders—including on unceded territories of Indigenous Peoples—and States and other territories that were used as test sites by nuclear-armed States in a colonial or otherwise exploitative context. Fourth, it considers the capacity each directly impacted State or Indigenous People has to address the ongoing impacts of nuclear testing, in order to identify where international assistance and cooperation are most urgently needed.

### Action 1: Provide international support to four States and one other territory directly impacted by atmospheric nuclear testing

Urgent international cooperation and assistance should be provided to four post-colonial States and one Non-Self-Governing Territory where atmospheric and in some cases also underground nuclear tests were conducted in a colonial context. This concerns, specifically, Algeria, Kazakhstan, Kiribati, the Marshall Islands, and Mā'ohi Nui (French Polynesia). The task is to reinforce their respective capacities to assess and meet their ongoing victim assistance and environmental remediation needs. International support must be provided, first and foremost, by the four responsible testing States—France, Russia, the United Kingdom, and the United States—as well as by other donors.

### Action 2: Scale up domestic efforts in four nuclear-armed States and one settler State directly impacted by atmospheric nuclear testing

China, France (in its overseas collectivity of Mā'ohi Nui), Russia, and the United States should significantly scale up their domestic efforts to assess and meet ongoing victim assistance and environmental remediation needs resulting from the atmospheric and underground nuclear tests they conducted on territories within their borders as currently recognized internationally, including on unceded territories of Indigenous Peoples. In addition, Australia as a settler State should strengthen its domestic efforts to assess and meet victim assistance and environmental remediation needs resulting from the atmospheric nuclear tests conducted by the United Kingdom on unceded territories of Indigenous Peoples. The United Kingdom must support these efforts.

### Action 3: Implement or update risk assessments in six States directly impacted by underground nuclear testing only

The Democratic People's Republic of Korea (North Korea), India, and Pakistan should conduct radiation risk assessments with the involvement of competent international bodies, ensuring a transparent evaluation of whether environmental remediation and victim assistance are needed after the underground nuclear tests they carried out on territories within their internationally recognized borders. With the support of competent international bodies, Turkmenistan, Ukraine, and Uzbekistan—where the Soviet Union conducted a small number of underground tests—should also provide updated assessments of the status of the relevant sites.

**Action 4: Undertake further research on the extent and impact of transboundary fallout from atmospheric nuclear testing**

Coordinated, international efforts should be initiated to determine the extent of transboundary fallout from atmospheric nuclear testing (where significant quantities of radioactive fallout have crossed national borders) and assess whether and how this affects indirectly impacted States. This will require the active cooperation of, and data transparency by, the five States that had atmospheric testing programmes – China, France, Russia, the United Kingdom, and the United States.

## Directly impacted States

This report categorizes as directly impacted by nuclear testing the fifteen States whose current internationally recognized borders encompass former nuclear test sites. As illustrated in Figure 2 overleaf, and as detailed in Table 2 below, six of the fifteen States are directly impacted by both atmospheric and underground nuclear tests. Three States are directly impacted by atmospheric tests only. The other six States are directly impacted by underground nuclear tests only.

**Table 2: States directly impacted by nuclear tests**

| Directly impacted by atmospheric and underground tests | Directly impacted by atmospheric tests only | Directly impacted by underground tests only |
|---|---|---|
| Algeria<br>China<br>France (Mā'ohi Nui)<br>Kazakhstan<br>Russia<br>United States | Australia<br>Kiribati<br>Marshall Islands | India<br>North Korea<br>Pakistan<br>Turkmenistan<br>Ukraine<br>Uzbekistan |

### Addressing direct impact from atmospheric nuclear tests

It is in States directly impacted by atmospheric nuclear testing that the resultant environmental and humanitarian impacts are most pronounced. Of the fifteen directly impacted States, atmospheric nuclear tests took place on the territories of nine: Algeria, Australia, China, France (in Mā'ohi Nui), Kazakhstan, Kiribati, the Marshall Islands, Russia, and the United States. Given that these nine States bear the brunt of the environmental and humanitarian consequences of nuclear testing, this report includes case studies covering each location. In each of the nine States directly impacted by atmospheric nuclear testing, the affected territories include unceded territories of Indigenous Peoples. In each case, affected populations are also often particularly vulnerable to harm resulting from nuclear testing, while being unable to access appropriate care or secure remedies for the violation of their rights.[4]

Of the nine where atmospheric nuclear testing took place, four—Algeria, Kazakhstan, Kiribati, and the Marshall Islands—were the sites of nuclear tests conducted in a colonial context by nuclear-armed States.

4 B. R. Johnston (ed.), *Half-Lives and Half-Truths*, School for Advanced Research Press, Santa Fe, NM, 2007; R. Jacobs, 'Nuclear Conquistadors: Military Colonialism in Nuclear Test Site Selection during the Cold War', *Asian Journal of Peacebuilding*, Vol. 1, No. 2 (2013); and N. Maclellan, *Grappling with the Bomb*, ANU Press, Acton, 2017.

Today, they are post-colonial States classified either as Least Developed Countries by the United Nations or as Low- and Middle-Income countries based on gross national income (GNI) per capita as published by the World Bank. As such, they are eligible to receive Official Development Assistance (ODA). These States are thus not only directly impacted by nuclear testing but are also among the least resourced to address its long-term consequences. The respective case studies in this report underscore the urgent need for international cooperation and assistance for the conduct of detailed needs assessment, the provision of victim assistance, and environmental remediation.

This report also calls for international support to Mā'ohi Nui. As an overseas collectivity of France and a Non-Self-Governing Territory—meaning it is formally recognized as still undergoing decolonization—Mā'ohi Nui is not ODA-eligible. Nonetheless, as the case study in this report demonstrates, it remains under-resourced. States, international organizations, and non-governmental organizations (NGOs) can provide much-needed support for needs assessment, victim assistance, and environmental remediation. Such international assistance must complement—but not replace—France's own obligations, an issue discussed below.

It was the nuclear weapons programmes of France, the Soviet Union, the United Kingdom, and the United States, respectively, that brought lasting harm upon Algeria, Kazakhstan, Kiribati, the Marshall Islands, and Mā'ohi Nui, and they therefore bear the primary responsibility for supporting them. But it is not their responsibility alone. For decades, the allies of the nuclear-armed States and the international community as a whole have neglected the humanitarian and environmental consequences of nuclear testing. It is high time for collective action. Given the relatively small number of four States and one other territory in need of international support and cooperation, it is entirely feasible to undertake the requisite collective action.

Australia, a High-Income Nation and settler State, is the fifth State that is not nuclear-armed, but which is directly impacted by atmospheric nuclear testing. In this case, the tests were conducted by the United Kingdom on unceded territories of Indigenous Peoples, albeit with the permission and support of Australia's then Prime Minister. This report includes a detailed case study on the current situation in Australia and calls for the urgent strengthening of its domestic efforts to assess ongoing needs, remediate contaminated land, and assist the populations affected by the tests. As the responsible testing State, the United Kingdom continues to bear the duty to support these efforts.

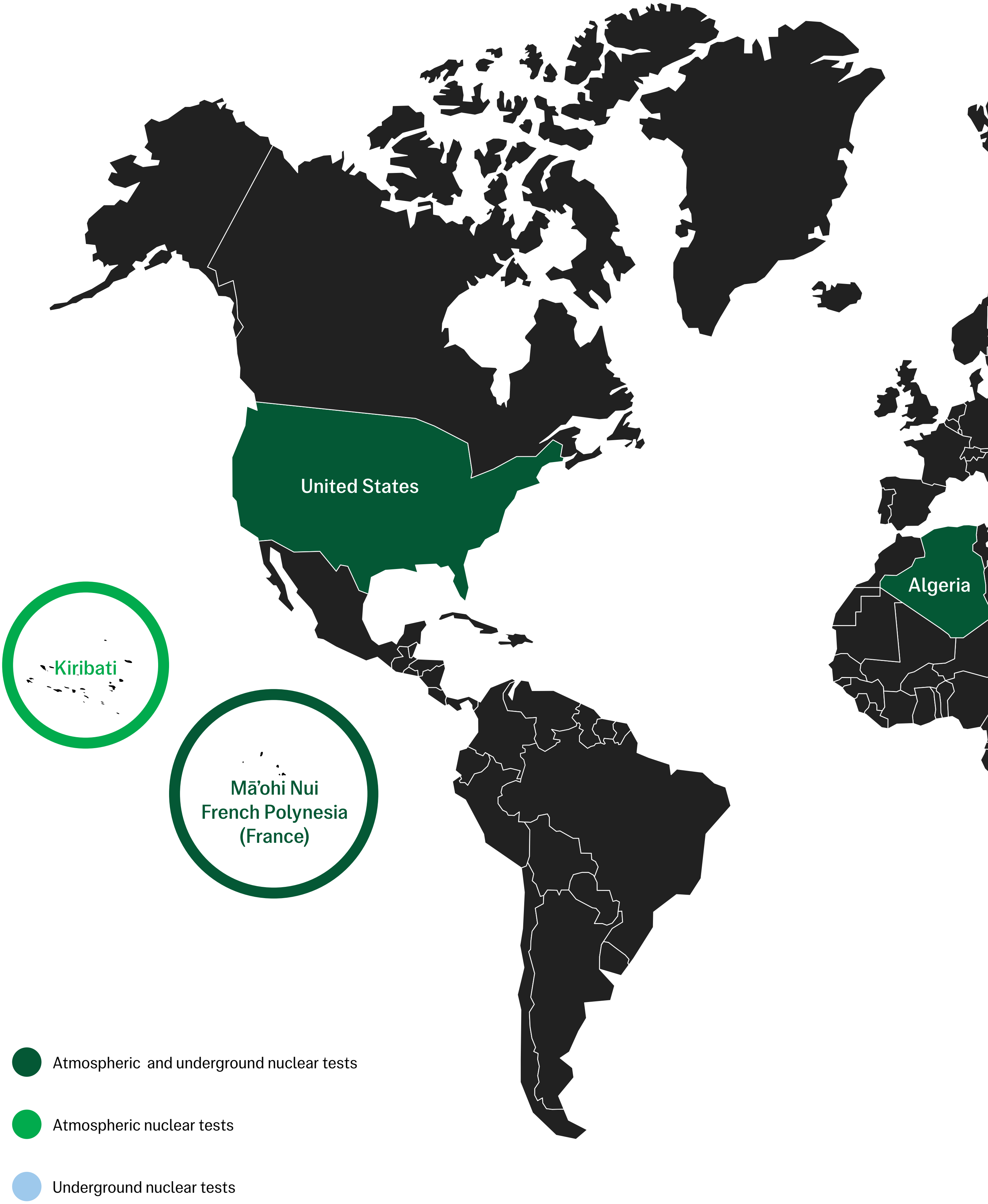
Finally, four nuclear-armed states—China, France (in Mā'ohi Nui), Russia, and the United States—continue to be impacted by atmospheric and underground nuclear tests they conducted within their current internationally recognized borders, including on unceded territories of Indigenous Peoples. As the relevant case studies in this report demonstrate, these States should urgently and significantly scale up their domestic efforts to assess ongoing needs, remediate contaminated environments, and provide assistance to their affected populations.

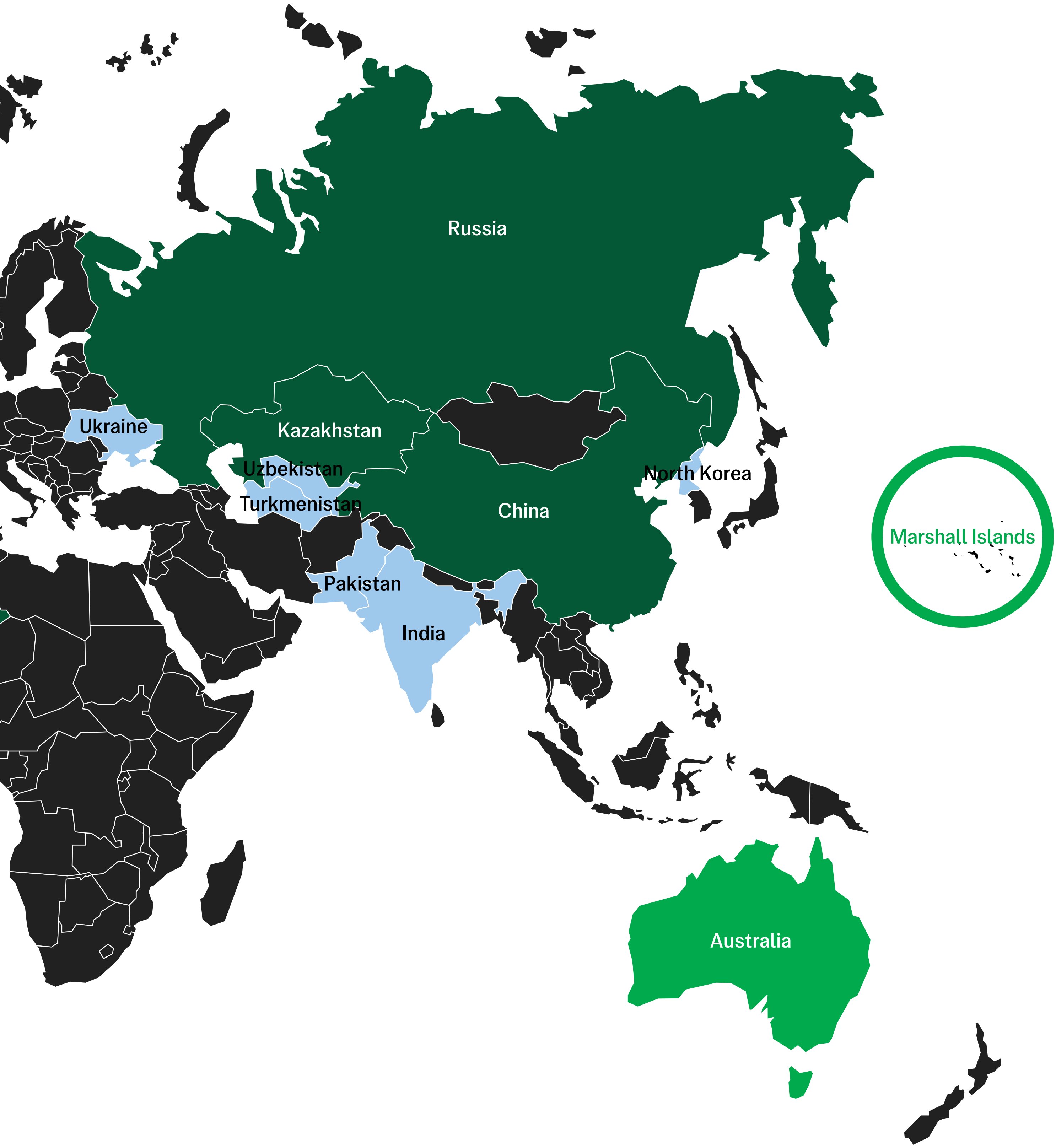
**Addressing direct impact from underground nuclear tests only**

Underground nuclear tests are generally less devastating in humanitarian and environmental terms than atmospheric tests, but they can still pose significant risks of harm. This can result from the contamination of groundwater, the venting of radioactive gases to the surface, and seismic and structural damage, all of which can affect nearby communities. This is discussed in more detail in Chapter 4.

As detailed in Table 2 above, six States may have experienced direct impacts that result exclusively from underground nuclear tests conducted on territories within their internationally recognized borders: North Korea (six tests), India (three tests), Pakistan (two tests), Ukraine (two tests), Uzbekistan (two tests), and Turkmenistan (one test). Of these States, the first three—India, North Korea, and Pakistan—are nuclear-armed States that conducted the tests on their own territory. The remaining tests were conducted by the erstwhile Soviet Union at sites in Turkmenistan, Ukraine, and Uzbekistan.

Figure 2: States directly impacted by nuclear testing worldwide




Russia
Ukraine
Kazakhstan
Uzbekistan
Turkmenistan
North Korea
China
Pakistan
India
Marshall Islands
Australia

The risks from underground nuclear tests must be assessed and monitored in each case. While current site conditions fall outside the scope of this report, they warrant further investigation. As stated above, this report urges, in particular, India, North Korea, and Pakistan to implement radiation risk assessments with the involvement of international experts, ensuring a transparent evaluation of any ongoing humanitarian and environmental consequences at the relevant test sites. Updated assessments should also be published on the conditions at the sites in Turkmenistan, Ukraine, and Uzbekistan.

**North Korea**

The regime in North Korea claims that all six of its nuclear weapons tests at its Punggye-ri underground test site were conducted safely, but the testing has likely caused local environmental degradation and created health risks for residents around the test site. The full extent of any harm is, though, obscured by a lack of access and information. In 2018, a study by Chinese geologists showed that the test site had partially collapsed under the stress of multiple explosions, leaving it vulnerable to radiation leaks.[5] In 2023, The Transitional Justice Working Group, a Seoul-based human rights group, warned that radioactive contamination may have spread through groundwater from the test site, potentially jeopardizing the health of people in North Korea and neighbouring countries.[6]

**India**

All of India's three nuclear tests (with a total of six nuclear explosive devices) were conducted underground at the Pokhran test site in the western state of Rajasthan. The tests were reportedly undertaken at depths of between 200 and 300 metres. The Indian government's official position is that there was no venting from the tests – and thus no atmospheric release of radioactivity. No independent confirmation of this statement is, though, available. As a result, health complaints of the residents of nearby villages cannot be causally linked to the tests. Fission products and residual unfissioned plutonium from the tests remain underground, however, posing a long-term threat to the subterranean environment.[7]

**Pakistan**

Pakistan's two nuclear weapon tests (detonating a total of six devices) were both underground, tunnel tests. No information is available on venting of radionuclides and no health studies are known to have been carried out. As a result, the complaints of nearby villagers about a variety of health problems cannot be validated by data.[8]

**Turkmenistan**

Two nuclear explosive devices were detonated in Turkmenistan. The devices were used to seal a leaking well on each occasion. The first device, with a 30 kt yield, was detonated at Urtabulak on 30 September 1966. The second device, this time with a 47 kt yield, was detonated at the nearby Pamuk gas field on 21 May 1968.[9] No information is available on any possible radiation leakage.

5 J. Borger, 'North Korea Nuclear Test Site Has Collapsed and May Be out of Action – China', *The Guardian,* April 26, 2018, at: https://bit.ly/43SsvH0.

6 C. Sang-Hun, 'North Korea Says It Tested ICBM as Warning to U.S. and South Korea', *The New York Times*, 21 February 2023, at: https://bit.ly/3HmcL6A.

7 ICAN Nuclear Test Impacts Map, at: https://bit.ly/4lPr2b4; M. V. Ramana and Surendra Gadekar, 'The Price We Pay', in M. V. Ramana and C. Rammanohar Reddy (eds.), *Prisoners of the Nuclear Dream*, Orient Longman, New Delhi, 2003, 438.

8 ICAN Nuclear Test Impacts Map.

9 M. D. Nordyke, 'The Soviet Program for Peaceful Uses of Nuclear Explosions', Report, Lawrence Livermore National Laboratory, October 1996, pp. 34–35.

### Ukraine

Two nuclear explosive devices were detonated in Ukraine.[10] On 7 July 1972, a leaking gas well in the Ukraine, about twenty kilometres north of the city of Krasnograd and sixty-five kilometres south-west of Kharkiv, was sealed with a nuclear explosion. The explosive yield is said to have been 3.8 kt. The Soviet Ministry for Atomic Energy claimed that all the leaks were completely contained, and that no radioactivity above background levels was detected at the surface of the ground during post-shot surveys. In fact, the explosion did not stop the gas blowing out and when residents returned to their homes just 30 minutes after the nuclear detonation many houses had broken windows and damaged walls. Test animals in restricted zones are said to have died. All information about radioactive contamination was, however, classified top secret.[11]

The second detonation in Ukraine was conducted with a view to reducing sudden releases of coal and methane gas during mining and thus to improve miner safety.[12] The operation on 16 September 1979 in the Donetsk region, at the 'Yunyi Komunar' mine in the city of Bunhe (then known as Yunokomunarivsk), involved the detonation of a nuclear explosive device with a relatively low yield of 0.3 kt at a depth of 903 metres. The explosion created an underground 'glass capsule' at a depth of 900 metres that contained 93 per cent of the radioactive products of the explosion. Coal continued to be extracted from the mine for another 23 years and official reports did not refer to the potential for irradiation of workers or the environment.[13]

Scientists have recorded, however, that the total concentration of radionuclides in aquifers within five kilometres of the mine indicated that contaminated water has reached drinking water levels.[14]

### Uzbekistan

One nuclear explosive device was detonated in Uzbekistan. In April 1972, a 14-kt nuclear bomb was detonated to seal a gas well in the Mayskii gas field about thirty kilometres south-east of the city of Mary in Turkmenistan.[15]

## Indirectly impacted States

The harms of atmospheric nuclear testing were not confined to the States and territories on which they occurred. Radioactive fallout from atmospheric nuclear testing has dispersed around the world, with significant quantities carried across national borders (so-called transboundary fallout) and detected in States thousands of miles away from 'ground zero'.[16] Accurate assessment of the extent and effects of nuclear fallout—particularly transboundary fallout—remains a significant challenge, due to limited monitoring at the time of testing and restricted access to data about the tests that were conducted. It is beyond the scope of this report to review the existing knowledge on transboundary fallout. Updated knowledge can and should, however, be sought

10 Ibid., p. 35.

11 O. Pysarenko, 'Nuclear explosions in Soviet-era Ukraine – What really happened?', *RBC-Ukraine*, 30 June 2025, at: https://bit.ly/479xAwA.

12 See, e.g., R. S. Norris and T. B. Cochran, 'Nuclear Weapons Tests and Peaceful Nuclear Explosions by the Soviet Union, August 29, 1949 to October 24, 1990', Draft, Natural Resource Defense Council, Washington, DC, 1996, at: https://bit.ly/4devtHi, p. 6.

13 Pysarenko, 'Nuclear explosions in Soviet-era Ukraine – What really happened?'.

14 Ibid.

15 Nordyke, 'The Soviet Program for Peaceful Uses of Nuclear Explosions', p. 35.

16 UNSCEAR, 'Sources and Effects of Ionizing Radiation', Annex C: Exposures to the public from man-made sources of radiation; Centers for Disease Control (CDC), 'A Feasibility Study of the Health Consequences to the American Population From Nuclear Weapons Tests Conducted by the United States and Other Nations', Report, Atlanta, GA, 2005; International Physicians for the Prevention of Nuclear War (IPPNW) and the Institute for Energy and Environmental Research (IEER), Radioactive Heaven and Earth: *The Health and Environmental Effects of Nuclear weapon testing in, on and above the Earth,* Zed Books, London, 1991; R. Prăvălie, 'Nuclear weapons tests and environmental consequences: a global perspective', *Ambio*, Vol. 43, No. 6 (2014), 729–44; and I. Anderson, 'Fallout in the South Pacific', *New Scientist*, 2 September 1995, at: https://bit.ly/47sZ2nk.

on the extent and impact of transboundary fallout from past atmospheric nuclear tests, to identify indirectly impacted States and the degree to which they continue to be affected.

Indeed, technological advances make it possible today to reconstruct and model the fallout from past, individual nuclear tests, allowing scientists to determine which countries were affected and to estimate the radiation levels they suffered. This research is only possible, however, if nuclear-armed States release data about their tests. In this respect, some significant progress has been recorded in recent years. Based on declassified US government data and detailed historical global weather information, and employing new atmospheric modelling methodology, Sébastien Philippe and four other experts completed a study in 2023 that reconstructed cumulative fallout from atmospheric nuclear tests in the United States, establishing that it affected all contiguous US states as well as Canada and Mexico.[17] Using the same methods, in 2021 the Moruroa Files project, a collaboration between journalists, researchers, and Princeton University, analysed more than 2,000 pages of declassified French documents and used the information to demonstrate that fallout in Mā'ohi Nui was considerably more extensive and intense than the French government had previously admitted.[18] While France has declassified some documents related to its nuclear tests in Mā'ohi Nui, it has not afforded the same level of transparency for its tests in Algeria. Similarly, China, Russia, the United Kingdom, and the United States each retain information that could enable further reconstruction of past fallout from their respective nuclear tests. In particular, better data are needed on where fallout has spread from Soviet nuclear tests.

Examples of States known to have been impacted, at varying levels, by transboundary fallout are included in Table 3 opposite. The table is intended to provide historical and scientific context rather than to suggest the extent of current risk. We call for coordinated international efforts to further assess the extent and impact of transboundary fallout. For affected communities, it is crucial that ongoing needs for support are identified, and it can be equally important to provide affected communities and governments with clear assurance when no ongoing impact is present.

17 S. Philippe, S. Alzner, G. P. Compo, M Grimshaw, and M. Smith, 'Fallout from U.S. atmospheric nuclear tests in New Mexico and Nevada (1945–1962)', *arXiv*:2307.11040, at: https://bit.ly/3UFpBjw.

18 N. Ahmed *et al.*, 'Moruroa files: Investigation into French nuclear tests in the Pacific', at: https://moruroa-files.org.

**Table 3:** States known to have been impacted by transboundary fallout from nuclear weapon testing[19]

| State | Impact |
|---|---|
| Canada | Fallout from Soviet tests in Novaya Zemlya[20] and from US tests[21] |
| Chad | Fallout from first nuclear test in Algeria[22] |
| Cook Islands | Fallout from French and UK tests in the Pacific[23] |
| Fiji | Fallout from French Pacific testing[24] |
| Finland | Fallout from Soviet nuclear tests[25] |
| Denmark (Greenland) | Fallout on Greenland from Soviet nuclear tests at Novaya Zemlya[26] |
| Libya | Fallout from French atmospheric testing in Algeria[27] |
| Mali | Fallout from first nuclear test in Algeria[28] |
| Mauritania | Fallout from first nuclear test in Algeria[29] |
| Mexico | Fallout from US tests[30] |
| Morocco | Fallout from first nuclear test in Algeria[31] |
| Niger | Fallout from first nuclear test in Algeria[32] |
| Norway | Fallout from Soviet tests in Novaya Zemlya and Semipalatinsk[33] |
| Senegal | Fallout from first nuclear test in Algeria[34] |
| Sweden | Fallout from Soviet tests in Novaya Zemlya and Semipalatinsk[35] |

19 In addition to the specific footnotes, details in Table 3 are drawn from the following global surveys: UNSCEAR, 'Sources and Effects of Ionizing Radiation', Annex C; IPPNW and IEER, *Radioactive Heaven and Earth;* and Prăvălie, 'Nuclear Weapons Tests and Environmental Consequences'.
20 Comprehensive Nuclear Test Ban Treaty Organization (CTBTO), 'Effects of Nuclear Weapon Testing by the Soviet Union'.
21 Philippe *et al.*, 'Fallout from U.S. atmospheric nuclear tests in New Mexico and Nevada (1945–1962)'.
22 Monitoring at N'Djamena (known at that time as Fort Lamy), which is around 2,400 km from Reggane, reported 10−9 Ci/m3. 'France-Algeria relations: The lingering fallout from the first nuclear tests in the Sahara', Time Note, undated but accessed 1 August 2025, at: https://bit.ly/4l1mltr.
23 B. Danielsson, 'Poisoned Pacific: The Legacy of French Nuclear Testing', *Bulletin of Atomic Scientists,* Vol. 46, No. 2 (1990), 22–31; H. R. Atkinson *et al.*, 'Report of a New Zealand, Australian, and Papua New Guinea Scientific Mission to Moruroa Atoll, October–November 1983', New Zealand Ministry of Foreign Affairs, Wellington, 1983; French Atomic Energy Commission, 'Memorandum of the Directorate for Nuclear Test Centres, 25 August 1988', Villecoublay, France, 1988.
24 M. Bolton, 'Fiji: Addressing the Humanitarian and Human Rights Concerns of Kirisimasi (Christmas and Malden Island) Veterans', International Disarmament Institute, New York, 2018, at: https://bit.ly/3B1ralt.
25 E. Lund and M. R. Galanti, 'Incidence of thyroid cancer in Scandinavia following fallout from atomic bomb testing', *Cancer Causes Control,* Vol. 10, No. 3 (1999); IAEA, *Chernobyl's Legacy*, Report, Vienna, 2006.
26 See, e.g., A. Aarkrog, H. Dahlgaard, and S. P. Nielsen, 'Marine radioactivity in the Arctic: a retrospect of environmental studies in Greenland waters with emphasis on transport of 90Sr and 137Cs with the East Greenland Current', *Science of the Total Environment,* Nos. 237–38 (30 September 1999), 143–51.
27 S. Elsaidi, 'The day the desert wind cried: French nuclear tests cast long shadow in Libyan Sahara', Middle East Eye, 29 January 2023, at: https://bit.ly/3uLLcgR.
28 'Le document choc sur la bombe A en Algérie', *Le Parisien*, 14 February 2014, at: https://bit.ly/4mnvFsl.
29 Ibid.
30 Philippe *et al.*, 'Fallout from U.S. atmospheric nuclear tests in New Mexico and Nevada (1945–1962)'.
31 'Le document choc sur la bombe A en Algérie', *Le Parisien*, 14 February 2014.
32 Ibid.
33 Lund and Galanti, 'Incidence of thyroid cancer in Scandinavia following fallout from atomic bomb testing'; C. C. Wendel *et al.*, 'Long-range tropospheric transport of uranium and plutonium weapons fallout from Semipalatinsk nuclear test site to Norway', *Environment International,* Vol. 59 (2013); and C. Digges, 'Arctic Frontiers forum totes up Russia's northern nuclear hazards', Online article, Bellona, 30 January 2018, at: https://bit.ly/3ZrBehA.
34 'Le document choc sur la bombe A en Algérie', *Le Parisien*, 14 February 2014.
35 Lund and Galanti, 'Incidence of thyroid cancer in Scandinavia following fallout from atomic bomb testing'.

Chapter 3:

# A Litany of Inaction

Matthew Breay Bolton

While the humanitarian and environmental consequences of nuclear testing are well-documented and severe, meaningful efforts to address them have been sporadic, fragmented, and woefully insufficient. This chapter explores the persistent failure of nuclear-armed States and international institutions to provide adequate assistance, transparency, or remediation for those harmed. It reveals a global architecture that, unlike responses to other forms of armed violence, has long treated nuclear testing as an internal matter – shielding the testing States from accountability and leaving victims to fend for themselves. As this chapter demonstrates, the status quo is no longer tenable, and there is growing momentum for change.

The phenomenon of nuclear colonialism, which describes the abuse of Indigenous Peoples and the exploitation of their lands to sustain the nuclear production process, has generated shockingly limited action on the part of the perpetrators. The harm caused by nuclear testing remains under-addressed and poorly communicated, while the risks are underestimated, due in part to efforts by nuclear-armed States to suppress open scientific inquiry into the effects of nuclear weapons.[1] In most cases so far, communities affected by nuclear weapons have received inadequate support. Affected Indigenous and Non-Self-Governing Peoples face exclusion even from sympathetic international forums, where statehood is a condition of full participation.

As a starting point, the States that have conducted nuclear tests should release their non-military-sensitive testing data publicly, wherever this can facilitate long-overdue needs assessments, environmental remediation, and victim assistance to alleviate the harm that their tests have caused and continue to cause. Environmental remediation and victim assistance are crucial in areas contaminated by nuclear-weapons testing, to protect the affected populations from avoidable suffering, to safeguard their rights, and to help restore damaged ecosystems. Yet, such efforts after nuclear-weapons testing have been wholly insufficient for decades and continue to be so, as demonstrated by the country case studies in this report. Responses have generally been limited to the national—even the local—level, and remedial approaches have differed considerably. Even low-threshold activities like risk reduction education and marking of contaminated areas are often not in place. In some cases, populations do not have access to knowledge about the level of threat, how to protect themselves, which areas not to access, and which food types to avoid. Where populations are in fact no longer exposed to ongoing risk, they may nevertheless suffer unnecessary psychological stress because of a lack of certainty and ongoing suspicion.

In areas under the jurisdiction of the State that has tested nuclear weapons, authorities often obstructed rather than promoted victim assistance. For example, in 1971, *Gensuikin*—the Japan Congress against Atomic and Hydrogen Bombs—tried to send a medical team to help the people of Rongelap Atoll in what is now the Marshall Islands, which was heavily affected by fallout from the US Castle Bravo atmospheric test in 1954. The United States, which was then administering the Islands as part of the UN Strategic Trust Territory, blocked the team from coming to the Islands.[2]

## An 'internal matter'

The consequences of nuclear weapon testing have not been addressed by the international community through a humanitarian framework until recently. While local health and social welfare systems, including military hospitals, assist those injured by landmines and explosive remnants of war (ERW), the vast majority of the victims of these munitions are people living in States whose public sector and economies had been severely degraded by warfare. As a result, assistance has mobilized strong norms of global engagement to address humanitarian needs arising from armed conflict. With respect to the problems caused by explosive ordnance, humanitarian agencies, including the UN, the International Committee of the Red Cross (ICRC), non-governmental organizations (NGOs), and bilateral donors support and even directly provide emergency healthcare, prostheses and orthoses, psycho-social rehabilitation, socio-economic support, risk reduction education, and demining. The relevant UN agencies coordinate through an Inter-Agency Coordination Group on Mine Action.[3] Over the five-year period of 2019–23, more than 30 States and the European Union (EU) gave a total of US$3.3 billion in international support to mine action programmes, dealing with landmines, cluster munition remnants, and other ERW.[4]

1 For a useful review of nuclear testing secrecy, see M. de Jong, N. Maclellan, C. Cantagallo, D. Hawkins, and P. Kingfisher, 'Challenging Nuclear Secrecy: A Discussion of Ethics, Hierarchies and Barriers to Access in Nuclear Archives', Report, Nuclear Truth Project, July 2023, at: https://bit.ly/4daN033.

2 L. P. Gunter, 'The woman who tore up the curtain of silence', Beyond Nuclear International, 2 September 2018, at: https://bit.ly/48F2Lgr.

3 UN, 'Inter-Agency Coordination Group Members', at: https://bit.ly/4avo9Gt.

4 ICBL-CMC, 'Support for Mine Action', *Landmine Monitor Report 2023*, at: https://bit.ly/3VynZde.

In contrast, there has been very little operational response to nuclear testing from international institutions and there has been no comparable global architecture for addressing the humanitarian and environmental consequences of nuclear weapons. Nuclear testing programmes occurred in territories that were, at least in a legal sense, at peace. Therefore, the suffering of those victimized by these programmes was treated by the international community largely as an internal matter of sovereign States – the extensive apparatus established to render humanitarian aid in the context of armed conflict was not activated.

Where testing States have acknowledged harm, they have tended to address it not through ongoing needs-based or rights-based programming, but rather through compensation schemes that function more to limit liability than to help victims in good faith. The broader humanitarian and development sectors should now seek to enhance their knowledge about the impacts, vulnerabilities, and needs generated by nuclear tests and incorporate this knowledge in their general programmes in the relevant areas. Appropriate international institutions and treaty bodies should establish mechanisms to overcome exclusion of affected communities from policymaking and that address their needs.

## The mandate gap

Since 1955, the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR)[5] has compiled detailed technical research on the sources and effects of ionizing radiation,[6] including in its landmark 2000 report on 'exposures to the public'.[7] In partnership with the UN Environment Programme (UNEP), it has produced a plain language handbook on radiation in 11 languages that serves as a useful resource for developing risk reduction activities.[8] The International Atomic Energy Agency (IAEA) is an intergovernmental body dedicated to 'cooperation in the nuclear field'[9] and has conducted technical assessments of radiological conditions in a variety of key locations, including former test sites in Algeria, the Marshall Islands, and Kazakhstan (see the relevant case studies in this report).[10] The IAEA also provides extensive guidance on environmental remediation and facilitates international cooperation to help build the capacity of national authorities. While not an inter-governmental body, the International Commission on Radiological Protection (ICRP), founded in 1928, has played a significant role in the establishment of policy norms regarding dosimetry and protection standards.[11]

However, UNSCEAR, the IAEA,[12] and the ICRP have been criticized for not being independent of the influence of the nuclear-armed States and the nuclear industry. Moreover, none of these institutions—or, for that matter, the World Health Organization (WHO), the Preparatory Commission for the Comprehensive Nuclear Test Ban Treaty Organization (CTBTO),[13] the UN Development Programme (UNDP), or UNEP—has a mandate to support and strengthen the capacities of national authorities in States affected by the legacies of nuclear testing. These States are confronted with almost overwhelming challenges of conducting national assessments of needs for environmental remediation and victim assistance and for planning and implementing the requisite interventions.

Even the ICRC, which has played a crucial role in advocating for the inclusion and implementation of victim assistance provisions in the UN Treaty on the Prohibition of Nuclear Weapons (TPNW),[14] has not itself

5 UNSCEAR was invited to comment on a draft of this report but declined to do so.
6 UNSCEAR, 'Historical Milestones', 2021, at: https://bit.ly/49MBF9B.
7 UNSCEAR, 'Sources and Effects of Ionizing Radiation', Report, Vienna, 2000, Annex C: Exposures to the public from man-made sources of radiation.
8 UNEP, *Radiation Effects and Sources*, UNEP, Vienna, 2016.
9 IAEA, 'About us', 2023, at: https://bit.ly/3IO5A4m.
10 Chapters 14, 15, and 16, respectively.
11 R. H. Clarke and J. Valentin, 'The History of ICRP and the Evolution of its Policies', ICRP Publication 109, 2008, at: https://bit.ly/4cFuNfc.
12 The IAEA was invited to comment on a draft of this report, but did not do so.
13 The CTBTO was invited to comment on a draft of this report, but declined to do so.
14 ICRC, 'The Obligation to Assist Victims and Remediate the Environment within a Framework of Shared Responsibility under the Treaty on the Prohibition of Nuclear Weapons', Geneva, 2023, at: https://bit.ly/4a7hBht.

engaged in implementation. It appears that the sole significant example is the UNDP's coordination of a project, 'Enhancing Human Security in the Former Nuclear Test Site of Semipalatinsk', from 2008 to 2010, with funding from Japan and the participation of the United Nations Volunteers (UNV), UNICEF, and the United Nations Population Fund (UNFPA).[15] This contrasts with the lengthy and multi-agency UN response to the Chernobyl disaster.[16]

This mandate gap, which has left affected States largely struggling alone to tackle the harmful legacies of nuclear testing, must urgently be closed. Either relevant existing intergovernmental organizations need to be given the mandate to capacity-build and support national authorities in affected States with national needs assessments, environmental remediation and victim assistance, or a new, dedicated international body needs to be established and resourced adequately. Such an agency, which would be expected to develop, review, and share methods for carrying out national needs assessments, environmental remediation, and victim assistance in nuclear testing contexts, and facilitate cooperation between stakeholders, would likely have great impact on the current, unacceptable situation.

## The role of global civil society

Given the lack of external support and sometimes outright hostility from nuclear testing States, victims of nuclear weapon activities have established networks of mutual support. Military personnel involved in nuclear weapon testing have often joined other nuclear veterans in organizing associations, including the National Association of Atomic Veterans (NAAV) in the United States, the British Nuclear Test Veterans Association, the New Zealand Nuclear Test Veterans Association, the Fiji Nuclear Veterans Association, the Australian Ex-Services Atomic Survivors Association, and the Association des Vétérans des Essais Nucléaires (AVEN) in France. Mā'ohi personnel of the French Pacific nuclear tests organized the group Moruroa e Tatou. Legacy of the Atomic Bomb, Recognition For Atomic Test Survivors (LABRATS) International has worked to build connections between associations of veterans (as well as other nuclear survivors).

Civilian victims have also built support networks. Association 193 has been advocating that France pay compensation to the people of Mā'ohi Nui since 2014 while Moruroa e tātou initiated its own advocacy campaign in 2010. The Australian Nuclear Free Alliance (ANFA) brings together Aboriginal people and relevant civil society groups concerned about existing or proposed nuclear developments in Australia, 'particularly on Aboriginal homelands'.[17] The Alliance for Nuclear Accountability is a coalition of organizations working on the humanitarian and environmental legacies of nuclear complexes in the United States. The Tularosa Basin Downwinders Consortium seeks compensation for those living downwind of the Trinity test in New Mexico. MISA4thePacific (a student-led movement created by Marshallese students in Suva) and the Marshallese Educational Initiative have built connections between Marshallese people working on nuclear legacy issues.

In 2021, Peace Boat and the International Campaign to Abolish Nuclear Weapons (ICAN) hosted a World Nuclear Survivors Forum online to bring together nuclear survivors and impacted communities from around the world 'to virtually meet, learn about each other's situations and needs, and share various actions and initiatives'.[18] In-person meetings have been held on the sidelines of the TPNW's Meetings of States Parties. Responding to obstruction from nuclear testing States, civil society, academia, and the media have uncovered and highlighted the humanitarian and environmental consequences of nuclear weapon testing. For example,

15 UNDP, 'Enhancing Human Security in The Former Nuclear Test Site of Semipalatinsk', Report, 22 December 2014, at: https://bit.ly/4a1hx2C.
16 UNDP, 'Chernobyl', News release, 2024, at: https://bit.ly/4cxRrGj.
17 ANFA, 'About Us', 2021, at: https://anfa.org.au/about/.
18 Peace Boat, 'World Nuclear Survivors Forum 2021', at: https://nuclearsurvivors.org.

in 1982, the Pacific Conference of Churches published a primer on the effects of nuclear weapon activities in Oceania.[19] International Physicians for the Prevention of Nuclear War (IPPNW) and the Institute for Energy and Environmental Research (IEER) jointly conducted a landmark global survey in 1991 of the harms caused by nuclear weapon testing – *Radioactive Heaven and Earth: The Health and Environmental Effects of Nuclear weapon testing in, on and above the Earth*. On the sidelines of the 2000 Review Conference of the Treaty on the Non-Proliferation of Nuclear Weapons (NPT), civil society activists convened a Nuclear Truth Commission inspired by the South African Truth and Reconciliation Commission, hearing testimony from survivors of nuclear weapon activities.[20]

As discussed in the previous chapter, the Moruroa Files project, a collaboration between journalists and Princeton University, in 2021 made public documents previously classified secret by the French government, and used this information to demonstrate that fallout from the French nuclear tests in Mā'ohi Nui was more extensive and intense than the French government had previously admitted.[21] Recent independent research has also indicated that the harmful effects of the first US nuclear test, Trinity, and the subsequent atmospheric tests on US metropolitan territory, have been significantly underestimated.[22]

Survivors' associations have often connected with broader social movements for disarmament, decolonization, and human rights. In Kazakhstan, the Nevada-Semipalatinsk movement rallied successfully from 1989 to 1991 for an end to Soviet nuclear tests.[23] Beginning in the late 1970s, the Nuclear Free and Independent Pacific (NFIP) movement drew regional attention to injustices faced by nuclear-affected communities. The NFIP had broad support throughout Oceania, from the grassroots to the elite levels, building on regional ecumenical, labour union, feminist, youth, sports, and cultural networks. The Pacific Conference of Churches and its global partner, the World Council of Churches, played pivotal financial, logistical and moral roles in the NFIP.[24] ICAN has developed a website identifying the impacts of nuclear testing and efforts to address and resist it.[25]

## Progress in the UN General Assembly

It was not until the 2010 Review Conference of the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) that all of that treaty's States Parties acknowledged the 'catastrophic humanitarian consequences' of nuclear weapons. This resulted in a series of international 'Humanitarian Initiative' meetings in 2013–14, which considered the neglected scientific evidence on the humanitarian impact of nuclear weapons. These meetings culminated in a 'Humanitarian Pledge'—later passed as UN General Assembly Resolution 71/47—committing States to prohibit nuclear weapons and address the 'rights and needs of victims'. During the same session, the Assembly also passed Resolution 71/258, paving the way for the negotiation of the TPNW.

The TPNW was adopted on 7 July 2017 at a diplomatic conference established by the UN General Assembly. A total of 122 States, more than three-fifths of the world's total, voted in favour of its adoption. It is the first treaty to include obligations on States Parties to assist the victims of nuclear detonations and undertake

19 S. Siwatibau and B. D. Williams, *A Call to a New Exodus: An Anti-Nuclear Primer for Pacific Peoples*, Pacific Conference of Churches, Suva, 1982.
20 A. Goodman, 'Nuclear Truth Commission Meets at the UN'. Democracy Now!, 2000, at: https://bit.ly/48Cn6mB.
21 N. Ahmed *et al.*, 'Moruroa files: Investigation into French nuclear tests in the Pacific', at: https://moruroa-files.org.
22 L. M. M. Blume, 'Trinity Nuclear Test's Fallout Reached 46 States, Canada and Mexico, Study Finds', *The New York Times*, 20 July 2023, at: https://bit.ly/4fcwPDX.
23 T. Kassenova, 'How Kazakhstan Fought Back Against Soviet Nuclear Tests', Carnegie Endowment for International Piece, 2022, at: https://bit.ly/3IkFtlk.
24 S. Firth, Nuclear Playground, University of Hawaii Press, Honolulu, 1987; T. K. Teaiwa, 'Bikinis and Other S/pacific N/oceans', *The Contemporary Pacific*, Vol. 6, No. 1 (1994), 87–109; R. H. Smith, The Nuclear Free and Independent Pacific Movement after Muroroa, I. B. Tauris, London, 1997; and D. Robie, 'Niuklia Fri Pasifik', 2015, at: https://bit.ly/3V2GUN1.
25 ICAN Nuclear Test Impacts Map, at: https://bit.ly/4lPr2b4.

environmental remediation of contaminated areas. It also obligates States Parties in a position to do so to provide international cooperation and assistance to affected States Parties to fulfil these obligations.

No nuclear-armed State has yet adhered to the TPNW and several potential donor States also remain non-parties. Nevertheless, in 2022, the TPNW's First Meeting of States Parties adopted the Vienna Action Plan, which included a set of standards and principles to set the stage for implementation of these provisions. The Second and Third Meetings of States Parties addressed reporting requirements and the possibility of a trust fund for victim assistance and environmental remediation.[26]

The growing acknowledgement of the humanitarian consequences of nuclear weapon testing has begun to transform global norms on assistance to victims of nuclear weapon use and testing and on cooperation and assistance to this end. A repeating UN General Assembly resolution urges the international community to provide assistance to Kazakhstan in formulating and implementing special programmes and projects for the treatment and care of the affected population, as well as in efforts to ensure economic growth and sustainable development in the Semipalatinsk region. General Assembly resolutions on the 'Question of French Polynesia' have addressed the legacies of nuclear testing; the latest (at the time of writing) recognized the 'significant health and environmental impacts of nuclear testing' by France, as well as the 'consequences of those activities for the lives and health of the people, especially children and vulnerable groups'.[27] The resolution takes note of the efforts made by the administering Power concerning the recognition and compensation of victims of nuclear tests, and 'in that regard encourages the administering Power to take steps to this effect'.[28]

In December 2023 and then again in December 2024, the General Assembly adopted a resolution on 'Addressing the legacy of nuclear weapons: providing victim assistance and environmental remediation to Member States affected by the use or testing of nuclear weapons'.[29] The resolution, which had been championed by Kiribati and Kazakhstan and co-sponsored by both States Parties and States not party to the TPNW, notes the 'humanitarian provisions' of the TPNW (as well as the significance of a resolution in the UN Human Rights Council on the Marshall Islands[30]). It encourages further international cooperation to assist victims, and to 'assess and remediate environments contaminated by the use and testing of nuclear weapons'.

In supporting victim assistance and environmental remediation after nuclear testing, States would also make a meaningful contribution to promoting the universality of the Comprehensive Nuclear-Test-Ban Treaty (CTBT) by highlighting the ongoing harm from nuclear-weapons testing. Moreover, they would be implementing their commitments under the consensus outcome document issued by the 2010 NPT Review Conference, which encouraged States and international organizations 'to consider giving appropriate assistance' for remediation of areas affected by 'radioactive contaminants'.[31] The NPT Review Conference in August 2022 also saw unprecedented attention given to the harms from past testing of nuclear weapons. Though unadopted, the draft final document of the conference welcomed 'the increased attention in the last review cycle on assistance to the people and communities affected by nuclear weapons use and testing and environmental remediation following nuclear use and testing and calls on States Parties to engage with such efforts to address nuclear harm'. No State ultimately sought to block this paragraph.[32] While there has previously been some attention to addressing harm from nuclear legacies under the NPT's discussion of 'peaceful uses' of nuclear energy, victim

26 'Report of the Meeting of States Parties to the Treaty on the Prohibition of Nuclear Weapons (TPNW)', UN doc. TPNW/MSP/2022/6, 2022, at: https://bit.ly/46FzYLA.
27 UN General Assembly Resolution 78/91, adopted without a vote on 7 December 2023, thirteenth preambular para.
28 Ibid., operative para. 10.
29 UN General Assembly Resolutions 78/240 and 79/60.
30 Human Rights Council Resolution 57/26.
31 2010 Review Conference of the Parties to the NPT, Final Document, Doc. NPT/CONF.2010/50, New York, 2010, at: https://bit.ly/4nb6Pgh, Vol. I, Part I, para. 71.
32 2020 Review Conference of the Parties to the NPT, Draft Final Document, Doc. NPT/CONF.2020/CRP.1/Rev.2, New York, 25 August 2022, at: https://bit.ly/4pdkYeK, para. 125.

assistance and environmental remediation have not seen significant attention nor been considered for mention in the NPT's outcome document under its disarmament pillar before.

Ultimately, this increased attention to the ongoing needs for environmental remediation and victim assistance will only have meaning if it is translated into actions on the ground that make a demonstrable positive difference in affected people's lives.

## Nuclear colonialism

Leila Hennaoui

The term 'nuclear colonialism' encapsulates an intersection of power, technology, and colonial ambitions, resulting in the profound oppression of Indigenous communities and their lands. Historically, this complex concept unfolds within a colonial framework, where nuclear processes—the extraction of radioactive minerals, nuclear weapon testing, and the disposal of nuclear waste—are intertwined. In particular, its effects are manifested in Algeria, Australia, Mā'ohi Nui (French Polynesia), and the Marshall Islands, as described in the respective case studies in this report. The origins of the term can be traced back to the early 1990s.[33] Military advancements and geopolitical transformations marked a new form of colonial oppression, illustrating the profound impact of the nuclear age on the dynamics of colonialism.[34] The processes of radium and uranium extraction, weapons testing, and radioactive waste disposal underscore the long-term consequences of nuclear activities, including the far-reaching exploitation and deep-seated inequalities inherent in nuclear colonialism.

Nuclear colonialism is a nuanced and multifaceted concept, extending beyond environmental injustice. At its core, it is a manifestation of historical and ongoing colonial violence, where governments and corporations target Indigenous Peoples and their lands to sustain the nuclear production process.[35] This exploitation is embedded within a broader tapestry of oppression – one that is marked by dispossession, segregation, assimilation, and violence. It emphasizes the reality that nuclear colonialism is not an isolated occurrence but an intrinsic part of a continuing history of injustice.[36] This form of colonialism has inflicted lasting harm on subjugated groups. Their lands and labour were exploited and, as a result, they still bear the brunt of radioactive pollution.[37] Building upon this tangible exploitation, nuclear colonialism unfolds into a multifaceted phenomenon, serving as an extension of colonization by creating a system where the colonizing nuclear State violates and extracts value from the land and lives of Indigenous Peoples. Colonizing nuclear-armed States employ obscurities to conceal the harms caused by their nuclear activities, emphasizing dominance and national security narratives while downplaying the true impact on marginalized communities.[38] The intertwining of practical exploitation and declarative strategies underscores the complex and insidious nature of nuclear colonialism.

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33 W. Churchill and W. LaDuke, 'Native North America: The Political Economy of Radioactive Colonization', in M. A. Jaimes (ed.), *The State of Native America: Genocide, Colonization and Resistance*, South End Press, Boston, MA, 1992, 241–66.

34 Urwin, 'Chain Reactions: Nuclear Colonialism in South Australia', 10.

35 D. Endres, 'From Wasteland to Waste Site: The Role of Discourse in Nuclear Power's Environmental Injustices', *Local Environment*, Vol. 14, No. 10 (2009), 921.

36 J. Urwin, 'Chain Reactions: Nuclear Colonialism in South Australia', PhD thesis, The Australian National University, Canberra, 2023, 4.

37 J. G. Warren, 'Apprehending the Slow Violence of Nuclear Colonialism: Art and Maralinga', in N. Marczak and K. Shields (eds.), *Genocide Perspectives VI: The Process and the Personal Cost of Genocide*, UTS ePRESS, Sydney, 2020, 137.

38 L. Hennaoui and M. Nurzhan, 'Dealing with a Nuclear Past: Revisiting the Cases of Algeria and Kazakhstan through a Decolonial Lens', *The International Spectator*, Vol. 58, No. 4 (2023), 93–94.

# Part II

# Impacts – The State of Scientific Knowledge

**Living with the Consequences:** In this photograph taken on 17 October 2016, Berik Syzdykov sits at the kitchen table in the apartment he shares with his mother in Semey, Kazakhstan. Syzdykov was born with congenital anomalies after his pregnant mother was exposed to radiation from a nuclear test conducted by the Soviet Union at the Semipalatinsk test site in Kazakhstan. He is blind, and has had multiple surgeries to address facial tumours. For people like Syzdykov, the ongoing impact of nuclear testing is not theoretical — it is a lived reality. Photograph © Philip Hatcher-Moore.

Chapter 4:

# The Environmental Effects of Nuclear Detonations

Friederike Friess

Nuclear testing has profound and long-lasting environmental consequences, primarily due to the release and global dispersion of radioactive material. These effects vary by explosion type, altitude, yield, and geography, with fallout contaminating land, water, and ecosystems for decades or longer. Fallout can be local or global, depending on whether material reaches the stratosphere. Subsurface and underwater detonations also present risks to groundwater and marine life. Historical examples like Bikini Atoll and Mā'ohi Nui (French Polynesia) demonstrate persistent environmental contamination, which is often underestimated or obscured by governments. Although nuclear accidents such as Chernobyl offer insights into radioactive effects, nuclear explosions often release more energy and differ in impact. Studies show radiation affects not just humans but entire ecosystems. Beyond radioactivity, nuclear warfare could disrupt global climate patterns, triggering a nuclear winter with catastrophic consequences for ecosystems and global food production.

Nuclear testing has long-term environmental consequences. Since these consequences are primarily caused by the dispersion of radioactive material, it is essential to understand the mechanisms by which nuclear explosions cause radioactive contamination. This chapter provides an overview of the current state of research on the topic and explains which factors are relevant for assessing the associated consequences. Beyond the testing of nuclear weapons, hostile use would obviously generate huge release of radioactive material. Other cases of radioactive contamination are nuclear accidents, mostly in the civilian sector, such as occurred at Chernobyl and Fukushima. Research on such incidents offers important insights for a better understanding of the consequences of nuclear testing.

## The long-term environmental consequences of a nuclear detonation

The detonation of a single nuclear weapon can unleash a cascade of environmental consequences, ranging from immediate, local devastation by fire and blast to long-lasting, potentially global effects. Immediate effects are not covered here, but rather the enduring impacts of nuclear explosions resulting from the dispersion of radioactive materials in the environment. These materials consist of multiple radioactive isotopes with various half-lives (isotopes are different versions of the same element that have different numbers of neutrons in the atomic nucleus). Radioactive material decays, which is to say, it releases particles and energy and changes into other material. The timescales over which these changes occur differ, depending on the isotope's half-life. After a nuclear explosion, radiation can continue to be a hazard for days, years, decades, or even millennia.

Beyond radioactivity, nuclear weapon use could disrupt global climate patterns, triggering a phenomenon known as a nuclear winter. This occurs when large amounts of smoke and dust from fires and explosions block sunlight from reaching the Earth's surface, causing temperatures to plunge, thereby disrupting agricultural output. A nuclear winter would have catastrophic consequences for ecosystems and food production around the world.[1]

## Radiation exposure caused by nuclear explosions

Various sources of radioactive material affect the aftermath of a nuclear explosion. First, fission products arise from the splitting of the fissile material contained within the weapon. This is the case for both atomic (fission) and hydrogen (fusion) bombs. Second, unfissioned fissile material (uranium and plutonium) also contributes to the radioactive residue. Third, the explosion causes neutron-induced activation products. The fission process releases neutrons, which then interact with formerly stable isotopes. This interaction transforms these isotopes into radioactive forms in a process known as activation. Residual radiation from these different sources can be differentiated into three types: induced radiation in the air, induced radiation on the ground, and fallout (of different kinds).[2]

In the air, neutron absorption produces carbon-14, which has a half-life of almost 6,000 years. Atmospheric testing in the 1950s almost doubled carbon-14 concentration in the atmosphere.[3] Induced radiation in the air has far-reaching consequences, potentially affecting the entire globe, while induced radiation on the ground is

1 A. Robock, 'Nuclear Winter', *WIREs Climate Change*, Vol. 1, No. 3 (2010), 418–27, at: https://bit.ly/3u06gQv (subscription required); L. Xia, A. Robock, K. Scherrer, C. S. Harrison, B. L. Bodirsky, I. Weindl, J. Jägermeyr, C. G. Bardeen, O. B. Toon, and R. Heneghan, 'Global food insecurity and famine from reduced crop, marine fishery and livestock production due to climate disruption from nuclear war soot injection', *Nature Food*, Vol. 3 (2022), 586–96, at: https://bit.ly/3ZTpQce.

2 Office of the Deputy Assistant Secretary of Defense for Nuclear Matters, *Nuclear Matters Handbook 2020*, Rev. Edn, Washington DC, 2020, 177.

3 R. Prăvălie, 'Nuclear Weapons Tests and Environmental Consequences: A Global Perspective', *Ambio*, Vol. 43, No. 6 (October 2014), 729–44.

concentrated primarily in the immediate vicinity of the detonation site. It is caused by neutron capture of light materials in the soil and dissipates to safe levels within a matter of weeks.[4]

In general, fallout consists of all kinds of radioactive materials that fall back to the (earth) surface after a nuclear explosion. When a nuclear explosion happens at ground level (surface burst), large quantities of soil or water are vaporized in the fireball. These materials combine with fission products and other radioactive materials. The resulting particles are initially carried up high into the atmosphere by the mushroom cloud, but eventually, after a certain amount of cooling, the material falls back to the Earth. Once it has settled on the ground and surface of buildings and vegetation, the radiation it produces is also called 'groundshine', since the radiation 'shines' from the ground. (It may also settle on the ocean.) Local fallout, sometimes extending over hundreds of kilometres out from the detonation site, can render large areas of land uninhabitable for extended periods.

For this type of fallout, isotopes with a rather short half-life, such as iodine-131 with a half-life of eight days, are of great importance.[5] Iodine-131 in the fallout can be inhaled or ingested in water or food products. For example, iodine-131 readily concentrates in cow's milk, thereby entering the food chain and eventually accumulating in the thyroid glands of humans and animals who consume it.[6] Radioactive material absorbed into the body through consumption, inhalation, or direct contact with skin poses a significant long-term risk, as it can damage internal organs.

Radioactive debris from a nuclear explosion that is not deeply buried underground disperses into the atmosphere. Parts that do not fall to the ground quickly can drift there for months or even years before being deposited as fallout – on a global scale. Therefore, isotopes with a half-life of about 30 years, such as strontium-90 and caesium-137, are important for assessing contamination by global fallout.[7] The extent to which the effects of nuclear weapon tests are confined to a specific region or spread globally largely depends on the altitude at which the radioactive particles are dispersed into the atmosphere.

Tropospheric fallout, also known as intermediate-time-scale fallout, is a type of radioactive fallout that occurs when radioactive particles from a nuclear explosion are dispersed in the lower part of the atmosphere, known as the troposphere. These particles are typically smaller than those that cause local fallout, and thus can travel long distances before settling on the ground, which typically occurs within months.

Stratospheric fallout occurs when radioactive particles are dispersed in the upper part of the atmosphere, known as the stratosphere. These particles are typically tiny and light, even smaller than for tropospheric fallout, and can be carried by winds for many years before eventually settling on the ground. Stratospheric fallout can be distributed more widely and persist for longer periods than tropospheric fallout. Typically, this type of fallout is also more difficult to detect and monitor. The transition between the troposphere and stratosphere, called the tropopause, varies between latitudes and seasons. Almost all global fallout can be attributed to (high) air bursts. For those explosions, the altitude ranges from a few hundred metres to tens of kilometres, depending on the specific weapon design and the desired effects. Low-altitude bursts produce the most immediate and widespread destruction, while high-altitude bursts generate more widely dispersed radioactive fallout.

For ground or surface bursts, the fireball touches the ground and causes a shock wave. In this case, destruction is concentrated at ground zero and the fallout is more localized. All kinds of surface or near-surface explosions create craters—or potentially even partially collapsed mountains—that alter the environment.

4 Office of the Deputy Assistant Secretary of Defense for Nuclear Matters, *Nuclear Matters Handbook 2020*, 177.
5 S. Glasstone and P. J. Dolan, *The Effects of Nuclear Weapons*, 3rd Edn, US Department of Defense and US Energy Research and Development Administration, 1977, 442.
6 G. F. Fries, F. J. Burmann, C. L. Cole, J. A. Sims, and G. E. Stoddard, 'Radioiodine in Milk of Cows Under Various Feeding and Management Systems', *Journal of Dairy Science*, Vol. 49 (1966), 24–27, at: https://bit.ly/48E5h7w.
7 UNSCEAR, 'Sources and effects of ionizing radiation: 2000 Report', Vol. I, Annex C, United Nations, New York, 2000.

Subsurface bursts are typically detonated at a depth of several hundred metres. Those deeply buried explosions are significantly different from surface and air nuclear bursts in terms of their effects, since almost all the energy is contained.[8] The initial fireball forms a cavity. It can melt and vaporize the surrounding rock. The high pressure of gas in the cavity might lead to the venting of radioactive material to the surface through cracks in the ground. When the cavity cools, the pressure declines and the cavity collapses. Radioactivity is mostly trapped in the solidified rock but can migrate.[9] If a subsurface nuclear explosion occurs near a water source, such as a river or aquifer, the radioactive material can contaminate the water. This needs to be studied and monitored in each case. Depending on the geological strata, the heat and pressure from a subsurface nuclear explosion can also release methane, a potent greenhouse gas, into the atmosphere.

The explosive yield has the most obvious impact on a nuclear weapon's effects. Thus, under otherwise identical conditions, a more powerful weapon will have a larger impact on the environment. The topography and landscape features determine how the energy of the explosion can spread.[10] Flat terrain may produce a large crater with uniformly spreading blast waves, causing widespread destruction while mountains can cause resonance and amplification, resulting in complex damage patterns. Heat can ignite forest fires. Urban areas suffer from building collapses, fires, and fallout contamination. For underwater explosions, a shock wave similar to the blast wave is formed in the body of water. If the water is shallow enough, a large surface wave might be produced. Radioactive material is transferred into the marine environment, where it is diluted or bonds to porous surfaces such as corals. Strontium and caesium compounds are generally soluble and available for uptake by plants and wildlife.[11] This way, radioisotopes can enter the food chain and potentially remain there throughout their half-lives.

Weather conditions significantly influence fallout, especially regional fallout. Strong winds can amplify the blast wave, spread radioactive fallout, and fan fires. Favourable winds can divert fallout away from populated areas as well as towards them. Rainfall can wash out fallout particles up to a certain altitude and suppress the spread of fire.[12] Wet, cloudy conditions generally mitigate the dispersion of nuclear explosions, since radioactive fallout is trapped in the water droplets that fall to the ground as rain. The production of radioactive hotspots by precipitation events is possible even at considerable distances.

The first nuclear weapon test was conducted with a comparably low yield at ground level, thus most of the nuclear fallout happened close to the test site. Initial predictions estimated that fallout would be limited to 320 kilometres.[13] At the onset of atmospheric testing, radioactive dust was identified at greater distances from the test sites, notably affecting the Kodak manufacturing plant in the United States located more than 3,200 kilometres away.[14] After that incident, it was obvious that the effects of nuclear weapons extend far beyond the immediate blast site and fallout zone. This triggered the first monitoring programmes for global nuclear fallout.[15] Strontium-90 is the isotope for which the best global measurements for hemispheric deposition exist.[16]

8 Glasstone and Dolan, *The Effects of Nuclear Weapons*, 3rd Edn, 61.
9 Ibid.
10 Ibid., 92*ff*.
11 J. M. Fenelon, D. S. Sweetkind, and R. J. Laczniak, 'Groundwater flow systems at the Nevada Test Site, Nevada: A synthesis of potentiometric contours, hydrostratigraphy, and geologic structures', Professional Paper 1771, US Geological Survey, United States, 2010; and J. F. Wild, W. Goishi, J. W. Meadows, M. N. Namboodiri, and D. K. Smith, 'The LLNL Nevada Test Site Underground Radionuclide Source-Term Inventory', in C. S. Shapiro (ed.), *Atmospheric Nuclear Tests*, Springer, Berlin/Heidelberg, 1998, 69–77, at: https://bit.ly/3Hw8TfO.
12 Glasstone and Dolan, *The Effects of Nuclear Weapons*, 3rd Edn, 442.
13 W. R. Kennedy, 'Fallout Forecasting-1945 Through 1962', Report No. LA-10605-MS, Los Alamos National Laboratory, United States, 1986.
14 P. Edwards, *A Vast Machine*, MIT Press, Boston, MA, 2010, Chap. 8, 'Nuclear Weapons Tests and Global Circulation Tracers', 207–15.
15 Ibid.
16 UNSCEAR, 'Sources and effects of ionizing radiation', Report, 2000.

## Global effects of nuclear explosions

Even today, stratospheric fallout from nuclear weapon tests and nuclear accidents is the most significant cause of exposure of the world population to human-made environmental sources of radiation. Since most of the tests and accidents took place in the northern hemisphere, this region is more contaminated by the presence of radioactive isotopes (e.g., carbon-14, caesium-137, and strontium-90) than is the southern hemisphere.[17] Carbon-14 amounts to about 70 per cent of the total effective dose in the long term. Only the entry into force of the Partial Test Ban Treaty, which prohibits all nuclear testing except for underground testing, limited the influx of radioactive particles into the atmosphere by nuclear explosions.[18]

Due to significantly increased—doubled—amounts of carbon-14 in the atmosphere owing to nuclear testing, the amount naturally transferred to the ocean also increased. Since most of the world is covered by water, a significant share of the radionuclides has been transferred into the marine environment. As a consequence, most of the carbon-14 produced by nuclear testing is stored in the oceans.[19] Humans can be exposed to radioactivity due to accumulation in marine life as well, but for the global population, the average annual effective dose lies well below generally accepted limits.[20] Looking at other isotopes, a great part of marine contamination with caesium-137 can be attributed to reprocessing facilities.[21]

The vast natural radiation present even before nuclear weapon tests makes it challenging to identify testing-induced cases.[22] There is a limited (but increasing) amount of data on low-level radiation effects. Since the 1950s, the scientific community has adopted a linear no-threshold (LNT) for low-level radiation.[23] These factors pose significant challenges in assessing the potential environmental and health impacts of radiation caused by nuclear explosions, even though the effects of these explosions can still be detected decades (or longer, such as in the case of carbon-14) after the detonation.

## Local effects of nuclear explosions

Recent studies have revealed that Bikini Island in Bikini Atoll, where 23 nuclear devices were detonated between 1946 and 1958, still exhibits elevated background gamma radiation levels. These are nearly twice the maximum allowable limit for total exposure (not just background gamma radiation) set by the Marshall Islands government and the United States.[24] This contamination is evident in the soil, where various fruits grown in the area are contaminated with caesium-137.[25] The ocean sediment and the water surrounding the atoll are also heavily contaminated, not just with the relatively short-lived caesium-137 but also with long-lived isotopes

17 Prăvălie, 'Nuclear Weapons Tests and Environmental Consequences: A Global Perspective'; and UNSCEAR, 'Sources and effects of ionizing radiation', Report, 2000.

18 I. Levin, T. Naegler, B. Kromer, M. Diehl, R. J. Francey, A. J. Gomez-Pelaez, L. P. Steele, D. Wagenbach, R. Weller, and D. E. Worthy, 'Observations and modelling of the global distribution and long-term trend of atmospheric 14CO2', *Tellus B: Chemical and Physical Meteorology* Vol. 62 (2010), 26–46, at: https://bit.ly/4b9j7QO.

19 Prăvălie, 'Nuclear Weapons Tests and Environmental Consequences: A Global Perspective'.

20 H. D. Livingston and P. P. Povinec, 'Anthropogenic marine radioactivity', *Ocean & Coastal Management*, Vol. 43 (2000), 689–712, at: https://bit.ly/47LfZb1.

21 Prăvălie, 'Nuclear Weapons Tests and Environmental Consequences: A Global Perspective'.

22 UNSCEAR, 'Sources, Effects and Risks of Ionizing Radiation, UNSCEAR 2012 Report: Report to the General Assembly, with Scientific Annexes A and B', UNSCEAR Reports, New York, 2015, at: https://bit.ly/3Sp91Ed.

23 National Research Council, *Health Risks from Exposure to Low Levels of Ionizing Radiation: BEIR VII Phase 2*, National Academies Press, Washington, DC, 2006, at: https://bit.ly/3vSlA1U; and J. S. Walker, *Permissible Dose: A History of Radiation Protection in the Twentieth Century*, University of California Press, Berkeley CA, 2000.

24 M. K. I. L. Abella, M. R. Molina, I. Nikolić-Hughes, E. W. Hughes, and M. A. Ruderman, 'Background gamma radiation and soil activity measurements in the northern Marshall Islands', *Proceedings of the National Academy of Sciences*, Vol. 116 (2019), 15425–34, at:_https://bit.ly/3SuMiXA.

25 C. E. W. Topping, M. K. I. L. Abella, M. E. Berkowitz, M. R. Molina, I. Nikolić-Hughes, E. W. Hughes, and M. A. Ruderman, 'In situ measurement of cesium-137 contamination in fruits from the northern Marshall Islands', *Proceedings of the National Academy of Sciences*, Vol. 116 (2019), 15414–19, at: https://bit.ly/42pNhM5.

such as plutonium-239 (which has a half-life of 24,000 years), plutonium-240 (a half-life of 6,500 years), and americium-241 (a half-life of 430 years).[26] Even with the naked eye, it is readily evident that this is an unusual location: the palm trees, for instance, are meticulously arranged in rows. They were planted in the 1960s as part of a restoration project.[27] Studies on atmospheric nuclear testing in Māʼohi Nui (French Polynesia) between 1966 and 1974 that drew on recently declassified information showed that government estimates of effective doses received by the public at the time were significantly underestimated.[28]

For many sites, however, no comprehensive data on radioactive contamination and the effects of nuclear testing on the environment are available.[29] One reason is the pressure for secrecy and the resistance of the nuclear-armed States in particular to allow open scientific investigations on the effects of nuclear explosions.[30] Nuclear accidents and nuclear explosions both release radioactive material into the environment, and studying the effects of nuclear accidents can provide insights into the potential consequences of nuclear explosions. With particular respect to the Chernobyl nuclear accident, a vast amount of literature considers the (environmental) consequences and the conditions in the exclusion zone.[31] Certain key differences between the two types of events—nuclear power plant accidents and nuclear detonations—can, though, influence the extent of impacts.

In particular, nuclear explosions are generally more powerful and often occur in the air, whereas nuclear accidents take place on the ground. In contrast, nuclear explosions are also often more controlled than nuclear accidents, which can lead to greater predictability regarding the amount and composition of radioactive material released into the environment. Interestingly, a substantial proportion of measured radiation exposure was originally attributed not to atmospheric nuclear weapon tests but to reactor accidents. This applies, for example, to contaminated wild boar meat in Central Europe, which has been linked to the Chernobyl nuclear accident. However, recent research has revealed that a significant portion of the contamination stems from nuclear weapon testing.[32]

In addition to studying the harmful effects of radiation on humans, researchers have also been investigating the consequences of radiation exposure on plants and animals since the early days of nuclear testing. One of the first surveys concluded that nuclear explosions only lead to ‘minor, transient disturbance to the plant and animal populations’.[33] This view is now outdated, with a growing body of research demonstrating the impact

26 E. W. Hughes, M. R. Molina, M. K. I. L. Abella, I. Nikolić-Hughes, M. A. Ruderman, ‘Radiation maps of ocean sediment from the Castle Bravo crater’, *Proceedings of the National Academy of Sciences*, Vol. 116 (2019), 15420–24, at: https://bit.ly/3Ui7n8C.

27 S. Scott, ‘What Bikini Atoll Looks Like Today’, *Stanford Magazine*, Stanford, CA, 2017, at: https://bit.ly/4950fAY.

28 S. Philippe, S. Schoenberger, and N. Ahmed, ‘Radiation Exposures and Compensation of Victims of French Atmospheric Nuclear Tests in Polynesia’. *Science & Global Security*, Vol. 30 (2022), 62–94, at: https://bit.ly/3SsSEGL.

29 Scientific Advisory Group (SAG), ‘Report of the Scientific Advisory Group on the status and developments regarding nuclear weapons, nuclear weapon risks, the humanitarian consequences of nuclear weapons, nuclear disarmament and related issues’, Second Meeting of States Parties, UN doc. TPNW/MSP/2023/8, 2023.

30 M. B. Bolton and E. Minor, ‘Addressing the Ongoing Humanitarian and Environmental Consequences of Nuclear Weapons: An Introductory Review’, *Global Policy*, Vol. 12 (2021), 81–99, at: https://bit.ly/3tVS0s2.

31 See, e.g., M. Balonov, ‘Health Effects of Reactor Accidents with Special Regards to Chernobyl: – A Review Paper’, *Hoken Butsuri*, Vol. 54 (2019), 161–71, at: https://bit.ly/4b7mOXd; I. Fairlie, ‘Chernobyl: consequences of the catastrophe for people and the environment’, *Radiation Protection Dosimetry* Vol. 141 (2010), 97–101, at: https://bit.ly/3U6Xo6h; A. Karaoglou, G. Desmet, G. N. Kelly, and H. G. Menzel, ‘The radiological consequences of the Chernobyl accident’, Report No. EUR 16544 EN, European Commission and the Belarus, Russian and Ukrainian Ministries of Chernobyl Affairs, Emergency Situations and Health, Brussels, 1996; G. Steinhauser, A. Brandl, and T. E. Johnson, ‘Comparison of the Chernobyl and Fukushima nuclear accidents: A review of the environmental impacts’, *Science of The Total Environment*, Nos. 470–471 (2014), 800–17, at: https://bit.ly/427JDWG; UN Chernobyl Forum Expert Group ‘Environment’, ‘Environmental Consequences of the Chernobyl Accident and their Remediation: Twenty Years of Experience’, World Health Organization (WHO), 2006 (and references therein).

32 F. Stäger, D. Zok, A.-K. Schiller, B. Feng, and G. Steinhauser, ‘Disproportionately High Contributions of 60-Year-Old Weapons-137Cs Explain the Persistence of Radioactive Contamination in Bavarian Wild Boars’, *Environmental Science & Technology*, Vol. 57 (2023), 13601–11, at: https://bit.ly/3ScoZjS.

33 DNA, ‘Operation Crossroads’, US Defense Nuclear Agency, United States, 1946, p. 158.

of ionizing radiation on the ecosystem.[34] Radiation effects for non-human species living in contaminated areas are discussed in Chapter 6 of this report.

Already in 1973, it was noted that indirect effects of the shock wave from nuclear tests had to be considered. This refers especially to the loss of fish or other marine organisms that are important resources for other species.[35] Using the French underground nuclear testing programme at Moruroa Atoll as evidence, however, it was shown later that impacts due to the physical shockwaves were short-term and that marine life populations are able to recover, provided that the integrity of the habitat is maintained and migration from neighbouring sites is possible.[36] Further, at the Bikini Atoll coral assemblage, about 70 per cent of the species assessed in 2002 were also recorded before nuclear testing.[37] Coral reefs are already under attack from other stressors, such as carbon dioxide emissions, leading to ocean acidification and rising temperatures, as well as human developments in the area.[38] Those stressors can interact in multiple ways,[39] making it difficult to attribute certain observations, such as a reduction in species, to nuclear testing or any one of the other stressors.

Obviously, detonation of a nuclear weapon represents a serious threat to local biodiversity.[40] That said, the subsequent, near absence of human beings might in fact benefit animals that are threatened by human activity.[41] There is contradictory data on the effect of ionizing radiation on wildlife, based on research conducted in the Chernobyl Exclusion Zone (CEZ), which has been largely untouched by humans since 1986. While some find positive effects on biodiversity,[42] others point to increased mutation rates due to radiation.[43] As an example, for dogs, it has been shown that animals living within an area with higher radiation levels are genetically distinct from dogs sampled outside the disaster site.[44] In other cases, the relationship between the release of radioactivity and observed effects is not as clear. In any case, more research is needed to better understand the consequences of radiation, especially in low doses.

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34 G. Cannon and J. G. Kiang, 'A review of the impact on the ecosystem after ionizing irradiation wildlife population', *International Journal of Radiation Biology*, Vol. 98 (2022), 1054–62, at: https://bit.ly/42878iu; M. Fukumoto (ed.), *Low-Dose Radiation Effects on Animals and Ecosystems: Long-Term Study on the Fukushima Nuclear Accident*, Springer, Singapore, and references therein; and International Atomic Energy Agency (IAEA), 'Effects of ionizing radiation on plants and animals at levels implied by current radiation protection standards', Technical Reports Series No. 332, IAEA, Vienna, 1992.

35 C. A. Simenstad, 'Biological Effects of Underground Nuclear Testing on Marine Organisms', Fisheries Research Institute, University of Washington, 1973, available at: https://bit.ly/3HsvZUI.

36 S. Planes, R. Galzin, J.-P. Bablet, and P. F. Sale, 'Stability of Coral Reef Fish Assemblages Impacted by Nuclear Tests', *Ecology*, Vol. 86 (2005), 2578–85.

37 Z. T. Richards, M. Beger, S. Pinca, and C. C. Wallace, 'Bikini Atoll coral biodiversity resilience five decades after nuclear testing', *Marine Pollution Bulletin*, Vol. 56 (2008), 503–15, at: https://bit.ly/49n4kRd.

38 J. V. Johnson, J. T. A. Dick, D. Pincheira-Donoso, 'A global analysis of coral bleaching patterns in association with mangrove environments under global warming', *Ecography*, 2023, at: https://bit.ly/3OdbJu8.

39 L. H. Pendleton, O. Hoegh-Guldberg, C. Langdon, A. Comte, 'Multiple Stressors and Ecological Complexity Require a New Approach to Coral Reef Research', *Frontiers in Marine Science*, Vol. 3 (2016).

40 C. Bonacic, R. A. Medellin, W. Ripple, R. Sukumar, A. Ganswindt, S. M. Padua, C. Padua, M. C. Pearl, L. F. Aguirre, L. M. Valdés, D. Buchori, J. L. Innes, J. T. Ibarra, R. Rozzi, and A. A. Aguirre, 'Scientists warning on the ecological effects of radioactive leaks on ecosystems', *Frontiers in Ecology and Evolution*, Vol. 10 (2023); and M. J. Lawrence, H. L. J. Stemberger, A. J. Zolderdo, D. P. Struthers, and S. J. Cooke, 'The effects of modern war and military activities on biodiversity and the environment', *Environmental Review*, Vol. 23 (2015), 443–60, at: https://bit.ly/3UeKdQD.

41 H. Hong, 'Radioactive Fish and Militarized Honeybees: The U.S. Nuclear Program's Unknown Impact on Ecosystems', *Pacific Standard*, 25 January 2017, at: https://bit.ly/47QFrvQ.

42 M. Aliyev, 'How Chernobyl has become an unexpected haven for wildlife', UNEP, 16 September 2020, at: https://bit.ly/48JC0Z0; Balonov, 'Health Effects of Reactor Accidents with Special Regards to Chernobyl: 'A Review Paper'.

43 A. P. Møller and T. A. Mousseau, 'Strong effects of ionizing radiation from Chernobyl on mutation rates', *Scientific Reports*, Vol. 5 (2015), Art. No. 8363, at: https://bit.ly/3xxHyZa.

44 G. J. Spatola, R. M. Buckley, M. Dillon, E. V. Dutrow, J. A. Betz, M. Pilot, H. G. Parker, W. Bogdanowicz, R. Thomas, I. Chyzhevskyi, G. Milinevsky, N. Kleiman, M. Breen, E. A. Ostrander, and T. A. Mousseau, 'The dogs of Chernobyl: Demographic insights into populations inhabiting the nuclear exclusion zone', *Science Advances*, Vol. 9, No. 9 (March 2023), at: https://bit.ly/3u2ZJo0.

Chapter 5:

# The Impact of Climate Change on Nuclear Risks

Linsey Cottrell

The adverse effects of climate change are already evident around the globe. Climate change will alter conditions at former nuclear test sites, influencing the risks they pose to people and to the wider ecosystem. Climate change will affect patterns of precipitation and temperatures, resulting in sea level rise and the creation of new or accelerated pathways through which radionuclides and other non-radiological contaminants could be mobilized from affected sites. Climate change can even result in large-scale shifts in community and ecosystem composition, which may affect their susceptibility to environmental contamination. Guidance is emerging on how to incorporate climate change into environmental risk assessment, although implementation is complicated due to research gaps and uncertainties. Only the Marshall Islands is considered to have incorporated the legacy of nuclear testing into its current national climate adaptation strategy.

The adverse effects of anthropogenic climate change are already evident around the globe. The World Meteorological Organization (WMO) had reported that 2023 was the hottest year on record, with greenhouse gas levels continuing to increase, record sea surface temperatures and sea-level rise, record low Antarctic sea ice, and multiple extreme weather events.[1] A new record was set the following year, with 2024 said by the WMO to be 'likely the first calendar year to be more than 1.5°C above the pre-industrial era'.[2] Warming and weather pattern changes can cause far ranging climate-related impacts including flooding, landslides, droughts, landscape fires, and soil erosion. Even with cuts to current levels of greenhouse gas emissions, climate change will still occur given historic emissions. The scale and extent of climate-change impacts depend on future emissions and the efficacy of climate-adaptation measures.

Climate change will alter conditions at former nuclear test sites, influencing the risks they pose to people and to the wider ecosystem. Current climatic conditions at the test sites are diverse, varying from arid, steppe, and permafrost environments to tropical islands. Climate change will affect patterns of precipitation and temperatures, resulting in sea-level rise and, in turn, the creation of new or accelerated pathways through which radionuclides and other non-radiological contaminants could be mobilized from affected sites. Climate change will also influence the behaviour and fate of radionuclides and other contaminants, as well as changes in soil and plant attributes which may alter the transfer of radioactivity in the environment.[3] Climate change can even result in large-scale shifts in community and ecosystem composition, which may affect their susceptibility to environmental contamination.

Risk assessment must take account of the different exposure scenarios (underground and atmospheric nuclear weapon tests) as well as the potential risk from the release or transportation of radionuclides and other contaminants due to physical landform changes or changes in climatic conditions. Risk assessment should consider actual or anticipated climate change, its effect on contamination sources, exposure pathways and receptors, and the durability and resilience of remediation or management options.[4] A review of the long-term performance of any cover or containment systems is important, especially where their physical integrity could be vulnerable to climate change and extreme weather events. By adopting conservative models and a precautionary approach, uncertainty in future climatic conditions can also be addressed.

## Guidance on assessment of climate change risks

Practitioner guidance on land contamination and accounting for the potential effects of climate change is available,[5] but research is ongoing to further understand the implications for risk assessment. For example, United Kingdom (UK) guidance highlights the importance of taking climate change into account,[6] and United States (US) guidance is available on considering climate effects when evaluating contaminated sites and implementing remedial strategies.[7] Current guidance highlights the importance of integrating climate impacts and the potential need to refine existing assessments. Further research on the impact of climate change on environmental radiochemistry is required, including on how the inclusion of climate impact should affect policies governing the management of contamination.[8]

1 WMO, '2023 shatters climate records, with major impacts', Press Release, 30 November 2023, at: https://bit.ly/3VbzoiJ.
2 WMO, 'State of the Global Climate 2024', 19 March 2025, at: https://bit.ly/3UG9thA.
3 P. Yadav and B. Singh, 'Radioecology: dissecting complexities of radionuclide transfer under climate change', *Global Climate Change*, 2021, Art. 13, 297–320.
4 Society of Brownfield Risk Assessment (SoBRA), 'The Climate Emergency: Practical Considerations in Brownfield Risk Assessment', Summer Workshop 2022 Report, Version 1.1, June 2023, at: https://bit.ly/3TuuRWr.
5 SoBRA, 'Guidance on Assessing Risk to Controlled Waters from UK Land Contamination under Conditions of Future Climate Change', Version 1, August 2022, at: https://bit.ly/49KGlM2.
6 UK Government, 'Land Contamination Risk Assessment (LCRM)', 2023, at: https://bit.ly/3T8CbGQ; and Sustainable Remediation Forum (SuRF) UK, 'Resilience and Adaptation for Sustainable Remediation', SuRF UK Bulletin 5, 2022, at: https://bit.ly/3Tv5eWG.
7 American Society for Testing and Materials, *Standard Guide for Remedial Action Resiliency to Climate Impacts*, ASTM E3249-21, 2021, at: https://bit.ly/3T8cG8x; and Interstate Technology and Regulatory Council, *Sustainable Resilient Remediation*, 2021, at: https://bit.ly/49MPvb2.
8 G. J. P. Deblonde, A. B. Kersting, and M. Zavarin, 'Open questions on the environmental chemistry of radionuclides', *Communications Chemistry*, Vol. 3, Art. 167 (2020), at: https://bit.ly/4c8kFen.

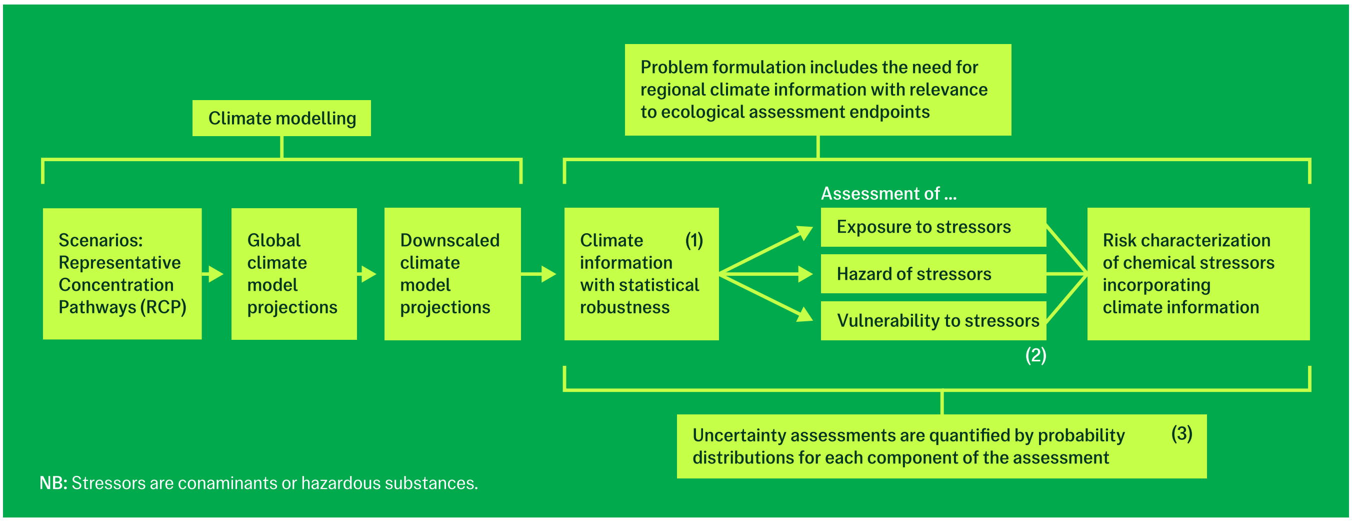
The International Atomic Energy Agency (IAEA) has developed a methodology to identify key processes around climate change that may affect radioactive waste disposal safety assessments, which incorporates longer term glacial and interglacial cycles and which can be tailored for site-specific scenarios.[9] Although not specifically for sites contaminated from nuclear weapon testing, some aspects are considered applicable to other radiologically contaminated sites, including uranium mines and related waste sites. Current IAEA guidelines on remediation strategies for environmental contamination only consider existing exposure situations and not longer-term climate change risks.[10]

Climate change and extreme weather events can impact factors imperative to the assessment of contamination and radiological risks, including:

- conceptual site models, which represent the area characteristics and show the relationship between contaminant sources, exposure pathways, and environmental receptors
- the potential linkages between each source, pathway, and receptor
- the current conditions and potential for an increase, reduction, or steady state of contamination levels
- any combined or cumulative factors
- any credible and foreseeable changes in the site setting or circumstances[11]
- any uncertainty in the datasets; and
- the degree of confidence in the assessment, which could undermine or enhance public confidence and the acceptance of findings and any decisions then taken.

One proposed approach to inform adaptive risk management strategies incorporates three key pillars in risk modelling,[12] namely the use of statistically robust spatial and temporal climate information; the quantification of climate impacts on the risk components; and use of probabilistic methods to determine relationships and uncertainty. While not specific to the assessment of radiological contamination, this approach, summarized in Figure 1 below, remains relevant.

**Figure 1: Proposed integration of climate model projections into environmental risk assessment**[13]




9 IAEA, 'Development of a common framework for addressing climate and environmental change in post-closure radiological assessment of solid radioactive waste disposal', Report, Vienna, 2020, at: https://bit.ly/3IqTQ7T.
10 IAEA, 'Guidelines for Remediation Strategies to Reduce the Radiological Consequences of Environmental Contamination', Report, Vienna, 2013, at: https://bit.ly/3v572w0.
11 According to BS EN ISO 21365 'Conceptual Site Models', 2020, a conceptual site model should include 'foreseeable events which could affect contaminant impacts or create new exposure pathways'.
12 Taken from S. J. Moe *et al.*, 'Integrating climate model projections into environmental risk assessment: a probabilistic modelling approach', *Integrated Environmental Assessment and Management*, Vol. 20, No. 2 (March 2024), 367–83, at: https://bit.ly/4a9AbVT.
13 Taken from ibid.

## Climate-change impacts on risk assessment components

Considerations in assessing climate change and its potential impact on exposure scenarios include fresh or seawater ingress, interactions at the soil and water interface, drainage patterns, wind and wave action, and ocean acidification or saltwater intrusion. All of these can affect soil erosion rates, and the transportation, mobility, and bioavailability of radionuclides and other contaminants.

Climate-induced landscape change (such as landslides), rainfall intensity, and sea-level rises will affect near surface hydrogeology, affecting potential discharge areas and the interface between impacted soil and groundwater. Shifts in land use practices, water abstraction points, or the relocation of people due to climate change may also affect near surface hydrogeology and geochemistry, which may be reflected in different groundwater recharge and flow characteristics.

For underground test sites, several processes can affect the concentration of subsurface contaminants in groundwater,[14] and this could be affected by climate change. This includes chemical speciation due to changes in pH or redox conditions,[15] organic complexation,[16] and microbial activity.

A summary of key climate change drivers, climate system changes, and examples of the impact of climate change on risk assessment components is given in Table 1. The examples given in the table are not exhaustive, but illustrate the wide range of potential impacts. Predicting the regional extent and scale of climate-related impacts is complex, and uncertainties remain due to the influence of other systems[17] and the limited spatial resolution of climate projection data. Various climate models are used to make projections of future climate, which largely depend on assumptions of the release rates of greenhouse gases.

Climate risk profiles can provide a high-level assessment of physical climate risks for a country, highlighting the emerging temporal and spatial risks based on different future climate scenarios. For each country chapter in Part IV below, a summary of the climate risk profiles is provided. This has been used to provide an initial high-level overview of the key climate-induced impacts on risk components for each case study area. Landslide risks have not been included at this stage. For small island States, global models typically do not have the spatial accuracy to reliably capture climate processes while the future influence of El Niño Southern Oscillation is uncertain.

Guidance is emerging on how to incorporate climate change into environmental risk assessment, although implementation is complicated due to research gaps and uncertainties. The national adaptation plan (NAP) process was established under the UN's Cancun Adaptation Framework (CAF).[18] The CAF was developed to build resilience and enhance action on climate adaptation. The process itself aims to reduce a country's vulnerability to the impacts of climate change by increasing adaptive capacity and resilience, and by facilitating the integration of relevant policies, plans, and processes. The CAF's NAP process is primarily for least developed countries, but invites developing countries to also develop their own NAPs. By January 2024, 53 nations had developed and submitted their NAP.[19] But only the Marshall Islands is considered to have incorporated the legacy of nuclear weapon testing into its current national climate adaptation strategy.

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14 Nuclear Decommissioning Authority, 'Geological Disposal. Behaviour of Radionuclides and Non-radiological Species in Groundwater Status Report', December 2016, at: https://bit.ly/3PcNcpv.

15 Redox, which refers to the reduction or oxidation conditions present, determines the solubility and mobility of chemical species in groundwater. Groundwater redox conditions can be influenced by recharge, flow, and chemical species.

16 Organic compounds can bind to radionuclides and non-radiological species, increasing their solubility and mobility.

17 Such as El Niño-Southern Oscillation (ENSO) across the Pacific Ocean, see: https://bit.ly/3wOAI11.

18 At: https://bit.ly/49LZIV1.

19 At: https://bit.ly/3Ta6soH.

**Table 1:** **Key climate-system changes and impacts on risk components resulting from greenhouse gas emissions, aerosols, and land use changes**

| Changes to the climate system | Examples of possible climate-change impact on risk components |
|---|---|
| Change in the hydrological cycles | **Localised flooding, leading to:**<br>• *breach or damage to containment infrastructure or capping systems*<br>• *disruption to maintenance of remedial systems*<br>• *soil washout and mobilization of contaminants*<br>• *sediment deposition on floodwater retreat* |
| Warming land, air, and oceans | **Sea level rise, salt-water intrusion, acidification, and coastal flooding, leading to:**<br>• *inundation of coastal waters*<br>• *breach or damage to containment infrastructure or capping systems*<br>• *changes in physico-chemical behaviour of contaminants (e.g. solubility, biological uptake)*<br>• *mobilization of contaminants* |
| | **Changes in ocean currents, leading to:**<br>• *changes in sediment transport and distribution of contaminants*<br>• *changes to impacts on marine species and seafood* |
| Melting sea ice and glaciers | **Droughts, leading to:**<br>• *desiccation, soil erosion and mobilization of contaminants*<br>• *pressure on water resources, reduced flow rates, increased groundwater abstraction and draw-down*<br>• *less water for dilution, attenuation, or dispersion* |
| Ocean acidification | **Landslides, leading to:**<br>• *breach or damage to bunds, containment or capping systems*<br>• *disruption to maintenance of remedial systems*<br>• *mobilization of contaminants* |
| | **High wind, leading to:**<br>• *scouring and soil erosion*<br>• *damage to containment infrastructure or capping systems*<br>• *distribution of airborne contaminants* |
| Changes in ocean currents | **Landscape fires, leading to:**<br>• *soil desiccation and distribution of airborne contaminants*<br>• *damage to containment infrastructure or capping systems*<br>• *changes in soil organic matter and mobilization of contaminants*[20] |
| Increased frequency of extreme weather (e.g. storms, tornados, tidal surges, hurricanes) | **Increased rainfall frequency and intensity, leading to:**<br>• *changes in soil moisture and groundwater levels*<br>• *changes in groundwater and surface flow rates and direction*<br>• *mobilization of contaminants* |
| | Temperature changes and extremes, leading to:<br>• *stress on material surfaces and their integrity*<br>• *failure or damage to containment infrastructure or capping systems*<br>• *changes in physico-chemical behaviour of contaminants (e.g. solubility, biological uptake)*<br>• *mobilization of contaminants*<br>• *species sensitivity to contaminants due to exacerbating effects*<br>-----------------------------------------------------------------------------------------<br>Potential for increased seismic activity from melting glaciers and rainfall intensity, leading to:<br>• *stress on material surfaces and their integrity*<br>• *failure or damage to containment infrastructure or capping systems*<br>• *changes in physico-chemical behaviour of contaminants*<br>• *mobilization of contaminants* |

20 See, with respect to the situation around Chernobyl: N. Evangeliou *et al.*, 'Fire evolution in the radioactive forests of Ukraine and Belarus: future risks for the population and the environment', *Ecological Monographs*, Vol. 85, No. 1 (2015), 49–72.

Chapter 6:

# The Health Effects of Ionizing Radiation

Tilman Ruff

Scientific knowledge of the harmful health effects of ionizing radiation has emerged over a long period of time. Despite efforts by vested interests to obscure these dangers, strong scientific evidence links radiation exposure to DNA damage, cancer, cardiovascular disease, and genetic effects, even at low doses. Particularly problematic to assess and address are isotopes which bioaccumulate and are recycled in organisms and ecosystems, while internal contamination by alpha or beta emitters is not easy to measure externally. Children, foetuses, rapidly dividing tissues and females are especially vulnerable.

No threshold exists below which radiation is risk-free, and collective low-dose exposure across large populations can lead to substantial long-term health burdens. Historical nuclear testing alone is estimated to cause millions of cancer deaths globally. While radiation effects are often not specifically identifiable, as many conditions and diseases for which they are a risk factor also have other causes, their public health impact is significant and enduring, demanding stronger oversight, exposure minimization, remediation where feasible, public and professional education, and accountability.

While life on Earth has evolved with the constant biological risks associated with background radiation, nuclear reactors and weapons have generated unprecedented potential for radioactive releases that are enormous in size and exceptionally broad in extent, potentially lasting for years or decades or more. Nuclear test explosions are the largest ever human source of radioactive contamination. This chapter of the report summarizes current evidence on the health effects of ionizing radiation.

The extent of the health effects of ionizing radiation is highly contested, largely due to interference and obfuscation by vested interests. The governments, bureaucracies, and corporations that are invested in nuclear weapons and/or nuclear power are often motivated to downplay radiation health risks.[1] There is firm evidence that on many occasions they have failed to collect relevant evidence and support regulation, while ignoring or rejecting evidence of radiation health impacts.[2] This has especially been the case in nuclear-armed States' management of their nuclear testing programmes and their ongoing legacies.[3]

## Nature, sources, and effects of ionizing radiation

Ionizing radiation includes various types of transmitted energy. Some types of ionizing radiation, such as X-rays and gamma rays, are part of the electromagnetic spectrum. This spectrum spans from long wavelength, low-energy radio, micro- and infrared waves, through visible light and ultraviolet radiation, to short wavelength, high energy X- and gamma rays. Such waves or particles are also known as photons. Other types of ionizing radiation consist of subatomic particles and fragments of atoms. Both electromagnetic and particulate radiation of high energy are called 'ionizing' because each of the various types (see Table 1 opposite) has sufficient energy to break chemical bonds and eject one or more electrons from atoms in a process called ionization. Unless otherwise specified, use of the term 'radiation' in this chapter means *ionizing* radiation.

Ionizing radiation can be produced by the spontaneous decay of radioactive elements, often repeatedly. These decay chains often have intermediaries which are also radioactive, until they eventually end up as stable elements. The decay chain, the rate at which each step occurs, and the type of radiation emitted are fixed physical properties of each radioactive element. The rate of radioactive decay is described by the half-life – the time it takes for half the amount of a radioactive element to disintegrate. Elements with long half-lives persist for long periods but their radioactivity is less intense than for elements which decay rapidly. Chemical elements exist in different atomic forms known as isotopes, with the same number of protons but varying numbers of neutrons in their nucleus. Some may be radioactive, in which case they are called radioisotopes.

Ionizing radiation can also be produced (such as in an X-ray machine) when rapidly moving, charged particles collide with a substance. Neutron radiation emitted by a nuclear explosion can induce radioactivity in materials which are not normally radioactive, such as by converting nitrogen in the air to carbon-14, which is radioactive with a half-life of 5,730 years.

Different types of radiation have widely differing capacities to penetrate tissues. Alpha particles are stopped by a thin layer of paper or clothing and do not penetrate through the dead upper layer of normal human skin.

1 K. Z. Morgan, 'Changes in international radiation protection standards', *American Journal of Industrial Medicine*, Vol. 25 (1994), 301–07; S. Boudia 'Global regulation: controlling and accepting radioactivity risks', *History and Technology* Vol. 23, No. 4 (2007) 389–406; R. H. Nussbaum, 'Manipulating public health research: the nuclear and radiation health establishments', *International Journal of Occupational Environmental Health*, Vol. 13 (2007), 328–30.

2 S. Wing, D. Richardson and A. Stewart, 'The relevance of occupational epidemiology to radiation protection standards', *New Solutions*, Vol. 9, No. 2 (1999), 133–51; T. A. Ruff, 'Health implications of ionising radiation', Chap. 8 in P. van Ness and M. Gurtov (eds.), *Learning from Fukushima. Nuclear power in East Asia*, ANU Press, Acton, 2017, 221–60, available at: https://bit.ly/4ay4gPK.

3 R. Alvarez, 'The risks of making nuclear weapons', in D. Quigley, A. Lowman, and S. Wing (eds.), *Tortured science*, Baywood Publishing, Amityville, NY, 2012, 181–98, and *cf*. other chapters in the volume; see also 2022 summaries of health and environmental impacts of nuclear tests in various locations worldwide at: https://bit.ly/3SLeN22.

However, ingested or inhaled alpha-emitting substances that release alpha particles within the body are highly damaging. Some beta particles (electrons) have sufficiently high energy to penetrate to the basal layer of skin where new cells are produced. Gamma and X-rays are highly penetrating, which is the basis for the value of X-rays in medical imaging.

**Table 1:** **Common types of ionizing radiation**[4]

| Ionizing radiation type | | Radiation weighting factor (biological effect, compared with photons)* | Stopped by |
|---|---|---|---|
| Electromagnetic radiation (photons) | Gamma rays (similar to X-rays) | 1 | Penetrating (providing the basis for the use of X-rays for imaging), stopped by dense materials (e.g. lead or concrete), but not by clothing |
| Subatomic particles | Alpha (helium nucleus) and other heavy fission fragments like atomic nuclei | 20 | Outer layer of skin, a sheet of paper (harm derives from internal exposure, e.g. when inhaled or ingested) |
| | Beta (electron) | 1 | A layer of clothing; some can penetrate to basal layer of human skin |
| | Neutron | 5–20 depending on neutron energy | Penetrating; concrete or earth most effective protection |

* A weighting factor of 1 means that for this amount of radiation energy the particular type of radiation causes the same amount of biological damage as X- or gamma rays; a factor of 2 means that type of radiation is twice as biologically damaging as gamma rays of the same energy, and so on. The weighting factor depends on the biological effect used as the endpoint.[5]

## Radiation sources and exposure pathways

People are exposed to radiation via different pathways. On a basic level, these pathways are either internal or external. Penetrating radiation from cosmic sources—photons or particles that travel down through the atmosphere, emanate from radioactive materials in or on the ground or are found in building materials or in the air—irradiate people externally. Direct contact with a source of penetrating radiation causes greatest exposure to the part in closest proximity. Inhalation, ingestion (via food, water, or environmental sources such as soil and dust, particularly in the case of children), or contamination of wounds or other skin breaks can cause exposure to radioactivity from radioactive materials that enter the body. In this case, even radiation that penetrates only very short distances can be harmful, especially if radioactive particles are retained in the body for long periods. Internal contamination, especially with substances which do not emit highly penetrating radiation (for instance, plutonium, strontium, and tritium) are more difficult to measure and may be neglected in assessing radiation exposure.

Different ways of living and different cultural practices can influence radiation exposure and need to be considered in estimating and measuring exposure. For example, in Australian desert sites of British nuclear testing, traditional practices for Aboriginal peoples, which involve sitting, cooking, eating, and sleeping on the ground, increase radiation exposure from groundshine and particularly dust inhalation, compared with living in a house with a non-earthen floor. Children are at risk of higher exposures because they are closer to the ground, their play raises dust, and they have a higher respiration rate proportional to their body weight. High winds and storms raise dust, posing a particular inhalation risk. High rates of respiratory infections and smoking

4 Centers for Disease Control and Prevention, 'Health effects of radiation', 2021, at: https://bit.ly/3SO2j9H; and European Nuclear Society, 'Radiation weighting factors', 15 August 2019, at: https://bit.ly/3wz56fq.
5 The appropriateness of the weighting factor of 1 for beta radiation is under discussion.

tend to increase dust retention and reduce clearance.[6] Locally sourced food, both plant and animal, causes greater ingestion of radioactive materials than food sourced from distant, less-contaminated places. Housing construction using local materials may also involve higher radiation exposure to inhabitants than use of distantly sourced construction materials. Ingestion of local ground or surface water may cause higher exposure to radioactive materials than rainwater or water piped from a distance.

Radioactive isotopes of biologically important elements are handled by our bodies in the same manner as the stable counterparts. Radioactive isotopes of elements with a low biological uptake may behave in a similar manner to chemically similar elements with a higher uptake. Some of these are concentrated in living things (and also up the food chain) and may be recycled in the biosphere. For example, the concentration of caesium-137 in fish in freshwater lakes may be 10,000 times higher than the concentration in the water in which the fish live.[7]

Tritium is a radioactive form of hydrogen. More tritium is emitted by nuclear weapon production and nuclear power plants than any other radioactive pollutant. Hydrogen is a component of water and most organic molecules. Thus, tritium becomes incorporated into water, and also can become organically bound, incorporated into organic molecules. Tritium and the beta radiation it emits have been often considered a low-level radioactive hazard. There is, however, accumulating evidence that the radioactive hazard from tritium is not minor. An extensive scientific review published in 2023 concluded that tritium is highly underrated as an environmental toxin.[8] It documents that the vast majority of studies to date indicate that tritium can have significant biological consequences in a variety of species, including DNA damage, impaired physiology and development, reduced fertility and longevity, and increased risk of diseases such as cancer. Its beta radiation is generally twice as harmful as X-rays, and harm is caused when it is ingested, for example in food. When organically bound, it persists for much longer in the body and is estimated to be three times as harmful as X-ray exposure. In this form, similar to other important isotopes such as caesium and strontium, tritium can concentrate up the food chain.

Radioactive materials may be solid, liquid, or gaseous. Materials, objects, and organisms which contain radioactive materials or become surface-contaminated by them emit radioactivity. In contrast, objects and organisms exposed to radiation but which do not contain radioactive materials are not a source of potential exposure or hazard to others.

The bulk of our natural background radiation exposure is derived from radon gas, the heaviest of the noble gases, a ubiquitous carcinogen produced by the decay of primordial uranium-235 and uranium-238 and thorium-232 present in the Earth's crust. Radon decays via a number of intermediaries (bismuth, polonium, and tellurium) which are more reactive and attach to aerosols and dust in the atmosphere; these may lodge in the lung when inhaled. These radon progeny deliver most of the radiation dose associated with radon. Radon is the second most important cause of lung cancer worldwide, exceeded only by tobacco smoking.[9]

In many parts of the world, medical radiation exposure has increased markedly in recent decades, and in some countries now accounts for similar or greater levels of radiation exposure across the population than does naturally occurring radiation. This is particularly due to increasing use of computed tomography (CT) scans.

6 G. A. Williams (ed.) Inhalation hazard assessment at Maralinga and Emu. Australian Radiation Laboratory ARL/TR087, May 1990, at: https://bit.ly/4jkScEF; P. N. Johnston, K. H. Lokan, and G. A. Williams, 'Inhalation Doses for Aboriginal People Reoccupying Former Nuclear Weapons Testing Ranges in South Australia', *Health Physics*, Vol. 63, No. 6 (December 1992), 631–40; and S. M. Haywood and J. G. Smith, 'Assessment of Potential Doses at the Maralinga and Emu Test Sites', *Health Physics*, Vol. 63, No. 6 (December 1992), 624–30.

7 M. A. Harwell and T. C. Hutchinson with W. P. Cropper, C. C. Harwell, H. D. Grover and 39 other contributors, *Environmental consequences of nuclear war. Vol II. Ecological and agricultural effects*, 2nd Edn, Scientific Committee on Problems of the Environment, John Wiley & Sons, Chichester, 1989, 217–23.

8 T. A. Mousseau and S. A. Todd, 'Biological Consequences of Exposure to Radioactive Hydrogen (Tritium): A Comprehensive Survey of the Literature' 11 April 2023, available on SSRN at: https://bit.ly/4gr6QtS.

9 World Health Organization, 'WHO Handbook of Indoor Radon', Geneva, 2009.

Table 2. **Selected radioactive isotopes from nuclear tests significant to human health**[10]

| Radioisotope | Main type(s) of radioactivity emitted | Half-life | Health significance and predominant means of exposure |
|---|---|---|---|
| Iodine-131 | Beta, gamma | 8 days | Ingestion; concentrated up the food chain (especially in milk); concentrated in the thyroid gland; causes thyroid disease including cancer – children have the highest uptake and are most vulnerable. |
| Caesium-137 | Beta, gamma | 30 years | External and ingestion; the body handles like potassium, the main positively charged ion inside cells; bio-concentrated; associated with many cancers; the **dominant global cause of radiation exposure to people from atmospheric nuclear test explosions** to date as well as from nuclear power plant accidents. |
| Strontium-90 | Beta | 28 years | Ingestion; the body handles like calcium, concentrating in bones and teeth; bioconcentrated; retained; causes leukaemia and bone cancer. |
| Plutonium-239 | Alpha | 24,400 years | Inhalation; retained; internal hazard; especially when inhaled, it causes lung cancer. Often used in nuclear weapons, plutonium isotopes are produced by absorption of neutrons by uranium atoms (e.g. in nuclear reactors). |
| Tritium (hydrogen-3) | Beta | 12.3 years | Ingestion, internal hazard; becomes incorporated in water molecules, does not bio-accumulate, but is more harmful when organically bound. |

Most nuclear test explosions used devices containing either highly enriched uranium (HEU, typically over 90 per cent uranium-235) or plutonium.[11] A few nuclear tests used uranium-233. Most modern nuclear weapons contain both HEU and plutonium. Uranium or plutonium can fission in about 40 different ways, producing altogether some 300 different radioactive elements, whose half-lives vary from a fraction of a second to many millions of years. As well as creating hundreds of new radioactive elements which did not exist before, a nuclear explosion (and the operation of a nuclear reactor) increase the total radioactivity from that of the starting material a million times or more.

## Why is ionizing radiation of biological importance?

Ionizing radiation is intensely biologically harmful, not because it contains extraordinarily large amounts of energy, but because its energy is bundled and delivered to cells in large packets. The energy of a diagnostic X-ray, for example, is typically around 15,000 times greater than the energy of a chemical bond. A whole-body dose of ionizing radiation of 4 gray (Gy) causes potentially lethal acute radiation sickness in humans.[12] Yet the energy delivered to a 70 kg adult human body by that dose of radiation amounts to only 280 joules – the same amount of energy as the heat absorbed by drinking a 3 millilitre sip of hot (60°C) tea or coffee.

Large complex molecular chains, especially of DNA, define who we are and regulate many biological processes. DNA is both our most precious inheritance and the most vital legacy we pass on to our children. These large molecules are particularly vulnerable to disruption by ionizing radiation. Radiation may damage DNA directly

10 Based on United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), 'Sources and Effects of Ionizing Radiation: UNSCEAR 1993 Report to the General Assembly with Scientific Annexes', United Nations, New York, 1993, Annex B, pp. 128-29.

11 International Physicians for the Prevention of Nuclear War (IPPNW) and the Institute for Energy and Environmental Research (IEER), *Radioactive Heaven and Earth: The Health and Environmental Effects of Nuclear weapon testing in, on and above the Earth*, Zed Books, London, 1991. The book is available as a PDF at: https://bit.ly/3vfFrIf.

12 US Department of the Army *et al.*, 'Multiservice Tactics, Techniques, and Procedures for Treatment of Nuclear and Radiological Casualties', Department of the Army, Washington, DC, 2014, pp. 3–8.

or cause indirect damage through the production of highly reactive chemicals, such as reactive oxygen species and other free radical ions, which then react with DNA. A variety of types of damage may result: single and double-strand DNA breaks; oxidative changes to the nucleotide bases that make up DNA; and deletions of sections of DNA – all can lead to gene and chromosomal damage. The frequency of chromosomal aberrations in blood lymphocytes, particularly dicentric forms (with two structures linking chromosome arms rather than the usual one), can be used within weeks of whole-body radiation to estimate the dose received. Stable and persistent chromosomal changes that do not kill affected cells, such as translocations (rearrangements of segments of chromosomes), have been demonstrated at increased frequencies even more than 50 years after exposure in Japanese 'hibakusha' (nuclear bombing survivors)[13] and New Zealand nuclear test veterans.[14]

DNA damage from radiation can have various outcomes, including repair, cell death (especially at high doses), impaired function, induction of cancer, or it can result in DNA changes that are transmissible to subsequent generations.[15] Cells have mechanisms to repair DNA damage, but these can be imperfect. DNA is most susceptible to radiation damage when cells are dividing, so rapidly dividing and growing tissues are most vulnerable, such as blood-forming cells in the bone marrow, germ cells in the ovary and testis, cells lining the gastro-intestinal tract, and hair follicles. Radiation exposure to a foetus in the womb can lead to foetal damage (such as mental retardation) and malformations. Young children and foetuses with more actively dividing cells essential to their growth and development are especially sensitive to radiation effects. Further, a cancer-prone mutation occurring early in prenatal life is likely to transmit to a larger number of daughter cells than a mutation that occurs later.

*Bystander effects* are a feature of many types of radiation whereby radiation damage to one cell damages nearby cells, even without initial DNA damage occurring. Inflammatory responses are thought to be involved.[16] *Genomic instability* describes radiation-related gene damage causing increased susceptibility to further damage, which can be transmitted from parent to daughter cells. Both bystander effects and genomic instability can be delayed.

## Radiation levels and effects

Radiation is measured in different ways. SI units (the international System of Units) are ordinarily used. The most basic unit of radioactivity measures the frequency of atomic disintegration – 1 becquerel (Bq) is 1 radioactive decay per second. The absorbed dose of radioactivity is measured by the gray – 1 Gy is 1 joule of energy deposited per kilogram of mass.

The **equivalent dose** measures the biological effect of the energy absorbed for a particular organ or tissue. It is the absorbed dose multiplied by the relevant tissue weighting factor (or quality factor), which reflects how sensitive a tissue is to radiation. There are five groups of tissue weighting factors spanning a fortyfold difference in radiation sensitivity. Most sensitive are the gonads (ovary and testis); the next most sensitive group includes red bone marrow (where blood cells are made), the stomach, the colon, and the lungs.

The **effective dose** is a summation of the equivalent doses to tissues and organs exposed, adjusting for the varying radiosensitivity of different tissues. It gives an indication of overall risk. Such summations are not an

13 Y. Kodama, D. Pawel, N. Nakamura, D. Preston, T. Honda, M. Itoh, M. Nakano, K. Ohtaki, S. Funamoto, A. A. Awa *et al.*, 'Stable chromosome aberrations in atomic bomb survivors: results from 25 years of investigation', *Radiation Research*, Vol. 156 (2001), 337–46.

14 M. A. Wahab, E. M. Nickless, R. Najar-M'Kacher, C. Parmentier, J. V. Podd, and R. E. Rowland, 'Elevated chromosome translocation frequencies in New Zealand nuclear test veterans', *Cytogenetic and Genome Research*, Vol. 121 (2008), 79-87.

15 Committee to Assess Health Risks from Exposure to Low Levels of Ionizing Radiation, *Health Risks from Exposure to Low Levels of Ionizing Radiation: BEIR VII, Phase 2*, National Academies Press, Washington, DC, 2006, Chap. 4, 157–234.

16 H. Tang, L. Cai, X. He , Z. Niu, H. Huang, W. Hu, H. Bian, and H. Huang, 'Radiation-induced bystander effect and its clinical implications', *Frontiers in Oncology*, Vol. 13 (2023), 1124412.

exact science, and are less meaningful where doses are divergent for different tissues. For example, a CT scan of the brain may deliver a 40–50 milligray (mGy) dose to the brain, which increases the risk particularly of brain cancer, but this translates into an effective whole-body dose of around 4.5 millisievert (mSv).[17] Alpha radiation from plutonium particles inhaled from nuclear test fallout can deliver a high, localised dose to surrounding cells in the lung; and beta radiation from strontium which accumulates in bones and teeth can disproportionately expose adjacent bone marrow.

Both equivalent dose and effective dose are measured in sievert (Sv). For penetrating radiation such as X-rays and gamma rays, the dose is the same whether measured in Gy or Sv.

The average global background level of radiation to which we are all exposed from radon decay, cosmic sources, and ingestion of low levels of naturally occurring radioactive substances, is about 2.4 mSv per year. A single back-to-front chest X-ray typically involves a dose of 0.01 mSv; a CT scan typically involves doses of 3–12 mSv or more. Acute exposures over 100 mSv produce effects on chromosomes measurable by laboratory testing. Doses below 100 mSv are generally categorized as 'low dose'.

## Deterministic effects

Some effects of ionizing radiation are described as deterministic, meaning that the higher the dose, the more severe the effect. Although individual susceptibility varies, at some level everyone who has been exposed will experience such effects. Such effects typically have a threshold below which they do not occur. These include acute radiation syndrome, cutaneous radiation injury (including radiation burns), and hair loss.

**Acute radiation syndrome** (ARS) is generally associated with external whole-body exposure to a large dose of radiation in a short time (minutes or hours) of typically more than 700 mGy, although mild symptoms can be seen with doses as low as 300 mGy.[18] The main cause of ARS is depletion of tissue stem cells. The classic ARS syndromes (which often overlap) are:

- Bone-marrow syndrome, which is associated with depletion of red and white blood cells and platelets, causing bleeding, infection, and anaemia. Deaths may occur following a dose of 1.2 Gy; 50 per cent of those exposed to between 2.5 and 5 Gy will die. Recovery can take from a few days to a few weeks.
- Gastrointestinal syndrome, with destruction of the gut lining at doses greater than 6–10 Gy.
- Cardiovascular/central nervous system syndrome at doses of 20–50 Gy. Death occurs within three days and no recovery can be expected.

In some nuclear test survivor communities, a high proportion of people developed anorexia, nausea, vomiting, diarrhoea, and skin rash within hours to days of being blanketed by test fallout. This is highly suggestive of prodromal symptoms of ARS, signifying acute exposure to high doses of radiation.

**Cutaneous radiation syndrome** (CRS) often accompanies ARS but can also occur without it if the skin is exposed to a dose of 2 Gy or more, particularly beta radiation.[19] Intensely painful redness, blistering, and ulceration of the skin can precede permanent hair and sweat gland loss; thinning; scarring; and recurrent ulceration, sometimes with death of the underlying tissue.

17 J. D. Mathews, A. V. Forsythe, Z. Brady, M. Butler, S. Goergen, G. Byrnes, G. Giles, A. Wallace, P. Anderson, T. Guiver, P. McGale, T. Cain, J. Dowty, A. Bickerstaffe, and S. Darby, 'Cancer risk in 680,000 people exposed to computed tomography scans in childhood or adolescence: data linkage study of 11 million Australians', *British Medical Journal*, Vol. 346 (2013), f2360.

18 Centers for Disease Control and Prevention (CDC), *Acute Radiation Syndrome: A Fact Sheet for Clinicians*, 4 April 2018, at: https://bit.ly/3RSuvcr.

19 CDC, *Cutaneous Radiation Syndrome: A Fact Sheet for Clinicians,* 2018, at: https://bit.ly/3RCtWC1.

For adults, the LD50/60 (the dose of radiation lethal for 50 per cent of exposed people within 60 days) is around 3 to 5 Gy. Doses around 10 Gy are uniformly fatal. The outcome is also affected by accompanying conditions, such as traumatic injuries, thermal burns, malnutrition and underlying medical conditions. It is estimated that in the aftermath of the nuclear bombing of Hiroshima, in the absence of effective or modern treatment, the LD50 was 2.5 Gy.[20]

Other deterministic effects include temporary (at doses greater than 150 mGy to the testis) or permanent sterility. Ocular cataracts have been considered deterministic—for instance, by the International Commission on Radiological Protection (ICRP) at doses greater than 500 mGy—but recent evidence from humans and other animals shows related risk even at low doses.[21]

**Prenatal exposure:** a number of authorities continue to advise that various adverse effects of prenatal radiation exposure are associated with a dose threshold; for example, the US Centers for Disease Control and Prevention (CDC) advise that 100–500 mGy within two weeks of conception may result in failure of the embryo to implant, and foetal growth may be impaired for such exposures between three and thirteen weeks' gestation. They advise that a dose of 500 mGy or higher renders failure of implantation highly likely. Such a dose is also associated with an increased risk of major malformations such as neurological (including brain) damage and growth retardation between three and twenty-three weeks' gestation. Risk of miscarriage is increased throughout the pregnancy, as is the risk of neonatal death from 24 weeks.[22]

However, the last assessment of radiation effects on the embryo and foetus by the US National Academies is in the Biological Effects of Ionizing Radiation (BEIR) IV report of 1988.[23] The report noted that in a study of 1,599 children exposed in utero in Hiroshima and Nagasaki, mental retardation was found to be apparently linearly related to dose during the sensitive period, and that the ICRP had reported that 'within the period of maximum vulnerability, the data it reviewed appeared to be consistent with a linear non-threshold response'.[24] The BEIR Committee did not examine the evidence reviewed by the ICRP in its 1986 report on the developmental effects of irradiation of the brain of embryos and foetuses. ICRP 49 notes that radiation exposure in utero increased the risk of both mental retardation and reduced IQ in a dose-related way without an evident threshold during the period of maximum vulnerability – 8 to 15 weeks' gestation, extending to 16 to 25 weeks' gestation.[25] The report concluded that 'the frequency of severe mental retardation rises from about one case per hundred individuals exposed to less than 0.01 Gy [10 mGy] to approximately 40 cases per hundred at an exposure of 1 Gy'.[26] 'Severe mental retardation implies an individual unable to form simple sentences, to solve simple problems in arithmetic, to care for himself or herself, or is (was) unmanageable or institutionalized.'[27]

Thus, evidence indicates that effects on at least the developing brain are without a lower threshold. Biologically, one would expect the same to be true for other organ systems, as is observed in a large variety of non-human biota (see the last subsection below, 'Radiation effects for non-human species living in contaminated areas'). Updated consideration of radiation effects on pregnant women and the embryos and foetuses they carry along with updated guidance on their protection are both warranted.[28]

20 T. Ohkita and J. Rotblat, 'Biological effects of nuclear war. Acute effects of radiation: the LD-50 value', in WHO, *Effects of nuclear war on health and health services*, 2nd Edn, Geneva, 1987, 83–93.
21 M. P. Little, E. K. Cahoon, C. M. Kitahara, S. L. Simon, N. Hamada, and M. S. Linet, 'Occupational radiation exposure and excess additive risk of cataract incidence in a cohort of US radiologic technologists', *Occupational Environmental Medicine*, Vol. 77, No. 1 (January 2020), 1–8.
22 CDC, 'Radiation and pregnancy: a factsheet for clinicians', 2020, at: https://bit.ly/3TIz0aZ.
23 Committee on the Health Risks of Ionizing Radiation, Board on Radiation Effects Research, *Health Risks from Exposure to Radon and Other Alpha Emitters. BEIR IV*, National Research Council of the National Academies, National Academies Press, Washington, DC, 1988.
24 Ibid., 384.
25 ICRP, 'Developmental Effects of the Irradiation on the Brain of the Embryo and Fetus', ICRP 49, *Annals of the ICRP,* Pergamon Press, 1986, at: https://bit.ly/49TbVqd.
26 Ibid., 31.
27 Ibid., 20.
28 A. Makhijani, 'Recommendations for the study on low-level radiation research, Memorandum to Committee on Developing a Long-Term Strategy for Low-Dose Radiation Research in the United States', National Academies of Sciences, Engineering, and Medicine, 7 January 2022, at: https://bit.ly/3xUI0AO.

## Probabilistic (stochastic) effects

The occurrence of these is a matter of probability. Although such effects are more likely at higher doses, there is no dose below which the risk is not increased, and once the effect occurs, its severity does not depend on the dose. These conditions generally have a range of other causes not linked to radiation. Cancer and cardiovascular disease (particularly heart attacks and strokes) are such effects. These effects occur at doses which produce no short-term symptoms or other effects. The elevated risks from radiation exposure accumulate and persist for the life of the exposed person.[29]

Such effects include increased risks of long-term genetic damage, chronic disease, and increases in almost all types of cancer,[30] proportional to the dose. Radiation both increases the chance of developing cancer and advances its onset. Once a cancer or other probabilistic effect develops, its behaviour and severity are not distinguishably different because of its association with radiation. And typically, no test can identify a radiation-associated cancer or heart attack from one caused by other factors. Radiation health effects, both deterministic and probabilistic, are associated with any and all types of radiation – cosmic radiation, medical X-rays used for diagnosis or treatment, nuclear test fallout, or any other source.

Despite the persistence of claims to the contrary, the evidence is conclusive that there is no dose of radiation below which no incremental health risk exists – all radiation exposure adds to long-term health risks. Even before the availability of recent data on unexpectedly high and early cancer rates in children following CT scans, it was estimated that 2.5 mSv of natural background radiation to the bone marrow each year would be the cause of up to 30 per cent of childhood leukaemia.[31] There is thus no level dose of radiation that is 'safe', in the sense that it is free of health risk.

Arguably the most authoritative and rigorous periodic assessments of radiation health risks are the BEIR reports produced by the United States (US) National Academy of Sciences. However, the most recent report, BEIR VII,[32] was published in 2006 and substantial new evidence has accumulated since then. The BEIR VII report estimated that the overall increase in risk of solid cancer incidence (occurrence) across a population is about 1 in 10,000 for each 1 mSv of additional radiation exposure. The increased risk for leukaemia is about 10 per cent of this. As, overall, about half of all cancers are fatal, the estimated increased risk of death from cancer is about half that – about 1 in 20,000 per mSv.

The maximum permitted dose limit recommended by the ICRP and most national radiation protection agencies for any additional, non-medical exposures for members of the public is 1 mSv per year (corresponding to about 0.11 microsieverts (μSv) per hour, a common unit of radiation exposure measurement).[33] With exposure to 1 mSv of radiation per year, on average one ray of radiation passes through the nucleus of every cell in the body annually. Some authorities, though, apply more protective criteria: for example, the level set by the US Environmental Protection Agency for clean-up of radioactively contaminated sites is 0.12 mSv per year.[34]

29 Lifetime risk is the usual basis for assessing long term radiation risk, for example in the dated but authoritative: Committee to Assess Health Risks from Exposure to Low Levels of Ionizing Radiation. *Health Risks from Exposure to Low Levels of Ionizing Radiation: BEIR VII, Phase 2*, National Academies Press, Washington, DC, 2006.

30 Cancers are often considered in two broad types: those of blood-forming organs (leukaemia), and those of solid organs.

31 R. Wakeford, G. M. Kendall, M. P. Little, 'The proportion of childhood leukaemia Incidence in Great Britain that may be caused by natural background radiation', *Leukemia*, Vol. 23 (2009), 770–76.

32 Committee to Assess Health Risks from Exposure to Low Levels of Ionizing Radiation, Health Risks from Exposure to Low Levels of Ionizing Radiation: BEIR VII, Phase 2, National Academies Press, Washington, DC, 2006.

33 ICRP, Application of the Commission's Recommendations to the Protection of People Living in Long-term Contaminated Areas After a Nuclear Accident or a Radiation Emergency, ICRP Publication 111, *Annals of the ICRP*, Vol. 39, No. 3 (2009).

34 US Environmental Protection Agency, Radiation risk assessment at CERCLA sites: Q&A, doc. EPA 540-R-012-13, May 2014, at: https://bit.ly/48ol4GH.

There has been a consistent trend over time that the more we know about radiation effects, the greater the evidence indicates those effects to be. Maximum permitted radiation dose limits have never been raised over time, however; they have always been lowered. For example, from 1950 to 1991, the maximum recommended whole-body radiation annual dose limits for radiation industry workers declined from approximately 250 mSv to 20 mSv. These recommended dose limits are not doses below which there is no health risk. Rather, they represent the most recent compromise between safety and optimal protection of people on the one hand, and commercial and other interests such as cost considerations on the other.

Ionizing radiation also increases the risk of occurrence and death from some non-cancer diseases, including cardiovascular and respiratory disease. Long-standing evidence has demonstrated this at moderate and high doses, and recent evidence has confirmed that circulatory disease mortality (principally from heart attacks and strokes) as well as deaths due to all causes other than cancer also increase at low total doses and dose rates, such as occur in most nuclear industry workers.[35, 36] Recent evidence demonstrates that higher environmental radon exposure, including within levels considered to require no remedial action, is associated with an increased incidence of stroke.[37] The increased risk of death from heart and other circulatory diseases is estimated to be comparable in magnitude to the radiation-related cancer risk, meaning that the total extra risk of dying because of exposure to radiation is likely to be around double the increased risk of death from cancer alone.

One important factor in understanding radiation health effects is that small doses received by a large number of people may cause significant consequences. For example, a United Kingdom (UK) study showed that the great majority (over 85 per cent) of radon-related lung cancer deaths across the UK occurred among people living in homes where the level of radon was less than 100 becquerel per cubic metre (Bq/m$^3$) of air, well below the level recommended as warranting remedial action of 200 Bq/m$^3$.[38] An additional average radiation dose across a population of 100 million people of only 1 mSv, using the traditional risk estimates above, can be expected to result in an additional 10,000 cancer cases; the same dose delivered to 1 billion people can be expected to cause 100,000 additional cases of cancer.

Past atmospheric nuclear tests have exposed, and continue to expose, every person on earth to radioactive fallout. While many test workers and people living near and downwind of nuclear tests received radiation doses of tens or hundreds of mSv, most of the global population received small doses. While the individual risk from such low doses is small, because of the great number of people exposed to the collective radiation dose, the aggregate health burden is largest among those who received low doses.

In 1991, a commission established by International Physicians for the Prevention of Nuclear War (IPPNW) and the Institute for Environmental and Energy Research published a study which used the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) reports of 1982 and 1988 estimating global population radiation exposures from atmospheric nuclear tests (5.44 million person-Sv to the year 2000 and 30.44 million person-Sv in total). They then applied the radiation risk estimates of the BEIR V report of the US National Academy

35 M. Gillies, D. B. Richardson, E. Cardis, R. D. Daniels, J. A. O'Hagan, R. Haylock, D. Laurier, K. Leuraud, M. Moissonnier, M. K. Schubauer-Berigan, I. Thierry-Chef, and A. Kesminiene, 'Mortality from circulatory diseases and other non-cancer outcomes among nuclear workers in France, the United Kingdom and the United States (INWORKS)', *Radiation Research*, Vol. 188 (2017), 276–90.

36 M. P. Little, T. V. Azizova, D. B. Richardson, S. Tapio, M.-O, Bernier, M. Kreuzer, F. A. Cucinotta, D. Bazyka, V. Chumak, V. K. Ivanov, L. H. S. Veiga, A. Livinski, K. Abalo, L. B. Zablotska, A. J. Einstein, and N. Hamada, 'Ionising radiation and cardiovascular disease: a systematic review and meta-analysis', *British Medical Journal*, Vol. 380 (2023), e072924, at: https://bit.ly/48ceBiG.

37 S. F. Buchheit, J. M. Collins, K. M. Anthony, S. M. Love, J. D. Stewart, R. Gondolia, D. Y. Huang, J. E. Manson, A. P. Reiner, G. G. Schwartz, M. Z. Vitolins, R. R. Schumann, R. L. Smith, and E. A. Whitsel, 'Radon exposure and incident stroke risk in the Women's Health Initiative', *Neurology*, Vol. 102 (2024), e209143; and L. Lu, Y. Zhang, C. Chen, R. W. Field, and K. Kahe, 'Radon exposure and risk of cerebrovascular disease: a systematic review and meta-analysis in occupational and general population studies', *Environmental Science and Pollution Research*, Vol. 29 (2022), 45031–43.

38 A. Gray, S. Read, P. McGale, and S. Darby, 'Lung cancer deaths from indoor radon and the cost-effectiveness and potential of policies to reduce them', *British Medical Journal*, Vol. 338 (2009), a3110.

of Sciences—the most up to date at the time—to estimate global cancer deaths attributable to atmospheric nuclear test fallout.[39] The study found that 430,000 additional cancer deaths worldwide attributable to these exposures could be expected in the human population by the year 2000, with 90 per cent confidence limits of 320,000 to 650,000. Together, caesium-137, carbon-14, strontium-90, and zirconium-95 delivered 76 per cent of this total dose. In the longer term, however, carbon-14, an activation product formed from nitrogen in the air from above-ground nuclear tests that emits beta radiation and has a half-life of 5,730 years, delivers 85 per cent of the total dose to the world's population over thousands of years to come.

The total excess cancer deaths over time were estimated to reach 2.4 million. More recent UNSCEAR (1993)[40] and International Council of Scientific Unions SCOPE 59 (2000)[41] reports use a very similar estimate for collective effective dose for the world population (30 million person-Sv); and the BEIR VII overall population fatal cancer risk estimate is similar to that in BEIR V. SCOPE 59 estimated 1.5 million excess cancer deaths over the next 10,000 years (less than two half-lives of carbon-14) attributable to past atmospheric nuclear testing. This translates to around 2 million deaths in total over time.

In light of the more accurate low-dose radiation risk estimates provided by recent studies, it is likely that these estimates substantially underestimate the true long-term toll of nuclear test explosions. The true number of excess cancer deaths will probably be higher again, as these estimates take no account of past or future leakage of radioisotopes into the biosphere from underground nuclear test sites. Additionally, as around half of cancers overall (other than non-melanoma skin cancers) are fatal, for all these estimates a comparable additional number of non-fatal cancer cases can be expected, as well as a similar number of cardiovascular deaths.

While hundreds of thousands and millions are large numbers of cancer cases and deaths, they will not generally be discernible because cancer is very common; these cases will occur over an extended period of time and be widely dispersed; and radiation-induced cancers cannot usually be differentiated by a specific biological signature. Therefore, people who suffer these cancers will not generally be identifiable. This means that public and government awareness of, and attention to, these risks is attenuated and accountability more readily avoided, compared with hazards whose victims are prompt and who can be identified and named. However, despite the inability to identify many individual victims of these excess cases of disease which have been and will be induced by test fallout (and will cause distress and health harm whether or not they ultimately prove fatal), the impact is real, warranting accountability of responsible institutions and individuals as well as feasible preventive and remedial public health action. The case for such action for those at greatest risk—exposed test workers and downwind communities—is even more compelling given that they are at greater individual risk and can be identified.

In the past, it was often considered that low doses of radiation were less harmful per unit of dose than higher doses, and that the same dose of radiation delivered more slowly was less harmful than the same dose delivered more quickly. This resulted in a dose and dose rate effectiveness factor (DDREF) being applied in many radiation health risk assessments. These adjust the risk estimates downwards by a factor typically between 2 (UNSCEAR, ICRP) and 1.5 (BEIR VII). However, recent studies quantify the risk of low radiation doses more accurately than historic data that were largely based on extrapolation of findings among Hiroshima and Nagasaki survivors with generally higher exposure. These show that no such downward dose rate adjustment should be applied, and that rather than the effects per unit of radiation exposure being less at low doses, they are in fact higher.

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39 *Radioactive heaven and earth: The health and environmental effects of nuclear weapon testing in, on and above the earth.*

40 UNSCEAR, 'Sources and Effects of Ionizing Radiation: UNSCEAR 1993 Report to the General Assembly with Scientific Annexes', Report, UN, New York, 1993, available at: https://bit.ly/41wK3pz, Annex B, p. 20.

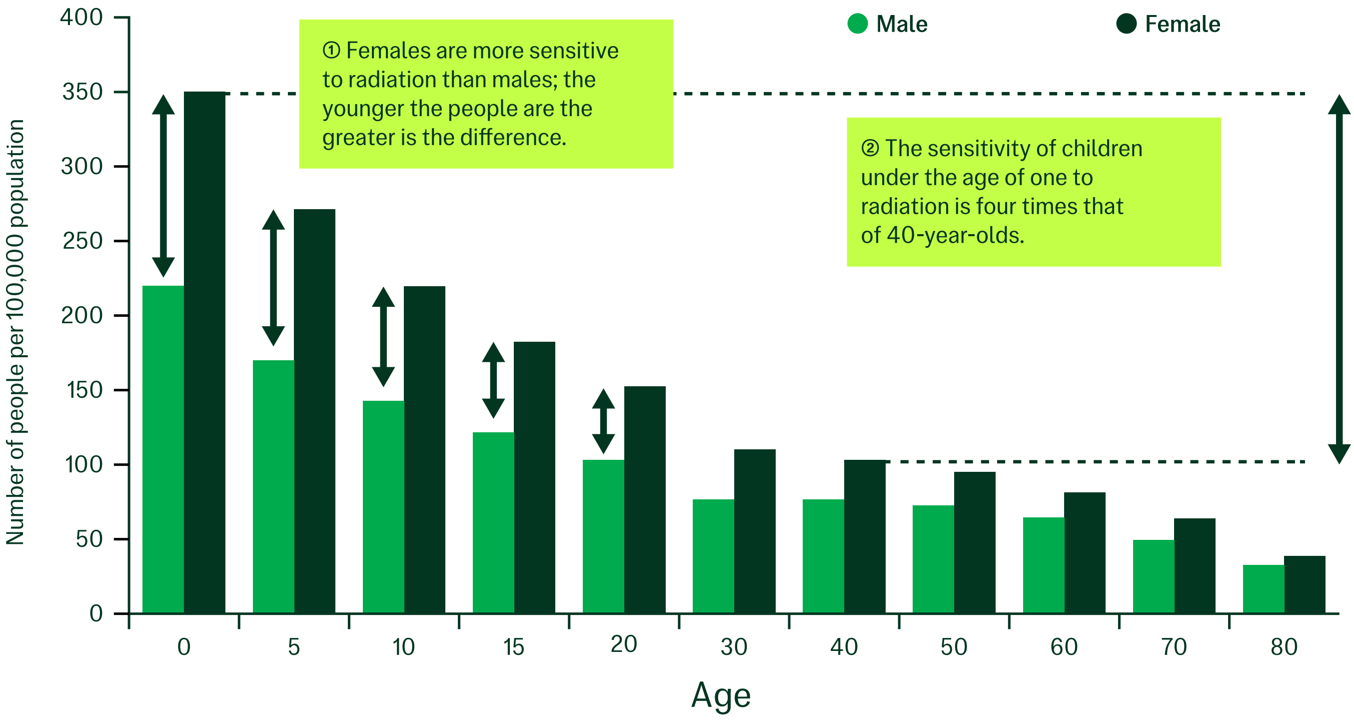
41 F. Warner and R. J. C. Kirchmann (eds.), *SCOPE 59. Nuclear Test Explosions: Environmental and Human Impacts*, Scientific Committee on Problems of the Environment (SCOPE) , John Wiley & Sons, New York, 1999, 220–21. This book is available as a PDF at: https://bit.ly/3uD2FIr.

## Populations with increased vulnerability to radiation health harm

Radiation risk is not uniform across a population. It is highest in very young children and declines gradually with age. Infants are overall about four times as sensitive to radiation's cancer-inducing effects as middle-aged adults.[42] A single X-ray to the abdomen of a pregnant woman, involving a radiation dose to the foetus of about 10 mSv, was shown in pioneering studies by Alice Stewart in the United Kingdom in the 1950s to increase the risk of cancer during childhood in her offspring by 40 per cent.[43]

In the BEIR VII assessment, following uniform whole-body exposure to the same level of radiation, women and girls are 52 per cent more likely to develop cancer than men and boys, and 38 per cent more likely to die of cancer than males. The difference is greatest at younger ages of exposure – for the same exposures occurring between 0 and 5 years of age, girls are 86 per cent more likely to develop cancer than boys.[44] The greater vulnerability of children than adults to radiation damage is substantial: for boys, exposures in infancy (below one year of age) are 3.7 times more likely to lead to cancer than the same exposure for a 30-year-old man; for infant girls compared with 30-year-old women, that risk is 4.5 times greater.[45] These differences relate to both increased sensitivity of the young and the usually longer remaining years of life for effects to become manifest. The relationship between overall cancer risk, age, and gender is depicted in Figure 1.

**Figure 1:** **Increased lifetime cancer risk by age and gender associated with an extra radiation dose of 10 mSv**[46]




42 Committee to Assess Health Risks from Exposure to Low Levels of Ionizing Radiation, *Health Risks from Exposure to Low Levels of Ionizing Radiation: BEIR VII, Phase 2*, National Academies Press, Washington, DC, 2006.

43 See, e.g., A. Stewart and G. W. Kneale, 'Radiation Dose Effects in Relation to Obstetric X-Rays and Childhood Cancers', *The Lancet*, Vol. 295, No. 7658 (6 June 1970), 1185–88, available at: https://bit.ly/43vBo7L.

44 A. Makhijani, B. Smith, and M. C. Thorne, 'Science for the Vulnerable: Setting Radiation and Multiple Exposure Environmental Health Standards to Protect Those Most at Risk', Institute for Energy and Environmental Research, Takoma Park, MD, 19 October 2006, pp. 35–40.

45 *BEIR VII, Phase 2*, 470-99.

46 Source: Fukushima Nuclear Accident Independent Investigation Commission (NAIIC), *The Official Report of the Fukushima Nuclear Accident Independent Investigation Commission*, National Diet of Japan, Tokyo, 2012, Chap. 4, p. 75, based on data from *BEIR VII, Phase 2*.

Increased vulnerability of young people also applies to the non-cancer health risks of radiation exposure. By way of example, in recent research on the British population, a similar increase in risk for young people occurs for cardiovascular disease. It was estimated that the increased lifetime risk of death from circulatory disease is about 10 times higher for a child exposed to radiation before 10 years of age compared with exposure after age 70. Similarly, an exposed child's risk of death from solid cancer was estimated to be more than 20 times higher than for exposure occurring over the age of 70, and about double that associated with the same exposure at age 30-39 years.[47]

The combined effects of exposure during early childhood and greater female susceptibility can be dramatic. For example, for intake of strontium-90, infant girls exposed to the same level of contamination are assessed to have an almost 21-fold higher risk of breast cancer than women aged 30 years. For ingested iodine-131, the risk for infant girls compared with 30-year-old women is nearly 33 times higher. This means that for the same level of radioactive contamination, the cumulative breast or thyroid cancer risk by ingestion over the first five years of life for girls is greater than that accumulated by women over their entire adult lives.[48]

These differential vulnerabilities are obscured by averaging risks across populations. Women are also at greater risk of cardiovascular disease than males.[49]

## The evolving evidence of radiation-related health harm

Long-term follow-up studies of Hiroshima and Nagasaki hibakusha have provided the bulk of historic data on which radiation health risks have been estimated and on which radiation protection standards have been set. The most recent published data from ongoing studies of the Hiroshima and Nagasaki survivors confirm a linear dose-response relationship between radiation dose and overall cancer risk, with no threshold.[50] They also suggest that the risk per unit dose is greater at lower radiation doses. They do not show a reduction in cancer risk for the same total exposure when radiation is delivered over a longer time, as bodies such as the ICRP still assume. They certainly do not show an absence of evidence of increased cancer risk at doses less than 100 mSv, as Japanese official bodies and educational materials for students and teachers still claim.[51]

The Japanese survivor studies have a range of methodological flaws which lean consistently towards underestimation of radiation risk. The most significant gaps are that the hibakusha studies:

- reflect a hardy survivor population
- misclassify some exposures (including counting some people who were exposed as unexposed)
- include relatively few people who received low radiation doses
- miss all cancer deaths occurring in the first five years and cancers other than leukaemia over the first thirteen years
- disproportionately exclude highly exposed persons; and

47 M. P. Little *et al.*, 'Systematic Review and Meta-analysis of Circulatory Disease from Exposure to Low-level Ionizing Radiation and Estimates of Potential Population Mortality Risks', *Environmental Health Perspectives*, Vol. 120, No. 11 (2012), 1503–11.

48 Makhijani, Smith, and Thorne, 'Science for the Vulnerable: Setting Radiation and Multiple Exposure Environmental Health Standards to Protect Those Most at Risk', p. 40.

49 Gillies *et al.*, 'Mortality from circulatory diseases and other non-cancer outcomes among nuclear workers in France, the United Kingdom and the United States (INWORKS)', pp. 276–90.

50 E. J. Grant, A. Brenner, H. Sugiyama, R. Sakata, A. Sadakane, M. Utada, E. K. Cahoon, C. M. Milder, M. Soda, H. M. Cullings, D. L. Preston, K. Mabuchi, and K. Ozasa, 'Solid cancer incidence among the Life Span Study of atomic bomb survivors: 1958–2009', *Radiation Research*, Vol. 187 (2017), 513–37.

51 Ministry of the Environment of Japan, *Booklet to provide basic information regarding health effects of radiation*, 3rd Edn, Tokyo, 2023, at: https://bit.ly/3TIAa6l.

- include ‘immortal person time’ – some exposed people were included in the study for many years during which any cancers they developed were not included.[52]

Powerful new epidemiological studies over the past fifteen years have provided estimates that are more accurate and which demonstrate greater radiation-related health risks than earlier estimates.[53] The most important of these new studies are summarized briefly below, but many are not yet reflected in official radiation risk estimates and radiation protection standards.

### Childhood leukaemia near nuclear power plants

Apparent excesses of leukaemia occurring in children living near nuclear power plants have caused concern and controversy over decades. A 2007 meta-analysis supported by the US Department of Energy examined all of the reliable data available worldwide, confirming a statistically significant increase in leukaemia for children living near nuclear power plants.[54] Subsequent studies support these findings, most definitively a large German study, which examined leukaemia among children living near any of Germany’s 16 operating nuclear plants over a 25-year period. It showed a highly statistically significant increase in leukaemia risk of more than twofold for children living within 5 kilometres of a nuclear plant, with elevated risk extending beyond 50 kilometres from a plant.[55]

### Childhood cancer following CT scans

A major part of growing medical radiation exposure worldwide is due to CT scans which involve effective whole-body exposures of 1 to 10 or more (up to 20+) mSv (and larger doses to the imaged organs). Numerous studies have documented cancer risks following CT scans in children which are far greater than previously estimated.

The largest national cohort of paediatric CT scans with organ doses to date is an ongoing Australian study of cancer risk after CT scans in 680,000 young people (aged under 20 years of age) compared with the 10.3 million young Australians who did not have CT scans, over the same 20-year period.[56] The study involved ten times as many people exposed and four times the total radiation dose as the Japanese survivor data for low doses of radiation (approximately 70,000 people who received less than 100 mSv). After an average duration of follow-up of only 9.5 years, it revealed a 24 per cent increase in cancer in the decade following one CT scan delivering an average effective dose of only 4.5 mSv, and 16 per cent greater cancer risk for each additional scan. Cancers occurred as early as two years after exposure. New cancers will continue to occur through the life of exposed individuals. For similar ages of exposure and lengths of follow-up, the risk for leukaemia related to CT radiation was similar to that among hibakusha, however the risk of solid cancer in the more powerful CT study was nine times higher for brain cancer[57] and solid cancers overall than in the hibakusha studies.[58]

52 Ruff, ‘Health implications of ionising radiation’, 221–60; D. B. Richardson, S. Wing, and S. R. Cole, ‘Missing Doses in the Lifespan Study of Japanese Atomic Bomb Survivors’, *American Journal of Epidemiology*, Vol. 177, No. 6 (2013), 562–68; and Mathews *et al*., ‘Cancer risk in 680,000 people exposed to computed tomography scans in childhood or adolescence: data linkage study of 11 million Australians’.

53 C. M. Kitahara, M. S. Linet, P. Rajaraman, and E. Ntowe, ‘A New Era of Low-Dose Radiation Epidemiology’, *Current Environmental Health Reports*, Vol. 2 (2015), 236–49.

54 P. J. Baker and D. G. Hoel, ‘Meta analysis of standardised incidence and mortality rates of childhood leukaemia in proximity to nuclear facilities’, *European Journal of Cancer Care*, Vol. 16 (2007), 355–63.

55 P. Kaatsch, C. Spix, R. Schulze-Rath, S. Schmiedel, and M. Blettner, ‘Leukaemia in young children living in the vicinity of German nuclear power plants’, *International Journal of Cancer*, Vol. 122, No. 4 (15 February 2008), 721–26.

56 Mathews *et al*., ‘Cancer risk in 680,000 people exposed to computed tomography scans in childhood or adolescence: data linkage study of 11 million Australians’.

57 N. R. Smoll, Z. Brady, K. J. Scurrah, C. Lee, A. M. de Gonzalez, and J. D. Mathews, ‘Computed tomography scan radiation and brain cancer incidence’, *Neuro-Oncology*, Vol. 25, No. 7 (2023), 1368–76.

58 Mathews *et al*., ‘Cancer risk in 680,000 people exposed to computed tomography scans in childhood or adolescence: data linkage study of 11 million Australians’.

Recent results from a nine-nation European study, the largest multinational CT study to date, show broadly similar findings.[59] A strong likelihood is that the dose-response curve for radiation-related cancer risk is not linear as generally assumed, but steeper at low doses, with a greater effect per mSv at low doses than at higher doses, particularly for children.[60]

### Childhood cancer and background radiation

Recent evidence demonstrates that background radiation, even involving quite small radiation doses, is more important in cancer causation than previously recognized. A UK study of data from the National Registry of Childhood Tumours dating from 1980 to 2006 found that the risk of a child developing leukaemia increased by 12 per cent for every additional mSv of cumulative radiation exposure to their bone marrow.[61]

A more impactful national study was undertaken in Switzerland, where alpine areas are associated with higher levels of background radiation than flatter sedimentary northern areas. Census data linked to Swiss Childhood Cancer Registry data identified a 3 per cent increased risk of cancer eight to eighteen years later for each mSv of cumulative external radiation exposure. Overall cancers increased by 64 per cent and leukaemia more than doubled for children living in areas where background external radiation levels were more than 1.8mSv/year, as compared with areas where levels were below 0.9 mSv/y.[62] A study in Finland has arrived at similar findings.[63] This evidence is reinforced by a large review of the effects of natural variation in background radioactivity on humans, animals, and other organisms, with higher background exposures linked to effects such as increased mutation rates, immunological changes, physical body changes, and increased cancer rates in many diverse plant and animal species, including humans.[64]

### Health risks for nuclear industry workers

The International Agency for Research on Cancer coordinates an important ongoing international long-term study of nuclear industry workers. The studies include 310,000 workers from France, the United Kingdom, and the United States, some of whom have been followed since 1944, with the total measured colon radiation dose (a common measure of internal organ exposure) more than five times the collective dose received by hibakusha who received low doses. The mean dose rate for the workers involved was only 1.1 mGy per year, less than background radiation in most places, with cumulative doses averaging 17.7 mSv, less than the dose limit for nuclear industry workers of an average of no more than 20 mSv in one year.

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59 M. Hauptmann, G. Byrnes, E. Cardis, M.-O. Bernier, M. Blettner, J. Dabin, H. Engels, T. S. Istad, C. Johansen, M. Kaijser, *et al*., 'Brain cancer after radiation exposure from CT examinations of children and young adults: results from the EPI-CT cohort study', *Lancet Oncology*, Vol. 24 (2023), 45–53; and M. B. de Basea Gomez, I. Thierry-Chef, R. Harbron, M. Hauptmann, G. Byrnes, M.-O. Bernier, L. Le Cornet, J. Dabin, G. Ferro, T. S. Istad, *et al*., 'Risk of hematological malignancies from CT radiation exposure in children, adolescents and young adults', *Nature Medicine*, Vol. 29 (2023), 3111–19, at: https://bit.ly/3TIAm5z.

60 N. R. Smoll, B. Brady, K. Scurrah, and T. D. Mathews, 'Exposure to ionising radiation and brain cancer incidence: The Life Span Study cohort', *Cancer Epidemiology*, Vol. 42 (2016), 60–65.

61 G. M. Kendall, M. P. Little, R. Wakeford, K. J. Bunch, J. C. H. Miles, T. J. Vincent, J. R. Meara, M. F. G. Murphy, 'A record-based case–control study of natural background radiation and the incidence of childhood leukaemia and other cancers in Great Britain during 1980–2006', *Leukemia*, Vol. 27 (2013), 3–9.

62 B. D. Spycher, J. E. Lupatsch, M. Zwahlen, M. Röösli, F. Niggli, M. A. Grotzer, J. Rischewski, M. Egger, and C. E. Kuehni (for the Swiss Pediatric Oncology Group and the Swiss National Cohort Study Group), 'Background ionizing radiation and the risk of childhood cancer: a census-based nationwide cohort study', *Environmental Health Perspectives*, Vol. 123, No. 6 (2015), 622–28.

63 A. Nikkilä, S. Erme, H. Arvela, O. Holmgren, J. Raitanen, O. Lohi, and A. Auvinen, 'Background radiation and childhood leukemia: A nationwide register-based case-control study', *International Journal of Cancer*, Vol. 139 (2016), 1975–82.

64 A. P. Møller and T. A. Mousseau, 'The effects of natural variation in background radioactivity on humans, animals and other organisms', *Biological Reviews*, Vol. 88 (2013), 226–54.

The solid cancer risk was statistically compatible with, but 50 per cent higher than that in 20- to 60-year-old male hibakusha, and will continue to rise as the subjects age.[65] The leukaemia risk identified was similar to that in 20- to 60-year-old male hibakusha. Site-specific estimates of mortality for different solid cancers in the INWORKS cohort confirm radiation-related increases across a wide range of cancer types.[66]

These large and powerful studies demonstrate risks even at very low-dose rates and doses similar to recommended limits for the general population. They do not support a reduction of risk for the same total dose if the dose is delivered over a longer time, and together with the other studies noted conclusively demonstrate the absence of a threshold for ionizing radiation-related cancer risk. Again, INWORKS suggests a greater effect per unit of radiation exposure at lower doses.[67] Of particular note is that adult males who make up 88 per cent of the INWORKS cohort are the population group least susceptible to radiation health harm.

### Radiation effects for non-human species living in contaminated areas

A large body of evidence has been gathered in recent decades on the effects of radiation on non-human biota living in radioactively contaminated areas, particularly around Chernobyl and Fukushima. In virtually every species and ecological community studied—from soil bacteria and fungi through trees to various insects, spiders, amphibians, diverse birds, large and small mammals, and diverse coastal marine organisms—adverse biological effects have been found in direct proportion to the degree of radioactive contamination, without any apparent threshold. Most effects are evident across the range of 1-10 mGy per year,[68] and effects are seen in individuals, populations, species, and ecosystems.

In plants, damage to DNA, reduced pollen viability and germination rates, impaired growth, abnormal growing tips, and abnormal leaf and overall plant size and morphology are seen. In animals, effects include DNA and other types of genetic damage, physical abnormalities, tumours, cataracts, reduced brain size with impaired neurological development and behaviour, reduced fertility including absent or depleted, dead, abnormal and immotile sperm, reduced lifespan and reduced organism numbers and biodiversity. Regrettably, UNSCEAR and the ICRP have ignored or dismissed this evidence.

It is biologically implausible that humans are immune from similar effects. As for recent human data, there is a similar trend for non-human species of larger biological impacts of radiation to be identified than previously recognized. Animals in the wild have been shown to be about eight times more sensitive to radiation than previously thought largely on the basis of laboratory studies.[69] Very few studies of non-human biota have been undertaken at nuclear test sites.[70]

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65 D. B. Richardson, E. Cardis, R. D. Daniels, M. Gillies, J. A. O'Hagan, G. B. Hamra, R. Haylock, D. Laurier, K. Leuraud, M. Moisonnier, M. K. Schubauer-Berigan, I. Thierry-Chef, and A. Kesminiene, 'Risk from occupational exposure to ionizing radiation: retrospective cohort study of workers in France, the United Kingdom, and the United States (INWORKS)', *British Medical Journal*, Vol. 351 (2015), h5359.

66 D. B. Richardson, E. Cardis, R. D. Daniels, M. Gillies, R. Haylock, K. Leuraud, D. Laurier, M. Moisonnier, M. K. Schubauer-Berigan, I. Thierry-Chef, and A. Kesminiene, 'Site-specific solid cancer mortality after exposure to Ionizing radiation. A cohort study of workers (INWORKS)', *Epidemiology*, Vol. 29, No. 1 (2018), 31–40.

67 D. B. Richardson, K. Leuraud, D. Laurier, M. Gillies, R. Haylock, K. Kelly-Reif, S. Bertke, R. D. Daniels, I. Thierry-Chef, M. Moisonnier, A. Kesminiene, and M. K. Schubauer-Berigan, 'Cancer mortality after low dose exposure to ionising radiation in workers in France, the United Kingdom, and the United States (INWORKS): cohort study', *British Medical Journal*, Vol. 382 (2023), e074520.

68 T. A. Mousseau, 'The biology of Chernobyl', *Annual Review of Ecology, Evolution, and Systematics*, Vol. 52 (2021), 87–109.

69 J. Garnier-Laplace, S. Geras'kin, C. Della-Vedova, K. Beaugelin-Seiller, T. G. Hinton, A. Real, and A. Oudalova, 'Are radiosensitivity data from natural field conditions consistent with data from controlled experiments? A case study of Chernobyl wildlife chronically exposed to low dose rates', *Journal of Environmental Radioactivity*, Vol. 121 (2013), 12–21.

70 See Chapter 16 on nuclear testing in the Marshall Islands for a few examples that do exist.

Chapter 7:

# Biological Factors and Gender Impacts Affecting Outcomes from Exposure to Ionizing Radiation

Mary Olson

Biological factors and gender critically influence outcomes from exposure to ionizing radiation, emphasizing long-overlooked vulnerabilities in females and children. Females—especially those exposed as children—suffer significantly higher lifetime cancer rates and reproductive damage than males. The outdated reliance on the 'Reference Man' in radiation protection standards has led to widespread underestimation of risk for non-male and young populations. Additionally, internal exposure from radioactive particles can be very high, posing greater long-term health risks including cancer, genetic damage, and infertility, than previously known. Despite mounting evidence, regulatory frameworks have been slow to adapt. Precautionary principles should be adapted, with better inclusion of sex- and age-specific data and a lifecycle approach to radiation protection in light of continuing global contamination from nuclear testing.

Study of the survivors of the atomic strikes by the United States on Hiroshima and Nagasaki in August 1945 has become the basis for many conclusions about radiation impacts on human health.[1] It is a testimonial to gender[2] in nuclear matters writ large that it took decades of tracking cancer among the atomic victims in the Life Span Study of atomic bomb survivors (LSS)[3] (a study that began in 1950 and which is ongoing) before the US National Academy of Sciences (NAS) finally acknowledged, in 2006, that ionizing radiation is more harmful to female bodies than to males.[4]

Biology—the science and study of life—has no more basic premise than that life is a cycle. In the 1970s, the utility of study of populations of organisms added great value to the field, but the view that the population can be effectively substituted for a species obscures the original understanding that there are cyclical life stages, and indeed that these stages unfold in distinct sexes for purposes of perpetutation of that species.

Every stage of the lifecycle is fundamental to the viability of a species, so the presumption that radiation impacts could be studied in an adult population without reference to exposures to children, combined with the presumption that biological sex was not a factor in radiation exposure outcome, means that a lot of radiation research prior to 2006 (and any research preserving these unsupportable presumptions today) feature a systematic under-reporting of radiation harm to the global population. Many people are omitted if only the young adult male 'counts'. The recognition of these factors came late and has been very slow in uptake.

## 'Reference Man'

Historically, atomic workers were sent into radioactive sites. Relatively few women were involved in the creation of the nuclear arsenal in the United States. In the Soviet Union, there may have been more female atomic workers, although the number was still relatively low compared to men. The primarily male military and paramilitary workforce first of the Manhattan Project and later in the United States during the Cold War led to use of 'Reference Man' for purposes of calculation of radiation exposure, harm, and also modelling compliance with regulation.

> Reference Man: between 20 and 30 years of age, weighing 70 kg, is 170 cm in height, and lives in a climate with an average temperature of from 10°C to 20°C. He is a Caucasian and is a Western European or North American in habitat and custom.[5]

Reference individuals are used to create a static 'case' where a single set of defined parameters creates a 'yardstick'; it is logical to have such a tool. Unfortunately, the adult male is the most radiation-resistant category of human being and so using it as a sole reference point results in underestimation of radiological danger and harm for children and for females of all ages. Atmospheric nuclear tests released and spread large quantities of radioactivity[6] across people of all ages and sexes, everywhere. Although the focus of this chapter is on human

1 In all cases in this chapter, 'radiation' refers to ionizing radiation.

2 Gender identity is personal. The term is often used interchangeably with 'biological sex' in the scientific literature on radiation. Only relatively recently have data been disaggregated by biological sex and, maybe, binary assignment by researchers.

3 The LSS is a research programme investigating life-long health effects based on epidemiologic (cohort and case-control) studies. Its goal is to investigate the long-term effects of atomic bomb radiation on causes of death and incidence of cancer. About 120,000 subjects selected from residents of Hiroshima and Nagasaki identified through the national census in 1950 have been followed since that time: 94,000 atomic-bomb survivors and 27,000 unexposed individuals. Radiation Effects Research Foundation, 'Life Span Study (LSS)', undated but accessed 18 August 2025, at: https://bit.ly/45DsYN3.

4 Committee to Assess Health Risks from Exposure to Low Levels of Ionizing Radiation, *Health Risks from Exposure to Low Levels of Ionizing Radiation: BEIR VII, Phase 2*, National Academies Press, Washington, DC, 2006.

5 International Commission on Radiological Protection (ICRP), *Report of the Task Group on Reference Man*, ICRP Pub No. 23, Pergamon Press, Oxford, 1975, 4.

6 See, e.g., S. Philippe, S. Alzner, G. P. Compo, M Grimshaw, and M. Smith, 'Fallout from U.S. atmospheric nuclear tests in New Mexico and Nevada (1945–1962)', *arXiv*:2307.11040, at: https://bit.ly/3UFpBjw.

impacts, the contribution from fission products in our environment to the planetary loss of biodiversity should not be ignored.[7]

Analysis in 2023 by Körblein of infant deaths during the period of atmospheric nuclear weapon testing[8] supports a previous finding by Tucker and Alvarez[9] that from the first nuclear detonation in 1945 (the Trinity Test), nuclear fallout kills babies (infant children, different from loss of pregnancy). Dr Körblein studied long-term trends in infant mortality rates in the United States and five major European States (France, Germany, Italy, Spain, and the United Kingdom). Between 1950 and 2000, an overall increase in infant mortality rate was estimated to be 20.6 per cent in the United States and 14.5 per cent in the five European States, translating to 568,624 excess infant deaths in the United States and 559,370 in the five European States combined. The study warns that the results should be interpreted with caution, but concludes that millions of young lives may have been lost from fallout from atmospheric nuclear testing in the Northern Hemisphere. Körblein posits that the immediate cause of death could be abnormal immune system function in the mother during pregnancy. The Hiroshima and Nagasaki data also suggest that exposure of children is far more damaging than exposure of adults, adjusted for all other factors.

A 2019 study by the current author[10] was a review of analysis of the LSS data published by the NAS in 2006 in the Biological Effects of Ionizing Radiation (BEIR) VII report,[11] examining the question of sex difference in radiation outcome. Her finding that biological sex is a causal factor in the outcome of radiation exposure was first published in 2011.[12] Her work was an independent confirmation of a prior finding by Makhijani and others, which had been published by the Institute for Energy and Environmental Research, also in 2006.[13] Chapter 6 above also includes details of research supporting the disproportionate greater harm to children compared to adults and females compared to males.

The findings from the data in the LSS, which looked only at cancer incidence and cancer death, are as follows: atomic radiation is more harmful when exposure is to children compared to exposure of adults, although the harm to children may not manifest until they become adults. Exposure of children results in three to seven times more cancer than the same exposure of adults, and this is not all childhood cancer: cancer incidence is observed across the lifetime. The survivor data are disaggregated by sex and organized by the age they were when exposed to the atomic bomb detonations in 1945. In the youngest age cohort, females suffered twice as much cancer across their lives as did the males exposed at the same age. Among the cohort that were adults at the time of exposure, for every two men who died of cancer, three women died. See Figures 1a and 1b overleaf.

The dataset formed by the LSS is tied solely to the human exposure to radiation from the flash of gamma and neutron radiation at the moment of detonation of the nuclear strikes in August 1945.[14] This means that only 'external exposure' to radiation is being studied. Further, since the LSS data collection began in 1950, only those who survived the bombing and five years after are represented. Furthermore, the omission of internal exposures in the research question, dose reconstruction, and application of the case-control in the LSS means that we do

7 S. Powell, 'Dwindling bird populations in Fukushima', Blog post, University of South Carolina, 14 April 2015, at: https://bit.ly/3REvJ9E.
8 A. Körblein, 'Statistical modelling of trends in infant mortality after atmospheric nuclear weapon testing', *PLOS ONE*, 2023, at: https://bit.ly/3vdf1H1.
9 K. Tucker and R. Alvarez, 'Trinity: "The most significant hazard of the entire Manhattan Project"', *Bulletin of the Atomic Scientists*, 15 July 2019, at: https://bit.ly/48mf8ym.
10 M. Olson, 'Disproportionate impact of radiation and radiation regulation', *Interdisciplinary Science Reviews*, Vol. 44, No. 2 (2019), 131–39, at: https://bit.ly/41z1mWK.
11 *Health Risks from Exposure to Low Levels of Ionizing Radiation: BEIR VII, Phase 2*.
12 M. Olson, 'Atomic Radiation is more Harmful to Women', Briefing Paper, Nuclear Information Resource Services, 2011, at: https://bit.ly/4misx1F.
13 Makhijani, Smith, and Thorne, 'Science for the Vulnerable: Setting Radiation and Multiple Exposure Environmental Health Standards to Protect Those Most at Risk', p. 40.
14 Olson, 'Disproportionate impact of radiation and radiation regulation'.

not know if these disproportionate harms to children and to females are associated with internal radioactivity from breathing contaminated air and eating and drinking contaminated foods and water. It is an important question that should be tracked not only for humans, but for all lifeforms. Nevertheless, the 2006 publication of data supporting questions on age and biological sex among the A-bomb survivors is landmark, reframing our understanding of ionizing radiation.

**Figures 1a and 1b:** **Outcomes of prompt radiation exposure to different life stages**[15]

**Lifetime risk of cancer incidence (acute exposure between birth and age five)**

**2 Boys** **4 Girls**

**Lifetime cancer fatalities among those exposed to ionizing radiation as adults**

**2 Men** **3 Women**

To date, little work has been done to ask, let alone to answer, the question 'why?' Why is biological sex a factor in the outcome of radiation exposures? The list of hypotheses is growing, including one by Bertell, who suggests that female bodies have a higher percentage of reproductive tissue than do male bodies. This is a testable hypothesis, but it is one that has not been tested to date. Since radiation is becoming ever more present in modern life, it is surprising that the issue of why radiation is often more harmful to female bodies compared to male bodies does not have more priority.[16]

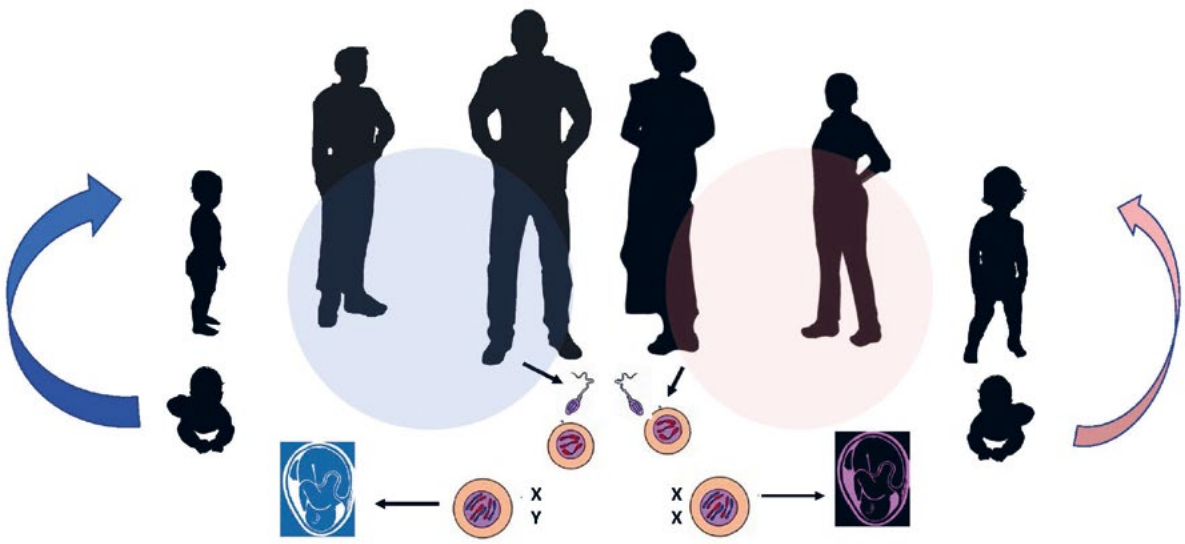
The current author, a biologist, argues that a key fundamental is missed: human beings (and all of life) exist as a life cycle. Figure 2 opposite illustrates this point. A population model is not sufficient, and unless the reference is based on the weakest link in the life-stage chain, the whole system will collapse. Each stage is required

15 This figure designed by the current author is based on her 2019 work, 'Disproportionate impact of radiation and radiation regulation', *Interdisciplinary Science Reviews*.

16 See further on this issue: A. M. Nichols and M. Olson, 'Gender and Ionizing Radiation: Towards a New Research Agenda Addressing Disproportionate Harm', Report, UNIDIR, Geneva, 2024, at: https://bit.ly/4jp2G6N.

for all. This view is necessary in order to look at whole communities and families that have been impacted by fallout over several generations. The consequences of not including the biological reality of the life stages and the presence of the reproductive cells throughout the individual lifespan when it comes to the impact of radiation exposure cannot be overstated.

**Figure 2:** **Ionizing radiation and our lifecycle**




**Full Human Lifecycle ∞**

## Lifecycle:

Primary reproductive cells
- Ova
- Sperm/Spermatogonia

Life stages of the individual are somatically female (xx), male (xy), or intersex
Stages: Embryo, Fetus, Infant, Child, Pubescent, Adult, Elder

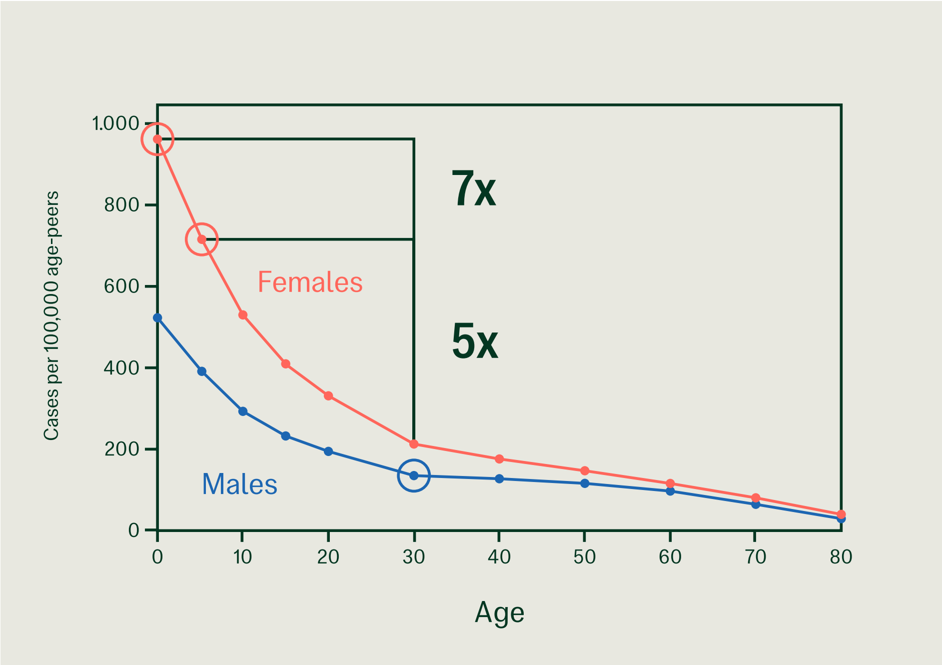
Exposure of a lifecycle to ionizing radiation at any life stage may produce outcomes across all life stages. Primary reproductive cells are present throughout the somatic cycle, therefore intergenerational outcomes are also possible from any exposure to ionizing radiation, though there are points of higher risk, such as pregnancy.

Each life stage is required for every other life stage to emerge. The reproductive cells, which are present in every life stage, can be harmed by radiation at any step. Often disruption of an ova or sperm results in failure to reproduce or infertility.
Figure © Mary Olson and Amanda M. Nichols.[17]

The consequences of not including the biological reality of the life stages and the presence of the reproductive cells throughout the individual lifespan when it comes to the impact of radiation exposure cannot be overstated. The importance of factoring and basing radiation protection on life stages and lifecycle are clearer in Figure 3 overleaf. The graph is a 'hypothetical scenario' constructed from the A-Bomb survivor data-set, where individuals all received the same level of radiation exposure of 20 millisievert (mSv). This is not what happened, but a data scenario is a valuable way to interrogate data. The author used the plotted data presented in Table 12D-1 in the NAS BEIR VII, 2006 report, adjusted for exposure level.

17 Reproduced from ibid.

**Figure 3:** **Increased cancer risk by age at exposure to 20 mSv radiation**




A fixed exposure hypothetical scenario of 20 mSv applied to the dataset on the survivors from the US nuclear strikes on Hiroshima and Nagasaki in 1945, in Table 12D-1, NAS, 2006, Biological Effects of Ionizing Radiation (BEIR VII), where the blue circle represents the data point undergirding Reference Man. Figure © Mary Olson, 2024.

The findings displayed in Figure 3 have not (yet) been embraced by radiation policy or regulation, which remain centred on the adult man instead of those most harmed. The blue circle on the plot shows the data underpinning Reference Man and the lines are drawn to show that he is seven times less harmed compared to those most-harmed – youngest girls. There are many reasons the radiation community has chosen to disregard basic biology, but continuing down that path is hazardous. Figure 3 is clear: if one is to achieve meaningful radiation protection, one cannot generalize radiation outcomes from an adult male body, or from a blended male and female, nor even from an averaged male and female. In 2006, Table 12D-1 in BEIR VII constituted the strongest evidence that female bodies are harmed by radiation more than males. In every age cohort in Figure 3, we can see females suffered more cancers than males—the pink line never crosses the blue line.

In 2024, the current author and Dr Amanda Nichols sampled published, peer-reviewed research on radiation health consequences.[18] They found 19 further papers showing greater harm to females than males, measured as cancers, blood cancers, cardio-vascular disease, and additional health consequnces. Published by the UN Institute for Disarmament Research (UNIDIR), the report as a sampled review of literature, simply points to what are very likely a very large number of such papers. Nonetheless, with confidence we can now say, with BEIR VII, at least 20 peer-reviewed sources show that females are harmed more than males.

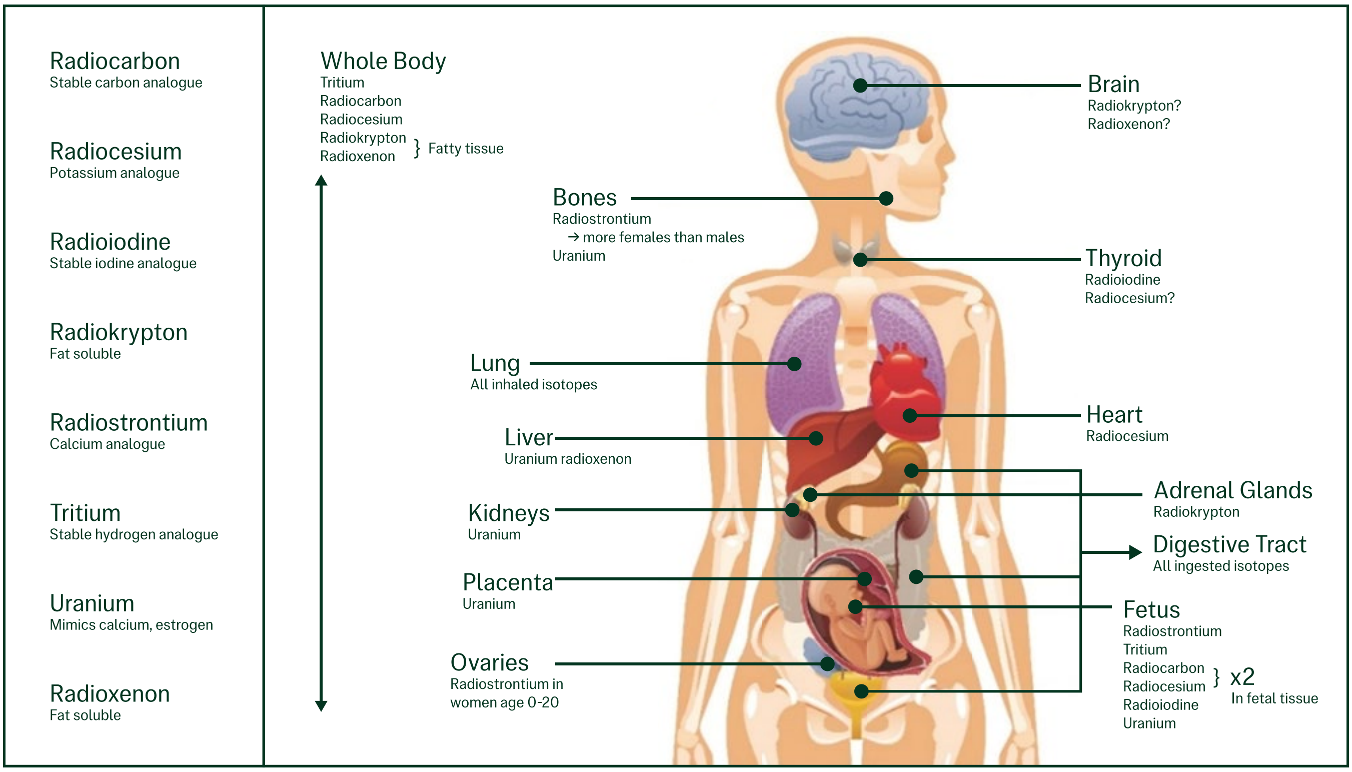
The radiation community (at the global level) has recently begun to engage with these findings, taking an approach that preserves the work based on an adult male by assigning females and children to a portfolio of 'susceptibility effects' and 'confounding factors.' Since there is already deep investment in an existing 'system of protection,' change is slow. Some updates have, however, been undertaken, for instance by merging adult male and adult female organs to make a 'blended' adult reference person.

18 Nichols and Olson, 'Gender and Ionizing Radiation: Towards a New Research Agenda Addressing Disproportionate Harm'.

## Internal exposure

Another fundamental factor in the outcomes of radiation exposure is the difference between external exposure to penetrating radiation—such as pure-energy X-rays and gamma rays—and exposure to internalized radioactive contamination from air, food, and water, where the impact of alpha and beta particles is fundamentally different to that of the energy rays (see Figures 4 below and 5 overleaf).

**Figure 4:** **Body map: fission products**






The chemical properties of radioactive atoms have similar chemical and biological properties as non-radioactive elements. As an example, strontium-90 is similar to calcium and deposits in teeth and bone; caesium is chemically similar to potassium and is taken up by muscle, including the heart.

When a radioactive element has entered our body via ingestion or inhalation, the emission of particles from radioactive decay are now inside tissues, organs and blood. Alpha particles emitted outside our body are so big they will stop in the outer non-living layers of the skin. Inside the body, because of its size, an alpha particle may cause 300 to 500 times more damage to cell structures compared to an X-ray[19] (see Table 1 overleaf). The beta particle can penetrate about a centimetre into our body from the outside, but, like the alpha particle, it is far more destructive when emitted inside the body. Beta decay is typical of strontium and tritium, two radionuclides that can cross the blood-barrier of the placenta during pregnancy (see Figure 4 above).

19 M. Kadhim, S. Salomaa, E. Wright, G. Hildebrandt, O. V. Belyakov, K. M. Prise, and M. P. Little, 'Non-targeted effects of ionizing radiation–implications for low dose risk', Authors' manuscript, at: http://bit.ly/3JkGqho, p. 6, published in *Mutation Research*, Vol. 752, No. 1 (2013), 84–98.

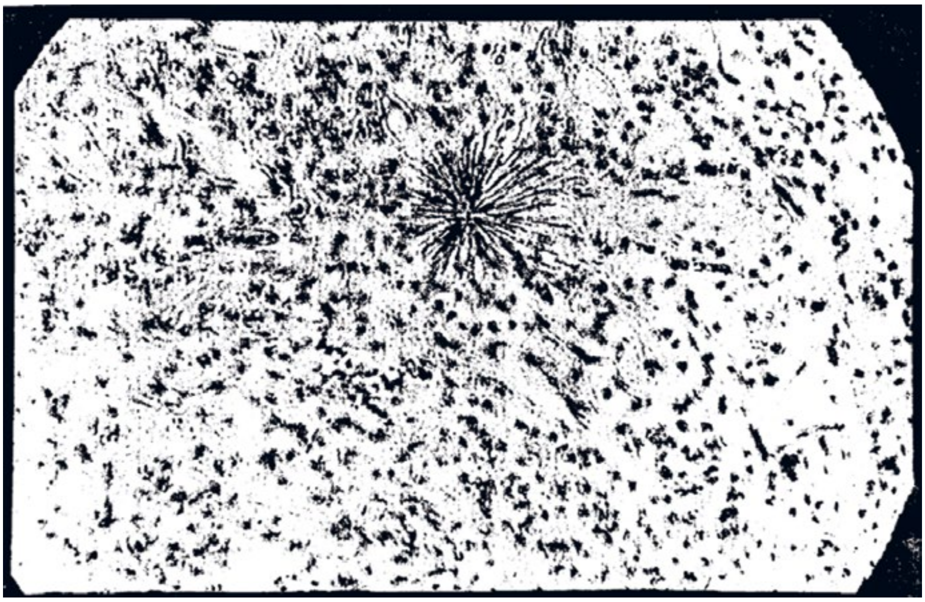
Table 1: **Selected biological impacts of particles and rays emitted by radioactive decay of elements**

| | Alpha emission | Beta emission | Gamma emission | Neutron emission |
|---|---|---|---|---|
| Atomic ionization | X | X | X | X |
| Damage from external exposure | | X | X | X |
| Break DNA strands | X | X | X | X |
| Damage/break chromosomes | X | X | X | X |
| Damage cell structures | X | X | X | X |
| Tear cell membranes | X | X | | |
| Reproductive cell harm | X | X | X | X |
| Harm pregnancy | X | X | X | X |
| Embrittle cardiovascular | X | X | X | X |
| Inflict burns | | X | X | X |
| Acute Radiation Syndrome | X | X | X | X |
| Cancer outcome | X | X | X | X |

Perhaps this era of extending focus to nuclear testing areas will engender greater interest in obtaining a better understanding of the harm from inhaling contaminated air and ingesting contaminated food and water. Of the great concern is communities where rainwater was collected and consumed or used to water family livestock, flocks, and gardens. These exposures were compounded by working in and inhaling contaminated soil.

Currently we cannot generalize the findings from the nuclear bomb survivors that biological sex is a factor in outcomes from radiation exposure originating from inside the body. This is because the data used in the LSS is primarily the prompt radiation from nuclear detonation, which makes it impossible to generalize to internal radiation exposure. A principle of precaution means we should proceed with the assumption that this is the case. At the very least, we should assume that internalized radioactivity is more harmful to pregnancy, infants, and children than it is to adults. Data could be collected from another large mammal impacted by radioactive food – bones are available from the Caribou (reindeer).

Figure 5: **Photograph of cell death due to deposition of plutonium particle in lung tissue. The particle is at the centre of the 'starburst' pattern.**



A particle of plutonium in lung tissue of an ape is at the centre of the pattern of lines. The radiation is not visible, but the cells it has killed are. The plutonium used to make nuclear weapons is Pu-239, which has a half-life of 24,000 years. Lung cancer is the principal risk from inhaled plutonium. If it is transported from the lung, it is generally deposited in bone and remains as a body burden for the rest of the individual's life. Photograph © Robert Del Tredici.

Those present at the time of nuclear detonation may be exposed to radiation that decays very quickly and which is highly radioactive. These very rapidly decaying radionuclides produce less or no impact on people far removed from the detonation in distance or time. Nevertheless, they should be included in calculations of both external and internal exposure for those who were nearby, and factored into the impact to reproductive cells in those individuals, their children, and subsequent generations. In addition, however, a nuclear detonation creates an immediate burst of deadly 'prompt' gamma rays and neutrons that impact the immediate area and, depending on the size of the bomb, spread out over a radius measured in kilometres. Thus, people present within several kilometres of ground zero are exposed to prompt gamma and neutron radiation.

Additional possible outcomes from concentrated exposures to ionizing radiation include cardiovascular diseases such as arteriosclerosis, heart attack, and stroke. Like cancer, female bodies are more likely to suffer radiation damage to this system compared to males. These findings were originally associated with medical radiation treatment. Study of these outcomes at lower exposures is ongoing.[20]

When it comes to some health outcomes due to radiation, the term 'stochastic' has been applied, particularly to cancer and reproductive impacts that are linked directly to DNA damage. To a large degree, for these outcomes, it does not matter the amount of radiation to which we are exposed – any has the potential to produce either cancer or reproductive harm. Radiation impacts our cells. Our bodies have repair mechanisms so radiation damage does not always result in bad outcomes. There is no way to know what exposure will result in harm. In general, however, the greater the exposure, the more likelihood of harm, but even a radiation exposure so small we cannot measure it can lead to a fatal cancer or a lost pregnancy.

## Intergenerational consequences

In contrast to a population-oriented view of radiological impacts, application of a lifecycle perspective allows a discussion of intergenerational outcomes from a somewhat different angle. An appreciation of the lifecycle affirms that reproductive cells are continuously present in the individual and may be harmed along with somatic cells, at any time. If the harm is catastrophic to the germ cells, it may contribute to infertility,[21] an effect which, by definition, is not 'visible' in a population study of any other health impact.

Some researchers, including the authors of an NAS report on genetic impacts among the 1945 atomic bomb survivors in Japan, have dismissed the dangers of radiation to early term pregnancies:

> We also recognize the obvious – that genetic effects resulting in foetal loss prior to the fifth lunar month of pregnancy would not be detected by this study but that early foetal losses would have both a relatively small emotional impact on the parents and a relatively small cost to society.[22]

While this may be true in some cases, it belies the hesitation reported by some in this same group to attempt pregnancy at all, as well as social stigma that came with being an atomic survivor, or their child, and even the grandchild of a survivor.[23] Losses of pregnancy contribute to these stresses.

20 D. B. Richardson, K. Leuraud, D. Laurier, M. Gillies, R. Haylock, K. Kelly-Reif, S. Bertke, R. D. Daniels, I. Thierry-Chef, M. Moissonnier, A. Kesminiene, and M. K. Schubauer-Berigan, 'Cancer mortality after low dose exposure to ionising radiation in workers in France, the United Kingdom, and the United States (INWORKS): cohort study', *The British Medical Journal*, 2023, at: https://bit.ly/3SO59Ne.

21 F. De Felice, C. Marchetti, F. Marampon, G. Cascialli, L. Muzii, and V. Tombolini, 'Radiation effects on male fertility', *Andrology*, Vol. 7, No. 1 (2019), 2–7, at: https://bit.ly/3UwG7Ui; and M. Skrzypek, A. Wdowiak, L. Panasiuk, M. Stec, K. Szczygieł, M. Zybała, and M. Filip, 'Effect of ionizing radiation on the female reproductive system', *Annals of Agricultural and Environmental Medicine*, Vol. 26, No. 4 (19 December 2019), 606–16, at: https://bit.ly/3SvDO0Z.

22 J. V. Neel and W. J. Schull (eds.), *The Children of Atomic Bomb Survivors: A Genetic Study*, National Research Council, National Academies Press, Washington, DC, 1991.

23 D. Normile, 'Aftermath: By allowing scientists to study their suffering, atomic bomb survivors have transformed our understanding of radiation's health effects', *Science Magazine*, 23 July 2020, at: https://bit.ly/3SO01bY.

Radiological impacts to DNA in primary germ cells that are not catastrophic may be passed on to the next generation. The genetic change may express in the somatic phenotype of the individual, and also be passed along in that individual's reproductive cells (germ-line) as new heritable traits subject to inclusion or exclusion in meiosis after conception. This has been seen in many organisms monitored in contaminated zones, including the post-1986 Chernobyl exclusion zone.[24] Not all genetic changes herald disorders. Dubrova and colleagues have identified novel, heritable gene sequences that are being transmitted among chronically radiation-exposed people in Kazakhstan. These markers have been tracked across two and three generations. These new genetic characteristics are not associated with any identifiable phenotypic outcomes, and are not evidence of disease.[25]

The same researchers who dismissed loss of early pregnancy among atomic bomb survivors[26] also made no finding of radiation-caused heritable mutations or congenital anomalies among the first generation (children), or the second generation (grandchildren) of the atomic bomb survivors, above that 'expected' or in comparison to a control population. It is difficult, however, to prove a negative. During pregnancy, radiological impact may be to the mother, to other ova still in her ovaries, or to the developing foetus, which has an individual genetic identity. Each of these are in a distinct life-phase, and radiation will impact each differently. One example of direct radiological impact from fallout to the foetus during gestation is as follows: Radioactive tritium, whether naturally occurring, from atmospheric nuclear weapons tests or fallout from the operation and refuelling of nuclear power reactors, can bond into a water molecule and be chemically identical to any other water molecule. When the tritiated water enters the body of a pregnant woman, it can cross the placental barrier as water and enter the developing foetus where it is found to be a causal agent in childhood leukaemia.[27]

In the end, when it comes to intergenerational consequences, the Manhattan Project initiated one of the largest 'un-controlled' experiments ever. There was an enormous 'body burden' to our planet resulting from the combined nuclear detonations, which exceed 2,000. This body burden is also, to varying degrees, in our own bodies, and most especially those who have been living with high levels of deposition. Every effort to prevent further fallout is an investment in global public health.

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24 T. Hinton, R. Alexakhin, M. Balonov, N. Gentner, J. Hendry, B. Prister, P. Strand, and D. Woodhead, 'Radiation induced effects on plants and animals: Findings of the United Nations Chernobyl Forum', *Health Physics*, Vol. 93, No. 5 (November 2007), 427–40, at: https://bit.ly/4bttjUM.

25 Y. E. Dubrova, R. I. Bersimbaev, L. B. Djansugurova, M. K. Tankimanova, Z. Z. H. Mamyrbaeva, R. Mustonen, C. Lindholm, M. Hultén, and S. Salomaa, 'Nuclear weapons tests and human germline mutation rate', *Science*, Vol. 295, No. 5557 (8 February 2002), 1037, at: https://bit.ly/3OwGf2d.

26 Neel and Schull (eds.), *The Children of Atomic Bomb Survivors: A Genetic Study*.

27 C. Folkers and L. P. Gunter, 'Radioactive releases from the nuclear power sector and implications for child health', *BMJ Paediatrics Open*, 2022; at: https://bit.ly/3w8GJoY; and I. Fairlie, 'Radiation and Childhood Cancer: the risks of low-level radiation with particular reference to cancer incidence and mortality among children', Report, 28 May 2021, at: www.ianfairlie.org.

Chapter 8:

# Psychological, Social, Economic, Cultural, and Political Impacts

Matthew Breay Bolton

Nuclear weapon testing has caused lingering harm that extends well beyond the physical health effects. Governments often acknowledge only a narrow set of radiogenic illnesses—primarily among veterans—and frequently neglect the broader psychological, social, economic, cultural, and political consequences. People who witnessed nuclear tests or were potentially exposed to ionizing radiation may suffer from chronic stress, anxiety, and depression, and display symptoms of trauma, including from worries about the potential health effects on themselves, their children, and grandchildren. These consequences are compounded by secrecy and denial. The establishment of nuclear test sites displaced significant numbers of people, often those coming from already marginalized communities. Indigenous and colonized peoples were driven away from ancestral lands, suffering economic disruption and loss of cultural identity, but without being granted due compensation or the opportunity to later return.

Nuclear weapon tests have reverberating impacts with psychological, cultural, social, economic, and political consequences. But when nuclear-armed States have accepted that there is a legacy of harm from nuclear testing, they usually focus on a narrow and not comprehensive list of physical medical ailments that they recognize as radiogenic. They also tend to focus on veterans rather than on the civilian victims of their testing. The focus on the medical consequences of nuclear testing may, intentionally or unintentionally, serve to limit the liability and responsibility of States for other humanitarian and environmental effects of nuclear explosions.

## Psychological and social impacts

Nuclear test experiences can have lingering impacts on survivors' mental health. People who witness nuclear tests or who were potentially exposed to ionizing radiation may suffer from chronic stress, anxiety, depression and/or trauma symptoms, including worries about the potential health effects on themselves and their children and grandchildren.[1] In interviews with United States (US) nuclear test veterans, Garcia found a common theme of difficult memories of the physical effects of nuclear detonations and their stressful aftermath of 'equipment or locales unexpectedly becoming radioactive (e.g., due to wind shifts, unpredictable 'hot spots', or aircraft that returned from contaminated areas) and ensuing frenzied scenes.'[2]

A study of 550 New Zealand nuclear test veterans published in 2005 similarly found many suffering from chronic stress. The study suggested these symptoms may be due to the 'high degree of uncertainty' about whether their health had been impacted by the radiation exposure.[3] A second study at Massey University found that 'nuclear veterans exhibited more depressive symptoms, and perceived their health and memory performance to be poorer than the Control group'. The researcher posited this as the result of subjects' 'hypervigilance' derived from anticipating future harm to their health.[4]

Such psychological impacts have sometimes been dismissed as an irrational fear of radiation, to be addressed through 'more effective risk communication'.[5] One of the first psychological studies of nuclear test veterans, conducted by Vyner, interviewed 11 participants who had reported psychological problems. Vyner found that the men's 'debilitating psychiatric symptoms' resulted from a 'pathological development of the self-diagnostic belief' that they would or had already been physically harmed by radiation.[6] A study of residents' aversion to engaging in agricultural activities in the Semey/Semipalatinsk test site region of Kazakhstan argued that accusations of 'radiophobia' shifts blame for concerns about radioactive legacies of nuclear testing away from the public domain and into 'a mental disorder located inside the head of its victims'.[7]

A recent comprehensive review of scholarship found that in numerous contexts and settings, proximity to nuclear detonations, accidents, and radioactive materials had psychological impacts.[8] For instance, they assert that the impact on mental health is 'the largest public health consequence following the Chernobyl disaster'. The review's authors urge caution in not dismissing the possibility that exposure to ionizing radiation, even at low

1 See, e.g., B. C. Murphy, P. Ellis, and S. Greenberg, 'Atomic Veterans and Their Families', *American Journal of Orthopsychiatry*, Vol. 60, No. 3 (July 1990), 418–27.

2 B. Garcia, 'Social-Psychological Dilemmas and Coping of Atomic Veterans', *American Journal of Orthopsychiatry,* Vol. 64, No. 4 (1994), 651–55.

3 J. Podd, J. Blakey, R. Jourdain, and R. E. Rowland, *New Zealand nuclear test veterans study – a pilot project (psychological impact)*, Massey University, Palmerston North, New Zealand, 2005, at: https://bit.ly/3TtQI1r.

4 R. L. Jourdain, '"Psychological Fallout": The Effects of Nuclear Radiation Exposure', Thesis for clinical psychology doctorate, Massey University, 2009, New Zealand, available at: https://bit.ly/49SsByC.

5 D. Ropeik, 'The dangers of radiophobia', *The Bulletin of Atomic Scientists*, Vol. 72, No. 5 (2016), 311–17.

6 H. M. Vyner, 'The Psychological Effects of Ionizing Radiation', *Culture, Medicine and Psychiatry*, Vol. 7 (1983), 241–61.

7 M. E. Stawkowski, 'Radiophobia had to be reinvented', *Culture, Theory and Critique*, Vol. 58, No. 4 (2017), 357–74.

8 G. Collett, K. Craenen, W. Young, M. Gilhooly, and R. M. Anderson, 'The psychological consequences of (perceived) ionizing radiation exposure: a review on its role in radiation-induced cognitive dysfunction', *International Journal of Radiation Biology*, Vol. 96, No. 9 (September 2020), 1104–18.

doses, may cause cognitive harm. For, in the absence of dosimetry and medical research, 'it is difficult to assess whether or not an individual's fear of radiation is unreasonable or excessive'. Nevertheless, the review concluded that 'perceived exposure' likely had a greater negative impact on cognitive functioning than the effects of actual exposure. This should not lead to dismissal of the need to understand and alleviate stress relating to radiation exposure, the authors concluded. In addition, further study is needed on how to communicate the risks of radiation exposure in ways that do not exacerbate psychological harm in affected communities.

Other studies have highlighted how exposure to nuclear detonations is experienced as an affront to a person's dignity that has lasting psychological effects. Garcia, for example, argued that the US nuclear veterans she interviewed expressed 'alarm at how little information they were given and how ill prepared they were for the nuclear-testing events'; she noted that many interviewees were 'especially disturbed by the lack of protective gear'.[9] The veterans experienced this lack of regard for their safety as a challenge to their sense of a 'just world', which meant that they had to reconcile 'a belief in their country' with 'experiences of a lack of governmental attention to their safety'. They have been forced to 'deal with the possibility of having had their lives undermined without apology, acknowledgment of error, or recognition of their service to their country.'[10]

The extensive practices of secrecy may limit victims' ability to seek information, peer support, and therapeutic care.[11] Indeed, it may inflict further psychological injury due to lack of acknowledgement or apology — even outright denial — from the responsible State.[12] I-Kiribati survivors have expressed a sense of humiliation that comes from the ongoing lack of recognition of or apology for the impacts of the UK and US nuclear tests on their land, which is experienced as a disregard for their humanity. 'If you hurt someone you should help them, because we are human beings', says Teeua Tetua, the president of the nuclear test survivors association in Kiritimati (Christmas Island). 'It should be known by the world, the cruel things that have been done.'[13] The 'psychological fallout'[14] from nuclear weapon testing may extend to the broader population. Following the cessation of nuclear testing in the region, Pacific Islands Forum leaders expressed concerns that 'painful memories … still haunt many people in the region'.[15]

Those who most suffer the consequences of social fears about radiation are often those who are perceived as most exposed to it. In several contexts, test participants and those who lived in the vicinity of detonations and/or fallout have reported experiencing continuing stigma, including social ostracization and economic marginalization.[16] Persistent secrecy and deliberate misinformation surrounding nuclear test programmes have a profoundly negative social impact on affected communities as they are unable to access crucial information about decisions and data that impact their health and wellbeing. The Chinese government, for instance, 'steadfastly refuses to acknowledge' the consequences of the Lop Nur atmospheric nuclear tests.[17] Much of the documentation that could aid assessment of the need for environmental remediation in Kiribati remains classified by the British Government.[18] Ian Zabarte, Principal Man of the Western Shoshone nation on whose

9 Garcia, 'Social-Psychological Dilemmas and Coping of Atomic Veterans'.

10 Ibid.

11 Knibbe, 'The Atomic Soldiers'.

12 B. R. Johnston (ed.) *Half-lives and Half-truths*, School for Advanced Research Press, Santa Fe, NM, 2007; Cody Murphy *et al*., 'Atomic Veterans and Their Families', 418–27.

13 B. Alexis-Martin, M. B. Bolton, D. Hawkins, S. Tisch, and T. Luscia Mangioni, 'Addressing the Humanitarian and Environmental Consequences of Atmospheric Nuclear Weapon Tests: A Case Study of UK and US Test Programs at Kiritimati (Christmas) and Malden Islands, Republic of Kiribati', *Global Policy*, Vol. 12, No. 1 (February 2021).

14 M. Wangh, 'The Psychological Fallout of Surface Nuclear Testing'. *American Imago*, Vol. 38, No. 3 (1981), 305–22; M. J. Carey, 'Psychological Fallout: Growing up nuclear', *Bulletin of the Atomic Scientists*, Vol. 38, No. 1 (1982), 20–24.

15 Pacific Islands Forum, Forum leaders' statement on nuclear testing, in New Zealand Ministry of Foreign Affairs and Trade (ed.), *The South Pacific Forum: regional cooperation at work*, *Information Bulletin*, Vol. 56 (1996).

16 See, e.g., A. M. Subica, N. Aitaoto, J. Greer Sullivan, B. F. Henwood, A. M. Yamada, and B. G Link, 'Mental illness stigma among Pacific Islanders', *Psychiatry Research*, Vol. 273 (March 2019), 578–85.

17 Z. Merali, 'Did China's Nuclear Tests Kill Thousands and Doom Future Generations?', *Scientific American*, 1 July 2009, at: https://bit.ly/3wzeMGR.

18 B. Alexis Martin and M. B. Bolton, 'Addressing British nuclear tests in Kiribati', Briefing Paper, UNA-UK, London, 2022, at: https://bit.ly/48s64Yq.

territories the Nevada Test Site is based, writes that the US government's 'culture of secrecy' has prevented people from understanding 'what has happened to us. … For more than 50 years, we have been suffering from this silent killer and … we need relief.'[19]

The choices of test and waste disposal sites were typically based on discriminatory racial and ethnic practices.[20] For example, a memorandum of the US Atomic Energy Commission classified top secret described the people downwind of the Nevada Test Site—many of whom were Native Americans, Mormons, and rural residents—as 'a low-use segment of the population'.[21] China's nuclear test programme was located in the Xinjiang Uyghur Autonomous Region, which has been subject to serious repression and environmental injustice. One researcher found the memories of the nuclear tests, as well as fears of ongoing contamination, remain a serious grievance of Uyghur people, many of whom feel the radioactive legacies form part of a broader attack on their religious and ethnic identity.[22] Documents of the British nuclear test programme in Kiribati demonstrate acceptance of racist assumptions leading to differing standards of radiation protection for 'civilised' versus 'primitive' peoples.[23]

## Displacement and economic impacts

The establishment of nuclear test sites displaced significant numbers of people, often those coming from already marginalized communities. Indigenous and colonized Peoples were driven away from ancestral lands without due compensation or opportunity to later return. The Soviet Union removed Indigenous Peoples from their homeland in Novaya Zemlya to set up its Arctic test site.[24] A 2024 report on the Marshall Islands' nuclear legacy by the Office of the UN High Commissioner for Human Rights (OHCHR) concluded that the US nuclear testing programme had fostered enduring economic, social, and cultural harms against Marshallese people. The report called for a transitional justice approach that, among other measures, would be aimed at providing 'adequate compensation for economically assessable damage, moral damages and loss of earnings, property and economic opportunities'.[25]

Test programmes have often created significant economic disruptions. While the infusion of cash into economically marginalized regions can stimulate local economies, it is not necessarily a sustainable form of development. Studies of Māʼohi Nui (French Polynesia) show that the test programme fuelled an unequal consumption economy, heavily reliant on imports. Rapid urbanization of the capital, Papeete, resulted in serious social problems, including lack of adequate housing, rising crime rates, undermining of longstanding cultural norms, substance addiction, gender-based violence, and sexual exploitation.[26]

Nuclear test programmes often enclosed large areas of land and water in Indigenous territories and/or those under colonial administration. Exclusion from these sites had cascading harmful impacts on those who had connections to them, including loss of economic livelihood (such as the ability to forage, hunt, and grow food),

19 I. Zabarte, 'A message from the most bombed nation on earth', *Al Jazeera*, 29 August 2020, at: https://bit.ly/4bmieo9.

20 T. B. Voyles, *Wastelanding: Legacies of Uranium Mining in Navajo Country*, University of Minnesota Press, Minneapolis, 2015; and N. Maclellan, 'Nuclear Testing and Racism in the Pacific Islands', in S. Ratuva (ed.) *The Palgrave Handbook of Ethnicity*, Palgrave Macmillan, Singapore, 2019, available at: https://bit.ly/430mYfs.

21 C. Gallagher, *American Ground Zero: The Secret Nuclear War*, MIT Press, Cambridge, MA, 1993, 109.

22 N. Baranovitch, 'The Impact of Environmental Pollution on Ethnic Unrest in Xinjiang: A Uyghur Perspective', *Modern China*, Vol. 45, No. 5 (2019), 504–36.

23 N. Maclellan, 'The Nuclear Age in the Pacific Islands', *The Contemporary Pacific*, Vol. 17, No. 2 (2005), 363–72.

24 V. I. Khalturin, T. G. Rautian, P. G. Richards, and W. S. Leith, 'A Review of Nuclear Testing by the Soviet Union at Novaya Zemlya, 1955—1990', *Science and Global Security*, Vol. 13, Nos. 1–2 (2005), 1–42.

25 'Addressing the challenges and barriers to the full realization and enjoyment of the human rights of the people of the Marshall Islands, stemming from the State's nuclear legacy', Report, OHCHR, UN doc. A/HRC/57/77, 24 September 2024, para. 55.

26 P. de Vries and H. Seur, *Moruroa and us: Polynesians' experiences during thirty years of nuclear testing in the French Pacific*, Centre de Documentation et de Recherche sur la Paix et les Conflits, 1997; and N. Maclellan and J. Chesneaux, *After Moruroa: France in the South Pacific*, Ocean Press, Melbourne, 1998.

limits to mobility, and access to culturally important sites.[27] Many protested against US and French exclusion zones around Pacific test sites as violations of the freedom of maritime navigation.[28] In Kazakhstan, economic activity in the region of the former test site at Semipalatinsk has been stunted by concerns about ongoing environmental contamination. According to the UN Development Programme (UNDP): 'Negative consequences include the degradation of the environment, an increase in different diseases, decrease in the standard of living, economic depression and psychological difficulties.'[29]

## Cultural and political impacts

Nuclear-armed States have often manipulated cultural, religious, and social norms in the interests of the test programmes. US Navy personnel tried to manipulate Bikinians' religious piety by using biblical references to try to persuade them to leave their islands voluntarily.[30] The Pacific Conference of Churches has highlighted the special responsibility of the Christian church in both condemning such abusive distortions of their faith and offering pastoral care to those who have suffered as a result of it.[31] Numerous commentators have shown how French Pacific nuclear testing perpetuated and actively promoted stereotypes of Māʼohi and other Pacific people as docile and sexualized.[32]

For many Pacific peoples, as well as Indigenous Peoples in North America and Russia, life-sustaining ecosystems are themselves sacred and hence nuclear testing represents a huge spiritual violation.[33] Some Indigenous environmental thinkers call for 'biocultural restoration' to restore not only ecosystems, but also human and cultural relationships to place.[34]

Affected communities' ability to address their concerns with nuclear test programmes has often been limited by their lack of self-determination.[35] The US government sited its Nevada test programme on the territory of the Western Shoshone nation, in violation of its treaty relationship.[36] French tests in Algeria were similarly interpreted by regional governments and social movements as an expression of its colonial and racist disregard for African peoples.[37] There is extensive evidence of French interference in the politics of Māʼohi Nui to limit expression of resistance to nuclear testing.[38] The Nuclear Free and Independent Pacific movement and many Pacific political leaders interpreted US, UK, and French nuclear tests as a violation of the region's rights to sovereignty.[39] Unlike the Human Rights Council, Paris Climate Agreement, or Biodiversity Convention, none of the nuclear arms control or disarmament treaties has a specific mechanism to facilitate meaningful participation of Indigenous and Non-Self-Governing Peoples.[40]

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27 See, e.g., P. N. Grabosky, 'A toxic legacy: British nuclear weapon testing in Australia', *Wayward governance: illegality and its control in the public sector*, Australian Institute of Criminology, Canberra, 1989, Chap. 16.

28 D. McTaggart and R. Hunter, *Greenpeace III: Journey into the Bomb*, Collins, London, 1978.

29 UNDP, 'Kazakhstan Still Recovering 60 Years after Soviet Bombing', 2009.

30 D. E. Richard, *United States Naval Administration of the Trust Territories of the Pacific Islands. Vol. III*, Government Printing Office, Washington, DC, 1957, 510.

31 S. Siwatibau and D. Williams, *A Call to a New Exodus: An Anti-Nuclear Primer for Pacific Peoples*, Pacific Conference of Churches, Suva, 1982, 68.

32 See, e.g., T. K. Teaiwa, 'Bikinis and Other S/pacific N/oceans', *The Contemporary Pacific*, Vol. 6, No. 1 (1994), 87–109.

33 See, e.g., M. Kahn, 'Tahiti Intertwined: Ancestral Land, Tourist Postcard, and Nuclear Test Site', *American Anthropologist*, Vol. 102, No. 1 (2000), 7–26.

34 Center for Native Peoples and the Environment, 'Biocultural Restoration', 2023, at: https://bit.ly/48FkGDV.

35 R. Jacobs, 'Nuclear Conquistadors: Military Colonialism in Nuclear Test Site Selection during the Cold War', *Asian Journal of Peacebuilding*, Vol. 1, No. 2 (2013), 157–177, at: https://bit.ly/429pAHt.

36 Zabarte, 'A message from the most bombed nation on earth'.

37 J. Allman, 'Nuclear Imperialism and the Pan-African Struggle for Peace and Freedom: Ghana, 1959–1962'. *Souls*, Vol. 10, No. 2 (2008), 83–102, available at: https://bit.ly/3TkkDJ5.

38 See, e.g., B. Danielsson and M.-T. Danielsson, *Poisoned Reign: French Nuclear Colonialism in the Pacific*, Penguin Books, New York, 1986.

39 A. Maurer, *The Ocean on Fire: Pacific Stories from Nuclear Survivors and Climate Activists*, Duke University Press, Durham, NC, 2024.

40 M. Bolton, 'Establishing a Mechanism to Ensure Meaningful Participation of Affected Communities, Indigenous Peoples and Non-Self-Governing Territories in the Work of the Treaty on the Prohibition of Nuclear Weapons', Working Paper, UN doc. TPNW/MSP/2025/NGO/6, 17 February 2025, available at: https://bit.ly/3GnaQ0W.


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# Part III

# Effective Interventions

**Radiation Legacy:** A man tests for radioactivity during a visit on 15 October 2022 to the Trinity Site in White Sands Missile Range in the United States. Trinity Site is where the first nuclear bomb was tested in July 1945. Photograph © Matt McClain, the Washington Post/Getty Images.

Chapter 9:

# Shared Responsibility for Nuclear Harm

Bonnie Docherty and Darvin Lisica

Effectively addressing the environmental and humanitarian impacts of past nuclear testing requires a framework of shared responsibility among all States. Affected States take the lead in environmental remediation and victim assistance due to their proximity and knowledge as well as for the protection of sovereignty, while other States, especially testing States, provide a range of support, including financial aid, technical expertise, information, and capacity building. This approach draws on legal precedents from humanitarian disarmament and international human rights law. It is operationalized through measures such as needs assessments, national plans, legal frameworks, focal points, and reporting systems. These measures should follow a set of guiding principles.

To effectively address the ongoing environmental and humanitarian impacts of nuclear testing requires both a collective effort of all States and practical steps for implementation. A framework of shared responsibility entitles affected States undertaking environmental remediation and providing assistance to victims to international support from other States, including, but not limited to, testing States. States should engage in concrete actions, establish specific mechanisms, and follow a set of principles in delivering a multifaceted and collaborative response to the impacts of nuclear testing.[1] This framework of shared responsibility spreads the burden for environmental remediation and victim assistance across all States and ensures that affected States have international support to address the harms they have suffered.[2]

Under this model, affected States take the lead in undertaking environmental remediation and victim assistance. This approach makes sense for both practical and legal reasons. Due to their geographic proximity to the sites and communities that have experienced the consequences of nuclear testing, affected States are better positioned to assess both the impacts and the resultant needs and then to respond to them. By taking ownership of planning, assessment, and implementation, affected States also protect their sovereignty and maintain control over which activities take place in their territory and how. As the chapter discusses, this approach follows the precedent set by humanitarian disarmament and international human rights law.

At the same time, other States should provide a range of support to affected States to help them deal with the effects of nuclear testing. They can provide, for example, financial, material, technical, or informational assistance. International law often limits this duty to States 'in a position to do so'. Given the breadth of assistance they can provide, however, all States should be able to provide some measure of support, even if this is only lessons learned from their own experiences or modest in-kind contributions. International organizations and the non-governmental sector also have a role and responsibility in this framework, both in terms of advocating for support to affected populations and in supporting national implementation measures, including capacity development of national authorities.

Testing States bear a moral and legal responsibility to support affected States even if they are not the only States that should provide international cooperation and assistance. Testing States inflicted the harm and therefore it is appropriate that they should provide significant assistance to address it. Like other States, they can provide a range of assistance, including financial, material, and technical assistance. Testing States are of course also uniquely situated to provide information about the devices and the detonations, and they can offer apologies to the victims. Given that nuclear-armed States have often been unwilling to adequately support environmental remediation and victim assistance efforts, the more broad-based framework of shared responsibility remains a humanitarian imperative. Nevertheless, this does not preclude affected States and individuals from seeking other forms of redress or legal remedies from the relevant testing States.

Different branches of law and practice offer ample precedent for a framework of shared responsibility for addressing the harm caused by specific weapons. The approach is firmly grounded in humanitarian disarmament law and associated implementation standards. For example, the 2008 Convention on Cluster Munitions establishes affected State responsibility for victim assistance and clearance of cluster munition remnants (analogous to nuclear contamination) and requires other States Parties in a position to do so to provide international cooperation and assistance.[3] It also politically commits user States to assist with

1 These points also apply to environmental remediation and victim assistance needs resulting from any *use* of nuclear weapons, but such use falls beyond the scope of this report, which focuses on nuclear testing.

2 For a discussion of the benefits of and precedent for the framework of shared responsibility for environmental remediation and victim assistance in the context of nuclear testing, see, e.g., Harvard Law School's International Human Rights Clinic (IHRC) and Conflict and Environment Observatory (CEOBS), 'Facing Fallout: Principles for Environmental Remediation of Nuclear Weapons Contamination', Report, President and Fellows of Harvard College, Cambridge, MA, June 2022, at https://bit.ly/4lFguem, pp. 24–27; IHRC and CEOBS, 'Confronting Conflict Pollution: Principles for Assisting Victims of Toxic Remnants of War', Report, President and Fellows of Harvard College, Cambridge, MA, 2020, at: https://bit.ly/4crxhxz, pp. 28–32.

3 Arts. 4, 5, and 6, Convention on Cluster Munitions; adopted at Dublin, 30 May 2008; entered into force, 1 August 2010 (CCM).

clearing the cluster munitions they left behind.[4] The Treaty on the Prohibition of Nuclear Weapons (TPNW) adopts the same approach, but creates an obligation for user and testing States to provide international assistance for both environmental remediation and victim assistance.[5]

International human rights law also adopts a shared approach to responsibility. The 1966 International Covenant on Economic, Social and Cultural Rights enumerates multiple rights that are relevant to environmental remediation and victim assistance and obligates States to take 'all appropriate means' to guarantee them 'individually and through international assistance and co-operation'.[6] The Covenant thus not only recognizes the role of States in caring for their own population, but also acknowledges that support from other States may be needed. Because economic, social, and cultural rights may take longer to implement, the Covenant allows States to realize them progressively.

## Implementation measures

The specific elements of environmental remediation and victim assistance will be elaborated on in Chapters 11 and 12, but there are several cross-cutting steps States should take to begin implementing their responsibilities in those areas. Affected States and, in the case of some measures, all States, should update existing policies and mechanisms or establish new ones. Overarching principles should guide this work at every stage.[7]

### Activities of affected States

If they have not already done so, affected States should create a national authority—or authorities—to coordinate and oversee all activities related to environmental remediation and victim assistance following nuclear testing. Such authorities should ensure that activities are conducted effectively, safely, and in alignment with national priorities and broader plans. National authorities should also cooperate with and facilitate support from stakeholders, including non-governmental organizations (NGOs), UN bodies, and donor States.

Affected States, through their national authorities, should assess the effects of nuclear testing in areas under their jurisdiction or control. In particular, these States should determine the extent and nature of environmental contamination and the health and socio-economic impacts on victims as well as their national capacity to respond. While assessments may require updating over time, initial assessments should focus on existing knowledge and programmes and what other information is required.[8] The national authorities should analyse the data with the assistance of experts, including local personnel and affected communities. On the basis of the assessments, affected States can plan and prioritize remediation and victim assistance.

Affected States should also develop national plans for engaging in environmental remediation and victim assistance. Such plans, including budgets and timeframes, facilitate the organization and management of

4 Art. 4(4), CCM, specifying that the user State Party 'is strongly encouraged to provide, *inter alia*, technical, financial, material or human resources assistance' to help the affected State Party with clearance of cluster munition remnants.

5 Arts. 6 and 7, Treaty on the Prohibition of Nuclear Weapons; adopted at New York, 7 July 2017; entered into force, 22 January 2021 (TPNW). Article 7(6) articulates the responsibilities of user and testing States Parties.

6 Art. 2(1), International Covenant on Economic, Social and Cultural Rights; adopted at New York, 16 December 1966; entered into force, 3 January 1976 (ICESCR). For more information on some of the rights implicated by nuclear testing, see below Chapter 13: The Possibility of Remedies under International Human Rights Law.

7 Multiple UN, civil society, and academic sources identify similar key elements of implementation. See, e.g., Actions 19 to 32 of the Vienna Action Plan in 'Report of the First Meeting of States Parties to the Treaty on the Prohibition of Nuclear Weapons', UN doc. TPNW/MSP/2022/6, Vienna, 21–23 June 2022, Annex II, para. 9; and IHRC, 'Implementing Victim Assistance and Environmental Remediation under the Treaty on the Prohibition of Nuclear Weapons', June 2022, at: https://bit.ly/3G7uizb, p. 2.

8 See, e.g., Action 30, Vienna Action Plan.

activities and help hold affected States to account. They make it easier to identify the types of international assistance needed, which makes that support more relevant and effective. To enhance efficiency, such plans can be incorporated into previously established national frameworks.[9] They may evolve as new information or technology becomes available.

### Activities of all States

Both affected States and States providing international cooperation and assistance should assign a government focal point to coordinate programmes to address the legacy of nuclear testing.[10] For affected States, their dedicated national authorities can fill this role. Other States should appoint focal points to coordinate the national ministries, local bodies, and non-State entities involved with nuclear testing-related environmental remediation, victim assistance, and international cooperation and assistance. Having a focal point increases the efficiency of these measures; provides a contact to handle requests for information; and promotes accountability by clarifying who has ultimate responsibility. In addition, States should adopt or adapt national laws and policies on environmental remediation, victim assistance, and international cooperation and assistance.[11]

Mechanisms for the provision of international cooperation and assistance from States, including but not limited to testing States, are also critical. They ensure the framework of shared responsibility can take effect and have humanitarian benefits because they facilitate the delivery of services that support environmental remediation and victim assistance. Such mechanisms should make it easier to prioritize among the needs of the affected State. As noted, assistance can come in a range of forms and should be a long-term commitment – because addressing the impacts of nuclear testing is a long-term undertaking. It should include capacity-building measures to promote sustainability, such as forward-looking funding strategies, the sharing of relevant expertise, skills training, and support to strengthen relevant national authorities and institutions.[12]

Affected States and those providing international cooperation and assistance should also establish a method for reporting. Topics include the effects of nuclear testing; progress made in responding to date; details of where international cooperation and assistance has been provided, who received the aid, and what aid is still needed; and lessons learned about the process. Reporting helps States reflect on the effectiveness of their projects and consider whether any changes are needed. Reports should be made publicly available to allow others to be involved in exchanging ideas, monitoring and evaluating results, and holding responsible actors to account.[13]

Precedent for these implementation measures comes in part from nuclear weapons policy. The Vienna Action Plan adopted at the First Meeting of States Parties of the TPNW in 2022 lays out many specific steps that States Parties commit to take to operationalize Articles 6 and 7 on victim assistance, environmental remediation, and international cooperation and assistance. The Action Plan calls for, inter alia, needs assessments, national plans, focal points, laws and policies, and mechanisms for international assistance. Other sources, including multiple publications by Harvard Law School's International Human Rights Clinic (IHRC), have recommended similar actions.[14]

9 See, e.g., Action 31, ibid.
10 See, e.g., Action 21, ibid.
11 See, e.g., Action 22, ibid.
12 See, e.g., Action 23, ibid.
13 See, e.g., Actions 27–28, ibid.; and IHRC, 'Reporting Guidelines for Articles of 6 and 7 of the Treaty on the Prohibition of Nuclear Weapons: Precedent and Recommendations', May 2023, at: https://bit.ly/3GgAkgR.
14 See, e.g., IHRC, 'Implementing Victim Assistance and Environmental Remediation under the Treaty on the Prohibition of Nuclear Weapons', p. 2.

Articles 6 and 7 of the TPNW and the commitments in the Vienna Action Plan draw on humanitarian disarmament law and associated standards. The Convention on Cluster Munitions, for example, lays out specific implementation steps in articles on clearance, victim assistance, and international cooperation and assistance. Those provisions obligate States to develop national plans, identify focal points, and adopt relevant laws and policies.[15] The Convention also requires reporting on these activities in a separate article.[16] Similar precedents can be found in other humanitarian disarmament instruments and the International Mine Action Standards (IMAS).[17]

## Guiding principles

In the course of their implementation activities, all States should uphold at least four guiding principles.[18] First, they should ensure every stage of the process is inclusive. In other words, States should meaningfully consult and actively involve affected communities and their representative organizations, civil society, international organizations, Indigenous Peoples, academics, and other stakeholders.[19] Experts bring with them a range of legal, scientific, operational, cultural, and other knowledge. Affected people have a unique understanding of the effects of nuclear testing, their needs, and how to best address them. Indigenous Peoples and ethnic minorities are among the most disproportionately affected groups, and their participation in nuclear policymaking is hindered by the same representational obstacles that led nuclear-armed States to disregard their exposure to harm from nuclear testing in the first place. Specific and official mechanisms should therefore be established to facilitate meaningful participation of affected communities—particularly marginalized communities and Indigenous and Non-Self-Governing Peoples—in policymaking on nuclear test legacies.

Second, States should uphold the principle of non-discrimination during the design and implementation of environmental remediation and victim assistance measures. They should not discriminate among victims or against victims based on their sex, age, race, ability, or other status. Third, States should make sure that the environmental remediation and victim assistance activities are transparent. Making information about a process available to all stakeholders encourages the exchange of lessons learned, facilitates monitoring, and promotes accountability. Finally, States should ensure programmes are accessible so that affected communities can receive the benefits to which they are entitled. To this end, States should overcome physical barriers by constructing health and other relevant facilities within reach of affected individuals and overcome informational barriers by distributing details about a programme in a language and format the local population can understand.[20]

The Vienna Action Plan, adopted at the TPNW's First Meeting of States Parties, calls on States Parties to conduct their activities related to environmental remediation as well as victim assistance and international cooperation and assistance in accordance with these principles.[21] It stresses the importance of ensuring inclusivity at all stages of these processes and commits States to follow the principles of accessibility, non-discrimination, and transparency.[22] Existing humanitarian law and policy also informs the principles. For example, the Convention on Cluster Munitions calls for inclusion and non-discrimination in its victim assistance article, and it has a transparency article that covers numerous topics.[23]

15 Arts. 4, 5, and 6, CCM.
16 Art. 7, CCM.
17 See, e.g., Arts. 6–7, Convention on the Prohibition of the Use, Stockpiling, Production and Transfer of Anti-Personnel Mines and on their Destruction; adopted at Oslo, 18 September 1997; entered into force, 1 March 1999 (APMBC); and IMAS 13.10: 'Victim Assistance in Mine Action', amended 17 January 2023, at: https://bit.ly/4qBhNOn.
18 See, e.g., Action 25, Vienna Action Plan. For a more in-depth discussion of these principles, see IHRC and CEOBS, 'Facing Fallout', Report, pp. 62–68, and IHRC and CEOBS, 'Confronting Conflict Pollution', Report, pp. 43–51.
19 See, e.g., Action 19, Vienna Action Plan.
20 IHRC and CEOBS, 'Confronting Conflict Pollution', Report, p. 43.
21 Action 25, Vienna Action Plan. See also IHRC and CEOBS, 'Facing Fallout', Report, pp. 62–68.
22 Actions 19–22, Vienna Action Plan.
23 Arts. 5 and 7, CCM.

The guiding principles have additional roots in international human rights law. People have a right to participate in decision-making at all stages of environmental remediation, victim assistance, and international cooperation and assistance – from design to implementation to monitoring. The right to information also calls for a transparent process.[24] The principle of non-discrimination, which prohibits discrimination on the basis of sex or gender, race, national or social origin, or other such status, is also fundamental to human rights law.[25] Accessibility under human rights law can encompass access to information and access to services such as health care.[26]

International environmental law provides similar precedent. The 1992 Rio Declaration on Environment and Development, an influential set of global environmental principles, states:

> Environmental issues are best handled with the participation of all concerned citizens, at the relevant level. At the national level, each individual shall have appropriate access to information concerning the environment that is held by public authorities, including information on hazardous materials and activities in their communities, and the opportunity to participate in decision-making processes. States shall facilitate and encourage public awareness and participation by making information widely available.[27]

The Convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters, also known as the Aarhus Convention, includes several provisions relevant to addressing the consequences of nuclear testing.[28] It only binds its 47 States Parties from Europe and Central Asia.[29] Nevertheless, it sets useful standards that can be applied to all States. For example, it requires States to collect and disseminate environmental information, provide public access to that information, and ensure public participation at different stages of a remediation process.

Ultimately the implementation measures discussed in this chapter aim to ensure that shared responsibilities for environmental remediation, victim assistance, and international cooperation and assistance are fulfilled in a coordinated, efficient, and accountable way. The underlying principles seek to maximize the effectiveness of projects from practical, legal, and ethical perspectives.

24 See, e.g., Art. 19(2), ICCPR.

25 Art. 2(1), ICCPR; Art. 2(2), ICESCR.

26 See, e.g., Committtee of Economic, Social and Cultural Rights, General Comment No. 14, The Right to the Highest Attainable Standard of Health, UN doc. E/C.12/2000/4, 11 August 2000, paras. 11–12.

27 Principle 10, Rio Declaration on Environment and Development, in Report of the United Nations Conference on Environment and Development, Rio de Janeiro, UN doc. A/CONF.151/26 (Vol. I), 12 August 1992, at: https://bit.ly/45O1Tsh.

28 Arts. 3–8, Convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters; adopted at Aarhus (Denmark), 25 June 1998; entered into force, 30 October 2001.

29 The list of States Parties is available at: https://bit.ly/3T2Gdk4.

Chapter 10:

# Mapping of Radioactive Contamination

Morten Sickel

This chapter discusses how to map radioactive contamination after a nuclear explosion. For fresh fallout, a sample may be collected from the surface, whereas for older fallout, samples should usually be taken deeper in the ground. Multiple samples at different depths from a ground profile will reveal how the contamination has been transported downwards and may, in certain cases, also give information about the history of the fallout. Other types of samples may also be collected, such as water, air, or various types of biota. When taking a measurement *in situ*, what is recorded is a weighted average of a larger area. Certain assumptions must be made about the vertical and horizontal distribution of the contamination if one wants to assess an activity concentration from the measurement.

Measurements in a contaminated area will mainly show decreasing levels of radionuclides as time goes by. One reason for this is the decay of radionuclides. In fresh fallout from a nuclear explosion or reactor accident, the bulk of the radiation will be from short-lived radionuclides, which will cause an initial rapid decay. After a few years, the dominating radionuclide will be caesium-137, which has a half-life of about 30 years.

The radionuclides will also move around in the environment with the same behaviour as their stable counterparts. That is to say, they will, to different degrees, be water soluble, be bound by minerals, or be taken up by different biota. Therefore, although the general contamination of an area will decrease over time, certain radionuclides may accumulate in particular areas and the contamination will, for a while, increase.[1] For those radionuclides that are strongly bound to mineral particles, the environmental turnover will often make them inaccessible to biota after some time. As an example, the nuclides caesium-137 and strontium-90 will both be generated in similar amounts in a nuclear weapon and they have similar half-lives, but caesium tends to be absorbed in clay minerals, whereas strontium is more mobile.[2]

The extent of any radioactive contamination of an area can be investigated using different techniques. These techniques have different costs, efficiencies, and sensitivities.

## Types of radiation

The three main types of radiation from radioactive materials have quite different behaviours. Alpha particles only travel for several centimetres in air and are not able to penetrate denser materials; beta particles travel tens of centimetres in air and can penetrate a few millimetres into denser materials; but gamma rays in principle can travel over an indefinite distance, although their intensity will decrease the further they travel. Gamma rays also have a much higher penetrating power. This makes it possible to survey large areas for gamma-emitting radionuclides whereas measurement for alpha- or beta-emitting radionuclides needs to be done in close proximity to those radionuclides.

Very few radioactive isotopes are pure alpha or beta emitters, and fallout from any given nuclear test will be a mixture of a large number of different radionuclides, with the greatest number being gamma-emitting. Therefore, a survey for gamma-emitting radionuclides will also point out areas that may be contaminated by pure alpha- or beta-emitting radionuclides.

Seen from a measurement point of view, another important difference between beta and alpha radiation on the one hand and gamma radiation on the other, is that the latter is sent out at discrete energies for each type of radionuclide, whereas beta radiation comes as a continuum up to a maximum for a given radionuclide. This means that for alpha and gamma emitters, a set of radionuclides can be identified and quantified from one sample, whereas for beta emitters normally only one type of radionuclide can be identified at a time.

## Measurement systems

In environmental sampling, a sample of some kind is taken into the laboratory, prepared, and measured in a controlled environment. This gives precise information on the sample, but of course that information is limited

1 In addition, bioaccumulation/bioconcentration and recycling in ecosystems can increase concentrations in biota by several orders of magnitude.

2 M. F. Abdel-Sabour, 'Fate of Cesium and Strontium in Soil-to-Plant System', *Journal of Radiation and Nuclear Applications*, Vol. 7, No. 2 (2022) 78–93, at: https://bit.ly/3UCO7RZ, at 89.

to what has been sampled. It is therefore important to use a sampling strategy that gives a high probability that the samples are representative for the area. If areas where radionuclides are suspected to have accumulated are sampled, this should be kept in mind during the data analysis.

For fresh fallout, a sample may be collected from the surface, whereas for older fallout, samples should usually be taken deeper in the ground. Several samples at different depths from a ground profile will reveal how the contamination has been transported downwards and may in certain cases also give information about the history of the fallout. Other types of samples may also be collected, such as water, air, or various types of biota. Biota samples may be interesting by themselves, namely, to assess contamination of food for people or livestock, or to assess radiation doses to certain species, but biota samples may also be of value since some may concentrate certain radionuclides. When taking air or water samples, the samples will normally be filtered in different ways to collect the radionuclides of interest in a smaller volume.[3]

### Measurement techniques

The simplest form of radiation measurement is a dose rate instrument, such as a Geiger-Müller counter (GM). These instruments are not able to distinguish between different radionuclides and thereby radiation of natural or anthropogenic origin, but if the natural background is either of low variability or very well mapped, dose rate measurements may give clear indications of areas that may be contaminated. To confirm contamination, other measurements must be performed.

By using a dose rate meter, it is possible to indicate the existence of alpha- or beta emitters while in the field, but the qualitative or quantitative analysis needs to be performed later in a laboratory. It will not be possible to detect buried alpha or beta emitters and it is not practically possible to completely map anything more than a small area. To perform qualitative or quantitative analysis of alpha- or beta-emitting radionuclides, a sample needs to be measured in a laboratory after chemical preparation of the sample. Gamma radiation can traverse longer distances and penetrate most materials, therefore allowing a wider range of measurement systems and techniques than for alpha and beta.

In addition to the dose rate meter, instruments for analysis of gamma-emitting radionuclides are usually divided in two different classes:

A high-resolution measurement, normally using a High Purity Germanium (HPGe) detector, yields a high-resolution spectrum. This gives the most information about the sample being measured and offers the possibility of distinguishing between a large number of different radionuclides. These detectors are expensive and difficult to handle as they need to be cooled down to around 100 kelvin. They also have a relatively low sensitivity.

A more rugged and cheaper instrument is the Sodium Iodide (NaI) detector. Although this has lower resolution and gives less information, in many cases with a modest number of radionuclides in the sample (i.e. most situations except for fresh fallout from nuclear reactors or nuclear weapons), the resolution they provide will be sufficient to recognize the radionuclides that are building up the spectrum. If the spectrum is too complicated for the low-resolution detector, it will be seen as a continuum and can be recognized as such.

There are also other types of detectors, several of which have resolutions between NaI and HPGe and without any cooling requirements, but for most applications either NaI or HPGe detectors are used. A laboratory

3 International Atomic Energy Agency (IAEA), 'Guidelines on Soil and Vegetation Sampling for Radiological Monitoring', Technical Reports Series No. 486, Vienna, 2019.

measurement will typically involve the use of HPGe detectors. Measurements may be done on fresh samples, or relatively straightforward sample preparation may be performed, such as drying or homogenization.

Whereas an environmental sample brings a bit of the environment to the detector, for gamma measurements, it is also possible to bring a detector out into the environment. When taking an *in-situ* measurement, what is recorded is a weighted average of a larger area. Certain assumptions must be made about the vertical and horizontal distribution of the contamination if one wants to assess an activity concentration from the measurement. Compared with a laboratory measurement, *in-situ* measurement covers a larger area, but less is known about the absolute levels of contamination. Thus, if the contamination is deeper in the ground than what is estimated, the real concentration will be higher than what is estimated, while if the contamination is not evenly distributed, a hotspot at a distance from the detector will give a lower estimated concentration than if the detector is moved closer to the hotspot. A sample brought to the laboratory will be problematic if the contamination is not evenly distributed, as the sample may have been taken inside or outside a hotspot.

*In-situ* measurements may be performed either with a fixed position measurement where a detector is kept in one position while doing a measurement, or mobile measurements where the detector is being moved around while doing the measurement (either being carried by a person or fixed to a vehicle). The most usual types of mobile measurements are backpack measurements, in which the detector is carried in a backpack; car-borne measurements, where the detector is mounted on or in a car; and airborne measurements where the detector is mounted in a piloted or remotely piloted aircraft. These types of measurements will have different parameters. In general, a detector will cover a larger area the greater the distance to the ground. On the other hand, the sensitivity will be worse the further away from the ground the measurement is taken. This downside can be counteracted by having a bigger detector volume. To have a sensible weight, a backpack detector often has a detector with a volume of one litre or less, whereas an airborne detector system may consist of tens of litres of detector volume.

Commercially available remotely piloted aircraft still have much lower carriage capacity than a directly piloted aircraft. Since the detector volume must be lower, backpack detectors are often used. To compensate for this, the flight altitude must also be lower. Thereby, at any given moment in time, the detector covers a smaller area than from a directly piloted aircraft. The positive consequence is that the measurement will have a higher spatial resolution; the negative is that it will take a longer time to cover a given area. Given those limitations, carrying a detector on a remotely piloted aircraft is often more comparable to a backpack measurement than a measurement from a directly piloted aircraft. Using an unmanned aircraft, it may be possible to take measurements in areas that, for some reason, a human carrying a detector cannot reach.[4]

All these types of measurements can be used in concert for a survey. If a large area is to be covered, a manned aircraft can cover the area in a relatively short time. The result from this type of survey may show radiation anomalies in which case vehicle-borne or backpack measurements can be performed to further map out the anomalies. Findings from those surveys can be used to find the right areas for sample collection or fixed position *in-situ* measurements and can also give estimates of how representative those measurements are for a larger area.

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4 The backpack method may be practical for small areas, such as islands in the Marshall Islands with very small surface areas.

Chapter 11:

# Environmental Remediation

Bonnie Docherty and Morten Sickel

Given the extensive environmental impacts of nuclear testing, undertaking environmental remediation should be a priority. While returning a nuclear test site to its pre-detonation state is rarely, if ever, feasible, remediation activities can have important environmental and humanitarian benefits. Environmental remediation encompasses a range of steps. States should begin with an assessment of the extent and nature of the contamination. As they proceed, they should design a process that provides the greatest benefits to the people affected and upholds key guiding principles. When undertaking remediation efforts, States should focus both on disrupting the pathways through which people are exposed to radiation and addressing the contamination itself. The nature of radiation may necessitate long-term measures that extend for years, decades, or even longer.

The goal for environmental remediation after an atmospheric nuclear test or other nuclear environmental contamination is to lower the radiation dose for any affected population and general biota.[1] As radionuclides have particular half-lives, contamination decays over time. Natural processes may also move radionuclides into parts of the environment where they are less accessible for humans and other living organisms. In some cases, however, these natural processes are too slow, and remediation measures are needed.

Ideally, such measures should be conducted as soon as possible, especially after an atmospheric event, because the contamination will be concentrated at the surface. Solid surfaces may be washed and the washing water collected. Depending on the areas and time of year, it may also be possible to perform low-impact activities that will remove a considerable part of the contamination. One of the most efficient such measures can be to remove a contaminated snow cover, while in other cases stripping away most over-ground parts of annuals (plants that complete their lifecycle within one growing season) may remove a large portion of the contamination. If remediation measures are conducted later, they are often less efficient, especially for releases from nuclear explosions and nuclear reactors, where short-lived radionuclides cause a high dose rate shortly after release. A range of steps can and should still be taken, however, to remediate the environment affected by nuclear testing, most of which dates back decades.

The remediation of contamination from past nuclear testing requires a long-term, multi-faceted effort. Harvard Law School's International Human Rights Clinic (IHRC) and the Conflict and Environment Observatory (CEOBS) have provided one set of guidelines for that process in the report 'Facing Fallout'. Their principles and in-depth commentary draw heavily on precedent from international law, including disarmament, human rights, and environmental law; nuclear policy; and relevant practice.[2]

## Sources of responsibility to remediate

Environmental remediation was specifically addressed in the 2017 Treaty on the Prohibition of Nuclear Weapons (TPNW), which incorporates a positive obligation related to environmental remediation for past use and testing of nuclear weapons. Article 6(2) states:

> Each State Party, with respect to areas under its jurisdiction or control contaminated as a result of activities related to the testing or use of nuclear weapons or other nuclear explosive devices, shall take necessary and appropriate measures towards the environmental remediation of areas so contaminated.[3]

The obligation in the TPNW draws on precedent from earlier disarmament treaties, including the 1997 Anti-Personnel Mine Ban Convention and the 2008 Convention on Cluster Munitions, which require their States Parties to clear anti-personnel mines and cluster munition remnants, respectively.[4] These legal instruments and the related standards that have been developed for so-called mine action operations to clear landmines and explosive remnants of war can thus offer models for some elements of environmental remediation in the nuclear weapons context.[5] For example, this precedent can inform: the application of humanitarian principles;

1 IAEA, 'Remediation Strategy and Process for Areas Affected by Past Activities or Events', Report, Vienna, 2022.

2 For a more detailed discussion of these steps, including precedent for them, see Harvard Law School's International Human Rights Clinic (IHRC) and Conflict and Environment Observatory (CEOBS), 'Facing Fallout: Principles for Environmental Remediation of Nuclear Weapons Contamination', Report, Cambridge, June 2022, at: https://bit.ly/4ew3B3G.

3 Treaty on the Prohibition of Nuclear Weapons; adopted at New York, 7 July 2017; entered into force, 22 January 2021 (TPNW).

4 Art. 5, Convention on the Prohibition of the Use, Stockpiling, Production and Transfer of Anti-Personnel Mines and on their Destruction; adopted at Oslo, 18 September 1997; entered into force, 1 March 1999 (APMBC); and Art. 4, Convention on Cluster Munitions, adopted at Dublin, 30 May 2008; entered into force, 1 August 2010 (CCM).

5 B. Docherty, 'Mine action in action: influencing law and policy on toxic remnants of war', *ICRC Humanitarian Law and Policy*, 21 December 2021, at: https://bit.ly/46qs34q.

methodologies for surveying, marking and fencing, and providing risk education; ways to actively engage national, provincial, and local stakeholders; and the creation of national implementation plans.

In other ways, of course, the nature of environmental remediation after nuclear testing differs substantially from mine action operations because of the distinctive challenges of dealing with radioactive contamination. The TPNW recognizes the difficulty of completing remediation and specifies that measures need only be taken 'toward' remediation. Nevertheless, affected States should make a long-term, good faith effort even if they cannot achieve perfection.

The responsibility to engage in environmental remediation after nuclear testing is also grounded in international human rights law. The contamination from testing implicates multiple human rights, such as the right to health and water. It also infringes on the right to a healthy environment.[6]

Progress in environmental remediation is facilitated by the framework of shared responsibility for environmental remediation, stemming from humanitarian disarmament and international human rights law and discussed in Chapter 9 above. While affected States should take the lead on remediating areas under their jurisdiction or control, they should receive support in the form of international cooperation and assistance from other States, including but not limited to testing States.

## Assessments and guiding principles

Environmental remediation projects should begin by assessing the nature, extent, and effects of the contamination from nuclear testing and the steps taken to address it to date.[7] While this report provides general information on the consequences of testing, remediation of specific sites requires detailed study. The information gathered can inform priorities and plans for action. Additional information-gathering and processing may be needed throughout the environmental remediation process and lead to refinement of remediation measures.

All remediation measures should be justified and optimized.[8] Justification entails ensuring that the benefits of remediation outweigh possible detriments.[9] The benefits of remediation could include lower doses to the population as well as the potential for a cleaner environment in the long term, whereas detriments could encompass resources used for the remediation, dangers to the workers involved, and the generation of waste and associated negative impacts on the local environment. For flora and fauna, the damage of habitats as a consequence of the remediation measures can do more harm than the benefit accrued from reduced doses, especially since radiation exposure is rarely a primary factor affecting their survival.

To implement remedial measures, the criteria for completion of the project should be defined. This will usually be done as a reference level, which is normally the expected dose for the population in the affected area. Given that environmental remediation in the context of past nuclear testing often constitutes a long-term, ongoing task, criteria for completion of stages may be more relevant. The first step of evaluating possible remediation measures would be to compare the expected dose to a screening criterion, typically as established by a

6 For information on the implications of nuclear testing on several human rights, see Chapter 13 below.

7 IAEA, 'Remediation Process for Areas Affected by Past Activities and Accidents', Safety Standards Series No. WS-G-3.1, 2007, at: https://bit.ly/4nNos70, paras. 3.14–3.17; and IHRC and CEOBS, 'Facing Fallout', Report, pp. 35–38.

8 IAEA, 'Getting to the Core of Environmental Remediation: Reducing Radiation Exposure from Contaminated Areas to Protect People', at: https://bit.ly/4lxavbc, pp. 2–5.

9 European Commission, UN Food and Agriculture Organization, IAEA, International Labour Organization, the OECD Nuclear Energy Agency, the Pan American Health Organization, the UN Environment Programme, and the World Health Organization, *Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards*, General Safety Requirements Part 3, GSR Part 3, Vienna, 2014, at: https://bit.ly/3IZG1gW.

competent national authority. To calculate the expected doses, the available information should be assessed with a view to identifying and understanding the types of contaminants in the area; the levels of contaminants; the distribution of contaminants; and the relevant exposure pathways where radionuclides in the environment may give doses to the population. This includes gathering knowledge about the lifestyle of the relevant population, the kind of food they eat, their drinking water sources, and where they spend their time.

If these initial assessments indicate that remediation measures may be justified, a more detailed assessment should be performed and a reference level defined. With this information, closer analysis will demonstrate whether the remediation is actually justified. In the detailed planning of a remediation, the range of possible measures should be evaluated and considered to see if each one can be justified and is feasible and available. Ideally, this analysis should generate a clearly prioritized remediation measure. That said, as further information may become available after the remediation work has started, measures that are initially given a lower priority may be implemented earlier. If some subgroups of the population are receiving higher doses than others, remediation measures to help those groups decrease their doses should be prioritized.[10]

The proposed project should also be optimized before any plans are finalized. Optimization calls for choosing and implementing the 'option [for environmental remediation] that produces the *greatest benefit* to the affected communities and the environment'.[11] In other words, it seeks the best option for communities, rather than one in which benefits simply outweigh costs. An optimization analysis should consider the effects on the environment, human health, society, culture, and the economy, as well as affected communities' preferences.[12] The results of this analysis should inform the design of an environmental remediation plan. The analysis should be updated periodically because new information may change the results of the assessment.

Throughout these and other steps of environmental remediation, States should be guided by a set of overarching principles. They are discussed in more detail in Chapter 9 on Shared Responsibility for Nuclear Harm. First, all stages of the process should be inclusive. In other words, States should meaningfully consult and actively involve affected communities and their representative organizations, civil society, international organizations, Indigenous Peoples (who have been disproportionately affected by nuclear testing), and other stakeholders. Second, States should uphold the principle of non-discrimination during the design and implementation of environmental remediation measures. Third, States should make sure that the environmental remediation activities are transparent to encourage the exchange of information among stakeholders, facilitate monitoring, and promote accountability. Finally, States should ensure that the process is accessible.

## Breaking exposure pathways

States should implement several measures to break pathways of exposure, which is to say, to block people's contact with nuclear contamination. Mine action precedent shows the value of establishing risk education programmes and marking and fencing contaminated sites. As shown by the case studies in this report, simple measures like these have often not yet been put in place, even decades after the nuclear tests were conducted. Reducing ingestion of contaminants is also critical for decreasing the health consequences of a radioactive substance.[13]

10 IAEA, 'Remediation Strategy and Process for Areas Affected by Past Activities or Events'.

11 IHRC and CEOBS, 'Facing Fallout', Report, p. 5.

12 The International Commission on Radiological Protection (ICRP), for example, calls for assessment of a range of considerations, declaring that optimization 'should ensure the selection of the best protection strategy under the prevailing circumstances, i.e. maximising the margin of good over harm.' 'Application of the Commission's Recommendations to the Protection of People Living in Long-Term Contaminated Areas after a Nuclear Accident or Radiation Emergency', ICRP Publication 111, *Annals of the ICRP*, Vol. 39, No. 3 (2009), at: https://bit.ly/3TVpSOV, p. 26. For further discussion of optimization and its basis in the existing nuclear policies of numerous agencies, see IHRC and CEOBS, 'Facing Fallout', Report, pp. 38–42.

13 IHRC and CEOBS, 'Facing Fallout', Report, pp. 43–47.

### Risk education

Risk education, an important tool for reducing exposure, involves implementation of programmes to inform communities affected by nuclear testing and its contamination of the dangers they face and ways they can protect themselves.[14] Programmes can come in many forms, such as visits to classrooms or community centres; posters or handouts; and radio, television, or social media messages. To make a difference, programmes need to reach their intended audience, which may be in geographically remote areas. The information should be culturally appropriate and available in local languages. Risk education programmes should also be tailored to the way that a community receives knowledge. For example, if the population does not have access to the internet or television, personal visits and flyers may be essential.[15]

Risk education has become a standard part of mine action programmes, which seek to reduce the civilian impact of landmines and explosive remnants of war, including cluster munition remnants.[16] States can look to models from that field and adapt them to the context of nuclear contamination.

### Marking and fencing

Demarcating contaminated sites and blocking access to them are other means of disrupting exposure pathways. While the effects of radiation are known to spread across time and space, States should clearly mark the most contaminated sites with unambiguous signs that identify 'no trespassing' areas and warn people of the risks. States should also surround such sites with fences or other barriers to physical access.[17] Such methods can help prevent unintentional entry onto contaminated sites and discourage intentional intrusions.

Like risk education, marking and fencing are core elements of mine action.[18] They are mentioned in the International Mine Action Standards, and both the Anti-Personnel Mine Ban Convention and the Convention on Cluster Munitions obligate States Parties to ensure these measures are taken and maintained as part of their clearance duties.[19] Nuclear contamination raises complications, and determining exactly where radioactive areas begin and end can be challenging. In addition, radioactive waste lasts for decades or centuries or beyond. Nevertheless, marking and fencing known sites and maintaining these systems over time can serve as a valuable tool of civilian protection.

### Reducing ingested doses

Internal radioactive contamination has the potential to cause significant harm, both because the radiation is originating from inside the body and because contaminated persons may bring the contamination with them, potentially for the rest of their lives. Internal contamination may be caused by eating or drinking contaminated food or drink; breathing in or swallowing contaminated particles in the air; or having contaminated particles enter wounds or mucus membranes.

14 M. E. Stawkowski, 'Forgotten Ground Zeros. Local populations exposed to radiation from former nuclear test sites', Danish Institute for International Studies, 2020, at: https://bit.ly/44ff2JD, p. 1 (including a recommendation to: 'Establish local education programs to prevent unintentional exposure to residual radioactivity').
15 See, e.g., International Mine Action Standard 12.10: Explosive Ordnance Risk Education (EORE), 1 September 2020, https://bit.ly/4exrUhE, para. 4.3.2.
16 Ibid.; Art. 6(7)(d), APMBC; and Art. 4(2)(c), CCM.
17 Stawkowski, 'Forgotten Ground Zeros', p. 1 (including a recommendation to: 'Cordon off and secure unmarked radioactive areas on nuclear test sites').
18 See, e.g., International Mine Action Standard 08.40: Marking Explosive Ordnance Hazards, 17 January 2023, https://bit.ly/4eFw07I.
19 Art. 5(2), APMBC; and Art. 4(2)(c), CCM.

There are three basic ways of reducing doses from food and drink: avoiding foodstuffs from certain contaminated areas; avoiding specific types of foodstuffs that are known to concentrate relevant radionuclides; or treating the food in ways that can remove radionuclides. When devising regulations or providing advice to reduce the ingested dose, it should also be considered if the measures to reduce the ingested dose may have other negative implications.

### Reducing ingested doses

#### Case 1: High levels in reindeer

The experience from fallout from nuclear testing and reactor accidents has shown that natural and semi-natural environments are more vulnerable to contamination than intensive agricultural areas. It has been known since the 1960s that reindeer that eat lichens have a high uptake of radionuclides, especially radioactive caesium. In Norway, after the Chernobyl nuclear accident in 1986, large amounts of fallout was identified in areas with wild or herded reindeer, with contamination of up to several kilobecquerels of caesium found in reindeer, far above the international levels of 600 Bq/kg set for foodstuffs. Applying this international limit to reindeer meat would have completely ended the turnover of reindeer meat, especially from the Indigenous reindeer herders in some parts of the country. This would have been a disaster for their culture and lifestyle. Since the limit is set for all kinds of foodstuffs and the general population in Norway does not eat much reindeer meat, it was decided to set a national limit of 6,000 Bq/kg for commercially sold reindeer meat. Later, this limit was reduced to 3,000 Bq/kg. Reindeer herders and hunters eating much more reindeer meat than the average population were given specific dietary advice and offered measurements of the meat they were eating. In addition, slaughter time was moved to a time of year when the reindeer had been eating more grass and less lichen thereby having lowered their internal contamination. An alternative could have been to keep the 600 Bq/kg limit and to handle all meat above that limit as waste. This was done the first year but it was extremely expensive and caused a large waste-handling problem.

#### Case 2: Free-ranging animals

In addition to wild and herded reindeer, free-ranging farm animals, especially sheep, in areas of Norway were contaminated as a result of the Chernobyl accident. These animals are taken back from the fields in the fall. The first year after the accident, meat was measured after the animals were slaughtered, and meat containing more than 600 Bq/kg of caesium was scrapped. This process was expensive, with compensation having to be paid out to the farmers, and resulting in considerable quantities of low- and medium-level radioactive waste that needed to be handled. The following year, a different system was put in place in order to minimize the amount of scrapped meat. As the animals were taken back from the fields, they were measured live to estimate their radiocaesium content. Animals with an excessively high content were fed grass from areas with low contamination to reduce their internal contamination. In addition, the animals were fed with feed containing Prussian blue, a chemical compound that binds with caesium making it biologically inaccessible. The combination of these interventions—live measurements, clean feeding, and Prussian blue—has meant that hardly any meat was scrapped in Norway due to high radiocaesium content after 1986. In some of the contaminated areas, these measures were still in use as late as 2024.

## Addressing contamination

Assuming comprehensive remediation is justified and optimized, States should directly address the contamination in addition to disrupting the pathways of exposure. It is a critical but long-term endeavour.

### Containment or treatment

Environmental remediation of sites contaminated by nuclear testing can involve containment or other forms of treatment.[20] If done properly, containment prevents the problem from spreading and denies people as

20 IHRC and CEOBS, 'Facing Fallout', Report, pp. 47-49.

well as animals access to the site. It can include capping, land encapsulation, and the creation of physical and cryogenic barriers.[21] Contaminants can be contained at the site of origin or moved elsewhere for extended storage.

Treatment of radioactive contamination can take numerous forms. It can stabilize contaminants or separate them from soil, water, or air. Methods include applying chemical agents, changing temperatures, using plants or microorganisms, or relying on nature.[22] Treatments to reduce the contamination of land and water can complement restrictions on using certain areas for farming or grazing. According to IHRC and CEOBS, 'Full decontamination may not be practical or possible, but these techniques can be used to treat radionuclides in order to lower contamination levels to safer exposure values, enabling future use of the affected areas.'[23]

### Material handling and waste management

Environmental remediation also involves careful management of contaminated material during its handling, transport, and storage.[24] For example, when States plan the method and route for moving contaminated waste, they should consider the quantity and type of waste and evaluate different options according to the principle of optimization.

States should take similar care to minimize the risks to people and the environment when creating waste storage facilities, whether permanent or temporary. States should assess potential humanitarian and environmental effects when deciding the location and design of facilities. Given that radiation can endure for centuries or even more, States should also plan infrastructure that will endure longer than they expect it will be needed.[25]

### Long-term site management

Long-term management of contaminated sites or waste storage facilities is an essential part of remediating nuclear weapons contamination.[26] Standards may vary, depending on whether the specific radiation will pose risks for thousands of years or a shorter period, but numerous elements will be common regardless.

This stage will necessitate several ongoing activities to guarantee the continued safety of environmental remediation.[27] Regular and frequent monitoring of infrastructure will help ensure the integrity and effectiveness of the project.[28] If contamination has escaped or treatment failed, the infrastructure can be repaired, the project redesigned, or implementation improved. In addition, monitoring provides data, which if made publicly available, can help hold States to account and provide lessons learned for other environmental remediation projects.

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21 US Environmental Protection Agency, 'Technology Reference Guide for Radioactively Contaminated Media', 2007, at: https://bit.ly/44fpyk9, p. 6.
22 Ibid., pp. 5–6.
23 IHRC and CEOBS, 'Facing Fallout', Report, p. 48.
24 Ibid., pp. 49–51.
25 See, e.g., IAEA, 'Developing Cost Estimates for Environmental Remediation Projects', Vienna, 2019, https://bit.ly/4kmaVjy, p. 10: The US EPA 'requires that the performance criteria be met over a minimum of 200 years, whereas the typical design life should be 1000 years'.
26 IHRC and CEOBS, 'Facing Fallout', Report, pp. 52–54; OECD NEA, 'Nuclear Site Remediation and Restoration during Decommissioning of Nuclear Installations', 25 August 2014, at: https://bit.ly/4lHkrza, p. 44.
27 IHRC and CEOBS, 'Facing Fallout', Report, pp. 52–54.
28 OECD NEA, 'Nuclear Site Remediation and Restoration during Decommissioning of Nuclear Installations', p. 12.

Given the long-term nature of site management, remediation infrastructure will also require maintenance as it ages. Failures identified during monitoring should, of course, be addressed. In addition, States should try to pre-emptively maintain the site to prevent the escape of dangerous radioactive contaminants.

Long-term site management requires well-trained staff to fill numerous roles. They may guard the site to prevent public access, supervise visitors if some access is allowed, or provide interpretation of a location that has become a public historic site. They are responsible for monitoring the integrity of containment measures, although they can seek help from local communities. Staff also maintain the infrastructure used to contain or store the contaminants, either at their original site or a new location.

Chapter 12:

# Victim Assistance

Matthew Breay Bolton

There is an urgent need to provide assistance to victims of nuclear weapon testing. Those exposed will experience varying levels of harm due to age, gender, and previous exposures. The challenging social, economic, and political context for some victims makes their resilience in the face of this risk more compromised. Given that victims are often unaware of the link between fallout and their suffering, assistance should be presumptive and precautionary rather than relying on finding specific, self-identifying victims, which will be inadequate. After detailed assessment of how nuclear testing has affected the health of individuals and their communities, victim assistance programmes should address both short- and long-term medical impacts. Such programmes should also provide psychological support, implement measures to promote socio-economic inclusion, and support cultural, religious, and traditional healing.

As discussed in previous chapters of this report, the international community has failed to address the consequences of nuclear weapon testing through a humanitarian framework until recently. The suffering of those victimized by these test programmes has been treated largely as an internal matter of sovereign States, and the extensive apparatus established to render humanitarian aid in the context of armed conflict was not activated. Where testing States have acknowledged harm, they have tended to address it not through ongoing rights-based programming, but rather through compensation schemes that function more to limit liability than to help victims in good faith.

Adequate assistance to people affected by the ongoing harm from nuclear testing has been delayed for far too long. First-generation test survivors are growing old and dying. There should now be urgency in the provision of assistance to affected communities. This chapter discusses the nature of victim assistance and what measures could respond to the humanitarian consequences of nuclear weapon testing in particular. For the purpose of this report, drawing on law, policy, and practice in humanitarian disarmament and human rights law, we have defined victims as 'a person, family, or community whose fundamental human rights have been directly and adversely affected by nuclear weapon testing programmes, detonations, and/or fallout.'

Indeed, both humanitarian disarmament and international human rights law provide significant precedent for effective and efficient nuclear victim assistance to affected individuals.[1] Victim assistance should cover emergency through to long-term healthcare, psycho-social support, economic empowerment, social inclusion, and a legal and policy framework that respects fundamental human rights.[2] Assistance should reflect the particularities of victims' identities and resultant forms of marginalization, including age, gender, sexuality, indigeneity, race, ethnicity, religion, disability, and economic class.

Adopted in 2017, the Treaty on the Prohibition of Nuclear Weapons (TPNW)—the first treaty specifically to require assistance to the victims of nuclear detonations—stipulates in Article 6:

> Each State Party shall, with respect to individuals under its jurisdiction who are affected by the use or testing of nuclear weapons, in accordance with applicable international humanitarian and human rights law, adequately provide age- and gender-sensitive assistance, without discrimination, including medical care, rehabilitation and psychological support, as well as provide for their social and economic inclusion.

As discussed in more depth above in Chapter 9, the TPNW's Article 7 on international cooperation and assistance spreads the burden of victim assistance to other States, including but not limited to testing States.

Much of the language of Articles 6 and 7 was drawn directly from the 2008 Convention on Cluster Munitions (CCM).[3] Accordingly, the International Committee of the Red Cross (ICRC) commentary on victim assistance in the TPNW suggests that the Treaty's provisions for victim assistance should be interpreted in a similar way to the equivalent provisions in the CCM. When necessary, however, the precedent set in the conventional weapons disarmament treaties should be adapted to the particular context of nuclear weapon use and testing.[4]

The responsibility to engage in victim assistance measures is not limited to States Parties to the TPNW because victim assistance has additional roots in international human rights law. States have a duty to realize,

1 B. Docherty and A. Sanders-Zakre, 'The origins and influence of victim assistance: Contributions of the Mine Ban Treaty, Convention on the Rights of Persons with Disabilities and Convention on Cluster Munitions', *International Review of the Red Cross*, No. 922 (November 2022), at: https://bit.ly/44AoJRW.

2 Geneva International Centre for Humanitarian Demining, *A Guide to Mine Action*, 5th Edn, Geneva, 2014, 187.

3 B. Docherty, 'From Obligation to Action: Advancing Victim Assistance and Environmental Remediation at the First Meeting of States Parties to the Treaty on the Prohibition of Nuclear Weapons', *Journal of Peace and Nuclear Disarmament*, Vol. 3, No. 2 (2020), 253–64.

4 ICRC, 'The Obligation to Assist Victims and Remediate the Environment within a Framework of Shared Responsibility under the Treaty on the Prohibition of Nuclear Weapons', Report, Geneva, 2023, at: https://bit.ly/49VpnKS, pp. 5–7.

for example, the right of 'everyone to the enjoyment of the highest attainable standard of physical and mental health.'[5] The right encompasses 'not only … timely and appropriate health care but also … the underlying determinants of health,' both of which are relevant in the case of nuclear testing.[6] States should also ensure nuclear weapons victims' rights to access information and facilitate participation in relevant policy, planning, and implementation decisions.

To address the humanitarian consequences of nuclear testing and follow legal precedent, therefore, States should adopt programmes that encompass a wide range of victim assistance, and adopt 'a broad understanding of who qualifies as a victim.'[7]

## Who is a nuclear test victim?

The nature of the impacts of nuclear weapons affects who is a victim. Those in the immediate vicinity of a nuclear detonation may suffer from the blast and heat energy and/or receive a high enough dose of radiation to generate deterministic effects. Such people may be easier to identify as victims.[8] But as discussed in Chapter 6 of this report, nuclear testing has increased the risk of health problems, notably (but not only) cancer, for everyone. Most of those who suffer the consequences will not necessarily know the connection between fallout and their illness.

As a result, an approach to assistance that relies on finding specific, self-identifying victims will be inadequate to address the humanitarian consequences of nuclear weapon testing. Needs assessment should not only list people who have declared themselves victims but also map the risks to people who may not know whether they fall into that group.

In addition, while people around the world are potentially victims of nuclear testing, as scientific literature has shown, some bear a greater share of the burden.[9] Indeed, certain people in particular countries and areas have been more exposed to risk than others. And among those exposed, different people will experience varying levels of harm due to age, sex, disability, and previous exposures. The particular social, economic, and political context for some victims can further compromise their resilience. Victim assistance in the nuclear testing context thus needs to be presumptive and precautionary, directing support and care to communities according to the risks they face and the capacities they have to address them.[10]

Indigenous Peoples have experienced particularly significant harm because the majority of nuclear test detonations occurred on their lands and territories. The TPNW's preamble recognizes 'the disproportionate impact of nuclear-weapon activities on indigenous peoples', the first international weapons treaty to make such an acknowledgement. The impact of nuclear test detonations has thus intersected with and exacerbated other forms of political, social, cultural, and economic marginalization, including of Indigenous Peoples from the realization of their rights to self-determination.

5 Committee on Economic, Social, and Cultural Rights, General Comment No. 14, The Right to the Highest Attainable Standard of Health, UN doc. E/C.12/2000/4, 11 August 2000, at: https://bit.ly/44HSbGN, para. 11.

6 Ibid.

7 ICRC, 'The Obligation to Assist Victims and Remediate the Environment within a Framework of Shared Responsibility under the Treaty on the Prohibition of Nuclear Weapons', Report, Geneva, 2023, at: https://bit.ly/49VpnKS, 4.

8 Harvard Law School International Human Rights Clinic (IHRC) and Conflict and Environment Observatory (CEOBS), 'Confronting Conflict Pollution: Principles for Assisting Victims of Toxic Remnants of War', Report, Harvard College, Cambridge, September 2020, at: https://bit.ly/4crxhxz.

9 D. Endres, 'The Most Nuclear-Bombed Place: Ecological Implications of the US Nuclear Testing Program', in B. McGreavy, J. Wells, G. F. McHendry Jr., and S. Senda-Cook (eds.), *Tracing Rhetoric and Material Life*, Palgrave Macmillan, Cham, 2018.

10 IHRC and CEOBS, 'Confronting Conflict Pollution: Principles for Assisting Victims of Toxic Remnants of War'.

Victim assistance policy making and implementation in the context of nuclear testing should therefore be undertaken in a manner consistent not only with human rights law generally but also with the UN Declaration on the Rights of Indigenous Peoples (UNDRIP).[11] In particular, States should uphold the UNDRIP's stipulation that they should obtain Indigenous Peoples' 'free, prior and informed consent before adopting and implementing legislative or administrative measures that may affect them'.[12] The UNDRIP also guarantees Indigenous Peoples 'the right to determine and develop priorities and strategies' for socio-economic programmes; 'the right to their traditional medicines and to maintain their health practices'; and the right to 'their histories, languages, oral traditions, philosophies, writing systems and literatures'.[13]

Some affected communities face added difficulties due to the historical context of the nuclear testing that made them victims. Victim assistance following nuclear testing often operates in the context of a (sometimes incomplete) decolonization process. Affected States such as Algeria, Kiribati, and the Marshall Islands were under colonial control (or occupation) at the time of the initiation of the test programmes, while Mā'ohi Nui (French Polynesia) remains a Non-Self-Governing Territory under French administration.

The status of many victims as politically marginalized, colonized, or members of the military made it easier for the respective nuclear testing States to severely restrict victims' enjoyment of their fundamental human rights. Victim assistance programmes should strive to mitigate that harm.

## Healthcare

### Assessment and dosimetry

Addressing the medical impacts of nuclear test programmes requires a comprehensive assessment of how testing has affected the health of individuals and their communities. At the core of victim assistance must be a concerted effort to identify the effects of past, present, and future doses of radiation resulting from nuclear testing. This process can be difficult in the face of deliberate obstruction of access to information about yield and fallout data by nuclear-armed States. As discussed in previous chapters of this report, a recent effort led by Princeton University's Program on Science and Global Security found that French authorities had underestimated by a factor of ten the number of people whose dosages met a threshold of eligibility for compensation.[14] It has also recently been found that the US Trinity test of July 1945 ejected radioactive fallout over a far larger area than previously acknowledged.[15]

While an aggregate estimate at the population scale may be useful for high-level strategic planning, a more granular picture is needed to guide appropriate health interventions. In 1993, for example, the New Zealand National Radiation Laboratory (NRL) estimated that an average person living in the South Pacific region covered by its monitoring network (Cook Islands, Fiji, Kiribati, Niue, Samoa, Tokelau, Tonga, and Tuvalu) would have received an effective radiation dose of 1.1 millisievert (mSv) from all atmospheric nuclear tests, most of it attributable to French Pacific testing. NRL noted that dosages were not evenly distributed across the population in the South Pacific, with a range of 0.9–1.7 mSv between islands. Niue and Samoa received more

11 UN General Assembly Resolution 61/295: 'United Nations Declaration on the Rights of Indigenous Peoples', adopted on 13 September 2007 by 143 votes to 4 (Australia, Canada, New Zealand, and the United States) with 11 abstentions (Azerbaijan, Bangladesh, Bhutan, Burundi, Colombia, Georgia, Kenya, Nigeria, Russia, Samoa, and Ukraine). The four States that voted against the resolution have subsequently changed their position and endorse the declaration. See: https://bit.ly/4eznRBE.

12 Art. 19, UNDRIP.

13 Arts. 23, 24, and 13, respectively, UNDRIP.

14 S. Philippe, S. Schoenberger, and N. Ahmed, 'Radiation Exposures and Compensation of Victims of French Atmospheric Nuclear Tests in Polynesia', *Science & Global Security*, Vol. 30, No. 2 (2022), 62–94.

15 L. M. M. Blume, 'Trinity Nuclear Test's Fallout Reached 46 States, Canada and Mexico, Study Finds', *The New York Times*, 20 July 2023, at: https://bit.ly/4fcwPDX.

radioactive fallout than other countries in the network.[16] Such population-level estimates do not, though, capture the specific radiological conditions on particular islands or communities. Moreover, as outlined in Chapter 7, dominant methods of dosimetry rely on the model of a 'Reference Man', underestimating the impact on women, the young, those reliant on subsistence diets, and those with a genetic predisposition to cancer.

An individual-level dose reconstruction is needed to guide medical advice and interventions for specific victims appropriately. This is a labour-intensive process so some States have established tools that can provide individual dose estimates based on population modelling. For example, the US National Cancer Institute offers an internet-based calculator for estimating 'the internal and external radiation dose received by your thyroid gland from radionuclides in fallout from nuclear tests conducted at the Nevada Test Site and sites outside of the United States (global fallout)' and 'your risk of developing thyroid cancer from that exposure'.[17] This calculator is, though, limited to the risk of thyroid cancer and only covers the United States. The US Environmental Protection Agency (EPA) offers a radiation dose calculator that enables a more comprehensive analysis of multiple sources of radiation, ranging from X-rays to gas camping lanterns, luminous wristwatches, and nuclear power plants. It is also available in both English and Spanish. However, it sets the dose of 'weapons test fallout' to a single aggregate figure of '1 mrem' (millirem) and it does not model for differences due to sex and age.[18]

### Screening and risk education

To ensure their right to health, communities located in the vicinity of nuclear test sites and/or in areas of concentrated fallout should have accessible screening for cancer, heart disease, reproductive health concerns, and other conditions associated with exposure to radiation. Screening should be conducted alongside clear, detailed, and culturally specific risk education tailored to the particular context to help people understand the risks. The combination of risk education and screening encourages early intervention to address health problems. Nevertheless, any data from such screening (and subsequent care) must not be used in medical research without the free, prior, and informed consent of patients. Indeed, the United States has provided screening services to victims of its atmospheric nuclear tests in the Marshall Islands. But these have been criticized for being wholly inadequate in gathering data on the health effects of radiation exposure, while also being conducted without the full and informed consent of patients.[19]

### Specialized services for diseases that are potentially radiogenic

Those diagnosed with potentially radiogenic diseases should receive care on a presumptive basis, in spaces where they feel most comfortable, in languages they understand, and while surrounded by their community support systems. As a result, victim assistance and aid programmes should support the development of high-quality oncological and cardiovascular care in communities in the vicinity of nuclear test sites and/or high deposition of fallout. Programmes should also include reproductive health services such as support for infertility, complicated pregnancies, and abnormal births; counselling regarding prospects for healthy conception and gestation; and support for children with cancer and other diseases.

16 K. M. Matthews, *Radioactive Fallout in the South Pacific: A history. Part 2: Radioactivity measurements in the Pacific Islands*, National Radiation Laboratory, 1992/1993.

17 National Cancer Institute, 'Thyroid Dose and Risk Calculator for Nuclear Weapons Fallout for the US Population', available at: https://bit.ly/3InEVv5.

18 EPA, 'Calculate Your Radiation Dose', 2023, at: https://bit.ly/3P7RoXD.

19 C. Pohle, '"Ashes of Death": The Marshall Islands Is Still Seeking Justice for US Nuclear Tests', *The Diplomat*, 1 March 2024, at: https://bit.ly/3T3Bsqp.

Such services should be confidential, available in the languages spoken by affected people, and must not be conducted as part of nuclear weapon research. Given that military veterans (as well as many civilians) may no longer live in the vicinity of the place of their exposure, victim assistance efforts should operate at the national as well as local level. For example, the US Veterans Administration offers specialized healthcare services across the nation for military veterans exposed to radiation in the course of their service.[20]

Nevertheless, such assistance for specialized care should not come at the cost of other healthcare services. Rather it should be provided in the context of improving access to high quality comprehensive healthcare.

### Addressing 'second order' health impacts

It is important not to take a reductive approach to the health impacts of nuclear weapons and limit attention to radiogenic diseases. There is evidence that disturbances to coral reefs from nuclear detonations and their staging bases in French Polynesia (Mā'ohi Nui) increased the incidence of fish contaminated by ciguatoxin, resulting in outbreaks and increased rates of ciguatera poisoning among those who ate the fish.[21] The British military regularly sprayed Kiritimati (in what is now Kiribati) with DDT during its test programme. The UK and US deployments also left behind toxic waste and explosive remnants of war (ERW) that have posed health risks to residents of Kiritimati.[22]

Nuclear testing programmes in the Pacific significantly disrupted local food systems. Displacing people from their home atolls disrupts people's long-standing cultural knowledge about local environments and thus livelihoods of fishing and gathering. When locally foraged or fished food is no longer considered safe for consumption due to radioactive contamination, people turn to preserved and processed foods that are often high in sodium and saturated fat and low in many micronutrients and fibre, and which can contribute to increased prevalence of heart disease, obesity, and diabetes.[23] As a result, victim assistance should be designed to support broad-based improvement of healthcare for communities particularly affected by nuclear weapon testing programmes, recognizing the multiple impacts. For example, the non-governmental organization (NGO) Canvasback Missions has both organized short-term visits of medical professionals to provide care in the Marshall Islands and also established a 'Wellness Center' on the grounds of Majuro hospital, which offers programming to address heart disease and diabetes.[24]

### Healthcare access

Victim assistance is incomplete if a service is inaccessible to those who need it. Many nuclear test-impacted communities struggle to access appropriate healthcare. Oncological services are often expensive and rarely available in the economically marginalized zones where nuclear testing occurred. For example, individuals with cancer in the Marshall Islands must travel to Hawaii, the Philippines, or Taiwan to get treatment. Unless they have supplemental insurance or other resources, they can bring only one support person with them and there is a cost cap on their care.[25] This removes them from family and community sources of support

20 US Department of Veterans Affairs, 'Benefits Overview for Radiation Exposure', 2017, accessed 12 December 2023 at: https://bit.ly/3lkQrqS.

21 T. A. Ruff, 'Ciguatera in the Pacific: A link with military activities', *The Lancet*, Vol. 333, No. 8631 (28 January 1989), 201–05.

22 B. Alexis-Martin, M. B. Bolton, D. Hawkins, S. Tisch, and T. Luscia Mangioni, 'Addressing the Humanitarian and Environmental Consequences of Atmospheric Nuclear Weapon Tests: A Case Study of UK and US Test Programs at Kiritimati (Christmas) and Malden Islands, Republic of Kiribati', *Global Policy*, Vol. 12, No. 1 (February 2021).

23 The Marshall Islands National Nuclear Commission, *Nuclear Justice for the Marshall Islands: A Strategy for Coordinated Action, FY2020-FY2023*, 2020, at: https://bit.ly/4c1CvzW.

24 Canvasback Missions, 'Wellness Center Stories', 2024, at: https://bit.ly/3V0h1gE.

25 The Marshall Islands National Nuclear Commission, *Nuclear Justice for the Marshall Islands: A Strategy for Coordinated Action, FY2020-FY2023*.

and means they do not receive care in the Marshallese language. Similarly, the association of Fijian test veterans has raised concern as to the lack of adequate healthcare on remote islands[26] and has called for the development of more comprehensive health and outreach services.[27] In the United States, victims without adequate health insurance may have difficulty receiving quality care.[28] Indigenous Peoples in Australia, the United States, and elsewhere are particularly underserved by the health system, resulting in significant health disparities in comparison with the non-indigenous population.[29] While it may be difficult to establish high-quality specialized care in certain locations, at a minimum there is a need for good systems of accessible primary care and efficient referral and support up a cascade of care.

## Psychological care

As outlined in Chapter 8 above, harms from nuclear testing are not solely physical – they may also manifest as psychological distress. Therefore, victim assistance programmes should provide psychological support, including psychiatric, therapeutic, and peer-group methods, as well as relevant cultural, religious, and traditional healing. For example, care may include listening to the victims' testimony of the harm they suffered and acknowledging the losses they incurred. In addition, risk education and screening coupled with culturally appropriate counselling can help manage psychological anxieties associated with radiation exposure.

Due to the marginalization of many communities affected by nuclear testing, resources for psychological support are often insufficient. In small communities there may be concerns about confidentiality. In the Marshall Islands, as of 2020, there was only one practicing psychiatrist and there were no psychologists or social workers.[30]

## Socio-economic inclusion

Given the social, economic, and cultural consequences of nuclear testing, victim assistance should not be limited only to medical and psychological care. Victim assistance programmes should address stigma, ensure social inclusion, and promote economic empowerment. For example, the provision of direct payments can mitigate lost livelihoods, cover medical expenses, and/or compensate for suffering. Sustainable development initiatives can provide broader socio-economic benefits to affected communities. Transitional justice mechanisms, including traditional practices of acknowledgement and memorialization, can facilitate efforts to discover the truth about and gain recognition of nuclear testing and its consequences.

### Direct payments

A common response to the socio-economic impact of nuclear weapon testing has been the provision of pensions and compensation or (more often) *ex gratia* payments, which do not constitute an acknowledgement of legal liability. Fijian veterans of the UK tests in Kiribati receive from the Fijian government a pension and

26 Alexis-Martin *et al*., 'Addressing the Humanitarian and Environmental Consequences of Atmospheric Nuclear Weapon Tests: A Case Study of UK and US Test Programs at Kiritimati (Christmas) and Malden Islands, Republic of Kiribati'.

27 Fiji Kiritimati Island Veterans Association and the Returned Soldiers and Ex-servicemen's association of Fiji, 'Positive Obligation Framework: Forgotten stories of Fiji Veterans exposure to Nuclear Testing on Kiritimati Island', UN doc. TPNW/MSP/2023/NGO/27, 30 November 2023, available at: https://bit.ly/49XHMXf.

28 Human Rights Watch, 'In Sheep's Clothing: United States' Poorly Regulated Nonprofit Hospitals Undermine Health Care Access', 15 June 2023, at: https://bit.ly/3wLGCjc.

29 G. Kruse, V. A. Lopez-Carmen, A. Jensen, L. Hardie, and T. D. Sequist, 'The Indian Health Service and American Indian/Alaska Native Health Outcomes', *Annual Review of Public Health*, Vol. 43 (2022), 559–76.

30 World Health Organization (WHO), 'Marshall Islands', *Mental Health Atlas 2020*, available at: https://bit.ly/3lj1KA6.

assistance with medical bills.[31] Kazakhstan provides lump-sum compensation and a higher pension 'in areas of extraordinary and maximal radiation risk' to those deemed as having suffered as a result of Soviet nuclear testing at Semey/Semipalatinsk. Those who are government employees receive a salary top-up and additional paid holiday.[32]

These programmes, however, have limitations. Given the economic challenges facing the Kazakh government, many eligible applicants had to wait years before they received the compensation to which they were entitled.[33] Some survivors have also raised concerns that the list of presumptive diseases determining eligibility is not comprehensive.[34] Similar challenges have beset the French compensation scheme for its nuclear tests in Algeria and Mā'ohi Nui.[35] The 'Morin Law' (named after Hervé Morin, the French Minister of Defence when the scheme began in 2010), is based on spatial boundaries, threshold doses, and a shorter list of presumptive diseases than the US Radiation Exposure Compensation Act (RECA). The French list has even been described as an 'unscalable wall' for many victims.[36] As discussed in the case study on the United States in Chapter 21 of this report, RECA too has its shortcomings (although its scope was broadened in July 2025).

As discussed in Chapter 9, victim assistance in the context of nuclear testing impacts should be based on a framework of shared responsibility, but that framework has often been lacking in practise. Some governments of affected States have developed their own schemes because nuclear testing States have refused to take responsibility for harm they inflicted and to assist foreign nationals. The United Kingdom, for instance, has not acknowledged any responsibilities to troops from Fiji and Aotearoa/New Zealand who participated in British nuclear tests. Fiji has objected in diplomatic forums, raising the 'tragic health circumstances' of its citizens who served in Kiribati and have been 'denied support and recognition from colonial authorities'.[37] In 2015, Fiji announced $5,000 one-off grants to veterans or their survivors, while asserting that these payments are not in lieu of compensation that should come from the UK government. [38] Aotearoa New Zealand has provided War Disablement Pensions to nuclear veterans who are diagnosed with diseases from a presumptive list, modelled on the one used by the United States.[39]

Several country case studies in this report detail direct payment measures. In short, while pensions, compensation and *ex gratia* payment schemes have been important tools for assisting victims, they often limit eligibility through arbitrary geographic, temporal, dosage, and/or diagnosis thresholds. Renewed efforts to build norms on victim assistance to nuclear test victims should consider ways to make such direct payment programmes a collaborative effort and more open, accessible, and needs-based, rather than focused on limiting liability.

31 Alexis-Martin *et al*., 'Addressing the Humanitarian and Environmental Consequences of Atmospheric Nuclear Weapon Tests: A Case Study of UK and US Test Programs at Kiritimati (Christmas) and Malden Islands, Republic of Kiribati'.
32 NPA, *Nuclear Weapons Ban Monitor 2021*, 95; Kazakhstan, 'Assessments of the consequences of nuclear tests on the territory of the Republic of Kazakhstan', UN doc. TPNW/MSP/2023/10, 2023, available at: https://bit.ly/430L6hY.
33 NPA, *Nuclear Weapons Ban Monitor 2021*, 95.
34 Ibid.
35 M. B. Bolton, 'The Human Rights Fallout of Nuclear Detonations: Reevaluating "Threshold Thinking" in Policies Assisting Victims of Atmospheric Nuclear Testing', *Global Policy*, Vol. 13, No. 1 (2022), 76–90.
36 N. Ahmed, G. Livolsi, and S. Philippe, *Moruroa files: Investigation into French nuclear tests in the Pacific*, 2021, at: https://bit.ly/3OAoejB.
37 Statement by Dr Satyendra Prasad, Permanent Representative of Fiji to the United Nations at the High-Level Meeting of the General Assembly to Commemorate and Promote the International Day Against Nuclear Tests', 2018, available at: https://bit.ly/3uVkQJo.
38 Alexis-Martin *et al*., 'Addressing the Humanitarian and Environmental Consequences of Atmospheric Nuclear Weapon Tests: A Case Study of UK and US Test Programs at Kiritimati (Christmas) and Malden Islands, Republic of Kiribati'.
39 New Zealand, 'Voluntary report on articles 6 and 7 of the Treaty on the Prohibition of Nuclear Weapons: Report submitted by New Zealand', UN doc. TPNW/MSP/2023/11, 2023, available at: https://bit.ly/48FCiiZ; J. Dockerty, J. Jolly, A. Kumar, and T. Larsen, 'The New Zealand nuclear veteran and families study, exploring the options to assess heritable health outcomes', *New Zealand Medical Journal*, Vol. 133, No. 1515 (22 May 2020), 70–78, at: https://bit.ly/3T5mvEe.

### Sustainable development

By themselves, payment schemes are insufficient if the wider socio-economic disruptions caused by nuclear test programmes are not also addressed, such as through broad-based efforts to promote sustainable development in affected communities. For example, using funding from Japan, the UN Development Programme (UNDP), in partnership with the UN Children's Fund (UNICEF), the United Nations Volunteers (UNV) programme, and the UN Population Fund (UNFPA) has supported a 'comprehensive rehabilitation' programme in the Semey/Semipalatinsk region of Kazakhstan, with a view to ensuring access to 'quality basic health and social services for vulnerable groups', and in order to build capacities for entrepreneurship and business, to provide economic and employment opportunities, and to 'mobilize communities and support NGOs and CSOs'.[40]

### Transitional justice

While not generally an element of victim assistance programmes related to conventional weapons, many communities affected by nuclear weapons have advocated for transitional justice mechanisms to address the pervasive systems of social and political marginalization that violate their civil and political rights. For example, in a joint statement delivered to the TPNW Second Meeting of States Parties, representatives of affected communities asserted: 'We deserve recognition, respect, and reparations'.[41] The Office of the UN High Commissioner for Human Rights (OHCHR) defines transitional justice as 'the full range of processes and mechanisms associated with a society's attempt to come to terms with a legacy of large-scale past conflict, repression, violations and abuses, in order to ensure accountability, serve justice and achieve reconciliation'. It lists as measures of transitional justice practices:

> truth-seeking, prosecution initiatives, reparations, and various measures to prevent the recurrence of new violations, including: constitutional, legal and institutional reform, the strengthening of civil society, memorialization efforts, cultural initiatives, the preservation of archives, and the reform of history education.[42]

In Australia, media and civil society attention (as well as UK government stonewalling) prompted the establishment of a 1985 Royal Commission led by Judge James McClelland to investigate legacies of British nuclear testing. The report revealed the extent of fallout and radioactive contamination was much higher than had been publicly disclosed, along with a disproportionate impact on Aboriginal peoples. It found that the British and Australian governments had systematically kept the humanitarian effects secret from the Australian people. The Commission recommended providing compensation to people potentially affected by the nuclear tests and to shift the 'onus of proof' from the claimant to the government. It also urged the Australian government to redress Aboriginal 'loss of use and enjoyment of their lands since the beginning' and to provide compensation, 'technology and services which Aboriginal people regard as necessary for them to re-establish their relationships with their land as rapidly as possible and with minimal hardship'.[43]

Following investigative reporting that revealed that the US nuclear programme had conducted medical experiments that exposed people to radiation without their consent in the period 1944–74, US President Bill Clinton established an Advisory Committee on Human Radiation Experiments in 1994.[44] The Committee delivered its final report the following year, recommending 'apologies and compensation' as well as greater

40 UNDP, 'Kazakhstan still recovering 60 years after Soviet bombing', Press release, 29 August 2009.
41 'Affected Communities Statement to the Second Meeting of States Parties to the TPNW', 2023, available at: https://bit.ly/3uUxU1M.
42 OHCHR, 'About transitional justice and human rights', 2023, at: https://bit.ly/3v6bZVf.
43 J. R. McClelland, *The Report of the Royal Commission into British Nuclear Tests in Australia*, Vol. III, Australian Government Publishing Service, Canberra, 1985, available at: https://bit.ly/48V8aAp.
44 E. Welsome, *The Plutonium Files: America's Secret Medical Experiments in the Cold War*, Delta, New York, 1999.

protections in human subject research.[45] President Clinton accepted the recommendation and delivered a rare apology from a nuclear weapon State 'to the survivors and their families and to all the American people who must be able to rely upon the United States to keep its word, to tell the truth, and to do the right thing.'[46]

After decades of denial by the French government, in 2004 the Assembly of Mā'ohi Nui established a Commission of Inquiry on the Consequences of Nuclear Tests (CESCEN) in French Polynesia. In 2006, it released a report on the consequences of the French Pacific atmospheric nuclear tests, condemning the 'lasting disruption of the environment and daily lives of the people'. The report recommended a presumptive approach to victim assistance and compensation, the inclusion of Mā'ohi civilians into radiation health policymaking, monitoring of the medical and social concerns of downwind communities, the opening of archives, and the development of memorials, in partnership with victim associations.[47] The report was supposed to be followed by a second investigation into the underground French tests in French Polynesia, but this was cancelled when the pro-French political parties regained control of the Assembly.[48]

Nevertheless, despite widespread demands from affected communities, no testing State has apologized for the harm specifically caused by nuclear weapon testing. When testing States acknowledge nuclear legacies, they usually recognize them as sacrifices in the interests of national security, rather than harm caused by wrongdoing. For example, in November 2022, the United Kingdom announced a new medal 'to honour the significant contribution of veterans and civilian staff from across the Commonwealth, who participated in Britain's nuclear testing programme'. British Prime Minister Rishi Sunak stated that the medal was 'an enduring symbol of our country's gratitude' for their 'contribution to our safety, freedom and way of life'.[49] Announcing the new medals for nuclear veterans, the UK government also declared that it would be investing '£450,000 into projects which will commemorate and build further understanding of the experiences of veterans who were deployed to Australia and the Pacific'.[50] This built on an earlier initiative, the Nuclear Community Charity Fund, which has been supporting memorialization efforts for British nuclear test veterans and their descendants.[51]

Some, though, have raised concerns that these government-sponsored memorials (and a similar effort to establish a nuclear museum in Papeete, Mā'ohi Nui)[52] promote official and often militaristic narratives, rather than acknowledging wrongdoing.[53] In a 2015 ceremony announcing grants to Fijian nuclear test veterans, then Prime Minister Josaia Voreqe Bainimarama condemned the lack of recognition or apology by the United Kingdom:

> Fiji is not prepared to wait for Britain to do the right thing. ... We need to erase this blight on our history. We need to lift the burden on our collective conscience. ... [T]hese men have been denied justice long enough.[54]

45 Advisory Committee on Human Radiation Experiments, 'Executive Summary', 1995, at: https://bit.ly/48FEas1.
46 Statement of William Clinton, 'Remarks on Accepting the Report of the Advisory Committee on Human Radiation Experiments', 1995, at: https://bit.ly/3wGIvxR.
47 Commission d'Enquête sur les Conséquences des Essais Nucléaires (CESCEN), *Les polynésiens et les essais nucléaires*, Assemblée de la Polynésie française, translation by author, 2006.
48 Bolton, 'The Human Rights Fallout of Nuclear Detonations'.
49 UK Cabinet Office, 'Nuclear test veterans to receive medal as event remembers their service 70 years on', Press release, 21 November 2022, at: http://bit.ly/3lyveS9.
50 Ibid.
51 The Nuclear Community Charity Fund, 'NCCF Memorial Project', 2023, at: https://bit.ly/4m3wTtu.
52 'Questions about Tahiti nuclear memorial', *RNZ Pacific*, 2018, at: https://bit.ly/3T3rwgs.
53 B. Alexis-Martin, E. Waight, and M. Blell, *Nuclear Families: A Social Study of British Nuclear Test Veteran Community Families*, Final Report, University of Southampton, May 2019, at: https://bit.ly/3Tn74c6.
54 'Nuclear test veterans: Britain urged to compensate Fijians over 1950s Christmas Island tests', *ABC News*, 3 February 2015, at: https://bit.ly/3TlcKDh.

Given the silences in official museums and archives, victim associations and civil society have taken initiative in memorialization practices. Moruroa e tātou initiated the establishment of a memorial on the waterfront in Papeete, Mā'ohi Nui, where affected communities gather annually to commemorate the ongoing costs of French nuclear testing.[55] The *Daily Mirror* newspaper built an online memorial to 'The human fallout of Britain's nuclear bombs'.[56] The Nuclear Truth Project issued a report in 2023 highlighting the 'entrenched barriers for affected communities' in accessing nuclear archives and made recommendations for increasing 'openness and transparency'.[57] The Auckland Museum in Aotearoa New Zealand has a website dedicated to the 'devastating impact on the local communities and environment' from Pacific nuclear testing.[58] While significantly smaller in scale, the Alele Museum in Majuro in the Marshall Islands also depicts the impact of nuclear testing on the Marshallese and has been the venue for commemoration of the Islands' Nuclear Victims Remembrance Day.[59]

## Age- and gender-sensitivity

All forms of victim assistance should be provided in a manner that is age- and gender-sensitive and without discrimination.[60] These standards are explicitly articulated in Article 6 of the TPNW. In addition, the Action Plan adopted at the TPNW's First Meeting of States Parties in Vienna called on States to conduct all assistance activities according to 'principles of accessibility, inclusivity, non-discrimination, and transparency and in coordination with affected communities', and mindful, as noted in the preamble of the TPNW, of the disproportionate impact of nuclear weapon use and testing on women and girls and Indigenous people.[61]

As a result, victim assistance addressing the harm of nuclear weapon testing should acknowledge the ways that marginalization makes specific groups of people more vulnerable, as well as the ways vulnerabilities may intersect with each other, including age, gender, biological sex, race, class, sexuality, disability, and indigeneity. As noted in earlier chapters on radiation and health,[62] exposure tends to affect people assigned as female more than those assigned as male, and younger people are more affected than those who are adult. Attention should be given to potential reproductive impacts from radiation exposure and how this may be expressed in men and women, as well as recognition that communities have suffered loss of pregnancies and children and need support in accessing reproductive healthcare.

It is important to note that elevated harm from child exposure to radiation occurs across a person's lifespan. Moreover, an affected individual may be exposed to varying levels of radiation during their life. Therefore, age-sensitivity is more complex than simply distinguishing between children and adults, but rather tracing how even adults' risk may be affected by how they were exposed as children.

Moreover, victim assistance planning and decision-making must be inclusive, enabling the participation of those who are most vulnerable to the consequences of nuclear weapon testing, and programmes must be implemented and evaluated with them in mind. For example, Kazakhstan offers free medical care to children who are living in areas recognized as being affected by radiation exposure.[63]

55 Délégation pour le suivi des conséquences des essais nucléaires & Moruroa e Tatou, 'Place du 2 juillet 1966: Lieu de mémoire et de culture', 2012; and 'Cinquante et Un Ans Après Le Premier Essai à Moruroa', *La Dépêche de Tahiti*, 20 June 2017, at: https://bit.ly/3T0zreD.

56 S. Boniface, 'The Damned', Special Report, *Daily Mirror*, at: https://damned.mirror.co.uk.

57 Nuclear Truth Project, 'Challenging Nuclear Secrecy', 2023, at: https://bit.ly/3Il6m8C.

58 Auckland Museum, 'Remembering Moruroa', undated but accessed 1 March 2024 at: https://bit.ly/3Inlsul.

59 Alele Museum, 'Exhibit – Nuclear Victims Remembrance Day Photographies', 2015, at: https://bit.ly/3TppF7q.

60 Art. 6(1), TPNW.

61 Action 25, Action Plan adopted at the First Meeting of States Parties to the TPNW, UN doc. TPNW/MSP/2022/CRP.7, Vienna, 23 June 2022, at: https://bit.ly/48Ez52X (2022 Vienna Action Plan).

62 See Chapters 6 and 7 above.

63 NPA, *Nuclear Weapons Ban Monitor 2021*, p. 95.

## Assessing the model of Japan's support system for hibakusha

While responding to the use of nuclear weapons in war rather than nuclear testing, Japan's Atomic Bomb Survivors Support Law provides one model of a comprehensive approach to victim assistance. The Law provides medical, health, and welfare support, including monthly allowances and funeral service expenses to the 'hibakusha' (the Japanese term for the atomic bomb survivors).[64] Japan's Support Law also asserts that 'the State shall work towards nuclear weapons abolition, endeavour to sustain research on the effects of atomic bomb radiation and undertake peace memorial projects to remember the victims of the bombings'.[65] However, the law limits the definition of hibakusha eligible for benefits to those who were 'directly exposed to the atomic bombings'; who entered 'specific areas of Hiroshima and Nagasaki within two weeks after the atomic bombings', who were 'relief and rescue workers, who were in a position to be affected by the injurious effects of the atomic bomb radiation', or who were babies in utero (born within nine months after the bombings) to a person recognized as hibakusha under one of the previous three categories.[66]

Following a long campaign for recognition, people who were outside the previously acknowledged geographic limits of the law, but who were nonetheless exposed to radioactive fallout, have been classified as 'persons requiring health status monitoring'. If they develop certain health conditions, they are classified as 'third-category hibakusha'.[67] A 2015 class action suit by Korean survivors allowed non-Japanese nationals to be recognized as hibakusha and to receive services from the Support Law.[68] However, some Korean survivors still struggle to be recognized.[69] Additionally, Nihon Hidankyō (the main organization of hibakusha and the 2024 Nobel Peace Prize laureate) has long called for the Support Law to be explicitly framed as 'State compensation', recognizing Japan's 'responsibility in the war of aggression that resulted in the atomic bombings'.[70] The Japanese government refuses to describe the Support Law as compensation (which might imply liability), nor does it recognize Nihon Hidankyō's understanding of its responsibility.

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64 Vasileva *et al*., 'Addressing the atomic bomb damage: Associations between 'state compensation' demands and aspects of survivors' suffering'.

65 Ibid.

66 Ibid.

67 Ibid.

68 T. Osaki, 'Supreme Court rules hibakusha overseas are entitled to full medical expenses', *The Japan Times*, 8 September 2015, at: https://bit.ly/3UYqV2r.

69 S. Kim, 'Hibakusha of "Korea's Hiroshima" Still Press for Redress', *The Japan Times*, 6 August 2015, at: https://bit.ly/4cbJOFk; T. Higuchi, 'Korean survivor of Nagasaki atomic bombing dies at 95 without recognition as hibakusha', *The Mainichi*, 15 January 2023, at: https://bit.ly/3uNwSEP.

70 Ibid.

Chapter 13:

# The Possibility of Remedies under International Human Rights Law

Stuart Casey-Maslen

There has still to be a successful claim for a remedy for past nuclear harm in a regional human rights court. Causation and jurisdictional problems are the reason for this anomaly. The human rights most affected by nuclear testing are set forth in the two international human rights covenants adopted in 1966: the Covenant on Civil and Political Rights, which protects the right to life and to freedom from ill-treatment, and the Covenant on Economic, Social and Cultural Rights, which safeguards the rights to health and to an adequate standard of living. The international community generally recognized the right of everyone to a healthy environment in 2022.

The legacies of nuclear testing have significant ongoing implications for the enjoyment of a range of human rights – civil and political as well as economic, social, and cultural. For those who witnessed nuclear test detonations at close quarters, the personal consequences can clearly be dramatic. But others are also affected by the spread of radioactive clouds, such as their descendants, given the potential impact of radioactivity on a person's DNA.[1] While previous chapters have focused on the need to remediate the environment and assist victims, this chapter explores the challenges of achieving legal accountability for past nuclear testing. There has still to be a successful claim for a remedy for past nuclear harm in a regional human rights court. Aside from the obvious challenge of proving causation, the problems are primarily jurisdictional in nature.

Any new nuclear test detonation today would be likely to violate a range of branches of international law, especially if it were conducted in the atmosphere. But most of the atmospheric tests were conducted in the 1950s and 1960s prior to the elaboration of the two international human rights covenants,[2] and did not even necessarily contravene applicable human rights law at the time. While the moral case for State responsibility for nuclear harm cannot be contested, the four key jurisdictional bases of international human rights law—geographical, material, personal, and temporal—continue to constitute weighty obstacles to formal accountability for past nuclear testing under international law.

## The jurisdiction of international human rights law

Four types of jurisdictions are required to obtain legal accountability for the harm caused by nuclear testing. Geographical jurisdiction concerns where international human rights law is applicable. Material jurisdiction concerns both what rights are safeguarded and in which situations they are protected. Personal jurisdiction addresses the duty bearers as well as the beneficiaries. Temporal jurisdiction concerns at what point in time human rights law becomes binding, and, potentially, when protection under a relevant treaty might end (such as through withdrawal from it).

### Geographical jurisdiction

Jurisdiction under international human rights law is primarily territorial. This encompasses both metropolitan and non-metropolitan territory, including a State's overseas territories. Thus, where a nuclear test was conducted on sovereign territory, there is no legal impediment to the applicability of the law. This means that testing on the continental United States (particularly in Nevada); in China (in Lop Nor, a lake region in the western province of Xinjiang); within the boundaries of the Soviet Union (particularly in Kazakhstan and Novaya Zemlya in the Arctic), as well as on the territory of the Democratic People's Republic of Korea (North Korea), India, and Pakistan all fell within the geographical jurisdiction of these States under international human rights law existing at the time.

The Trust Territory of the Pacific Islands (TTPI), which included the territories of the Marshall Islands, was a UN trust territory administered by the United States from 1947 to 1994. UN Security Council Resolution 21 granted the Administering Authority full jurisdiction over the Territory.[3] It also required the Authority to 'encourage the development of fisheries, agriculture, and industries'; to 'protect the inhabitants against the loss of their lands and resources'; to 'protect the rights and fundamental freedoms of all elements of the

1 See inter alia Chapter 6 for detail on this issue.
2 International Covenant on Economic, Social and Cultural Rights; adopted at New York, 16 December 1966; entered into force, 3 January 1976 (ICESCR); and International Covenant on Civil and Political Rights; adopted at New York, 16 December 1966; entered into force, 23 March 1976 (ICCPR).
3 UN Security Council Resolution 21, adopted by unanimous vote in favour on 2 April 1947, Art. 3.

population without discrimination'; and to 'protect the health of the inhabitants'.[4] This the United States manifestly failed to do.

France's testing in Moruroa Atoll in Māʼohi Nui (French Polynesia) unquestionably falls within France's geographical jurisdiction for international human rights law. The same responsibility pertains to French nuclear testing in Algeria prior to that nation's independence in July 1962, which comprised four atmospheric tests. But most of France's testing of its nuclear explosive devices occurred in the Sahara after Algerian independence.[5] The United Kingdom conducted nuclear testing in Australia decades after the 'Commonwealth of Australia' became a self-governing Dominion within the British Empire. The tests, which comprised detonations of nuclear explosive devices and other devices that dispersed plutonium into the atmosphere, have caused persistent environmental harm. The tests were authorized by the Australian prime minister of the time, Robert Menzies (without even consulting his Cabinet, much less Australia's parliament).

### Material jurisdiction

The human rights most affected by nuclear testing are set forth in the two international human rights covenants adopted in 1966. The International Covenant on Civil and Political Rights protects the rights to life and to freedom from cruel, inhuman, or degrading treatment ('ill-treatment' for short).[6] In its 1996 advisory opinion on the threat or use of nuclear weapons, the International Court of Justice made it clear that the Covenant applied to the use of nuclear weapons (it did not address the issue of testing in any meaningful manner, but the Covenant also certainly applies).[7] The International Covenant on Economic, Social and Cultural Rights safeguards the rights to health and to an adequate standard of living.[8] Only in July 2022 did the international community generally recognize the right of everyone to a healthy environment.[9]

Also relevant to material jurisdiction is the context for nuclear testing. The Cold War did not amount to an armed conflict as that term is understood in international humanitarian law nor did it constitute a 'public emergency which threatens the life of the nation' allowing derogation from certain civil and political rights. In any event, the rights to life and to freedom from ill-treatment are non-derogable.[10] The rights to health and to an adequate standard of living are subject to progressive development although an irreducible core applies at all times.

### Personal jurisdiction

Personal jurisdiction in international human rights law governs the persons who are entitled to enjoy certain rights under treaty or customary law and also identifies the States which are required by law to respect and ensure those rights. With respect to the Covenant on Civil and Political Rights, France acceded to the treaty in 1980; the Soviet Union ratified in 1973 (with Russia as the successor State at the end of 1991); the United Kingdom joined in 1976; and the United States ratified in 1992. North Korea adhered to the Covenant in 1981 (and later tried, but failed to withdraw from it as the depositary found that withdrawal was not possible).

4 Ibid., Art. 6(2) and (3).
5 Global Zero, 'The Legacy of French Nuclear Testing in Algeria Shows How Nuclear Weapons Perpetuate Colonialism', 1 June 2023, at: https://bit.ly/3GpSWr3.
6 Arts. 6 and 7, ICCPR.
7 International Court of Justice, *Legality of the Threat or Use of Nuclear Weapons*, Advisory Opinion, 8 July 1996.
8 Arts. 12 and 11(1), ICESCR.
9 UN General Assembly Resolution 76/300: 'The human right to a clean, healthy and sustainable environment'; adopted on 28 July 2022 by 161 votes to nil with 8 abstentions (Belarus, Cambodia, China, Ethiopia, Iran, Kyrgyzstan, Russia, and Syria).
10 Art. 4(2), ICCPR.

China is a signatory but not a State Party to the Covenant. India and Pakistan are both States Parties to the Covenant – India acceding in 1979 and Pakistan ratifying in 2010.

Under the Covenant, each State Party undertakes to respect and to ensure 'to all individuals within its territory and subject to its jurisdiction' the rights recognized therein. This is interpreted to apply both to acts on sovereign territory and to certain acts committed abroad.[11] Thus, the Human Rights Committee declared in its General Comment 36 on the right to life that: 'This includes persons located outside any territory effectively controlled by the State whose right to life is nonetheless affected by its military or other activities in a direct and reasonably foreseeable manner'.[12] The United States, however, does not acknowledge that the Covenant applies extraterritorially.[13]

With respect to the Covenant on Economic, Social and Cultural Rights, the Soviet Union ratified in 1973 (with Russia as the successor State at the end of 1991); the United Kingdom adhered in 1976; France acceded in 1980; and China ratified only in 2001. The United States is a signatory but not a State Party to the Covenant. The Covenant on Economic, Social and Cultural Rights does not specify the limits of its personal jurisdiction.

### Temporal jurisdiction

Temporal jurisdiction concerns whether a given act falls within the jurisdiction of a particular court or tribunal based on when it occurred. This is particularly an issue with respect to the date on which a State became party to a particular treaty. As a consequence, events that took place prior to a State becoming party to a human rights treaty and which involved a potentially unlawful killing may well not be subject to adjudication according to the substantive component of the right to life. It is unlikely that the significant and ongoing harm to victims from events that occurred decades ago will meet the requirements of temporal jurisdiction. That said, the procedural component of that right—the duty to investigate suspicious death—may persist for many years, including after a State becomes party to the salient human rights treaty, thereby according jurisdiction to a court that it would otherwise not have in a particular case.[14]

An enforced disappearance that occurred prior to a State becoming party to a relevant human rights treaty but which is still not resolved may thus manage to overcome the obstacle of temporal jurisdiction, but only with respect to the duty to investigate.[15] The harm from nuclear weapons may not become apparent for years or decades after exposure, just as the fate of the disappeared person may only become known years or decades after they are detained or abducted, so at the least an effective investigation could be required under the rights to life and to freedom from ill-treatment.

## Selected rights most affected by nuclear testing

### The right to life

The right to life comprises three main elements: a prohibition on arbitrary deprivation of life, a duty to protect life, and a duty to investigate potential violations of the right to life.[16] While only a very small number of people

11 International Court of Justice, *Legal Consequences of the Construction of a Wall in the Occupied Palestinian Territory*, Advisory Opinion, 9 July 2004, paras. 109, 111.
12 Human Rights Committee, 'General Comment No. 36 – Article 6: Right to Life', UN doc. CCPR/C/GC/36, 3 September 2019, para. 63.
13 Fifth Periodic Report of the United States under the Covenant on Civil and Political Rights, UN doc. CPR/C/USA/5, 19 January 2021, para. 14.
14 See, e.g., European Court of Human Rights, *Mocanu and ors* v. *Romania*, Judgment (Grand Chamber), 17 September 2014.
15 Ibid., paras. 210, 211.
16 See, e.g., Human Rights Committee, General Comment No. 36: Article 6: right to life, UN doc. CCPR/C/GC/36, 3 September 2019, *esp*. paras. 4, 6, 7, 21, and 27; and S. Casey-Maslen, *The Right to Life under International Law: An Interpretive Manual*, Cambridge University Press, Cambridge, 2021.

are thought to have been killed directly in the course of nuclear testing, the lives of a great many have been prematurely curtailed by radiation.[17] These deaths represent a failure to protect life as required by conventional and customary law. As discussed in Chapter 6 above, a 1991 study by the International Physicians for the Prevention of Nuclear War (IPPNW) and the Institute for Environmental and Energy Research predicted that globally approximately 2.4 million people would die from cancers resulting from atmospheric testing.[18] In the United States, which conducted almost half of all the more than 2,000 nuclear test detonations worldwide at its Nevada test site, an academic study published in 2017 estimated that fallout from nuclear testing contributed up to 460,000 excess deaths between 1951 and 1973, with the cumulative number of excess deaths attributable to these tests comparable to the deaths resulting from the bombings of Hiroshima and Nagasaki.[19]

### The right to freedom from ill-treatment

Torture is defined under the 1984 Convention against Torture as any act by which severe pain or suffering, whether physical or mental, is intentionally inflicted on a person for a purpose, including for any reason based on discrimination of any kind. The Convention definition requires that the pain or suffering be inflicted by or at the instigation of or with the consent or acquiescence of a public official or other person acting in an official capacity.[20] Forcing people to witness or be present at a test detonation at close hand violates the prohibition on torture or other ill-treatment.

In 2010, *The Guardian* reported that soldiers stationed in Algeria in 1961 (the Green Jerboa test at Reggane) had been subjected to 'tactical experiments' carried out to 'study the physiological and psychological effects of atomic weapons on man'. France's Minister of Defence Hervé Morin confirmed that about one hundred soldiers had been involved in exercises which aimed to test the effects of fallout on human beings. But, he declared, the time had come 'to stop analysing historic events from the standpoint of 2010. It was another era', he said.[21] The British *Buffalo* series of nuclear tests conducted in south Australia from September to October 1956 involved an 'Indoctrinee Force' of mainly commissioned officers who were positioned less than nine kilometres from ground zero. The 283 men were dressed in shorts, shirts, and long socks.[22]

A violation of the right to freedom from ill-treatment is even more serious when individuals—typically soldiers—are sent over part of the contaminated area shortly after a test has occurred. For example, in decades past both France and Russia sent troops over an area that had recently been subject to a nuclear test detonation. Two separate French tests involved French soldiers conducting reconnaissance in the contaminated environment wearing protective equipment. On 27 December 1960, the French 3 kt test code-named *Gerboise Rouge* involved around 100 soldiers while the French 1 kt test on 25 April 1961 code-named *Gerboise Verte* involved 195 soldiers, both of which took place at Reggane in the Sahara.[23] The French Ministry of Defence claimed that the doses they received were 'low' and were 'well below the annual doses'.[24]

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17 M. Finaud, '75 years later, nuclear weapons still kill', Opinion Editorial, Global Insights, Geneva Centre for Security Policy, 6 August 2020, at: https://bit.ly/47Jvpxl.

18 *Radioactive Heaven and Earth: The Health and Environmental Effects of Nuclear weapon testing in, on, and above the Earth*, Zed Books, London, 1991, at: https://bit.ly/3RoM7fB.

19 K. Meyers, 'Some Unintended Fallout from Defense Policy: Measuring the Effect of Atmospheric Nuclear Testing on American Mortality Patterns', Online article, University of Arizona, 24 October 2017, at: https://bit.ly/3uQnvDC.

20 Art. 1(1), Convention against Torture and Other Cruel, Inhuman or Degrading Treatment or Punishment; adopted at New York, 10 December 1984; entered into force, 26 June 1987. At the time of writing, 175 States were party to the Convention. Of the States confirmed to have tested nuclear weapons, only India (a signatory) and North Korea are not States Parties.

21 L. Davies, 'French soldiers "deliberately exposed to radiation" during nuclear tests', *The Guardian*, 16 February 2010, at: https://bit.ly/49upSvG.

22 Tynan, *Atomic Thunder: British Nuclear Testing in Australia*, 102, 104.

23 V. Jauvert, 'Sahara, les cobayes de Gerboise verte', *Le Nouvel Observateur*, 5 February 1998.

24 'Essais nucléaires : Gerboise verte, la bombe et le scoop qui font plouf...', Blog post, Libération.fr, 16 February 2010, archived at: https://bit.ly/3uzyDVp.

On 14 September 1954, near Totskoye, a village in the Ural mountains 600 miles south-east of Moscow, the Soviet armed forces had air-detonated a 20 kt bomb as part of a military exercise. The detonation was deliberately close to where 45,000 Red Army troops and thousands of civilians were gathered. The purpose of the exercise, which was filmed, was to assess the extent to which troops could fight in an area immediately after it had been hit by an atomic bomb. The film documents soldiers with little or no protective gear running through 'an inferno of dust, heat and radiation'.[25] It was reported that the number of people suffering from tumorous illnesses in the province increased by 500 per cent between 1950 and 1994.[26]

In 1954, as a result of the Castle Bravo test in the Marshall Islands, many Marshallese suffered from burns and radiation diseases. The military did not evacuate residents of Rongelap until two days after the test occurred. Three years later, the people of Rongelap returned. After the release of previously classified documents, it became clear that some scientists and researchers within the Atomic Energy Commission (AEC) wanted to study people living in radiation-contaminated environments. This may have influenced the decision to allow the Marshallese of Rongelap to return to the atoll in 1957. An AEC scientist at the meeting where the decision was taken stated:

> It would be very interesting to go back and get good environmental data, when people live in a contaminated environment. Now, data of this type has never been available. While it is true that these people do not live, I would say, the way Westerners do, civilized people, it is nevertheless also true that they are more like us than mice.[27]

### The right to health

The right of everyone to enjoy the highest attainable standard of physical and mental health is recognized in the 1966 Covenant on Economic, Social and Cultural Rights[28] and, for children specifically, in the 1989 Convention on the Rights of the Child.[29] The right is also recognized in regional instruments such as the Protocol of San Salvador to the American Convention on Human Rights.[30] Atmospheric nuclear testing or underground testing with venting amount to serious violations of this right given the serious health risks associated with radiation.

Between 1946 and 1958, the US military detonated 67 nuclear explosive devices in the Marshall Islands whose combined explosive yield equated to more than 108 megatons (Mt) (a yield greater than 7,000 Hiroshima bombs). These acts exposed islanders to massive levels of nuclear radiation. It is claimed that, at the time of the testing, scientists believed that exposure to nuclear radiation did not increase the risk of congenital anomalies.[31] But no comprehensive epidemiologic studies were conducted among the Marshallese to identify other types of cancers or serious illnesses that could result from nuclear radiation exposure. Medical care is one of the main reasons why many Marshallese go to Hawaii. Dr Neal Palafox, a physician and professor at the

25 M. Simons, 'Soviet Atom Test Used Thousands as Guinea Pigs, Archives Show', *The New York Times*, 7 November 1993, at http://bit.ly/3gZDQut.

26 E. Carter, 'The Soviets Trained to Fight under Nuclear Detonations. Soldiers Suffered as a Result', War Is Boring, 7 February 2015, at http://bit.ly/3h5WYHs.

27 Cited in Atomic Heritage Foundation, 'Marshall Islands', 2022, at: https://bit.ly/3NbPu74.

28 Art. 12(1), CESCR.

29 Art. 24, Convention on the Rights of the Child.

30 'Everyone shall have the right to health, understood to mean the enjoyment of the highest level of physical, mental and social well-being.' Art. 10(1), Additional Protocol to the American Convention on Human Rights in the Area of Economic, Social and Cultural Rights ('Protocol of San Salvador'); adopted at San Salvador, 17 November 1988; entered into force, 16 November 1999.

31 W. N. Nembhard *et al.*, 'Nuclear Radiation and Prevalence of Structural Birth Defects among Infants Born to Women from the Marshall Islands', *Birth Defects Research*, Vol. 111, No. 16 (October 2019), 1192–1204, available at: https://bit.ly/3uInUlo.

University of Hawaii, practised medicine in the Marshall Islands. 'Sometimes you run out of medicines. We don't have antibiotics; we run out of surgical sutures. We reused gloves', Dr Palafox told ABC News.[32]

The town of Reggane in the Algerian Sahara counted more than 6,000 inhabitants in 1960. Abderrahmane Toumi's family moved to the oasis after the tests ended in 1965. But later in life he became so affected by the suffering of the local population that in 2010 he set up an association to fight for those who were suffering from the effects of nuclear radiation, the 'El-Gheith El-Kadem'.[33] Researchers identified long-term effects around 20 years after the first bomb was detonated. 'Many of those who were contaminated have already passed away due to unknown medical causes. They were told they had rare illnesses but they didn't really know the specific nature of their illness', Mr Toumi declared.

### The right to an adequate standard of living

Socio-economic inclusion is integral to the right to an adequate standard of living as protected in Article 11(1) of the Covenant on Economic, Social and Cultural Rights. In fact, nuclear colonialism and subconscious or overt racism characterized much early nuclear testing. An American newsreel report on the testing in the Marshall Islands in the 1950s referred to the Marshallese as 'savages, but happy savages'. Today, radiation related cancers and congenital anomalies are a major problem faced by the Marshallese. When the United States forced evacuations of islands such as Enewetak, residents could no longer eat their traditional foods, unable to farm or fish on their lands. Many were given canned imported foods.[34] Diabetes—a consequence of large quantities of these imported, processed foods—and cancer are the top two causes of death. Environmental issues such as rising sea levels and degradation attributed to the nuclear testing often force residents to move between atolls or seek a new home.[35]

With respect to the nuclear tests at Maralinga in Australia, concerns occasionally raised about the welfare of local Indigenous People were rebuffed by the Australian government. One senior official even criticized a 'lamentable lack of balance' in 'apparently placing the affairs of a handful of natives above those of the British Commonwealth of Nations'.[36]

### The right to a healthy environment

In 2022, the international community recognized the right to a clean, healthy, and sustainable environment as a human right.[37] At the regional level, the right to a healthy environment was included in the 1981 African Charter on Human and Peoples' Rights.[38] Under the 1988 Protocol of San Salvador, everyone 'shall have the right to live in a healthy environment'. The States Parties to the Protocol 'shall promote the protection, preservation, and improvement of the environment'.[39] While there is not a universally agreed definition of the right to a healthy environment, the right is generally understood to include among its core elements clean air,

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32 S. Yamashita, L. Griswold, and J. Schlosberg, 'America's forgotten nuclear migration: The Marshallese displaced by US bomb testing face new challenges', *ABC News*, 18 July 2023, at: https://bit.ly/3GpqPIq.

33 L. A. A., 'Essais nucléaires français en Algérie : Les préjudices toujours visibles', *Le Jeune Indépendant*, 13 February 2021, at: https://bit.ly/3RrHWif.

34 Yamashita, Griswold, and Schlosberg, 'America's forgotten nuclear migration: The Marshallese displaced by US bomb testing face new challenges'.

35 Atomic Heritage Foundation, 'Marshall Islands', 2022.

36 Justice J. McClelland, *Royal Commission into British nuclear tests in Australia*, Vol. 1, 1985, §8.4.38.

37 UN General Assembly Resolution 76/300, operative para. 1.

38 'All peoples shall have the right to a general satisfactory environment favourable to their development.' Art. 24, African Charter on Human and Peoples' Rights; adopted at Nairobi, 27 June 1981; entered into force, 21 October 1986.

39 Art. 11(1) and (2), Protocol of San Salvador.

non-toxic environments in which to live, access to safe water and adequate sanitation, and healthy biodiversity and ecosystems.[40]

Castle Bravo, the largest US nuclear detonation in history, was conducted at Bikini Atoll on 1 March 1954. Bravo was the first test of a deliverable hydrogen bomb. The fallout it generated, which was composed of pulverized coral, water, and radioactive particles, spread eastward affecting nearby Indigenous populations and US service personnel. Traces of radioactive material were later found in parts of Australia, India, Japan, Europe, and the United States. It was the worst radiological disaster in US history, resulting in a worldwide backlash against atmospheric nuclear testing and nuclear weapons more generally.[41]

On islands such as Bikini Atoll, the average background gamma radiation is far larger than the maximum value stipulated in an agreement between the governments of the Marshall Islands and the United States. Scientific testing of sediment from two bomb craters in the northern Marshall Islands found consistently high values of strontium 90. Although detecting this radioisotope in sediment does not directly translate into contamination in soil or food, the finding suggests the possibility of danger to ecosystems and people.[42]

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40 'Right to a healthy environment: good practices, Report of the Special Rapporteur on the issue of human rights obligations relating to the enjoyment of a safe, clean, healthy and sustainable environment', UN doc. A/HRC/43/53, 30 December 2019, para. 2.

41 Atomic Heritage Foundation, 'Marshall Islands', 2022.

42 H. Rapaport and I. N. Hughes, 'The U.S. Must Take Responsibility for Nuclear Fallout in the Marshall Islands', *Scientific American*, 4 April 2022, at: https://bit.ly/3R8TrL0.


Test site Alamogordo, New Mexico.

# Part IV

# Country Case Studies

**The First One:** A replica of 'The Gadget', the first nuclear explosive device detonated, photographed in the National Museum of Nuclear Science in Albuquerque, New Mexico, United States. The Gadget was tested at the Trinity Test site in New Mexico on 16 July 1945. It was a plutonium implosion device, similar in design to the Fat Man bomb dropped on Nagasaki the following month. The Trinity test was a pivotal moment in history, marking the first detonation of a nuclear weapon. Photograph © Jon G. Fuller, VW Pics/Science Photo Library/NTB.

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Chapter 14:

# Addressing the Impact of French Nuclear Testing in Algeria

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**Unknown Locations:** France continues to withhold records of the location of some of its nuclear waste burial sites in Algeria, preventing effective survey and remediation. In this photograph, which was taken on 25 February 2010, a man walks past a fence at the entrance of the former French nuclear bomb test site of Tena Fila mountain at In Ekker in Tamanrasset, 2,000 kilometres south of Algiers. Photograph © Fayez Nureldine, AFP/NTB.

## Key Facts on Nuclear Testing in Algeria

**Testing State:** France

**Testing period:** 1960–66

**Number of tests:** 17, of which 4 were atmospheric and 13 underground. A further 40 experiments with fissile material were also conducted.

**Test locations:** In Ekker and Reggane in the Algerian Sahara

**Health impacts:** Tests caused significant radiation exposure, leading to displacement and long-term health issues like cancer, psychological disorders, infertility, and congenital disabilities among civilians, military personnel, and Indigenous Peoples. This is compounded by a lack of access to justice or medical care.

**Indigenous and nomadic populations affected:** near the town of Reggane and possibly (from the Beryl test) the town of Mertoutek.

**Environmental contamination:** The tests left a lasting legacy of environmental degradation. Radioactive waste, including plutonium, was buried in unmarked locations. Even some known test sites are poorly secured.

**Lack of transparency and accountability:** Criticism has been levelled at both French assessments and the 2005 report of the International Atomic Energy Agency (IAEA) for minimizing contamination risks. France continues to withhold information on its nuclear tests in Algeria, including records of the location of some of its nuclear waste burial sites, preventing necessary surveys and environmental remediation.

**Barriers to compensation:** The French 2010 Morin Law theoretically allows compensation for a list of cancers. But because of bureaucratic, linguistic, and evidentiary hurdles only 2 of 1,026 successful claims have been Algerian.

**Ongoing inaction:** France has never provided intergovernmental compensation to Algeria for its nuclear testing. France has also declined to provide details of the tests in Algeria from its confidential archives. Only limited clean-up has been conducted. There is no information on any ongoing or planned victim assistance or environmental remediation efforts. Algeria established a national environmental remediation authority in 2021, but progress is unclear.

> Don't give us money, but come clean up the sites that you have contaminated.
>
> Algeria's President Abdelmadjod Tebboune (2024)[1]

## History of testing in Algeria

Between 13 February 1960 and 16 February 1966, France detonated a total of seventeen nuclear explosive devices in the vicinity of the towns of In Ekker and Reggane in the Algerian Sahara (see Figure 1 overleaf). Most of the tests came after Algeria had gained independence from France.[2] Of the seventeen detonations, four were atmospheric explosions in Hammoudia-Reggane that were highly polluting while the other thirteen took place underground at Taourirt Tan Afella near In Ekker.[3]

In 1957, the French government decided to create a test field in the Sahara. For this purpose, an area of 108,000 square kilometres was allocated to the defence establishment to carry out the nation's first nuclear tests. The Saharan Centre for Military Experiments (CSEM), intended for atmospheric tests, was located about fifty kilometres south of Reggane. The very first atmospheric test, 'Gerboise bleue', was conducted on 13 February 1960 at the CSEM. Suspended from a pylon, the test detonation is reported by the International Atomic Energy Agency (IAEA) to have equated to between 40 and 80 kt of TNT. Three more tests occurred in the Gerboise series, each with a reported yield of less than 10 kt. The last of these was conducted on 25 April 1961.[4]

Subsequently, a series of thirteen underground tests followed the four atmospheric tests and a new experimental site, the Oasis Military Experiment Centre (CEMO), was built for this purpose in the Hoggar mountain range, near In Ekker, 150 kilometres north of Tamanrasset.[5]

During the French nuclear testing programme in Algeria, the Sahara was also the scene of a total of forty significant complementary experiments, all of which are reported to have been without the release of nuclear energy but with the spread of fissile material – the Pollen series at the Adrar Tikertine site north-west of the Taourirt Tan Ataram massif in the CEMO and the Augias series at the CSEM.[6] According to a classified French

1 Cited in A. Guliyev, 'Algeria calls on France to confront its nuclear past – "Come clean up the sites that you have contaminated"', Caliber, 14 February 2025, at: https://bit.ly/4obRo8J.

2 Global Zero, 'The Legacy of French Nuclear Testing in Algeria Shows How Nuclear Weapons Perpetuate Colonialism', 1 June 2023, at: https://bit.ly/3GpSWr3. The terms of the Evian agreements of March 1962 and in particular those relating to military questions specified that 'France will use for a period of five years the sites including the installations of In Ekker, Reggane and the whole of Colomb-Béchar-Hamaguir, the perimeter of which is delimited in the attached plan, as well as the corresponding technical location stations.'

3 IAEA, 'Radiological Conditions at the Former French Nuclear Test Sites in Algeria: Preliminary Assessment and Recommendations', Radiological Assessment Report Series, 2005, at: https://bit.ly/3UPyhVR, p. 5.

4 Ibid., p. 7.

5 French Ministry of Defence, 'Dossier de présentation des essais nucléaires et leur suivi au Sahara', Délégation à l'Information et à la Communication de la Défense, January 2007, available at: https://bit.ly/3OUfrZT, p. 1 (unofficial translation).

6 IAEA, 'Radiological Conditions at the Former French Nuclear Test Sites in Algeria: Preliminary Assessment and Recommendations', Radiological Assessment Report Series, 2005, at: https://bit.ly/3UPyhVR, p. 5. See also C. Bataille, et H. Revol, *Rapport sur les incidences environnementales et sanitaires des essais nucléaires effectués par la France entre 1960 et 1996 et élément de comparaison avec les essais des autres puissances nucléaires*, Office parlementaire d'évaluation des choix scientifiques et technologiques, 5 February 2001, p. 42; A. Mansouri, 'التفجيرات النووية الفرنسية في الصحراء الجزائرية: إرث استعماري' ['French nuclear explosions in the Algerian desert: A heavy colonial legacy'], *Maçadir Review*, Vol. 7, No. 1 (2019), 9–45.

Defence document, the five Pollen experiments between 1964 and 1966 were 'aimed at evaluating plutonium contamination in the event of a weapon accident'.[7] A comparison with the available information on the Pollen series with the information on the atmospheric Ganymede series of safety tests conducted by France in Mā'ohi Nui (French Polynesia), which are included in the French total of nuclear tests there, shows that they share the same characteristics. In both cases, a model nuclear weapon is used, physically installed high up on a tower, with plutonium dispersed over a vast area. As discussed in the case study on Mā'ohi Nui, some of the atmospheric and underground safety tests there did lead to release of nuclear energy. The Augias series of experiments in Algeria, conducted between 1961 and 1963, sought to study 'the behavior of plutonium' using small quantities of the material either in closed tanks (the first nine experiments), open tanks (three), or in the open air above a hole dug into the ground (twenty-three).[8] They appear to be similar to the Arpège and Meknès experiments in Mā'ohi Nui.

Figure 1: The location of nuclear tests in Algeria © AVEN


## Assessments

### French Ministry of Defence assessments and defined safety thresholds

On 6 January 1958, the French Ministry of Defence created a Site Security Consultative Commission (CCS), which was responsible for studying safety issues relating to nuclear testing. In February 1959, the Nuclear Experiments Operational Group (GOEN) was created to ensure security in accordance with the standards proposed by the CCS. In 1958 and 1959, the CCS defined:

7 This report is not officially declassified, but it is public. 'Rapport sur les essais nucléaires français 1960-1996, tome 1: La genèse de l'organisation et les expérimentations au Sahara CSEM et Cemo'. 198.

8 IAEA, 'Radiological Conditions at the Former French Nuclear Test Sites in Algeria: Preliminary Assessment and Recommendations', Radiological Assessment Report Series, 2005, p. 5.

- A safety distance of 50 kilometres between the test points and the Reggane base
- The areas to be controlled (fallout zones and a 300-kilometre zone with systematic monitoring of sensitive points)
- An airspace prohibited at the time of firing with a radius of 50 kilometres; and
- Radiation protection standards applicable during the tests.[9]

The dose limits applied to the public as defined by the CCS—15 millisievert (mSv) per year—were said by the French authorities to be 'consistent with those of the ICRP [International Commission on Radiological Protection] in its publications of 1954 and 1958 and included in the circular from the State Secretariat for Public and Population Health of 3 June 1957'. In 1961, however, the annual dose limit was reduced to 5 mSv per year. France claims that the Blue Gerboise trial did not lead to any sedentary or nomadic population exceeding the 5 mSv limit:

> The following doses were estimated from the highest atmospheric activities for populations located in the following places: Arak (0.2 mSv), Amguid (0.1 mSv), Ouallen (0.6 mSv). The highest values of water radioactivity were detected immediately after the 'Blue Gerboise' test in Bordj Arak, El Golea, and In Salah. These values decreased rapidly. The food products measured showed very low levels of contamination which did not require any restriction of consumption.[10]

Today, French regulations stipulate that the general population should not be subjected to more than 1 mSv per year. Exceptionally, though, certain personnel may be subjected to dosages as high as 40 mSv per year.[11]

France reported that the Gerboise tests were carried out in an area where winds blow towards 'vast desert spaces'. The fallout zone, measured twenty-four hours after the test, was between 10 and 150 kilometres in length and between 10 and 20 kilometres wide, depending on the energy released by the relevant test and the prevailing weather conditions. The fallout area from Blue Gerboise, by some distance the most powerful, was consequently the most extensive. France, however, claimed that a few months after each test, the area where contamination was detectable was limited to a radius of between 100 and 300 metres.[12] A radioactivity monitoring network had been set up to measure external exposure and radioactivity of air, water, soil, and plants. In addition, control of the food chain was carried out in many countries in Africa and Europe.[13] France has claimed that while the atmospheric detonations were not the subject of any particular 'incident', four of the thirteen underground experiments (Beryl, Amethyst, Rubis, and Jade, in chronological order) were 'not completely' contained. The first two tests led to expulsion of radioactive lava from the underground test site tunnels and in the other two cases, releases were limited to gaseous or volatile radioelements. To this 'must be added the accident of 19 April 1962', which occurred during a pellet firing (a plutonium physics test, without the release of nuclear energy).[14]

### The IAEA assessment report

While the French official assessment outlined safety measures and provided insights into the radiological situation, questions were raised about its impartiality and hence its reliability. As a consequence, in 1999, Algeria asked the International Atomic Energy Agency (IAEA) to assess contamination at the nuclear test sites.[15] In late November and early December of that year, the IAEA organized an expert mission whose members came

9 French Ministry of Defence, 'Dossier de présentation des essais nucléaires et leur suivi au Sahara', p. 2.
10 Ibid., p. 4.
11 Ibid., p. 2.
12 Ibid., p. 4.
13 Ibid.
14 Ibid., p. 3.
15 A request based on IAEA resolution GC(42)/RES/19 (1998): 'Nuclear testing' and Resolution GC(39)/RES/23 (1995), which called 'on all States concerned to fulfil their responsibilities to ensure that sites where nuclear tests have been conducted are monitored scrupulously and to take appropriate steps to avoid adverse impacts on health, safety and the environment as a consequence of such nuclear testing'.

from France, New Zealand, Slovenia, the United States, and the IAEA itself. Together with Algerian experts, the mission travelled to the sites used by France for the test detonations. The eight-day mission conducted extensive assessments that included monitoring of dose rates resulting from residual radioactive material. Environmental samples, including sand, solidified lava, vegetation, and water from wells were collected, with analysis performed later in IAEA laboratories in Austria.

In 2000, France sent the IAEA a document detailing the location of the experiments, the techniques used, the radiological situation of the sites in 1966 and 1967, and its extrapolation of data to 1999. Five years went by. Then in 2005, on the basis of all of these data, the IAEA finally published its report.[16] The report concluded, taking into account the—generally—very low level recorded of residual artificial radioactivity, that it was unnecessary to remediate the test sites or to develop more precise mapping of contamination in order to estimate the doses likely to be received. External dose rate measurements conducted at 76 locations and analysis of 25 environmental samples indicated no annual exposures exceeding accepted international guideline values for public exposure.

The IAEA report did, however, recommend that the Algerian authorities prohibit access to the areas around the four especially polluting tests—the sites of the White and Blue Gerboise atmospheric tests at the Reggane test site and the Beryl and Amethyst tests at Taourirt Tan Afella—and to clean up the relevant zones if economic development were to occur in any of those zones. A single location, the E2 gallery at Taourirt Tan Afella, where accidental release of fission products had occurred, required the building of a security fence to exclude the public.[17]

While concern about the accuracy of the French assessments had led to the decision to seek an independent IAEA assessment, the work of the Agency too has been criticized. In particular, the role of the French member of the mission has been questioned,[18] as has the adequacy of the sampling methodologies employed.[19] In Algeria, a leading nuclear physicist, Kazem Aboudi, questioned the timing of the report's release, highlighting the delay between the collection of samples in 1999 and the publication of the report in 2005. He also criticized the IAEA's reliance on information provided by the French authorities, which might tend towards bias in the assessment process. He further criticized the report for its lack of detailed information on radiation levels and the absence of recommendations addressing the medical and environmental implications for affected populations.[20]

## Human effects

Notwithstanding the overall positive tenor of the reports by the French Ministry of Defence, as other archival documents have revealed, the Saharan nuclear detonations were neither safe nor contained.[21] General Charles Ailleret, who oversaw the nuclear testing project, had stated that 'the total absence of all signs of life' was 'essential' in choosing the sites in Algeria.[22] In fact, more than 6,000 Indigenous and nomadic people inhabited the town of Reggane, which is only less than 50 kilometres away from the first detonation site. In addition, 6,500 French personnel and 3,500 Algerian manual labourers (at least some of whom were reported to be prisoners) were close enough to be exposed to radiation, many of whom eventually suffered from cancer and other chronic diseases due to their exposure to radiation and the polluted environment.[23]

16 IAEA, 'Radiological Conditions at the Former French Nuclear Test Sites in Algeria: Preliminary Assessment and Recommendations', 2005.
17 Ibid., p. 33.
18 B. Barrillot, *Essais nucléaires français: l'héritage empoisonné*, 4th Edn, Observatoire des armements/CDRPC, 2012, 82. From 2002 to 2014, the French expert was director of the Valduc centre in the Côte d'Or region of France, whose main mission is the research, design, and manufacture of nuclear weapon components and related activities.
19 P. Bouveret, 'Quand viendra le jour où la France devra rendre des comptes?', *Damoclès*, No. 168, February 2023.
20 Interview with Kazem Aboudi, *Echorouk Daily*, 12 February 2007, available at: https://rb.gy/mf8ugr.
21 H. M. Barker *et al.*, 'Loom of the Future: Nuclear Decolonization and UW', Henry M. Jackson School of International Studies, University of Washington, Seattle, WA, 2022, at: https://bit.ly/3UzVwTN.
22 'France-Algeria Relations: The Lingering Fallout from Nuclear Tests in the Sahara', *BBC News*, 26 April 2021, at: https://bit.ly/417Djyf.
23 Centre de documentation et de recherche sur la paix et les conflits, 'Les essais nucléaires et la santé' ['The Nuclear Tests and Health'], Proceedings of the Conference on 19 January 2002 at the Senate, Lyon, Observatoire des armes nucléaires françaises (CDRPC), 2002.

In an article published in 2021, *The Economist* reported that Abdelkrim Touhami was still a teenager when, on 1 May 1962, French officials told him and his neighbours to leave their homes in the southern city of Tamanrasset. France was about to detonate 'Beryl' in the desert approximately 150 kilometres away, but the authorities had asserted that the blast would be contained underground. Things did not go as planned, however, because the underground shaft at the blast site had not been properly sealed. Among those exposed were French Minister of Defence, Pierre Messmer and Minister of Scientific Research, Gaston Palewski. A number of people from a local village were also exposed to radiation.

According to Messmer, a few seconds after the explosion, spectators saw 'a kind of gigantic blowtorch flame that started exactly horizontal in our direction. … This gigantic flame was extinguished quickly but was followed by the release of a cloud which was ochre-coloured at first, but then quickly turned black.' The ministers (and everyone else nearby) ran as radioactive particles leaked into the air. Nevertheless, in the months and years that followed, locals would go to the area to recover scrap metal from the blast for use in their homes.[24] Mr Palewski would die of leukaemia 22 years later, persuaded, Messmer says, that his cancer was caused by the accident.

The official report to the French Senate claimed that 37 people were exposed to between 100 and 200 mSv by the test while 12 had exposures to between 200 and 600 mSv. A total of 17,750 people in the vicinity were recorded as having had 'no exposure'.[25] A report by the International Physicians for the Prevention of Nuclear War (IPPNW) published in 2023, however, notes that the official dose estimates have not been independently confirmed. Furthermore, they are only *external* exposure estimates, meaning that people listed as unexposed may well have received internal doses.[26] Nevertheless, France has claimed that any person participating in the tests and likely to be exposed to ionizing radiation, whether military or civilian,

> was subject to medico-radiobiological monitoring (medical visit, blood test, dosimetry of external exposure, and possibly measurement of internal contamination by spectrometry). Dosimetry of individual external exposure was carried out from the start of the tests in a systematic manner: 24,000 people were monitored, including nearly 8,000 for the four atmospheric detonations. In this regard, it should be noted that it seems that among the other nuclear powers we do not find systematic practices of dosimetric monitoring.[27]

The error with the Beryl test had followed a serious incident in a plutonium experiment just two weeks earlier. The official report to the French Senate in 2002 explained that on 19 April 1962 a pyrotechnic charge of 10 kilograms applied to a capsule containing 25 grams of plutonium had 'exploded prematurely'. A tenth of the plutonium was dispersed into the atmosphere as a result. Ten people working less than 50 metres away were directly affected by the accident and suffered significant radiological contamination. The victims were evacuated to Percy hospital in Clamart in France. Twenty-two other people who were also affected 'benefited from a systematic assessment at Percy hospital after their return to mainland France. Except for one soldier who suffered traumatic after-effects linked to the explosion, none of these people is known to have suffered any functional after-effects'.[28] Three other underground tests were also not contained: Amethyst (30 March 1963), Rubis (30 October 1963), and Jade (30 May 1965). However, France asserts that these 'technological incidents' had 'no significant radiological impact on personnel'.[29]

24 'The long legacy of France's nuclear tests in Algeria', *The Economist*, 24 June 2021.
25 C. Bataille and H. Revol, 'Report on the environmental and health impacts of the nuclear tests performed by France between 1960 and 1996 and elements of comparison with the tests performed by the other nuclear Powers', Report INIS-FR—1395 to the French Senate, Paris, 2002.
26 IPPNW, 'The Devastating Consequences of Nuclear Testing: Effects of Nuclear weapon testing on Health and the Environment', Report, November 2023, 13.
27 Bataille and Revol, 'Report on the environmental and health impacts of the nuclear tests performed by France between 1960 and 1996 and elements of comparison with the tests performed by the other nuclear Powers', pp. 24 and 25.
28 French Ministry of Defence, 'Dossier de présentation des essais nucléaires et leur suivi au Sahara', p. 3.
29 Ibid.

In 2011, Mr Touhami founded Taourirt, a civil society organization dedicated to identifying the location of nuclear waste left by France. The location of many contaminated materials buried by the French in the desert has not been made public. Even known test sites are said to have been poorly secured, including by the Algerian government. In 2010, the French parliament passed the Morin Law (the legislation discussed further below), which is meant to compensate those with health problems resulting from exposure to the nuclear tests. But the law only pertains to certain illnesses (23 cancers) and requires claimants to show they were living near the tests when they took place. This is difficult enough for Algerians who worked for the French armed forces – few had formal contracts. It is almost impossible for anyone else, as they lack the required documentation.

### The impact on Indigenous populations

A sedentary population of around 40,000 people at the time of the tests lived in the palm groves of Reggane, and the Touat valley north of the town. Before each test, fallout modelling was conducted based on meteorological forecasts. According to the French Ministry of Defence, 'The results of this modelling made it possible to ensure that the radioactive cloud formed following the tests would be heading towards an uninhabited area. These conditions made it possible to trigger the test.'[30]

The nomadic populations of Kel Torha (240 people) may have been highly exposed to the fallout from the Beryl test.[31] There are testimonies to this effect from the local population, but no health data are available. The case of the village of Mertoutek, forty-seven kilometres east of Tan Afella, which was under the Beryl fallout path, also raises many questions. In 1992, a European parliamentarian conducted a series of interviews with Touaregs from the Hoggar who reported that they had been unable to have children, and that their wives had suffered repeated miscarriages. According to these testimonies, 'all these families died'.[32] New testimonies (recorded in 2013) report the deaths of seventeen people.[33] The case of this village requires an effective, official investigation by Algerian health authorities.

But in addition to the direct impact on Algerians close to the detonations, Algerian scholars have claimed inhumane treatment of Algerians as human subjects during the third atmospheric explosion, 'Red Gerboa'. It is said that 150 Algerian prisoners from Sidi Bel Abbès prison were tethered to poles near the explosion site to study human behaviour in the aftermath of a nuclear blast.[34] If the reports are true (they have been firmly denied by French officials), it is not known whether they were killed in the explosion, subjected to radiation, or indeed what ultimately happened to them.

French atmospheric nuclear tests (notably Gerboise bleu) certainly affected neighbouring States. Although the facts remain difficult to establish, evidence indicates that the population in the Fezzan region of Libya suffered significant increases in the rates of cancer following the 1960 tests. According to the investigations carried out with local people and officials, thousands of people in Libya continue to suffer consequences from the French nuclear tests.[35]

30 Ibid., p. 1.

31 C. Bataille et H. Revol, *Les incidences environnementales* des essais nucléaires effectués par la France entre 1960 et 1996 et les éléments de comparaison avec les essais des autres puissances nucléaires, Office parlementaire d'évaluation des choix scientifiques et technologiques, 2002, at: https://bit.ly/49ehak2, p. 32.

32 S. Fernex, 'Essais nucléaires en Algérie, recueil de témoignages', Les Verts au Parlement Européen, Brussels, 1992.

33 E. Leuvrey and B. Hadjih, 'AT(h)ome', documentary, Les Écrans du large, 2013, at: https://bit.ly/3vomN1i.

34 See M. Khiati, Les Irradiés Algériens: un Crime d'État, ANEP Éditions, Algiers 2018; Mansouri, 'French nuclear explosions in the Algerian desert: A heavy colonial legacy'; A. Bedjaoui, *Cinema and the Algerian War of Independence: Culture, Politics, and Society,* Palgrave Macmillan, 2020. See also a documented interview of a former German legionnaire who recounted the story of the prisoners in Karl Gass' film, *Allons enfants de l'Algérie* (1961) and also in Azzedine Meddour's archival film *Combien je vous aime* (1985).

35 S. Elsaidi, 'The day the desert wind cried: French nuclear tests cast long shadow in Libyan Sahara', Middle East Eye, 29 January 2023, at: https://bit.ly/3uLLcgR.

### The impact on military personnel

'We were guinea pigs who have had no proper medical support', Michel Verger, the president of the French nuclear veterans organization Aven,[36] told *The Guardian* newspaper in 2008. Drafted to fight in the war in Algeria when he was 20 years of age, Verger took part in the first test in 1960. 'I was wearing shorts', he said. 'We were made to lie face down on the ground, eyes closed and arms folded and not watch the flash, but immediately afterwards we had to get up with an apparatus round our necks and measure and photograph the impact. I had no sunglasses. There was one pair between 40 [soldiers].'[37]

The 'Beryl incident' on 1 May 1962, however, stands out as the nuclear test in Algeria with the most serious humanitarian effects. In 2008, Aven conducted a survey among nuclear test veterans. The survey concluded that 35 per cent of those polled had suffered one or more types of cancer, and that nearly one in five was infertile. Blood cancer and cardiovascular problems were common among nuclear project veterans and their children and grandchildren were facing similar health issues.[38] To this day, however, no detailed epidemiological studies on the health effects of the nuclear tests at Reggane on soldiers have been conducted.

In 2010, *The Guardian* reported on a leaked French defence report dating back to April 1961 which revealed that soldiers stationed in Algeria in 1961 had been subjected to 'tactical experiments' carried out to 'study the physiological and psychological effects of atomic weapons on man'. After the report's release, France's Minister of Defence Hervé Morin confirmed that about one hundred soldiers had been involved in exercises (Red and Green Gerboa), which aimed to test the effects of fallout on human beings. But, he declared, the time had come 'to stop analysing historic events from the standpoint of 2010'. It was 'another era', he said.[39]

### Transgenerational human effects

The communities living near the former test sites continue to bear the brunt of the long-term health consequences of radiation exposure. High rates of congenital anomalies, cancers, and other chronic illnesses persist, perpetuating a cycle of suffering and adversity among the population.[40] The damage the nuclear detonations inflicted on people and the environment remains a source of deep resentment, seen as proof of discriminatory colonial attitudes and disregard for the value of local lives. 'Diseases related to radioactivity are passed on as an inheritance, generation after generation', according to Abderahmane Toumi, head of the Algerian victim support group, El Gheith El Kadem. 'As long as the region is polluted, the danger will persist', he said, citing severe health impacts from congenital anomalies and cancers to miscarriages and sterility.[41]

The IAEA noted in 2005 that in relation to cancers in Algeria,

> it is the likelihood, rather than the severity of the disease, that is increased by radiation exposure. For most organs, the likelihood or risk increases linearly with increasing radiation dose and is often assumed not to have a threshold. In addition, experimental studies in animals and plants have shown hereditary effects from radiation. Although hereditary effects have not been observed in humans, it is considered prudent for the purposes of setting standards to assume that they do occur. These

36 An acronym for, in the English translation, The Association of Nuclear Test Veterans.
37 A. Chrisafis, 'France finally agrees to pay damages to nuclear test victims', *The Guardian*, 27 November 2008, at: https://bit.ly/49GCShl.
38 Atomic Heritage Foundation, 'History: French Nuclear Program', 14 February 2017, at: https://bit.ly/49kVHqH.
39 L. Davies, 'French soldiers "deliberately exposed to radiation" during nuclear tests', *The Guardian*, 16 February 2010, at: https://bit.ly/49upSvG.
40 'Les essais nucléaires et la santé', CDRPC, 2002.
41 Agence France-Presse, 'France's 1960s nuclear tests in Algeria still poison ties, Algiers', *France 24*, 29 July 2021, at: https://bit.ly/3USu0kr.

> radiation induced malignancies and hereditary effects are termed stochastic effects because of their probabilistic nature. The induction of stochastic effects is assumed to take place over the entire range of doses, without a threshold level. Under certain conditions, primarily of relatively high doses and/or large numbers of people exposed, stochastic effects may be epidemiologically detectable in the exposed population as an increase in their incidence.[42]

In 2023, SHOAA for Human Rights, an independent non-governmental organization (NGO) based in London and which advocates for human rights in Algeria, declared that:

> Despite more than 60 years having passed since the French nuclear tests in Algeria, France still evades responsibility and insists on keeping the nuclear test files highly classified. This is despite numerous efforts by concerned parties to at least identify nuclear waste burial sites in order to take necessary measures to protect the environment and the population as a precautionary step, due to fears of radiation exposure in areas where various types of cancer cases have increased, along with incidents of abnormal births and congenital deformities recorded in those areas and other disturbing health phenomena.[43]

## Societal effects and displacement

Local testimonies highlight the inadequate precautions that had been taken to protect people. In the context of the first explosion, local people were instructed to evacuate their homes and seek cover using only blankets, while French experts and dignitaries present at the site were provided with special black glasses.[44] Additionally, accounts from manual labourers at the Reggane test site describe instances of arbitrary arrest, deportation to Reggane, and forced labour in hazardous conditions without appropriate equipment or training.[45]

The IAEA reported in 2005 that vegetation in the affected areas 'is sufficiently sparse for animals led to graze by nomadic herders to be almost constantly on the move, with at most a few days in one area. Livestock movements are also dictated by distances to available water sources, and animals would not normally be able to stay in the … area for more than a day or two. Grazing animals could ingest residual radionuclides incorporated in plants through root uptake or deposited on plants as dust.' Visual inspection in 1999 suggested that 'deposited dust would dominate intakes and the concentrations in the dust would reflect the surrounding surface soil concentrations. Radionuclides ingested by grazing animals and transferred to meat or milk could contribute to radiation exposures of herders and their families.'[46]

### Nuclear colonialism in Algeria

The French nuclear detonations between 1960 and 1966 in the Sahara had severe and persistent impacts for the local population, badly damaging their lives and wellbeing and causing long-term environmental contamination.[47] The Algerian experience reveals a convergence of colonial ambitions and geopolitical

42 IAEA, 'Radiological Conditions at the Former French Nuclear Test Sites in Algeria: Preliminary Assessment and Recommendations', p. 55.
43 SHOAA, 'The French nuclear tests in Algeria: An open letter on the occasion of the International Day against Nuclear Tests', Press Release, London, 29 August 2023, at: https://bit.ly/49JoqoF.
44 C. Chanton, *Les Vétérans des Essais Nucléaires Français au Sahara: 1960-1966*, L'Harmattan, Paris, 2006.
45 See the testimonies documented in publications of the Algerian National Center for Studies and Research in the National Movement and the Revolution, CNERMNR, 2000, at: https://bit.ly/49yCmSA.
46 IAEA, 'Radiological Conditions at the Former French Nuclear Test Sites in Algeria: Preliminary Assessment and Recommendations', p. 31.
47 Centre National d'Études et de Recherches sur le Mouvement National et la Révolution du 1er novembre 1954 (CNERMNR), *Les Essais Nucléaire Français en Algérie : Études, Recherches & témoignages* ('French Nuclear Tests in Algeria: Studies, Research & Testimonies'), Algiers, 2000.

pursuits. The Evian Accords that recognized Algerian independence in 1962[48] marred the post-independence period by granting France continued access to Algeria's Saharan military and nuclear bases.[49] Eager to join the 'atomic club' alongside global powers the United States, the Soviet Union, and the United Kingdom, France's nuclear activities in the Sahara mirrored a complex interplay between colonial ambitions and geopolitical advancements.[50]

The enduring consequences of French nuclear imperialism manifested in the insidious 'slow violence' inflicted upon the Sahara desert.[51] This reality was starkly illustrated by the actions of French colonial authorities in 1966, as they disposed of contaminated equipment and materials from the nuclear test sites by simply burying them in the sand.[52] France's nuclear testing in the Sahara is also said to have intersected with 'the advent of multilateral science diplomacy'.[53] Using technical arguments to override opposition to the testing both domestically and internationally, French officials, including Ministers of the Armed Forces Pierre Guillaumat and Jules Moch, emphasized safety while downplaying potential risks.[54]

But they were not ultimately successful. The transnational anti-nuclear movement, born during the Cold War, directly linked the threat of nuclear war and testing with the African struggle for independence. African leaders at the Monrovia Conference in 1959 denounced the decision by France to use Algerian land for nuclear testing.[55] The 'Sahara Protest Team' emerged to pressure France into abandoning nuclear testing. Comprising members from the United States, the United Kingdom, France, Ghana, Nigeria, and Basutoland (Lesotho), the team garnered support from Ghana's ruling party, the Convention People's Party. Ghana supported the team's journey to challenge nuclear imperialism in the Algerian Sahara.[56] The team aimed to occupy the test site in

Reggane, starting a 2,100-mile journey from Accra on 6 December 1959. Despite gaining media attention and public support, their efforts were thwarted by the French army in Burkina Faso, then a French colony, forcing them to withdraw. Attempts were made twice more, but threats of deportation, equipment confiscation, and surveillance by the French led to the protesters abandoning the project.[57]

48 The Accords were a key stage in the path to achieving Algeria's independence in 1962, agreed between the French government and the Algerian Front de Libération Nationale's (FLN) after a long and difficult negotiation process. While the accords focused primarily on the political and territorial aspects of the Algerian conflict, specific provisions regarding nuclear testing were not explicitly mentioned. The Accords granted France a five-year lease to maintain military and nuclear testing bases in the Sahara region. However, the lack of explicit reference to nuclear testing in the Accords left room for interpretation and subsequent challenges by Algerian leaders. Although the French military officially left their base in 1967, a secret annex in the Evian Accords allowed the French army to remain at the B2-Namous military site in the northern Sahara, near the town of Beni-Wenif to carry out chemical weapons tests until 1978. See V. Jauvert, 'Quand la France testait des armes chimiques en Algérie', Le Nouvel Observateur, No. 1720, 29 October 1997.

49 Kazem Aboudi, an Algerian professor of nuclear physics, uses the term 'nuclear crimes', at the least to describe what occurred in Algeria. His work in Arabic is entitled يرابيع رقان وجرائم فرنسا النووية ['Reggane's jerboas and French Nuclear Crimes']. See also Algérie Presse Service, 'Explosions nucléaires françaises au Sud algérien : des crimes contre l'humanité imprescriptibles', 12 Février 2024, at: https://bit.ly/48u2FIC.

50 R. Panchasi, 'An Atomic 'Adventure' in Empire: Algeria, April 1961', Jadaliyya, 2022, at: https://bit.ly/3SSspcZ.

51 J. -M. Collin and A. R. Cooper, 'Africa and the Atomic Bomb: Part II: The Sahara holds nuclear secrets', Inkstick Media, 3 June 2021, at: https://bit.ly/3UxlJlU.

52 J.-M. Collin and P. Bouveret, 'Radioactivity Under the Sand: The Waste From French Nuclear Tests in Algeria – Analysis with Regard to the Treaty on the Prohibition of Nuclear Weapons', e-Paper, Heinrich Böll Foundation, 2020, at: https://bit.ly/48dS9F9.

53 L. Tiglay, 'Nuclear Policy in the Age of Decolonization: French Nuclear Tests in the Sahara, African Peace Mobilization, and the Advent of the Global Nuclear Order 1957–1967', Dissertation Summary, Ohio University, United States, accessed 10 February 2024 at: https://bit.ly/3UFpWUK.

54 A. R. Cooper, 'Saharan Fallout: French Explosions in Algeria and the Politics of Nuclear Risk during African Decolonization (1960–66)', PhD thesis, University of Pennsylvania, 2022; and C. Mayoux, 'Le soutien britannique aux essais français pendant la décolonisation africaine (1959-1960) : un paradoxe', Relations internationales, Vol. 194, No. 2 (2023), 27–47, at : https://bit.ly/3wgubMg.

55 J. Allman, 'Nuclear Imperialism and the Pan-African Struggle for Peace and Freedom: Ghana, 1959–1962', *Souls*, Vol. 10, No. 2 (2008), 102–83.

56 D. Tawfik, 'The Impact of Anti-Nuclear Global South Movements on the Control of Nuclear Weapons', Paradigm Shift, 2022, at: https://bit.ly/3OJ05HE.

57 N. Liu, 'International Team Campaigns against Nuclear Testing in Africa (Sahara Protest) 1959–1960', The Global Nonviolent Action Database, 2011, at: https://bit.ly/49C3nVf.

### Post-independence realities: negotiating the legacy of nuclear colonialism

Even after Algeria's independence, the legacy of nuclear colonialism persisted. The Evian Accords had marked a 'nuclear compromise' insofar as they granted France a five-year lease for its Saharan military and nuclear testing bases. Algerian leaders argued for a reinterpretation of the accords in light of the political circumstances of the time, emphasizing that the concessions they had made were temporary or circumstantial. The complex interplay between territorial concerns, nuclear testing, and the negotiations surrounding the Evian Accords shaped the post-colonial landscape of Algeria, reflecting the delicate balance between political aspirations, health, and environmental considerations in the aftermath of decolonization.

Given the violence of the struggle for decolonization, Algeria remains a sensitive subject in French discourse.[58] Today, the harmful remnants of France's nuclear infrastructure persist, either 'buried' beneath the Saharan sands or 'freely circulating' above.[59] The Algerian government has still to receive all of the available information on France's test sites. The scope of the initiative by President Macron on 9 March 2021 to declassify so-called '*secret-défense*' archives[60] covers only documents relating to the Algerian war and excludes documents related to nuclear testing. Without this information, there is little hope for successful decontamination. The colonial aspect of French nuclear testing contaminates also the political dynamics precluding the acknowledgment of—and redress for—historical injustices.

## Victim assistance

The needs for victim assistance today among affected Algerians and French military personnel and their children and grandchildren have not been quantified. While some studies of the impact of the nuclear tests and trials have been conducted, none has concluded with a clear exposition of victim assistance needs. In 2008, a report was submitted to the French Parliament on behalf of the Committee on Cultural, Family and Social Affairs on the Draft Law (No. 1258) on the recognition and compensation of victims of tests or nuclear accidents.[61] It noted that several thousand people are potentially affected by the health consequences of nuclear tests and accidents, which are still poorly assessed. It goes on to say that studies on the health impacts of nuclear tests and accidents are often late, sometimes contradictory, and based on questionable data.

The study further notes that a body of objective evidence tends to corroborate the hypothesis of a causal link between the tests and radiation-induced pathologies, even at low doses. It points to AVEN's health study based on some 1,500 responses from its members to a questionnaire. Of these, 90 per cent of veterans reported illness and one third reported suffering from at least one and up to three different cancers. The annual incidence of cancer in France is only 17 per cent for men under 65. The precocity of the development of the disease is also noteworthy: 76.4 per cent of cancer patients report having been affected before the age of 60.[62]

As far as blood cancers are concerned, the proportion of lymphomas (38 cases) and myeloma (12 cases) is 25 times the rate of the French population. Other pathologies also have a particular impact: cardiovascular diseases (15.3 per cent of patients), digestive diseases (13.9 per cent) and muscle and bone diseases (9.3 per

58 A. R. Cooper, 'A new window into France's nuclear history', *Bulletin of the Atomic Scientists*, 16 September 2022, at: https://bit.ly/49zA2ui.

59 S. Henni, 'Nuclear Powers: France's Atomic Bomb Tests in the Algerian Sahara', *The Architectural Review*, 23 June 2022, at: https://bit.ly/3SVARbl.

60 Communiqué de presse de la présidence de la République, 'Le Président a entendu les demandes de la communauté universitaire pour que soit facilité l'accès aux archives classifiées de plus de cinquante ans', 9 March 2021, at: https://bit.ly/4ctaD7W.

61 Rapport fait au Nom de la Commission des Affaires Culturelles, Familiales et Sociales sur la Proposition de Loi (N° 1258) de Mme Christiane Taubira relative à la reconnaissance et à l'indemnisation des victimes des essais ou accidents nucléaires, Registered at the Office of the President of the National Assembly on 19 November 2008.

62 Ibid., p. 16.

cent). While the French authorities did not deem it necessary to monitor the health status of the descendants of the nuclear test veterans, AVEN also notes the high incidence of hereditary diseases among the children of veterans. A total of 209 people declared one or more miscarriages by their partners, while 306 did not have children (a situation that one quarter of these respondents attributed to a sperm abnormality). At least 14 per cent of children born after the tests (335 out of 2,391) suffer from congenital anomalies while 15.9 per cent (382) suffer from pathologies such as allergies, sterility, and epilepsy.[63]

While assessment of the needs for and provision of victim assistance in France has primarily focused on French military personnel and their families, the situation in Algeria lacks comprehensive official evaluation. Independent studies by scholars and organizations have, though, sought to evaluate the impact and needs of affected communities. For instance, Professor Aboudi's research team (students from Reggane in Oran University's Department of Biochemistry) conducted extensive studies in the town of Reggane between 1990 and 2005, analysing more than 1,000 samples and identifying elevated rates of disease and other health disorders among populations residing near test sites. These included increasing incidence of blood and lung cancer, decline and spacing of births, lower rates of fertility, early miscarriages, congenital deformities, and skin and eye diseases. Data analysis revealed a disturbingly high incidence of cancer among youth as well as disturbances in enzyme activity and changes in blood characteristics.[64]

In post-independence Algeria, the provision of care for cancer patients became a public health challenge – one that was only really addressed from 1975 onwards. In terms of infrastructure, the main facility for cancer treatment was the Pierre et Marie Curie Cancer Centre in Algiers (CPMC). Until the early 2000s, there were only four Anti-Cancer Centres (ACCs) in Algeria—in Algiers, Blida, Constantine, and Oran—although university departments of the various medical and surgical specialties took care of cancer patients within their specialties. The National Anti-Cancer Plan, endowed for the period between 2015 and 2019 with 185 billion dinars (about €1.6 billion at the time) was under the supervision of the Presidency of Algeria.[65] Noting the absence of a specialized cancer care facility in Reggane,[66] the study called for the urgent establishment of a multidisciplinary research centre to address the long-term health consequences of nuclear testing in Algeria.

Further complicating victim assistance, as Collin and Bouveret have recalled:

> It is extremely difficult to make an assessment of the health of local people. At that time, there was no monitoring of these people's health nor were there any medical studies listing the number of cases of cancer (that were possibly due to the nuclear tests). Added to this is the low number of files on Algerian residents submitted to CIVEN [France's Committee for compensation of victims of nuclear testing; see below]. However, as various investigations by journalists have shown … the radioactive cloud created by the Beryl accident reached the village of Mertoutek (some 60 kilometres away), where many people (17) died suddenly following this incident. The residents of this village are still suffering from the presence of radioactivity.[67]

There is no information on any ongoing or planned victim assistance efforts beyond what has been achieved as a result of the Morin Law. An apparent change of attitude from the Algerian government may, though, herald

63 Ibid.

64 K. Aboudi, 'التأثيرات اللاحقة للتجارب النووية الفرنسية في الصحراء الجزائرية (1960-1966) في المجالين البيئي والصحي' ['The Post-Effects of French Nuclear Tests in the Algerian Desert (1960–1966) on Environmental and Health Fields']; and إستعمال الأسلحة المحرمة دوليا طيلة العهد الإستعماري الفرنسي في الجزائر: الأسلحة النووية نموذجا ['The Use of Internationally Prohibited Weapons During the French Colonial Era in Algeria: Nuclear Weapons as a Model'], Centre National d'Etudes et de Recherches sur le Mouvement National et la Révolution du 1er Novembre 1954 (CNERMNR), 2007, 69-89.

65 A. Bounedjar, M. A. Melzi, H. Idir, and N. Heba, 'General Oncology Care in Algeria', Chap. 2 in H. O. Al-Shamsi, I. H. Abu-Gheida, F. Iqbal, and A. Al-Awadhi (eds.), *Cancer Care in the Arab World*, Springer, 2022, 15–29, at: https://bit.ly/3T8dJXc, 17–18.

66 Interview with Kazem Aboudi, *Echorouk Daily*, 12 February 2007.

67 Collin and Bouveret, 'The Waste From French Nuclear Tests in Algeria', p. 38.

future progress. Until now, the government has maintained that the question of compensation for victims should be settled between the complainants and France. But in late 2022, the Algerian President announced a new position, calling on France also 'to take charge of the medical care needed by the people on site'.[68] This change in stance may renew the pressure on France to support the victims. Algerian media reported in February 2024, based on information from the government, that inhabitants of the regions where testing took place are still suffering from the consequences, with new cases of cancer, congenital malformations, disability, sterility, and chronic psychological disorders being recorded every year.[69] The June 2025 report by the French Parliament, L'Assemblée nationale, on French nuclear testing,[70] focused on French Polynesia, with little time and space given to the situation in Algeria.

## Environmental contamination

The first test, Blue Gerboa, is said to have resulted in nuclear fallout from the bomb being detected as far away as Burkina Faso, Côte d'Ivoire, Libya, Senegal, and Sudan and even in parts of Western Europe. Water in Arak, a village close to Tamanrasset, a city in southern Algeria, was heavily contaminated, as was the Chadian capital of N'Djamena.[71] An official map unearthed in 2014 by *Le Parisien*, a French newspaper, even showed fallout from the test reaching western Sicily and southern Spain thirteen days after the detonation.[72] Air concentrations of radioactivity were detected as far away as Sweden.[73] In 2025, sixty-five years after the 70 kt detonation, SHOAA for Human Rights, in a joint statement with 29 other NGOs, described the bomb as 'a devastating humanitarian and environmental catastrophe' whose consequences 'continue to cast a long shadow over present and future generations.' They emphasized 'the urgent need for both the French and Algerian governments to take concrete steps to close this painful chapter in history and work jointly to guarantee the rights of victims and protect future generations from similar threats.'[74]

Following the four atmospheric tests in the Reggane region, in 1961 the French authorities decided to conduct underground tests at In Ekker, 700 kilometres away in the Hoggar mountain range. But even some of the underground tests caused pollution, as this chapter has described.[75] In total, the French tests in Algeria resulted in the contamination of hundreds of thousands of square kilometres of land in the Algerian Sahara and beyond.[76] The declassified military documents reported by *Le Parisien* revealed the extent of radioactive fallout from these tests across Africa and the Mediterranean (see Figure 2 opposite).

68 Y. Thréard, 'Abdelmadjid Tebboune : Il est urgent d'ouvrir une nouvelle ère des relations franco-algériennes', *Le Figaro*, 29 December 2022.

69 Algérie Presse Service, 'Explosions nucléaires françaises au Sud algérien : des crimes contre l'humanité imprescriptibles', 12 February 2024, at: https://bit.ly/48u2FIC.

70 Commission d'enquête relative à la politique française d'expérimentation nucléaire, à l'ensemble des conséquences de l'installation et des opérations du Centre d'expérimentation du Pacifique en Polynésie française, à la reconnaissance, à la prise en charge et à l'indemnisation des victimes des essais nucléaires français, ainsi qu'à la reconnaissance des dommages environnementaux et à leur réparation, Report, Vol. 1, Assemblée Nationale, Paris, June 2025, at: https://bit.ly/3Ub5IRk.

71 Monitoring at N'Djamena (known at that time as Fort Lamy), which is around 2,400 km from Reggane, reported 10−9 Ci/m3. 'France-Algeria relations: The lingering fallout from the first nuclear tests in the Sahara', Time Note, undated but accessed 1 August 2025, at: https://bit.ly/4l1mltr.

72 See 'Le document choc sur la bombe A en Algérie, *Le Parisien*', Hoggar, 14 February 2014 (Updated 15 October 2017), at: https://bit.ly/417BQct.

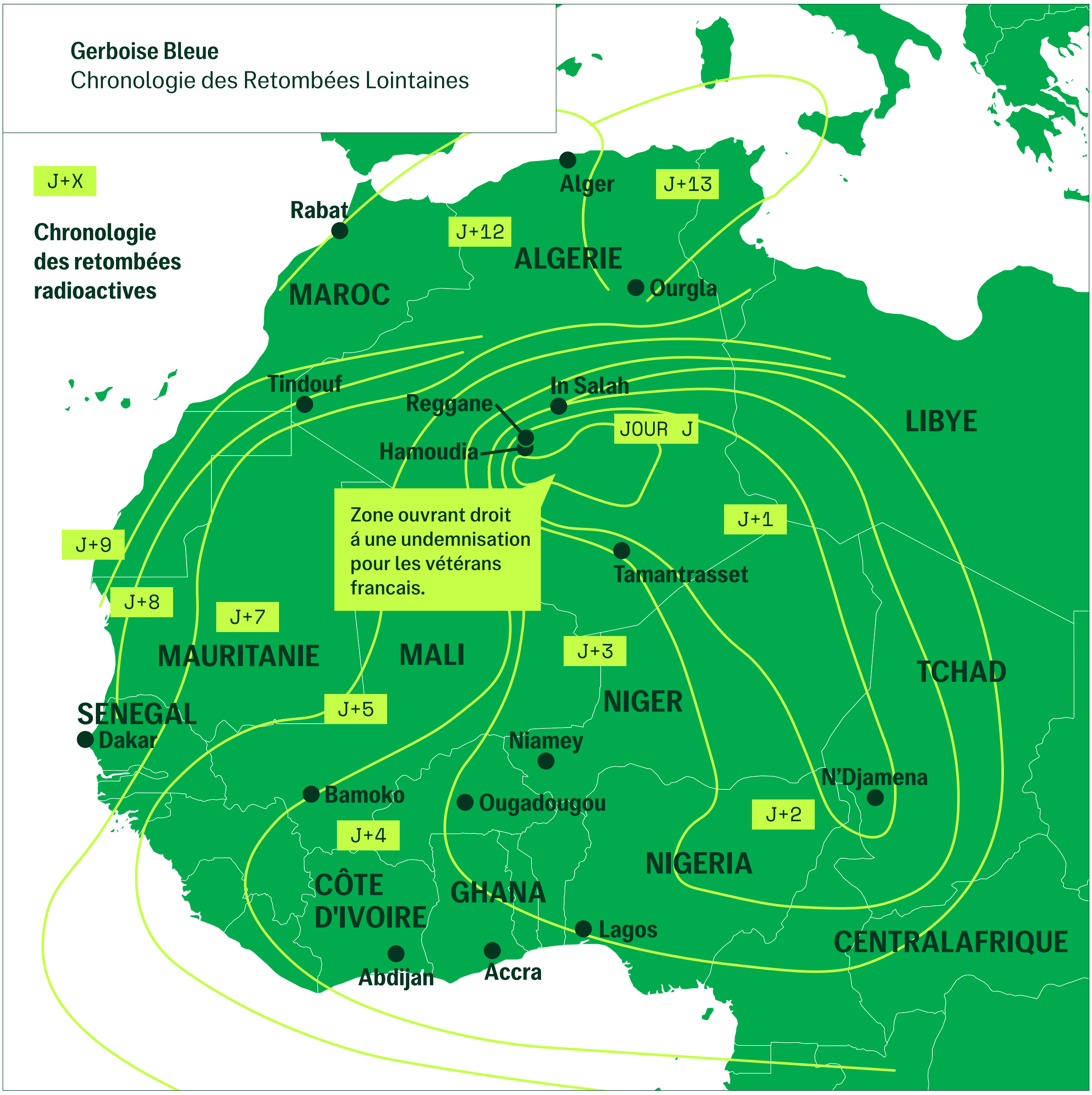
73 G. Lindblom, 'Advection over Sweden of Radioactive Dust from the First French nuclear Test Explosion', *Tellus,* Vol. 13, No. 1 (15 November 1960), 106–12.

74 Joint Statement by 30 Organizations on the 65th Anniversary of the First French Nuclear Explosion in Algeria: A Global Call for Accountability and Justice, Press release, 13 February 2025, at: https://bit.ly/4oiKG0C.

75 'France-Algeria relations: The lingering fallout from nuclear tests in the Sahara', *BBC,* 27 April 2021, at: https://bit.ly/3wtWaYJ.

76 S. Henni, 'Nuclear Powers: France's Atomic Bomb Tests in the Algerian Sahara', *The Architectural Review*, 23 June 2022, at: https://bit.ly/3SVARbl.

Figure 2: Regional Fallout from the French Nuclear Tests in Algeria[77]




In a 2014 article entitled 'French Nuclear Tests: When Will There Be Real Transparency?', Barrillot denounced France's ambiguity toward its nuclear testing and the radioactive consequences in the Algerian Sahara and on the lives of the Algerian people. He asks: 'Is it not time now for complete transparency and for the French government to begin negotiations with the Algerian government on this painful page of the history of French-Algerian relations in order to agree on concrete actions of "rehabilitation" and "reparation"?'[78]

In the decades after the nuclear testing in the Sahara, the enduring legacy of radioactive contamination has continued to raise environmental concerns. In 2021, in order to map the radioactivity present in the Hammoudia areas, a team of Algerian researchers used satellite imagery to find that '421,679 entities of fragments' of yellow

77 Based on map reproduced in Elsaidi, 'The day the desert wind cried: French nuclear tests cast long shadow in Libyan Sahara'.
78 Cited in S. Henni, 'Jerboasite: Naming French Radioactive Matter in the Sahara', e-flux Architecture, December 2022, at: https://bit.ly/3uQ3UUw.

and black sands are present over an area equal to 4,814 square kilometres.[79] According to Algeria's National Ministry of Defence, 'the contamination is in the fused sand. In the case of typical samples from Reggane, the activity concentrations are about 1 MBq per kilogram of sand for the Plutonium and up to 0.1 MBq per kilogram of sand for the Cesium-137'. The same method applied to the Tan Afella site, calculating that the total surface area of radioactive lava, mostly from the failed Beryl test, is 5.65 square kilometres.[80]

In February 2021 and March 2022, for instance, Saharan dust carried northward by seasonal winds polluted France and other European countries with radioactivity.[81] Similar instances have continued to occur on a regular basis since then.[82] ACRO's observations highlight the persistent presence of radioactive particles in the Sahara Desert. Notably, a 'boomerang effect' was detected, wherein Saharan dust storms transported fine radioactive particles over Europe, resulting in detectable levels of caesium-137 in areas such as the Jura region in Eastern France.[83] These realities serve as a reminder of the enduring radioactivity in the Sahara and its potential transboundary environmental implications.[84]

## Environmental remediation

The French Ministry of Defence reported that the CSEM and CEMO sites were returned to the Algerian authorities in 1967, after dismantling of the technical installations and cleaning and sealing of the galleries.[85] But from the outset, France's approach to the nuclear tests in Algeria was to bury all radioactive waste in the desert sands. France has never revealed exactly where this waste was buried, nor how much of it there was. A 1997 report from the French parliamentary office for evaluating scientific and technological options [Office parlementaire d'évaluation des choix scientifiques et technologiques] stated: 'There is no precise data on the issue of waste materials which could have resulted from the series of experiments conducted in the Sahara.'[86]

In 2021, Tayeb Zitouni, the former Minister of Veterans Affairs of Algeria, accused France of 'refusing to hand over topographical maps that make it possible to determine the burial sites of polluting, radioactive or chemical waste not discovered to date'. France, he said, has not carried out any technical initiative to clean up the sites and France has not taken any humanitarian action to compensate the victims.[87] Some of the buried nuclear waste is of particular concern. This is the case of the 12 steel tanks (part of the Operation Augias experiments) where complementary, subcritical experiments were carried out with plutonium pellets of up to 25 grams. These tanks are thought to be still buried under the sands of the Sahara.[88]

There are no ongoing environmental remediation efforts by France. According to an interview given by Algerian General Bouzid Boufrioua, military engineering units in the Reggane and In Ekker regions carried out missions

79 M. Naili, D. Telaidja, F. Eddadaoudi et L. Bouchama, 'Les risques sanitaires des mutations environnementales en Algérie d'un territoire vierge à un territoire violé radioactivement', *Revue Espace, Territoires, Sociétés et Santé,* Vol. 4, No. 7 (July 2021), 55–68.

80 L. M. Simohamed, 'Country presentation: ALGERIA', Technical Meeting for the International Working Forum on Regulatory Supervision of Legacy Sites, IAEA, Vienna, 17–21 October 2011.

81 R. Cereceda, 'Irony as Saharan dust returns radiation from French nuclear tests in the 1960s', *Euronews*, 1 March 2021, at: https://bit.ly/3SXncQ0.

82 See, e.g., Y. Xu-Yang et al., 'Radioactive contamination transported to Western Europe with Saharan dust', *Science Advances*, Vol. 11, No. 5 (31 January 2025), at: https://bit.ly/4ml3CEO.

83 ACRO, 'Nuage de sable du Sahara: une pollution radioactive qui revient comme un boomerang' ['Cloud of sand: Radioactive pollution returns like a boomerang'], Press release, 2021, at: https://bit.ly/43m8lnb.

84 IPPNW, 'The Devastating Consequences of Nuclear Testing: Effects of Nuclear weapon testing on Health and the Environment', 14.

85 French Ministry of Defence, 'Dossier de présentation des essais nucléaires et leur suivi au Sahara', Délégation à l'Information et à la Communication de la Défense, January 2007.

86 Collin and Bouveret, 'The Waste From French Nuclear Tests in Algeria', p. 5.

87 GEO with Agence France-Presse, 'Nuclear tests in Algeria: France called upon to "assume its historic responsibilities"', 28 July 2021 (updated 2 November 2021), at: https://bit.ly/49oiBxn.

88 Collin and Bouveret, 'The Waste From French Nuclear Tests in Algeria', p. 20.

to 'secure and protect areas polluted by nuclear testing'.[89] In particular, they demarcated sites and provided medical assistance to the local population. Similarly, although the Algerian authorities do not have precise information on all the nuclear waste burial zones, they do have knowledge of certain sites. In 2021, Algeria's People's National Army Chief of Staff, Lieutenant General Saïd Chanegriha, asked the French Army Chief of Staff in a meeting for 'assistance in providing topographical maps enabling the location of the burial zones, which have not yet been discovered'.[90]

In 2021, the Prime Minister of Algeria, Abdelaziz Djerad, signed a decree on the establishment of a national authority to remediate former French nuclear test sites. This was, according to officials, an important step towards Algeria's ratification of the Treaty on the Prohibition of Nuclear Weapons (TPNW). There has, however, been no information since then on the activity of the Agency or the implementation of a programme of action.

## The impact of climate change[91]

High-level climate profiles covering Algeria suggest little change in precipitation for the area, but high temperatures and increased drought intensity. Previous preliminary assessments by the IAEA reported dry stream beds near the Adrar Tikertine site at In Ekker, indicating intermittent torrential rain, with local people confirming occasional flooding.[92] A summary of trends and potential climate-related impacts is given in Table 1.

**Table 1:** **Summary of key climate trends and impacts, Reggane and In Ekker, Algeria** [93, 94, 95]

<table>
<tr><th>Climate system/ hazard</th><th>Historic trends</th><th>Projected trends</th><th>Possible impact on risk components</th></tr>
<tr><td>Temperature</td><td>Significant increases</td><td>Temperature increases, with larger increases during the hottest monthst</td><td rowspan="3">Source: changes in physico-chemical behaviour affecting mechanisms by which contaminants may be released. Includes physical landforms changes caused by soil desiccation, erosion, and high winds.<br><br>Pathway: changes to release of airborne contaminants.<br><br>Receptor: changes in species assemblages and/or sensitivity to contaminants, and exposure routes for people.</td></tr>
<tr><td>Precipitation</td><td>Not given</td><td>Little change*</td></tr>
<tr><td>Drought</td><td>Not given</td><td>Increasing evaporation rates, with drought intensity and duration expected to increase</td></tr>
</table>

* Projections uncertain

## Legal issues

As discussed above, in 2010, the French parliament passed the Morin Law on the recognition and compensation of victims of French nuclear testing which should, in theory, compensate victims of nuclear radiation in Algeria. To

89 'Entretien avec le général Bouzid Bouffira, chef de division du génie de combat au CFT', *El Djeich* (Monthly review published by the Algerian army), No. 691, February 2021.
90 'Monsieur le général de corps d'armée, Saïd Chanegriha, reçoit le chef d'état-major des armées françaises', *El Djeich*, No. 694, May 2021.
91 This section of the chapter was contributed by Linsey Cottrell.
92 IAEA, 'Radiological Conditions at the Former French Nuclear Test Sites in Algeria'.
93 WHO/UNFCCC, Climate and health country profile – 2015, Algeria, at: https://bit.ly/48NFDfX.
94 Met Office, ODI 'Climate risk report for the Middle East and North Africa (MENA) region', 2021, at: https://bit.ly/4cbgaA6.
95 ThinkHazard! High-level hazard profile for Reggane, at: https://bit.ly/3V9Ja4S; and for Amguel, at: https://bit.ly/43hVIte.

claim compensation, the person should show that he or she resided or stayed in the areas around test centres in Algeria during the nuclear testing period (so between 1960 to 1967) and that they suffer from one (or more) of the radiation-induced diseases listed in the decree (23 cancers have been recognized since 2018). This law does not recognize indirect victims ('victime par ricochet') or transgenerational victims, although a French parliamentary report of June 2025 recommended a change in this regard.

The Committee to Compensate Victims of Nuclear Tests (CIVEN), which was created by the law, reported in 2023 that only two of 1,026 cases where money has been paid was to an Algerian – all the others are French soldiers and civilians who worked for the French army in Algeria or French Polynesia, or nationals from Mā'ohi Nui. In response, the French Ministry of Foreign Affairs said that the authorities 'will continue to examine the cases presented'.[96] But according to CIVEN's report for 2023, to date only sixty-nine Algerians had filed a compensation claim (from a total of 2,846 claims) with three of these filing a claim in 2023.[97]

There are four main reasons for this very low number. First, the zones delimiting the fallout from nuclear testing exclude the surrounding villages (such as Mertoutek and Ideles). While the zones in Polynesia had similar restrictive characteristics at the outset, they were extended in 2013 to cover the entire Polynesian territory, following the declassification of documents showing the extent of radioactive fallout. Second, Algerian claimants (particularly the nomadic population) face significant difficulty in obtaining documents proving their presence in the areas and on the dates determined, as well as their medical records. Third, documents explaining rights to claim and the application process have only been available in Algerian Arabic on the CIVEN website since November 2023,[98] after years of requests by ICAN France. Fourth, the procedures are for the most part digital, requiring Internet access.

### Court judgments

In November 2023, the Strasbourg Administrative Court dismissed a claim by the relatives of Algerian victims on jurisdictional grounds. The court found that the action failed on the basis of a lack of temporal jurisdiction. A widow and her three children had demanded damages after the death of a spouse suffering from cancer following exposure to ionizing radiation on nuclear test sites (from 1961 to 1962) in the Sahara.[99] 'It's an incomprehensible decision for the families', their lawyer, Maître Cécile Labrunie, told Agence France-Presse. 'For us, the starting point of the limitation period is the moment when these families finally obtain the offer of compensation as beneficiaries, and therefore recognition for their loved ones of the status of radiation victims.' They pledged to appeal: 'The Ministry of the Armed Forces will not always be able to hide behind questions of admissibility to absolve itself of its responsibility.'[100]

The following month, two plaintiffs sought to have the death of their military husbands, which occurred several years after nuclear tests in Algeria and Polynesia, respectively, to be recognized as a harm by the administrative court of Dijon. This time the lawsuit foundered on the issue of causality.[101] Aven had denounced the 'lack of the right to reparation'. The two widows, both 'indirect' victims ('par ricochet', in French), were suing the Ministry of the Armed Forces. The Morin Law 'is limited because it only compensates direct victims, unlike other compensation systems based on national reparation', such as victims of asbestos, terrorist attacks, or road

96 BBC, 'France-Algeria relations: The lingering fallout from nuclear tests in the Sahara'.
97 CIVEN, 'Activity Report 2023', p. 6.
98 At: https://bit.ly/4cvtGyr.
99 Tribunal Administratif de Strasbourg, 'Victimes « par ricochet » des essais nucléaires', Press release, Strasbourg, 10 November 2023, at: https://bit.ly/3OVKhkW.
100 'Nuclear Tests in Algeria and Polynesia: Compensation Requests from Relatives Rejected', *The Maghreb Times*, 11 November 2023.
101 Administrative Court of Dijon, Second Chamber, 19 December 2023, Case No. 2202568, at: https://bit.ly/3I9cDUT.

accidents, explained Maître Labrunie. Absent from the Court proceedings, due to fragile health, was Monique Goret, Gérard's widow, who died of lymphoma in 1999. He was site manager at In Ekker during the so-called Beryl incident of 1 May 1962.[102]

In another case, a French court has held out some hope for nuclear compensation claims by test veterans. A court in Nantes ordered the State to compensate three veterans irradiated during nuclear tests between the 1960s and 1990s. Partial judgment in favour of the plaintiffs was affirmed on appeal in 2020.[103] The court had received 13 applications from veterans or widows whose claims for compensation had been denied by the Ministry of Defence. The three veterans, two of whom served in Algeria and the third who was a navy mechanic in French Polynesia in the 1960s, have developed a total of seven cancers.[104]

### Intergovernmental compensation and reparation

France has never provided intergovernmental compensation to Algeria for its nuclear testing. France has also declined to provide details of the tests in Algeria from its confidential archives. This is in contrast to significant information it has provided on the tests it conducted in French Polynesia.

Since 2008, though, there have been a number of instances where the Algerian and French authorities have come together to discuss issues related to French nuclear testing in Algeria and have taken initiatives to address them. These collaborative efforts have often occurred during periods of political rapprochement between the two nations. Despite the establishment of committees and working groups, progress has been limited, with these initiatives often failing to yield significant results. Moreover, France has often portrayed nuclear testing as part of a shared historical narrative to be reconciled, while Algeria demands acknowledgment of responsibility and adequate reparations for affected communities.[105]

In the past, two bilateral initiatives have been undertaken to address the repercussions of French nuclear testing in Algeria. The first was in December 2007, during a visit to Algiers by the then President of France, Nicolas Sarkozy. It was announced that an Algerian-French committee would be established to assess polluted sites, determine risks to residents and the environment, and propose rehabilitation measures. However, no report or recommendations from the committee's work were made public, making it difficult to ascertain the extent of its activities and meetings.[106] The second attempt took place in 2014, following declarations made during President François Hollande's visit to Algiers in 2012. This time, a new Algerian-French working group was formed with the objective of discussing the conditions for submitting compensation claims for Algerian victims, in line with the Morin Law. The group convened once in 2016 but did not release any minutes or recommendations from this meeting.[107]

Since 2017, the Macron administration in France has made renewed efforts to address historical grievances with Algeria, beginning with the commissioning of reports and culminating in the establishment of a joint commission with Algerian President Tebboune. Within the French report addressing memory issues of colonization and the Algerian War, which was drafted in the latter half of 2020 by Benjamin Stora at President Macron's request, the treatment of French nuclear testing in Algeria is limited. Despite the gravity of the issue, the report only briefly touches on nuclear testing within a segment titled 'Other subjects. Other challenges'. One of the

102 'Dijon: two widows victims "by ricochet" of nuclear tests attack the Ministry of the Armed Forces', Teller Report, 5 December 2023, at: https://bit.ly/3ON9GwT.
103 Cour administrative d'appel de Nantes, Fifth Chamber, 30 March 2020, Case No. 19NT03307, at: https://bit.ly/3SNQRuN.
104 Report on Radio New Zealand, 26 November 2016, at: https://bit.ly/4bZJXvx.
105 Bouveret, 'Quand viendra le jour où la France devra rendre des comptes?', p. 6.
106 Collin and Bouveret, 'The Waste From French Nuclear Tests in Algeria', p. 45.
107 Ibid.

22 recommendations of the report addresses nuclear tests in the Sahara and calls for the establishment of the 'Memories and Truth' commission.[108]

During President Emmanuel Macron's state visit to Algiers in August 2022, the two nations' leaders decided to establish a joint committee of historians tasked with settling their differences and confronting the past.[109] This commission plans to address the issue of nuclear testing. But at the time of writing, no new reports or statements have been published, reflecting a lack of political will on both sides of the Mediterranean.

In December 2024, Algerian President Abdelmadjid Tebboune brought the matter back into the spotlight, calling on France to take responsibility for the environmental harm caused by its nuclear testing. 'Don't give us money, but come clean up the sites that you have contaminated,' Tebboune declared in an address to Parliament. The following month, in January 2025, Algeria's Minister of Environment and Quality of Life, Nadjiba Djilali, reinforced the appeal, emphasizing that colonial France must 'fully assume its historical, moral and legal responsibilities' in dealing with the radioactive waste it left behind. Bouveret voiced his disappointment over the lack of engagement from the French government. 'The main obstacle is the lack of political will from French authorities to concretely assume the consequences of their nuclear policy,' he said, highlighting the ongoing tensions surrounding this unresolved matter.[110]

108 B. Stora, 'Les Questions Mémorielles Portant Sur La Colonisation et La Guerre d'Algérie', Report, January 2021, available at: https://bit.ly/4bXgt1f.

109 A. Ouali, 'ANALYSIS – Algeria and France: Is the new rapprochement sustainable?', 1 November 2022, at: https://bit.ly/3Trr1OZ.

110 A. Guliyev, 'Algeria calls on France to confront its nuclear past: "Come clean up the sites that you have contaminated"', Caliber.az, 14 February 2025, at: https://bit.ly/3FYauhk.

Chapter 15:

# Addressing the Impact of French Nuclear Testing in Mā'ohi Nui (French Polynesia)

Tamatoa Tepuhiarii and Nabil Ahmed

**Desecrated Oceans:** Angelo Tehuira-Hioe, 64 years of age, holds a photograph of a mushroom cloud from a nuclear bomb test in Mururoa near his home in Hao, Mā'ohi Nui, on 30 April 2024. Angelo worked in Mururoa during the nuclear testing and has had a neuroendocrine tumour. From a cultural perspective, nuclear testing continues to exert a deep and lasting impact on Mā'ohi people, for whom the land, ocean, air, waters, and all living beings are sacred. Photograph © Adam Ferguson/The New York Times/NTB.

## Key Facts About Nuclear Testing in Mā'ohi Nui

**Testing State:** France

**Testing period:** 1966–96

**Number of tests:** 193 (46 atmospheric and 147 underground tests), including 15 safety tests. A further 15 experiments with fissile material were conducted in the air.

**Test locations:** Moruroa and Fangataufa atolls, with fallout spreading across the territory of Mā'ohi Nui and far beyond.

**Destabilized structures:** The underground detonations have destabilised the geological structures of Moruroa and Fangataufa atolls.

**Health consequences:** The full public health impact of French nuclear testing in Mā'ohi Nui remains unclear, though studies report unusually high rates of thyroid cancer and myeloid leukaemia, as well as birth deficits and congenital anomalies.

**Indigenous Peoples affected:** The Mā'ohi across the territory were seriously affected by radiation, displacement, and social and cultural dislocation.

**Research gap:** In 2012, the French Ministry of Defence acknowledged the need for proper, independent epidemiological studies in relation to the nuclear tests.

**Strained health care:** The health care system in Mā'ohi Nui is struggling to provide adequate health services for affected populations.

**Lack of accountability:** French information campaigns downplayed the risks of the nuclear tests. To this day, France has not fully recognized its responsibility for the consequences of its nuclear tests in Mā'ohi Nui, although a June 2025 French parliamentary report has called for the authorities to take greater responsibility for the harm inflicted on the Mā'ohi people and their territories.

**Limited compensation:** France provides for limited compensation to defined categories of victim under a 2010 law. Since 2010, only 417 people from Mā'ohi Nui have been recognized as victims of French nuclear testing.

> I started to see that our cancers and illnesses in Mā'ohi Nui are linked to the radiation our people have been exposed to from the bombs. It is not just "bad genes". … The health consequences and cost of France's nuclear actions continue to be borne by our people, yet France still refuses to take responsibility for them.
>
> Hinamoeura Morgant Cross,
> Member of the Assembly of Mā'ohi Nui (2024)[1]

## History of testing in Mā'ohi Nui

On 2 July 1966, Mā'ohi Nui (French Polynesia)[2] was subjected to the territory's first atmospheric nuclear test, in an operation code-named Aldebaran. A 28 kiloton (kt) nuclear explosive device was detonated over Moruroa Atoll, in the Tuamotu archipelago. Between 1966 and 1996, France carried out 193 nuclear tests in Moruroa and Fangataufa atolls – 46 atmospheric tests (including five 'safety tests') and the other 147 conducted underground (including ten safety tests).[3] The scale, scope, and consequences of these nuclear tests have been kept largely concealed from Mā'ohi people for decades by the French authorities. To this day, France has neither fully acknowledged its responsibility for the nuclear tests nor has it established a fair and equitable compensation mechanism for victims of a silent and slow health disaster.

The political context of French colonialism is key to better understanding the history of nuclear testing in Mā'ohi Nui. France annexed the territory in 1847. In 1958, during the Mā'ohi Referendum, the Mā'ohi leader Pouvanaa Oopa pushed for independence, following a path taken by French colonies in South-East Asia and Africa.[4] In October 1958, Mr Oopa, who also served as a deputy in the French Parliament (the first Mā'ohi to sit in the Parliament of the French Republic), was charged and convicted of arson and inciting unrest for which he was sentenced to eight years' imprisonment. It is believed that the charges were trumped up for political reasons. Mr Oopa was then exiled in France and his political party was dissolved.[5]

At the end of Algeria's war of independence, peace negotiations between Paris and Algiers (in 1962) saw France agree to cease its atmospheric nuclear testing at the Oasis Military Experiments Centre near In Ekker. French negotiators did, though, secure five further years for its nuclear testing programme in Algeria despite the country's declaration of independence.[6] The French military, however, decided to shift its nuclear testing

1 Cited in T. Fuatai, '"So many people have cancer" — living with the French nuclear legacy in the Pacific', E-Tangata, 9 February 2025, at: https://bit.ly/46CuJfF.

2 The legal name of Mā'ohi Nui is French Polynesia but using the name Mā'ohi Nui is a way to recognize the efforts to create an Indigenous name for this territory. The term Mā'ohi was first used by Duro Raapoto in the late 1970s. See B. Saura, *Mā'ohi ou l'identité bafouée*, Au vent des îles, Papeete, 2013.

3 International Atomic Energy Agency (IAEA), 'The Radiological Situation at the Atolls of Mururoa and Fangataufa', Main Report, Vienna, 1998, at: https://bit.ly/3uvGdRo.

4 B. Danielsson and M.-T. Danielsson, *Moruroa notre bombe coloniale*, L'Harmattan, Paris, 1993, 5–14.

5 M.-H. Villierme, *'Pouvanaa te metua, L'élu du peuple'*, TV documentary, Tuatau Production, 2012.

6 Art. 4, Evian Accords, 'Déclaration de principes relative aux questions militaires', *Journal officiel de la République française*, 20 March 1962, 3030. See the previous chapter for details.

programme to Mā'ohi Nui.[7] In 1962, without consultation with local leaders, France's Defence Council voted to confirm Moruroa Atoll as the main test site for the Centre d'Expérimentations du Pacifique (CEP).[8]

In May 1963, French and Mā'ohi workers started construction on Moruroa, Fangataufa, and Hao atolls even though the atolls were part of the Mā'ohi heritage. France went as far as to declare Moruroa and Fangataufa atolls as 'uninhabited', which was disingenuous as they were still being exploited by the *Tahitia* company and the territories were being claimed by many families on the neighbouring atoll of Tureia.[9] On 6 February 1964, however, the Permanent Commission of the Assembly of French Polynesia (Mā'ohi Nui) in Tahiti voted to allow testing on Moruroa and Fangataufa atolls.[10]

Moruroa and Fangataufa atolls were 'ground zero' for France's nuclear testing programme with a total of 41 nuclear bombs detonated over them along with five atmospheric safety tests.[11] The detonations in the atmosphere involved different modes of explosive device, some placed on barges in the lagoons, others suspended from high-altitude balloons, and others dropped from the air. The total explosive yield in the atmosphere equates to somewhere between 7.6 and 10.8 megatons (Mt) of TNT – between 510 and 720 times that of the bomb dropped on Hiroshima.[12] The atmospheric safety tests were conducted on towers located in the northern area of Moruroa Atoll known as the Colette zone, resulting in plutonium dispersion over an area of 190,000 square metres.[13] The tests involved varying quantities of fissile material and are reported to have generated 'almost' no fission products.[14]

France's 46 atmospheric tests were all conducted after the treaty banning atmospheric tests (the Partial Test-Ban Treaty) was adopted in 1963, finally moving its testing programme underground only in 1974.[15] In addition to the five atmospheric safety tests mentioned above, France conducted a total of 15 'experiments' in Mā'ohi Nui in the air – the Arpège series in 1970 and the Meknès series in 1978. These experiments were conducted using chemical explosives and plutonium.[16]

Between 5 June 1975 and 27 January 1996, France detonated 137 nuclear explosive devices and a further 10 devices in safety tests underground at the same two atolls.[17] According to a report by the International Atomic Energy Agency (IAEA), the recorded yield of each of these tests ranged from 1 kt up to 118 kt. The largest detonation, of a device called Hyrtacos, took place beneath Fangataufa lagoon on 14 November 1990.[18] In three of the underground safety tests some fission occurred.[19]

7 J.-M. Regnault, *Le nucléaire en Océanie, tu connais ? Les essais atmosphériques (1946–1974)*, Api Tahiti, 2021.
8 J.-M. Regnault, Notes in the Defence Council Archives of 27 July 1962.
9 *Supplément au Journal officiel des Etablissements français de l'Océanie*, 1 May 1925, 219.
10 Assembly of French Polynesia, *Les Polynésiens et les essais nucléaires*, Report of the Investigations Commission on nuclear tests, 2006, text available at: http://moruroa.assemblee.pf/ in Archives 2006.
11 The safety tests (in French 'essais de sécurité') were 'designed to ensure the safety of nuclear weapons, meaning the impossibility for a nuclear weapon, under any accidental circumstances or external aggression, to trigger a nuclear reaction.' The French definition of 'safety tests' is thus similar to that used by the United States. See: 'Les essais nucléaires en Polynésie française : Pourquoi, comment et avec qu'elles conséquences', CEA/DAM, September 2022, p. 55.
12 IAEA, 'The Radiological Situation at the Atolls of Mururoa and Fangataufa', Main Report, Vienna, 1998, at: https://bit.ly/3uvGdRo, pp. 27–28.
13 C. Bataille et H. Revol, *Rapport sur les incidences environnementales et sanitaires des essais nucléaires effectués par la France entre 1960 et 1996 et élément de comparaison avec les essais des autres puissances nucléaires*, Office parlementaire d'évaluation des choix scientifiques et technologiques, 5 February 2001, p. 77.
14 CEA, 'Les Atolls de Mururoa et de Fangataufa, Les expérimentations nucléaires – Aspects radiologiques', Commissariat à l'Energie Atomique, 2007, p. 157. According to the IAEA, two of the atmospheric safety tests produced a small nuclear yield. See: IAEA, 'The Radiological Situation at the Atolls of Mururoa and Fangataufa', Main Report, p. 26.
15 T. Rauf, 'French nuclear tests: A fool's errand', *The Nonproliferation Review*, Fall 1995, 49–57, at: https://bit.ly/3ODQ12z.
16 Commission d'information, 'Rapport de la Commission d'information sur les essais nucléaires français en Algérie et en Polynésie française', Assemblée nationale, France, 2001.
17 See French Commissariat à l'Énergie Atomique et aux énergies Alternatives (CEA), 'Les essais nucléaires en Polynésie française : Pourquoi, Comment, et Avec Quelles Conséquences?', Report, September 2022, at: https://bit.ly/3xf2Pqo, p. 59.
18 IAEA, 'The Radiological Situation at the Atolls of Mururoa and Fangataufa', Main Report, pp. 28–30.
19 Ibid.

Under pressure from several States from Asia and the Pacific, including Australia and New Zealand, France declared a moratorium on underground tests on 8 April 1992 under the presidency of François Mitterrand. In 1995, his successor, Jacques Chirac, authorized a final round of underground explosions, which ended on 27 January 1996 after protests by Mā'ohi people and as a result of international pressure. Today in Mā'ohi Nui, civil society organizations such as Moruroa e Tatou ('Moruroa and Us'), Association 193, and Tamarii Moruroa (Moruroa's children); and pro-independence movements such as Tavini Huira'atira No Te Ao Ma'ohi (Servant of the Mā'ohi people) and Te Tāvini Hui Raatira (The Servant of the Raatira's people); and religious movements such as the Ètārētia Porotetani Mā'ohi (the Mā'ohi Protestant Church) continue to seek justice for the harm inflicted by the tests.[20]

## Assessments

Exposing the true impact of French nuclear tests is as important for French civilian and military veterans and former Mā'ohi workers as it is for Mā'ohi people. This search for the truth has often collided with State laws that protect France's nuclear secrets.

In 1996, in response to international political pressure, the French Ministry of Defence funded a series of reports on its nuclear testing programme in Mā'ohi Nui. In 1998, France also permitted the IAEA to conduct a study on the radiological conditions at the atolls of Moruroa and Fangataufa. The IAEA report found the radiological conditions around the atolls at the time did not pose a threat to public health but did not retroactively examine exposures during the atmospheric tests.[21] Moreover, official and institutional reports often relied on data provided by the French Ministry of Defence, which refused all requests for independent access to the sites and relevant data from the parliamentary committee of inquiry established to examine the impact of the tests and from independent experts.[22] The same system of self-monitoring and self-regulation by the French Ministry of Defence and the French Commissariat à l'énergie atomique et aux énergies alternatives (CEA) is still in force.

In 2013, a set of declassified documents from the French Ministry of Defence were made public following a prolonged legal battle between French and Mā'ohi victims' rights organizations and the government. The archive consists of 233 documents totalling approximately 2,000 pages, which broadly cover the period 1966–74 during which France conducted the 41 atmospheric tests in Mā'ohi Nui. The documents revealed new information about radioactive fallout that affected the local populations.[23]

## Human effects

### The impact on Mā'ohi people and French civilian and military personnel

Nearly 14,000 Mā'ohi individuals were hired under the CEP framework, with some staying for more than a decade on the nuclear testing atolls. Most Indigenous workers were not informed about the risks associated with their activities on the nuclear sites. The only documents in Tahitian were their employment contracts, which prohibited workers from discussing their activities on nuclear sites.[24] Military and local staff were employed for various tasks, including the construction and maintenance of facilities and services. During the period of atmospheric

20 One of the first anti-nuclear movements was the political party 'Tavini Huira'atira No Te Ao Mā'ohi' in 1977. The first anti-nuclear association was 'Moruroa E Tatou' in 2002.

21 Ibid.

22 See, e.g., the draft resolution put forward by Dominique Voynet for the creation of a commission of inquiry into the health and environmental consequences of the nuclear tests in Polynesia between 1966 and 1996, French Senate, Draft Resolution No. 247, 9 March 2006.

23 They are available at: https://moruroa-files.org.

24 Art. 5, CEA employment contract, 1966, available in French and Tahitian.

testing, thousands were involved in decontaminating polluted areas after each explosion. Throughout the series of atmospheric trials that took place between May and October of each year, hundreds of civilian staff from the CEA and specialized French businesses came to Moruroa to undertake technical and scientific work.[25]

The exact number of personnel and civilians affected by the atmospheric testing, including both French and Mā'ohi employees at the CEP, remains unknown, but there is credible evidence that the French nuclear testing programme caused radio-induced cancers among test site personnel.[26] The French Ministry of Defence has stated that approximately 126,000 people were present on the nuclear sites in Mā'ohi Nui between 1966 and 1998.[27]

### Transgenerational health impacts

The full extent of public health impacts such as radiation-related cancer from French nuclear tests in Mā'ohi Nui is unknown. This is due to a combination of lack of exposure data, lack of access to information, and French State policies of nuclear secrecy. On the one hand, observational studies have revealed one of the highest incidences of thyroid cancer in the world as well as an elevated rate of myeloid leukaemia in Mā'ohi Nui.[28] Doctors specialising in child psychiatry and children's neurodevelopmental diseases have reported that they observed malformations and neurodevelopmental retardation.[29] On the other hand, a population-based case control study by Vathaire and others—supported by French defence and health authorities, and which used available cancer registry data in Mā'ohi Nui—found a low risk of thyroid cancer as a result of radiation exposure. The authors acknowledged, however, that their results were based on limited exposure data.[30] They also reported that their dose estimates were similar to those estimated by the French Army in 1977 and 1997.

In 2006, the French Ministry of Defence released new dose reconstruction studies for the six tests that produced the highest levels of radioactive fallout. The revised estimates were higher than the Ministry's own previous calculations and did not account for the continued exposure of local populations through food and water consumption.[31] In the same year, the French Ministry of Defence stated that the dosage levels should not lead to a detectable number of excess thyroid cancers in people living in Mā'ohi Nui.[32] In December 2012, however, the Ministry acknowledged the need for serious and independent epidemiological studies in relation to nuclear tests.[33] Previous studies commissioned by the Ministry of Defence had either downplayed the link between nuclear tests and health impacts or withheld known information from the public.[34]

25 P. de Vries and H. Seur, 'Moruroa et nous, Expériences des Polynésiens au cours de 30 années d'essais nucléaires dans le Pacifique Sud', Centre de documentation et de recherche sur la paix et les conflits, Lyon, 1997.

26 Moruroa Files, 'Evidence of a Lie', at: https://bit.ly/4fr3HsF.

27 DSND/ASN, *Rapport du Comité de liaison pour la coordination du suivi sanitaire des essais nucléaires* français, May 2007, at: https://bit.ly/3UYPuMx, Annex H.

28 C. Bouchardy, S. Benhamou, F. de Vathaire, R. Schaffar, and E. Rapiti, 'Incidence rates of thyroid cancer and myeloid leukaemia in French Polynesia', *International Journal of Cancer*, Vol. 128 (2011), 2241–43.

29 I. Petrou, 'Nuclear Tests in French Polynesia: Need for Clarification of the Radiological Situation', *Asia Pacific Journal of Public Health*, Vol. 27, No. 2 (March 2015), 232–33.

30 F. de Vathaire, V. Drozdovitch, P. Brindel, F. Rachedi, J.-L. Boissin, J. Sebbag, L Shan, F. Bost-Bezeaud, P. Petitdidier, J. Paoaafaite, J. Teuri, J. Iltis, A. Bouville, E. Cardis, C. Hill, and F. Doyon, 'Thyroid cancer following nuclear tests in French Polynesia', *British Journal of Cancer*, Vol. 103, No. 7 (28 September 2010), 1115–21.

31 The 2006 reports of government dose reconstruction on key nuclear tests are available at http://moruroa.assemblee.pf/.

32 Ministry of Defence, 'The radiological dimension of French nuclear tests in Polynesia', Paris, 2006, 296.

33 Ministry of Defence, 'Compte-rendu de la 3ème réunion de la commission consultative de suivi des essais nucléaires du 11 décembre 2012', Paris, 26 March 2013.

34 For instance, two Institut National de la Santé et de la Recherche Médicale (INSERM) studies found no link between cancers and the nuclear tests: 'Mortality from cancer in French Polynesia between 1984 and 1992. Role of distance to the Moruroa atoll. Comparison with other countries', 1994; and 'Cancer incidence in French Polynesia between 1985 and 1995. Incidence of place of birth and place of residence in relation to the Moruroa atoll', 1998. The 'Sépia santé' study published in 2009, which assessed the health of French military veterans from the tests in Polynesia, even suggested that the veterans were in 'better health' than their French compatriots of the same generation. Sepia Santé, 'Etude épidémiologique de mortalité des vétérans des essais nucléaires dans le Pacifique', 12 October 2009.

Between 1966 and 1969, the Director of Mangareva Island School, situated some 400 miles downwind of the detonations, observed concerning effects on students. Some experienced hair loss in tufts and nausea after the atmospheric explosions.[35] Mangareva is one of the regions of Mā'ohi Nui most heavily impacted by fallout. The Moruroa Files investigation documented the impacts on the families of fourteen individuals from the Mangareva islands who had developed thyroid and breast cancers. All had lived in the islands during the French nuclear tests. While a clear link between atmospheric tests and cases of cancer on Mangareva cannot be established definitively, the Polynesian Ministry of Health has acknowledged a thyroid cancer cluster there, declaring that it 'leaves little doubt about the role of ionizing radiation ... in the advent of this excess of cancer (cases)'.[36] Journalists working on the Moruroa Files investigation also uncovered a February 2017 email circulating between French Ministry of Defence services which revealed that one third of the 6,000 civilian and military personnel stationed at the test sites between 1966 and 1974 were likely to suffer from radiation-induced illnesses (or may still do so).

Medical research on the hereditary transmission of genes altered by radiation exposure as a result of nuclear tests is very recent and remains, to date, inadequate. In Mā'ohi Nui, Dr Christian Sueur, a child psychiatrist now working in France, reported several cases of mental retardation and oligophrenia (congenital dementia) or atypical infant cancers among descendants of former Mā'ohi workers on Moruroa Atoll. Dr Sueur also reported an apparently significant number of dead either in utero or at birth along with pregnancies that did not come to term. In early 2013, these discoveries convinced the authorities monitoring the impact of nuclear tests to provide funding for research into the genetic impact of the nuclear tests in Mā'ohi Nui. A team of geneticists from the Institut National de la Santé et de la Recherche Médicale (INSERM) were contacted and responded favourably to the idea. In May 2013, however, political changes in leadership in Mā'ohi Nui resulted in the removal of the INSERM delegation, leaving the future prospects of the proposed study of genetic impact uncertain.[37]

As Chapter 7 of this report has discussed, radiation exposure is known to have adverse effects on women's reproductive health, affecting their ability to conceive, carry pregnancies to term, and have healthy children.[38] Mā'ohi girls and women were particularly vulnerable to the effects of radioactive fallout from French nuclear tests. In October 2023, in a shadow report to the 86th Session of the Committee on the Elimination of Discrimination Against Women (CEDAW), Mililani Ganivet[39] underscores this finding by reference to the case of Hinamoeura Morgant Cross, a mother of two diagnosed with leukaemia, and who has several other female family members also diagnosed with cancer. Her struggles mirror those of many Mā'ohi women affected by the harmful legacy of French nuclear testing. Ms Ganivet also mentions similar consequences for Tina, a 57-year-old resident of Fa'a'ā, one of Tahiti's most populous towns. Her husband had worked on Moruroa Atoll and she tragically lost five infants, all of whom had suffered from multiple skin-related illnesses, shortly after birth.

## Societal effects and displacement

The economic, social, and cultural transformations arising from the employment of thousands of workers (estimated at 10 per cent of the total population), who were recruited from the outer islands of Mā'ohi Nui to work for the CEP, were profound. This included a significant migration of families of workers towards Tahiti as the administrative and economic centre, which had not been prepared for the sudden influx. Shantytowns appeared

35 B. Barrillot, M.-H. Villierme, and A. Hudelot, *Témoins de la bombe : mémoires de 30 ans d'essais*, Editions Univers Polynésiens, Papeete, 2017, 5.

36 See: https://bit.ly/3OAoejB.

37 Dr Christian Sueur, 'Mise en évidence d'une vulnérabilité génétique dans la descendance des populations exposées aux essais nucléaires atmosphériques, et des anciens travailleurs polynésiens du Centre d'Essais de Pacifique', Research Project, 13 March 2013.

38 A. Riser *et al.*, 'Report from the CDC Division of Reproductive Health's Emergency Preparedness Resources and Activities for Radiation Emergencies: Public Health Considerations for Women's Reproductive Health', *Journal of Women's Health*, Vol. 32, No. 12 (2023).

39 M. Ganivet, Shadow report to the 86th session of the Committee on the Elimination of Discrimination against Women, The consequences of nuclear testing on women's rights in French Polynesia, Mā'ohi Nui, submitted by Moruroa e tātou, Development Alternatives with Women for a New Era (DAWN), 2023, at: https://bit.ly/43TXfHD.

in the city of Papeete and neighbouring Fa'a'ā to accommodate the internal migration. At the same time as France was building its nuclear infrastructure, in 1962, an international airport opened in Fa'a'ā, opening up Mā'ohi Nui as a destination for tourism. While the nuclear testing programme created an initial, short-term economic boom, the end of atmospheric testing in 1974 ushered in decline for an economy increasingly dependent on the French military-industrial complex.[40] Across the islands, subsistence agriculture and fishing—once the main sources of livelihood—suffered badly, and within a decade most food was imported.[41] The high wages paid by the CEP contributed to a rise in the cost of living – and an artificial sense of prosperity.

In addition, the influx of many families of the CEP's metropolitan staff, mainly to Tahiti, accelerated the spread of French at the expense of Mā'ohi languages (dialects). These changes led to a loss of cultural space for younger generations of Mā'ohi,[42] through new social management and organization in the spheres of public information, education, and administration.[43] The interaction between French civilians and Mā'ohi people led to significant changes in Indigenous lifestyle. This included the reorganization of islands such as Tahiti, Mangareva, and Hao (where a major military base, later associated with a large outbreak of ciguatera fish poisoning, was established for the test programme).[44] An increasing amount of Indigenous land was taken for the construction of accommodation, offices, and other infrastructure. From a cultural perspective, nuclear testing continues to exert a deep and lasting impact on Mā'ohi people, who have had strong connections with the land, ocean, air, waters, and all living beings, both human and non-human, in different ways. It creates feelings of anxiety, discord, and a profound sense of disrespect towards their identity.[45] These effects are deep-seated and persistent.

### Nuclear colonialism in Mā'ohi Nui[46]

The historical tapestry of Mā'ohi Nui unravels with the threads of colonial violence, environmental degradation, and economic exploitation driven by France's nuclear practices. French nuclear testing in Polynesia strategically excluded Tahiti while selecting smaller islands and atolls such as Moruroa and Fangataufa atolls as testing sites.[47] The decision was not solely taken on scientific grounds but was driven by political motives, serving to suppress local independence movements.[48] There is also a strong economic motivation: France's management of the exclusive economic zone (EEZ) around Mā'ohi Nui gives it both national economic advantage and regional influence.[49] Representing nearly 40 per cent of France's global EEZ, the region's wealth in rare-earth elements, which are essential for high-tech manufacturing, constitutes a significant geopolitical issue and underscores the enduring impact of nuclear colonialism in Mā'ohi Nui.

The establishment of the CEP in 1962 is seen as a tool to safeguard France's strategic interests. The subsequent military influx disrupted the socio-economic fabric of the territory, with a cascade of consequences for the local

40 G. McKay, 'The effects of nuclear testing in French Polynesia', *Chrestomathy: Annual Review of Undergraduate Research*, Vol. 7 (2008), College of Charleston, Charleston, SC, 109–16.

41 M. Kahn, 'Tahiti Intertwined: Ancestral Land, Tourist Postcard, and Nuclear Test Site', *American Anthropologist*, Vol. 102, No. 1 (March 2000), 7–26.

42 J. Chesneaux, *Tahiti après la bombe. Quel avenir pour la Polynésie ?*, L'Harmattan, Paris, 1995; and B. Barrillot (ed.), M.-H. Villierme, and A. Hudelot, *Témoins de la bombe: mémoires de 30 ans d'essais*, Editions Univers Polynésiens, Papeete, Tahiti, 2017, témoignage de Hiro Tefaarere in 46–48.

43 A. Peyrefitte, *C'était de Gaulle*, Gallimard, Fayard, 1994, 122.

44 'The Devastating Consequences of Nuclear Testing. Effects of Nuclear weapon testing on Health and the Environment', Report IPPNW, November 2023, at: https://bit.ly/3yjWn1N, p. 25.

45 T. Pifao and H. Morgant Cross, Youth seminar for Truth and Justice, Poems, February 2023.

46 This section was contributed by Leila Hennaoui.

47 R. Jacobs, 'Nuclear Conquistadors: Military Colonialism in Nuclear Test Site Selection during the Cold War', *Asian Journal of Peacebuilding*, Vol. 1, No. 2 (2013), 157–77, at: https://bit.ly/427OIOI, at p. 170.

48 Ibid.

49 S. Bouamama, 'L'œuvre négative du colonialisme français en Polynésie: Du "bon sauvage" à la bombe nucléaire colonial' ('The negative work of French colonialism in Polynesia: From the "noble savage" to the colonial nuclear bomb'), CADTM, 27 August 2018, at: https://bit.ly/3HnSOJ0.

population. The 46 atmospheric tests and the later underground detonations compromised atoll foundations, even risking their collapse in certain circumstances. Successive disclosures over past decades have exposed a pattern of secrecy, limited compensation to the victims, and a disregard for worker safety by the French authorities.[50] A study published in 2016 by the 'Observatoire des armements'[51] highlights the long-term impact of the explosions. The underground explosions weakened the seabed, posing a risk of atoll collapse. The fallout resulted in devastating health consequences, including birth deficits and persistent health issues.[52] Today, the soil remains contaminated with toxic and radioactive debris, including heavy metals and plutonium. This contamination is linked to a significant number of Mā'ohi children suffering from congenital malformations and anomalies, and ongoing health problems.[53]

France's engagement in deliberate misinformation campaigns downplayed the risks of nuclear testing in Mā'ohi Nui. In response, the collective efforts of local organizations, journalists, and researchers have been crucial. The delayed acknowledgment in 2006 and subsequent compensation initiatives in 2016 exposed the State's reluctance to fully address the ramifications of nuclear colonialism.[54] Declassified documents published by French newspaper, *Le Parisien*, in 2013 revealed that fallout and contamination from the nuclear tests in Mā'ohi Nui had been far more extensive than ever officially acknowledged.[55] The Moruroa Files investigation, together with the book *Toxic* by members of the investigative team, sought to refine dose estimates and expose the excessive secrecy surrounding France's nuclear programme. The investigation revealed that the population had been exposed to significantly higher levels of radioactivity than had been publicly acknowledged and that the French authorities had neither warned nor protected the affected communities.[56]

## Victim assistance

As an overseas territory of France, compensation mechanisms available to victims of nuclear testing in Mā'ohi Nui fall under French law. On 5 January 2010, 44 years after the first French nuclear test, the French government established a compensation scheme for victims known as the Loi Morin. The law created the Comité d'Indemnisation des Victimes des Essais Nucléaires (CIVEN) to process claims. As discussed in more detail under the section below 'Legal issues', CIVEN has faced significant criticism, including for its high rejection rates and restrictive criteria.

In 2024, a newly elected member of the French National Assembly, Mereana Reid-Arbelot, set up a commission of inquiry with the aim of amending the Loi Morin in order to make it more equitable to the victims of French nuclear testing in Mā'ohi Nui.[57] In June 2025, the parliamentary commission issued its first report, which called for the elimination of the requirement for a millisievert threshold to assess the impact of radioactivity on the

50 A. Maurer, 'Snaring the Nuclear Sun: Decolonial Ecologies in Titaua Peu's Mutismes: E "Ore te Vāvā"', *The Contemporary Pacific*, Vol. 32, No. 2 (2020), 371–97, at: https://bit.ly/47BMVTq, at 389–90.
51 L'Observatoire des armements (The Arms Monitor), formerly known as the Center for Documentation and Research on Peace and Conflict (CDRPC), is a non-profit organization actively involved in a worldwide network monitoring nuclear tests and producing analyses of nuclear weapons issues. The Observatory is dedicated to supporting civil society efforts in defence and security matters, advocating for progressive demilitarization.
52 '50e anniversaire des essais nucléaires français dans le Pacifique : la France doit réparation aux victimes' ('50th Anniversary of French Nuclear Tests in the Pacific: France Owes Reparation to Victims'), *Sortir du nucléaire*, 30 June 2016, at: https://bit.ly/3vDod7H.
53 Observatoire des armements, 'Essais nucléaires: Les atteintes aux enfants' ('Nuclear tests: The Impact on Children'), Notes d'analyse No. 4, February 2016, at: https://bit.ly/3u4XT60.
54 A. Maurer, 'Snaring the Nuclear Sun: Decolonial Ecologies in Titaua Peu's Mutismes: E "Ore te Vāvā"', *The Contemporary Pacific*, Vol. 32, No. 2 (2020), 371–97, at: https://bit.ly/47BMVTq, at 389–90.
55 'Essais nucléaires : ce que l'État a caché pendant 50 ans' ('Nuclear Tests: What the State Concealed for 50 Years), *Le Parisien*, 3 July 2013, at: https://bit.ly/3Sq6f1J.
56 S. Philippe and T. Statius, *Toxique: Enquête sur les essais nucléaires français en Polynésie* (*Toxic: Inquiry into French Nuclear Tests in Polynesia*), Presses Universitaires de France, 2021.
57 C. Perdrix, 'Nucléaire: Une Nouvelle Commission d'Enquête à l'Assemblée Nationale Pour Modifier la Loi Morin', *Radio 1 (Tahiti)*, 10 March 2024, at: https://bit.ly/44S8zmz.

human body and a right to compensation for indirect, 'par ricochet' victims (notably the partner of a direct victim and their children). The report further advocated research into the transgenerational effects of exposure to ionizing radiation and the institution of a national day of remembrance in France. The date proposed was 2 July, reflecting the date of the first test at Moruroa in 1966.[58] The detonation resulted in significant fallout. The radioactive cloud from the Aldebaran test went all the way to Mangareva, prompting the evacuation of the French Overseas Minister while locals remained in the dark. Classified documents obtained decades later showed that the level of radiation found in unwashed salad four days after the test were 666 times the regular amount.[59]

Since 1985, the majority of radiation-related illnesses have been covered by Mā'ohi Nui's social security system: US$1.07 billion for 12,584 patients suffering from the 23 diseases on the CIVEN list, more than half of whom have died.[60] The politician and activist Hinamoeura Morgant Cross, mentioned above, has described a health care system that is struggling to provide adequate health services for people that suffer from illnesses that potentially could be radiation-induced. Only as an adult she became aware of the scale of the French nuclear tests in her home islands.

> I said to myself. How come you don't know this? You're 30 years old. You're educated and smart.... I started to see that our cancers and illnesses in Mā'ohi Nui are linked to the radiation our people have been exposed to from the bombs. It is not just "bad genes".... The health consequences and cost of France's nuclear actions continue to be borne by our people, yet France still refuses to take responsibility for them. Our government in Mā'ohi Nui spends millions every year to cover the health system costs of radiation-induced disease. France doesn't contribute anything to that. And because our hospitals aren't well-equipped, some people need to go to France or other countries for proper diagnosis and treatment. For example, we don't even have a PET [Positron Emission Tomography] scan machine, which is often critical for diagnosing cancer. Anyone who needs this scan has to go overseas, often to New Zealand, and that's only if they get funding through the government to cover the cost.[61]

## Environmental contamination

Between 1966 and 1974, a total of forty-one atmospheric nuclear tests and five atmospheric safety tests were conducted over Moruroa and Fangataufa atolls. However, prevailing wind and weather conditions spread fallout across the territory of Mā'ohi Nui, its environment and inhabited areas, and far beyond. As noted above, fallout from the first nuclear test in 1966, Aldebaran, was among the most contaminating of all the tests. Records show that contamination at a level of 61 million becquerels per square metre was measured on the Mangareva Islands, 424 kilometres away from the test site at Moruroa. The location of the islands is significant because none of its 450 inhabitants was aware of the potential risks from contamination, having been informed by the French authorities that the area was located outside of the radiological danger zone.

In fact, the Mangareva Islands would be exposed to fallout on 31 separate occasions, placing the archipelago among the most contaminated regions in Mā'ohi Nui.[62] The Encelade test of 1971 (440 kt) was almost 30 times

58 Commission d'enquête relative à la politique française d'expérimentation nucléaire, à l'ensemble des conséquences de l'installation et des opérations du Centre d'expérimentation du Pacifique en Polynésie française, à la reconnaissance, à la prise en charge et à l'indemnisation des victimes des essais nucléaires français, ainsi qu'à la reconnaissance des dommages environnementaux et à leur réparation, Report, Vol. 1, Assemblée Nationale, Paris, June 2025, at: https://bit.ly/3Ub5IRk, pp. 243, 390, 397, 398, 399, 402.

59 K. Feldmann, 'Beyond radioactivity: how French nuclear tests changed Polynesia forever', *Equal Times*, 15 October 2018, at: https://bit.ly/4ldk2ns.

60 Email from Heinui Le Caill, Elected representative of the city of Papeete, 15 May 2024.

61 R. Kiddle, 'So Many People Have Cancer: Living with the French Nuclear Legacy in the Pacific', E-Tangata, 5 November 2023, at: https://bit.ly/4kkTCQL.

62 At: https://bit.ly/3JgvmS9.

more powerful than the US atomic bomb dropped over Hiroshima. During this and other atmospheric tests, significant radiation fell over not only the Mangareva Islands but also more populated islands such as Tahiti and Tureia. The Centaure test of 1974, an experimental plutonium-based nuclear device that generated an energy equivalent of 4 kt, exposed an estimated 87,500 people to fallout. The entire population of Tahiti may have received effective doses greater than 1 millisievert (mSv).[63]

In addition to the radioactive fallout of atmospheric tests, between 1967 and 1982, the CEP dumped more than 3,200 tonnes of contaminated materials, radioactive waste of different categories, and vehicles, rockets, and aircraft into the Pacific Ocean off the coasts of Hao and Moruroa atolls.[64] In particular, the atoll of Hao, located some 800 kilometres to the west of Moruroa, served as an airport base for the CEP. Decontamination facilities for aircraft, naval vessels, and laboratories for analysing samples collected from radioactive clouds were located on Hao during the atmospheric tests between 1966 and 1974, resulting in contamination in Hao beyond that from fallout that may have reached this atoll.

From 1982 to 1998, the CEP disposed of several tons of radioactive waste of all categories into the upper sections of the 25 shafts of underground explosions at Moruroa.[65] In 2006, a French law on 'transparency and nuclear safety matters' had exempted military activities from the common rules.[66] In 2012, a representative of the Ministry of Defence stated that Moruroa and Fangataufa atolls were unsuitable for any normal human activity.[67] The two nuclear atolls are now assumed to host radioactive material that does not meet any of the standards set by the French National Radioactive Waste Management Agency (ANDRA).[68]

The 147 underground nuclear test explosions have destabilised the geological structures of Moruroa and Fangataufa atolls. In 1977, 1978 and 1979, three external slopes on the south-west side of Moruroa collapsed creating a wave that submerged the coral crown of the atoll. On the northern side of Moruroa, major faults appeared both on the surface and on the outer slopes. In 1998, the International Geomechanical Commission identified and photographed these faults – whose existence had for a long time been denied by the CEP.[69] In early 1979, protective measures were ensured for the personnel involved at the testing sites and for monitoring the stability of Moruroa which continue to the present day. In January 2011, the CEA published a report on the simulation of a collapse on the northern side of Moruroa Atoll, which had been weakened by the 28 underground tests conducted below it.[70] The report supports the possibility of a landslide of rock mass six times greater than the one in 1979. It describes a wave of 20 metres in height, which would only cause minimal flooding upon reaching the neighbouring and inhabited atoll of Tureia (100 kilometres away) in 10 minutes. A warning system (TELSITE) has been installed to detect underground movements on the atoll, demonstrating the reality of this risk. In the event of a landslide, the north of Tureia, where the main village is located, would be affected by a wave with a water height of between fifty centimetres and one metre.[71]

63 S. Philippe, S. Schoenberger, and N. Ahmed, 'Radiation Exposures and Compensation of Victims of French Atmospheric Nuclear Tests in Polynesia', *Science and Global Security*, Vol. 30, No. 2 (2022), 62–94.

64 Ministry of Defense – DSND, 'Details of radioactive waste dumping in Moruroa and Hao', 2006. This figure is subject to a number of uncertainties, as the study by J-M. Collin and P. Bouveret study indicates ('Déchets nucléaires militaires : la face cachée de la bombe atomique française', ICAN France/Observatoire des armements, 2021), since the figures provided by the CEA do not correspond to those used by the French National Radioactive Waste Management Agency (ANDRA).

65 Moruroa e tātou, 'Moruroa. Environmental Risks and Climate Change Testing Consequences', Report, September 2010.

66 Art. 2(3), Law No. 2006-686 of 13 June 2006 on transparency and nuclear security.

67 N. Barbe and T. Derouet, 'Nuclear tests: a never-ending legacy', Documentary, *LCP*, 2012.

68 The IAEA estimates the quantity of high-level radioactive waste in the sediments and subsoils of the two atolls at nearly 40 tonnes. IAEA, 'The Radiological Situation at the Atolls of Moruroa and Fangataufa', Main Report, p. 102.

69 C. Fairhurst, *Rapport de la Commission géomécanique internationale. Problèmes de stabilité et d'hydrologue liés aux essais nucléaires en Polynésie française*, La Documentation française, Paris, 1999.

70 CEA, Conséquences pour l'atoll de Tureia d'un glissement de terrain de grande ampleur à Moruroa, 2011.

71 'Déplacement du Haut-commissaire de la République et du Commandant des Forces Armées en Polynésie française sur l'île de Moruroa', Press release, 9 February 2022, at: https://bit.ly/4ctmKBW.

## Environmental remediation

On several occasions, the Government of Mā'ohi Nui requested verification of the radiological status at the locations of facilities and laboratories at Hao linked with the testing, but without success.[72] In 2006, the Board of Inquiry of the Assembly of Mā'ohi Nui called the attention of the Ministry of Defence to the dilapidated state of the former military base in Hao, describing it as an 'open-air bin' left for the inhabitants of the atoll.[73] In 2009, the French authorities decided to clean up the decommissioned base at Hao, announcing a multi-year programme of works. The assessment report on the chemical pollution of the naval air base was published in June 2012 revealing large-scale pollution by hydrocarbons, heavy metals, and polychlorinated biphenyls (PCBs).[74]

Recent French governments have recognized environmental impacts from nuclear tests. President François Hollande declared in 2016: 'I recognize that the nuclear tests carried out between 1966 and 1996 in French Polynesia had an environmental impact, caused health consequences and, and this is a paradox, leading to social upheaval when the testing itself ceased.' Similarly, President Emmanuel Macron declared in 2021: 'This debt is the fact of having hosted these tests, in particular those between 1966 and 1974, which we absolutely cannot say were clean.' There is, though, no legislative recognition of the effects of nuclear experiments on the biodiversity and natural spaces of the atolls of Moruroa and Fangataufa, and more generally of all Mā'ohi Nui.

As with the health consequences, the environmental consequences are considerable. At the end of the nuclear tests, the environmental risks prompted a senator from Mā'ohi Nui, Richard A. Tuheiava,[75] to work with civil society on a bill for monitoring of the consequences of environmental aspects of the nuclear tests in Mā'ohi Nui. This proposal was tabled in November 2010 in the upper house of the French parliament. Although the goal of this text was to return to Mā'ohi Nui the atolls of Moruroa and Fangataufa, it was also about recognizing, for the first time in a national law, the health consequences for French veterans and the military by the provision of compensation, which would then be expanded to Mā'ohi and Algerians. This text was adopted by the Senate at first reading on 18 January 2012 and transferred three times to the desk of the National Assembly,[76] but without being examined thereafter.

Similarly, the former Member of Parliament for Mā'ohi Nui at the French National Assembly, Moetai Brotherson, tabled a bill in March 2021 seeking to address and repair the consequences of the French nuclear tests. This proposal for the law was rejected during the third public session in June 2021. The text proposed combining the environmental and health consequences of nuclear tests in a single legislative instrument. Article 1 of the bill presented a mechanism for the creation of a commission responsible for developing a programme for the decontamination, treatment, sanitation, and management of nuclear test sites as well as of materials and waste resulting from the nuclear activity generated by nuclear tests. Like the 2010 bill, the 2021 text is one of the few to take these environmental consequences into account. The report of 9 June 2021 made on behalf of the Commission for National Defence and the Armed Forces on the proposed law (No. 3966), aimed at taking charge of and repairing the consequences of French nuclear tests, specifies as follows: 'Moruroa still presents today worrying signs of future ecological and human disasters.'

72 Assemblée de la Polynésie, *Les Polynésiens et les essais nucléaires*, 2006, Vol. II, Rapport CRIIRAD, 115; Letter from the President of French Polynesia, No. 5124/PR of 19 July 2010; and Letter from the President of French Polynesia, No. 3440/PR of 10 June 2011.

73 See the documentary by Sébastien Legay, *Hao, the forgotten atoll*, broadcast as part of the investigative journalism programme '*Envoyé spécial*' on the France 2 TV channel.

74 Artelia Study 'Impact Study of Soil and Water Pollution and Risk Assessment, Hao Atoll – Tuamotu Archipelago – French Polynesia', June 2012.

75 S. Massau, *Paroles d'un autochtone – Entretiens avec le sénateur Richard Ariihau Tuheiava*, Haere Pō, 2011.

76 Text No. 4192 sent to l'Assemblée nationale on 18 January 2012; Text No. 62 sent to the French Parliament on 2 July 2012; Text No. 48 sent to the French Parliament on 6 July 2017.

## The impact of climate change[77]

For Moruroa and Fangataufa atolls, the climate risk profile for the nearby Cook Islands has been referenced to provide an indication of climate trends. A summary of trends and potential climate-related impacts is given in Table 1. Temperature changes, sea-level rise, and storm surges have the potential to affect the plutonium-contaminated lagoon sediments in Moruroa and Fangataufa atolls, and influence exposure pathways through the mobilisation of contaminants and possible seafood consumption. Species may also become more susceptible to contaminants due to other exacerbating and climate-related effects.

In 2012, attention was drawn to the need to consider the impacts and effects of climate change on the release of radionuclides at Moruroa and Fangataufa atolls,[78] but surveillance reports published by France's Nuclear Radiation and Safety Institute (ISRN) do not indicate that climate change risks are yet being assessed.[79] The IRSN Research Steering Committee has published recommendations on addressing climate change in nuclear safety and radiation protection research.[80] While this does not specifically highlight nuclear weapon test sites, it noted particular challenges posed by waste storage facilities and tailings storage ponds.

**Table 1:** **Summary of key climate trends and impacts, Moruroa and Fangataufa**[81]

<table>
<tr><th>Climate system/ hazard</th><th>Historic trends</th><th>Projected trends</th><th>Possible impact on risk components</th></tr>
<tr><td>Temperature</td><td>Increasing</td><td>Increase in average temperatures, and regular heatwaves above 30°C expected</td><td rowspan="5">Source: changes in physico-chemical behaviour and leaching, affecting mechanisms by which contaminants may be released. Includes physical landform changes and erosion caused by sea-level rise, storms, high winds, or wave action<br><br>Pathway: changes in water infiltration, water tables/sea-levels, flow rates and ocean currents; changes to release of airborne contaminants<br><br>Receptor: changes in species assemblages and/or sensitivity to contaminants. Shift in people's proximity/exposure routes to sources</td></tr>
<tr><td>Precipitation</td><td>No change</td><td>Uncertain, yet likely increase in extreme rainfall events*</td></tr>
<tr><td>Drought</td><td>Not given</td><td>May decrease*</td></tr>
<tr><td>Sea level rise</td><td>Sea level risen regionally (Cook Islands) by more than 10 centimetres since 1950</td><td>Projected to rise at around the global average rate</td></tr>
<tr><td>Flood, cyclones, tsunami, and storm surge</td><td>Very high exposure and vulnerability</td><td>Frequency of cyclones may decline, yet sea-level rise could enhance cyclone-induced storm damage, and wind speeds and precipitation intensity may increase. A 40% chance of a potentially damaging tsunami occurring in the next 50 years.*</td></tr>
</table>

* Projections uncertain

77 This section was contributed by Linsey Cottrell.
78 C. Chaumeau, 'France urged to clean up deadly waste from its nuclear tests in Polynesia', *The Guardian*, 7 February 2012, at: https://bit.ly/49HuFtN.
79 IRSN monitoring reports for the French Polynesia available at: https://bit.ly/48IA5mJ.
80 IRSN Opinion on taking climate change into account in the orientation of nuclear safety and radiation protection research, 2023, at: https://bit.ly/48SXJNn.
81 Approximation only using Climate Risk Country Profile: Cook Islands, The World Bank Group, 2021, at: https://bit.ly/4a30nBp; and ThinkHazard! High-level hazard profile for French Polynesia, at: https://bit.ly/4a7f1r8.

## Legal issues

The French government compensation scheme for victims of nuclear testing, the Morin Law, rests on the presumption of causality – that individuals who were present in specific geographic areas in Mā'ohi Nui and Algeria, where France conducted nuclear tests and who developed specific cancers, could be eligible for compensation. The original law included a 'negligible risk' clause where the Comité d'indemnisation des victimes des essais nucléaires (CIVEN) had the power to decide whether the causal link between the level of exposure and the cancer suffered by individual claimants was insignificant. In 2017 and 2018, respectively, the French State removed the negligible risk exception, replacing it with the limit value for the effective dose threshold of 1 mSv in a calendar year defined as acceptable for the public in France (under the Loi EROM).[82] However, the 1 mSv threshold applies only to claims made after January 2019. Claims submitted between March 2017 and December 2018 follow the standard presumption of causality without a threshold.

Victims who suffer from one of the 23 cancers officially linked with nuclear tests who were present in Mā'ohi Nui during the testing period are eligible for compensation, unless CIVEN determines the radiation dose received by individuals was under the 1 mSv threshold. The dose calculations used in compensation claims were retroactively produced by the CEA in 2006 and have not been independently verified. A recent re-evaluation of doses based on declassified French government documents and atmospheric transport modelling found effective doses received by the public that may have exposed approximately 110,000 people, almost 90 per cent of the population of Mā'ohi Nui to radiation levels above 1 mSv in any given year.[83] The results of the aforementioned provisions seem particularly unsatisfactory and have been the source of both national and international controversy. As discussed above, fourteen years after the creation of the compensation scheme, only 417 requests had been accepted for Mā'ohi Nui (eleven from 2010 to 2017). Furthermore, no provision addressing the environmental consequences of nuclear tests has yet been adopted.

Under the Morin Law, eligibility to file a claim with CIVEN is limited to individuals born before 1 January 1999. The law stipulates that claimants must have been in Polynesia (Mā'ohi Nui) between 2 July 1966 (date of the first nuclear test) and 31 December 1998 (the date of closure of the CEP). This cut-off date makes it impossible to establish recognition of the transgenerational nature of the health impact resulting from nuclear testing.

### Court judgments

Between 2010 and 2017, CIVEN received 1,039 applications, of which only 31 were successful.[84] From 2010 to 2017, there were sixteen offers of compensation with agreement from CIVEN and seventeen with an agreement from the minister, compared to 65 following a court decision. In total, as the 2023 activity report from CIVEN shows, 2,846 applications have been received. In 2023, 564 new medical folders were submitted for compensation during the year. Of these, 495 files originated from Mā'ohi Nui, but only 108 were ultimately approved for compensation.[85] Since 2010, a total of 1,026 people have been recognized as victims of French nuclear testing – 417 from Mā'ohi Nui, 607 from mainland France, and 2 from Algeria.

As CIVEN has acknowledged, despite the growing number of individuals seeking compensation, the administrative process remains challenging for Mā'ohi people,[86] with the validity of the main criteria and the

82 The Loi EROM is the Law for a Real Equality in the French Overseas Territories.

83 S. Philippe, S. Schoenberger, and N. Ahmed, 'Radiation Exposures and Compensation of Victims of French Atmospheric Nuclear Tests in Polynesia', *Science and Global Security*, Vol. 30, No. 2 (2022), 62–94, at: https://bit.ly/48ameFK.

84 CIVEN, Activity Report 2019, at: https://bit.ly/3UAJKZ5, pp. 11–12.

85 CIVEN, Activity Report 2023, at: https://bit.ly/3yPh3iM.

86 For example, the forms used to draw up a file have only been available in Tahitian since October 2017.

administration process still posing major obstacles for applicants.[87] The establishment of French institutions in Tahiti, such as the 'Mission de Suivi des Conséquences des Essais Nucléaires' and the 'Centre Médical de Suivi', which are primarily responsible for gathering data on former workers and their relatives to facilitate medical examinations and establish medical records for compensation purposes may facilitate the granting of compensation. Additionally, the 'Délégation du Suivi des Conséquences des Essais Nucléaires', which is tasked with identifying the full extent of France's responsibility, may enable the victims to pursue justice.

87 CIVEN, Activity Report 2022, at: https://bit.ly/4bSXhBI.

Chapter 16:

# Addressing the Impact of Nuclear Testing by the United States in the Marshall Islands

Ivana Nikolić Hughes and Ariana T. Kilma

**Ongoing Displacement:** This image from 27 January 2014 shows the 80-metre-deep Bravo Crater in Bikini Atoll. The crater was created on 1 March 1954 by a 15 Mt nuclear explosive device detonated by the United States. The people of Bikini were displaced because of the nuclear testing and the atoll remains unpopulated, with only temporary caretakers living on the island for months at a time. Photograph © Asahi Shimbun via Getty Images.

## Key Facts about Nuclear Testing in the Marshall Islands

**Testing State:** United States

**Testing period:** 1946–58

**Number of tests:** 67 atmospheric nuclear tests (23 at Bikini Atoll and 44 near Enewetak Atoll), with a cumulative explosive yield equal to 7,000 Hiroshima bombs. 64 of the tests were conducted in the air and three underwater.

**Castle Bravo:** The US conducted its largest nuclear detonation ever, Castle Bravo, at Bikini Atoll on 1 March 1954. It was the worst radiological disaster in US history.

**Impacts:** The tests impacted Bikini, Enewetak, Rongelap, Utirik, and other atolls, resulting in widespread radiation exposure and forced relocations, leading to ongoing challenges in securing sustainable food sources, the loss of cultural practices, and long-term health and environmental damage.

**Indigenous Peoples affected:** The Marshallese were seriously affected by radiation, displacement, and social and cultural dislocation. Bikini Atoll remains unpopulated to this day while the Rongelapese have also yet to return to their homes.

**Contamination:** Independent research has revealed high levels of radiological contamination in soil, food, and ocean sediment, and highlighted the need for a nationwide radiological survey and environmental remediation efforts. United Nations Human Rights Council Resolution 51/35, adopted in 2022, declares that radiation and contamination pose serious threats to the environment in the Marshall Islands.

**Runit Dome:** The Runit Dome houses nuclear waste from a clean-up at Enewetak and even the Nevada test site, posing ongoing risks to health and the environment.

**Distrust:** There is widespread distrust among Marshallese toward information shared by the US Department of Energy due to past misinformation.

**Claims Tribunal:** The Marshall Islands Nuclear Claims Tribunal was designed under the Compact of Free Association with the United States to award compensation for cancers and other serious health effects from nuclear testing.

**Call for support:** In 2024, the Human Rights Council adopted a resolution calling for international support to the Government of the Marshall Islands in its efforts to improve the health of its people and environment.

> I just want our people to experience justice.
>
> National Nuclear Commission Chairperson
> Ariana Tibon-Kilma (2025)[1]

## History of testing in the Marshall Islands

The Republic of the Marshall Islands, a collection of twenty-nine coral atolls and five islands in the Pacific just north of the equator and west of the international dateline, became an independent nation in 1986. From 1946 until 1958, it was the first site of a massive nuclear testing programme in the aftermath of World War II. The Marshall Islands was under Japanese rule from 1920 until 1944 when the United States captured the islands from the occupying Japanese forces. In 1947, the Marshall Islands became part of the Trust Territory of the Pacific created by the United Nations. It was administered by the United States.

Six months after the nuclear bombings of Hiroshima and Nagasaki, a representative of the United States, Commodore Ben Wyatt, asked the local population on Bikini Atoll in the northern Marshall Islands to leave their homes, their islands, and their lagoon to make room for the testing programme – 'for the good of mankind and to end all wars'. Commodore Wyatt promised the small group of Marshall Islanders that they and their families would be able to return home in the near future. In accepting the relocation, the Bikinian leader King Juda stated, 'We will go believing that everything is in the hands of God'.[2]

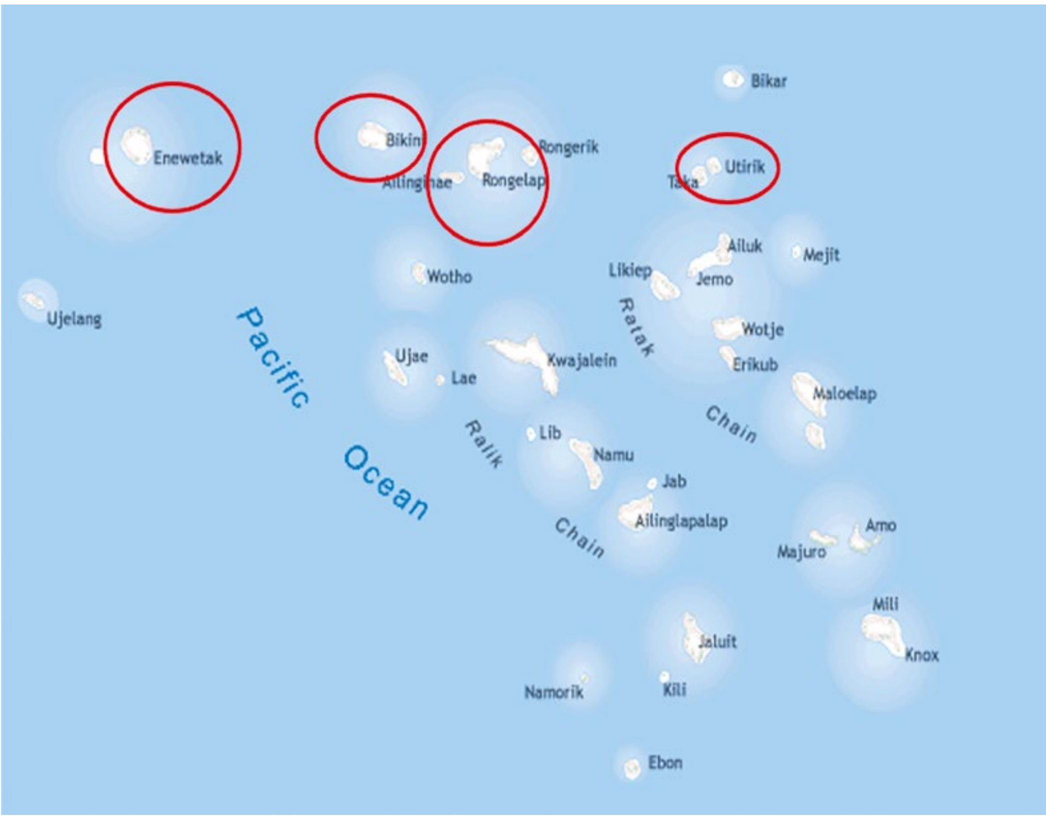
The nuclear legacy of the Marshall Islands would come to include not only the people of Bikini, but also the people of Enewetak Atoll (another northern atoll, where tests began in 1948);[3] the people of Rongelap and Utirik atolls (where populations were exposed to large amounts of radiation during and after the infamous Castle Bravo test); and many other atolls of the Marshall Islands, which have been negatively impacted to various degrees by radiation, displacement, and other challenges stemming from the testing programme.[4] In addition to the devastation the Indigenous populations suffered, more than 42,000 US military and civilian personnel participated in the programme, with thousands becoming atomic veterans in the process.[5] Another 6,000 veterans were involved in an extensive clean-up of Enewetak Atoll from 1978 till 1980.[6] The legacy of suffering, including the physical and mental health impacts, continues for all of these affected groups as well as their descendants.

The first tests, code-named Able and Baker, which formed part of Operation Crossroads, were conducted in the Bikini lagoon in July 1946. By July 1958, when the testing programme ended, the United States had conducted

1 'I want our people to experience justice', Blog post, *Pacific Island Times*, 1 March 2024, at: https://bit.ly/44WsfaC.
2 J. Niedenthal, 'A history of the people of Bikini following nuclear weapon testing in the Marshall Islands: With recollections and views of elders of Bikini Atoll', *Health Physics*, Vol. 73, No. 1 (July 1997), 28–36.
3 S. L. Simon and W. L. Robison, 'A compilation of nuclear weapons test detonation data for U.S. Pacific ocean tests', *Health Physics*, Vol. 73, No. 1 (July 1997), 258–64.
4 G. Johnson, *Don't Ever Whisper, Darlene Keju, Pacific Health Pioneer, Champion of Nuclear Survivors*, Giff Johnson, 2013, 370.
5 Personal communication from Paul Griego, National Association of Atomic Veterans, 1 March 2024.
6 US Department of Veterans Affairs, 'Radiological cleanup At Enewetak Atoll', Last updated 20 September 2023, at: https://bit.ly/42ZQMsM.

a total of 67 nuclear tests in and over the Marshall Islands – 64 in the air and the remainder underwater.[7] The programme included the detonation of thermonuclear bombs as well as fission bombs. The first hydrogen nuclear explosive device, named Ivy Mike, which had an explosive yield equivalent to 680 Hiroshima bombs, was tested on 1 November 1952 in the north of Enewetak Atoll.[8] This was followed by the testing of Castle Bravo on 1 March 1954 in Bikini Atoll, which was the most powerful nuclear weapon that the United States ever tested, equivalent in explosive power to 1,000 Hiroshima bombs. In addition, due to the wind directions on the day of the Bravo test, there was not only massive contamination of Bikini, but also surrounding atolls, many of which, including Rongelap and Utirik, were populated at the time.[9] Whether this was an accident as the United States has maintained, with the yield far higher than expected and an unexpected change in the winds on the morning of the test, is contested.[10] The cumulative yield of all nuclear tests in the Marshall Islands was equivalent to 7,000 Hiroshima bombs.[11] As the Marshall Islands recalled in a statement at the UN in New York in November 2023,

**Figure 1:** **Map of the Marshall Islands, highlighting Enewetak, Bikini, Rongelap, and Utirik Atolls**




7 'Addressing the challenges and barriers to the full realization and enjoyment of the human rights of the people of the Marshall Islands, stemming from the State's nuclear legacy. Report of the Office of the United Nations High Commissioner for Human Rights', UN doc. A/HRC/57/77, 4 September 2024, para. 10. The United States lists 66 nuclear tests as having been conducted in the Marshall Islands, while the Nuclear Claims Tribunal lists 67. The discrepancy is the nuclear test code-named Yucca, which the United States still records as occurring in the Pacific Ocean even though the site was within what is now the Exclusive Economic Zone (EEZ) of the Marshall Islands. In addition, one of the 88 US safety tests (number 146 with zero yield) took place in Enewetak Atoll.

8 The 'George' shot, which was performed on 9 May 1951, was the 'largest fission explosion to date' that 'succeeded in igniting the first small thermonuclear flame ever to burn on earth'. Atomic Archive, '"George" Shot Is Pivotal', undated but accessed 23 September 2024, at: https://bit.ly/4ey8RT9.

9 A. S. Bordner, D. A. Crosswell, A. O. Katz, J. T. Shaha, C. R. Zhanga, I. Nikolic-Hughes E. W. Hughes, and M. A. Ruderman, 'Measurement of background gamma radiation in the northern Marshall Islands', *Proceedings of the National Academy of Sciences of the United States of America*, Vol. 113, No. 25 (2016), 6833–38 at: https://bit.ly/3He9hmM.

10 S. Winchester, *Pacific: The Ocean of the Future*, Harper Collins, 1991, 1–25.

11 M. K. I. L. Abella, M. R. Molina, I. Nikolić-Hughes, E. W. Hughes, M. A. Ruderman, 'Radiological investigations of 4 atolls in the northern Marshall Islands: Background gamma radiation and soil activity concentrations', *Proceedings of the National Academy of Sciences of the United States of America*, Vol. 116 (2019), 15425–34.

UN Trusteeship Resolutions 1082 and 1493 remain the only instances where a UN organ has specifically authorized [nuclear] detonations. These resolutions were passed to deny our petitions to halt testing, and made assurances of our well-being. Despite measures of progress, we remain in pursuit of unmet claims, and of present and future risks of exposure which well exceed our capacity to adequately address. This is not a historical or legacy issue but a major contemporary challenge, and one which our future generations will face.[12]

## Assessments

The nuclear testing programme in the Marshall Islands took place under the auspices of the US Atomic Energy Commission (AEC), which was replaced in 1974 by the Nuclear Regulatory Commission (NRC) and, since 1977, by the US Department of Energy (DoE).[13] To this day, scientists from DoE travel regularly to the northern Marshall Islands to make measurements in impacted areas.[14] However, despite the clear commitment to continuing to collect data and even a willingness to publish at least some of their findings in peer-reviewed scientific journals and in DoE reports, there is an understandable lack of trust on the part of the Marshallese people in the information shared by DoE. Some of this comes simply from the fact that the DoE inherited the work of the AEC, which in the aftermath of the testing assured impacted communities more than once that radiation levels they had been experiencing were safe, only for the Marshallese to find out otherwise.

Peer-reviewed papers published by the Lawrence Livermore Laboratory through to 2010 included a variety of studies addressing radiological contamination and its sources for inhabitants of the northern Marshall Islands, as well as modelling radiation exposure through internal and external pathways.[15] The accuracy of some of this research is questioned, as revealed by a comparison of actual background gamma radiation measurements by Columbia researchers in 2015 compared with the DoE's modelled values.[16] The International Atomic Energy Agency (IAEA) published a report on the radiological conditions in Bikini Atoll in 1998, which included a review of literature, primarily from the DoE, as well as the results of a brief monitoring mission on Bikini Island.[17] The measurements made during the monitoring mission were generally consistent with those stated in the literature reviewed.

A few points need to be made about the IAEA report. First, it only concerns Bikini Atoll, and primarily Bikini Island. Second, it does not distinguish between the vulnerability of different populations to estimated radiation exposure (for example, women and children as compared with adult men).Third, it does not provide values for external gamma radiation measured on Bikini Island, but rather estimates of the overall dose from background gamma radiation that people living on the island would accumulate under specific conditions (spending specific amounts of time in specific parts of the island). Fourth, it uses the units of Bq/g for activity concentrations of different isotopes in soil and in food, rather than Bq/kg, which is the derived SI unit used for IAEA reports and limits.

In their conclusions, the authors of the IAEA report claim that: 'No independent corroboration of the measurements and assessments of the radiological conditions at Bikini Atoll is necessary'. It is also asserted

12 Statement of H.E. Ms. Amatlain E. Kabua Ambassador and Permanent Representative of the Marshall Islands, Second Meeting of States Parties to the Treaty for the Prohibition of Nuclear Weapons (TPNW), New York, 29 November 2023, at: https://bit.ly/3B4bY6R, 1.

13 A. L. Buck, *A History of the Atomic Energy Commission*, Report, Washington, DC, July 1983, at: https://bit.ly/3P7WaEp.

14 Office of Environment, Health, Safety, and Security, 'International Health Studies and Activities', undated but accessed 1 March 2024 at: https://bit.ly/3SVOd6m.

15 W. L. Robison and T. F. Hamilton, 'Radiation doses for Marshall Islands Atolls affected by U.S. nuclear testing: All exposure pathways, remedial measures, and environmental loss of $^{137}$Cs', *Health Physics*, Vol. 98, No. 1 (January 2010), 1–11.

16 Bordner *et al*., 'Measurement of background gamma radiation in the northern Marshall Islands'.

17 IAEA, *Radiological Conditions at Bikini Atoll: Prospects for Resettlement*, Report, Vienna, 1998.

that: ‘Provided certain remedial measures are taken, Bikini Island could be permanently inhabited’, referring primarily to the exceedingly high concentrations of caesium-137 in foodstuffs. In the intervening decades, though, independent measurements and assessments have revealed potential inconsistencies with the earlier research and identified unanswered questions, which reinforce the need for remediation measures in Bikini. The extent to which such measures have been taken is not clear more than 25 years after the IAEA recommended them. In particular, the DoE did not address the strontium-90 hazard, focusing instead on caesium-137 in the environment and remediation of caesium using potassium-based fertilizer.[18]

Independent research has been scant as it is difficult to travel to the Marshall Islands, especially the northern atolls, and to obtain funding for such research. Nevertheless, research teams have conducted a number of studies over the past ten years, including of radiological conditions in a range of atolls in the northern Marshall Islands, with a focus on water,[19] soil,[20] food,[21] and ocean sediment,[22] as well as in wildlife[23] and coral.[24] Some of these results are described in more detail in the section below, ‘Environmental contamination’. Assessments of the impact of radiation exposure on health, which have also been limited in extent, are described in the section below, ‘Human effects’.

## Societal effects and displacement

The nuclear legacy of the Marshall Islands is a patchwork of stories that differ from atoll to atoll and from decade to decade. It is a complex narrative of impacts on various atoll populations and their own histories and relationship to the nuclear testing and its aftermath. Here we briefly describe the history and current state of displacement of Bikini, Enewetak, Rongelap, and Utirik populations, noting that inhabitants of other atolls in the Marshall Islands have also been negatively impacted by the nuclear testing conducted in the 1940s and 1950s.

### Bikini Atoll

Bikinians were the first to be directly affected by the nuclear weapon testing programme in the Marshall Islands.[5] They had to leave their home atoll in March 1946 to make room for the thousands of incoming military personnel, scientists, and engineers, as well as the tests that would start that summer. The Bikinians were relocated by the US military to nearby Rongerik Atoll, which had been uninhabited up to that point, and for good reason. Sustainable food sources, such as coconuts, breadfruit, pandanus, and fish and other seafood from the lagoon, were sparse or inedible and the food supplies that the United States provided to the community were limited. Two months into their stay on Rongerik, Bikinians began pleading to be moved back to their own island; two years after their initial relocation, they escaped near starvation by being moved to Kwajalein Atoll.

18 Email from Giff Johnson, Editor, Marshall Islands Journal, 17 May 2024.

19 K. O. Buesseler, M. A. Charette, S. M. Pike, P. B. Henderson, and L. E. Kipp, ‘Lingering radioactivity at the Bikini and Enewetak Atolls’, *Science of the Total Environment*, Vol. 621 (15 April 2018), 1185–98.

20 H. I. E. Rapaport, I. Nikolic-Hughes, E. W. Hughes, ‘Initial Strontium-90 concentrations in ocean sediment from the northern Marshall Islands’, *Journal of Radiation Research and Applied Sciences*, Vol. 15, No. 1 (2022), 17–20.

21 C. E. W. Topping, M. K. I. L. Abella, M. E. Berkowitz, M. R. Molina, I. Nikolić-Hughes, E. W. Hughes, and M. A. Ruderman, ‘In situ measurement of cesium-137 contamination in fruits from the northern Marshall Islands’, *Proceedings of the National Academy of Sciences of the United States of America*, Vol. 116, No. 31 (15 July 2019), 15414–19.

22 E. W. Hughes, M. R. Molina, M. K. I. L. Abella, I. Nikolić-Hughes, and M. A. Ruderman, ‘Radiation maps of ocean sediment from the Castle Bravo crater’, *Proceedings of the National Academy of Sciences of the United States*, Vol. 116 (2019), 15420–24.

23 C. Conrad *et al.*, ‘Anthropogenic uranium signatures in turtles, tortoises, and sea turtles from nuclear sites’, *PNAS Nexus*, Vol. 2, No. 8 (22 August 2023), 241.

24 J. A. Corcho-Alvarado, C. Guavis, P. McGinnity, S. Röllin, T. Ketedromo, H. Sahli, I. N. Levy, K. de Brum, M. Stauffer, I. Osvath, and M. Burger, ‘Assessment of residual radionuclide levels at the Bokak and Bikar Atolls in the northern Marshall Islands‘, *Science of the Total Environment*, Vol. 801 (20 December 2021), 149541.

In Kwajalein, the Bikinians lived in tents next to a US Navy runway for six months, before being moved yet again to Kili Island and to Ejit Island, where most of the population has been living ever since.[11] Kili Island is not an atoll and therefore lacks a lagoon. This has led not only to ongoing challenges with having sustainable food sources, but also to a loss of cultural practices, as the life of people in the atolls revolves around the lagoon. From 1970 until 1978, a portion of the population moved back to Bikini Island, only to learn from the DoE scientists that they were internally accumulating large amounts of caesium-137 (one of the main radioactive isotope contaminants), and to have no choice but to go back to Kili or Ejit Island in the Majuro Atoll. Bikini remains unpopulated to this day, with only temporary caretakers living on the island for months at a time.[10]

### Enewetak Atoll

Enewetak Atoll was the second site of nuclear testing, with detonations starting in 1948.[6] The people of Enewetak were moved off the atoll to make room for the testing in December 1947. Like the Bikinians, they were moved to an uninhabited atoll (Ujelang), where land and food availability were both far more limited than in Enewetak.[25] They remained there until 1980, at which point most of the population moved back to Enewetak following the extensive radiological clean-up effort conducted by the United States in 1978–80. But this clean-up effort, which involved removal of top-soil to eliminate the radioactive contamination, did not extend to most islands in the atoll. Moreover, on remediated islands, native crops, such as coconuts, breadfruit, and pandanus were no longer as plentiful or as large and nutritious as they were prior to the testing. This is because the removal of topsoil also led to the removal of existing trees as well as nutrients to support fruit and crop growth. In turn, lack of reliable and sustainable food sources has made the Enewetak population heavily dependent on deliveries of processed food by ship a few times a year.[23]

Finally, the small population that lives in the south of the Enewetak Atoll, is located some 15 miles from the Runit Dome, the nuclear waste repository that houses the nuclear waste from the Enewetak clean-up and, as was reported recently, even the Nevada test site in the United States.[26] Much has been written about the Runit Dome and the fact that sea level rise and more frequent or powerful storms threaten the structural integrity of the concrete covering radioactive waste.[27] Dr Terry Hamilton, the lead scientist for Marshall Islands studies at the Lawrence Livermore National Laboratory, thus stated in a 2014 report:

> If the Cactus crater concrete containment structure on Runit Island were located in the United States proper (or subjected to U.S. regulatory authority), it would be formally classified as a Low-Level Radioactive Waste Disposal Site and be subject to stringent site management and monitoring practices. A long-term groundwater monitoring program would almost certainly form an integral part of these activities.[28]

Yet in the 44 years since the US government completed the Runit Dome, there has been no 'stringent site management' despite the presence of a civilian community nearby. Moreover, the DoE only began monitoring the dome when the US Congress, in response to appeals from Enewetak and Marshall Islands leaders, adopted public law 112-149 in July 2012.[29]

25 K. Wall, 'The Poison and the Tomb: One family's journey to their contaminated home', Mashable, 2015, at: https://bit.ly/439lXlp.
26 S. Rust, 'Radiation in parts of the Marshall Islands is far higher than Chernobyl, study says', *Los Angeles Times*, 2019, at: https://lat.ms/3V3zwkc.
27 M. Gerard, 'America's Forgotten Nuclear Waste Dump in the Pacific', *SAIS Review of International Affairs*, Vol. 35 (2015), 87–97.
28 T. Hamilton, *A Visual Description of the Concrete Exterior of the Cactus Crater Containment Structure*, Report LLNL-TR-653147, Lawrence Livermore National Laboratory, February 2014, Executive Summary, 2.
29 Email from Giff Johnson, 17 May 2024.

### Rongelap Atoll

Rongelap Atoll, located about 100 miles from Bikini, was on a direct path of the fallout from the Castle Bravo test. About four hours after the detonation, radioactive debris reached the atoll, leaving in a short amount of time a layer about five centimetres thick. Children played in the fallout thinking that it was snow. But by nightfall, the population was experiencing acute radiation sickness, with vomiting, diarrhoea, headaches, skin itching, and eventually skin burning and hair falling out.[30] An evacuation was not carried out until two days after the test, at which point those affected were taken to Kwajalein Atoll, where they lived in tents by the airstrip. Later in 1954, the Rongelap people were moved to Ejit Island in Majuro Atoll, where US authorities built a small temporary village for the displaced Rongelap islanders. They remained there until 1957, when they were returned to Rongelap Atoll.

At that time, the AEC claimed that the atoll was safe for re-habitation even though it had not undergone any nuclear clean-up. Indeed, Dr Robert Conard of Brookhaven National Laboratory noted that having the Rongelapese return to their home atoll 'affords the opportunity for a most valuable ecological radiation study on human beings. The various radionuclides present on the island can be traced from the soil through the food and into the human being'.[31]

Both exposure to the fallout from Bravo and the subsequent return have led to the long-standing view that the people of Rongelap were used as guinea pigs in radiation experiments. In 1985, the Rongelap representative in the Marshall Islands Parliament, Senator Jeton Anjain, contacted Greenpeace, asking the organization to take his people to Mejatto Island in Kwajalein Atoll. The 10-day evacuation aboard the *Rainbow Warrior* has been described in detail.[32] The people of Rongelap have yet to return to their homes.

### Utirik Atoll

Utirik Atoll suffered a similar fate to Rongelap on the day of Bravo, although with a smaller overall exposure, given that it is located farther away from Bikini (480 kilometres).[33] Utirik Island was evacuated of its residents three days after the fallout reached them and transported to Ebeye Island on Kwajalein Atoll. In May 1954, just a few months after the Bravo test, they returned to Utirik where they have been living ever since.

## Human effects

### The impact on Indigenous populations

There is good evidence that people living in the northern Marshall Islands in the decades since the testing were living in contaminated environments that have had a huge and long-term negative impact on their health. What is missing is a comprehensive medical assessment of those long-term impacts. Evaluation of the ongoing health impacts on the affected Indigenous populations in the Marshall Islands must include specific contexts of each community's history.

30 See, e.g., J. A. Schwartz, '"A 'Voice to Sing": Rongelapese Musical Activism and the Production of Nuclear Knowledge', *Music and Politics*, Vol. 6, No. 1 (Winter 2012), at: https://bit.ly/44YdqEr; B. McDiamid, 'A defining moment in history: 40 years ago, the Marshall Islands fought to protect their future and defied the US', Greenpeace, 6 June 2025, at: https://bit.ly/4lTQRGR.

31 G. Alcalay, 'Human Radiation Experiments in the Pacific', Nuclear Age Peace Foundation, 21 March 2014, at: https://bit.ly/439m5kT.

32 B. Hoffman, 'Mejato Diary', Eyes of Fire, 1985, at: https://bit.ly/3UXBiDC.

33 W. L. Robison et al., 'Utirik Dose Assessment', Report, Lawrence Livermore National Laboratory, 1999.

When it comes to physical health, radiation-specific impacts and other health impacts have resulted from the loss of land and cultural and sustainable practices and the concomitant reliance on imported foods and an unhealthy diet largely consisting of rice and canned and preserved products. This contrasts starkly with the fresh food diet of fish, seafood, and locally grown fruits and crops prevalent throughout the nation prior to the nuclear testing. The first category includes various cancers as well as negative maternal health outcomes, such as miscarriages and congenital anomalies.[34] The second category includes a wide variety of health ailments, including diabetes, which today is present in about one third of the population.[35]

Exposure to radiation occurred in different contexts for populations from different atolls. Two types of exposures are the short-term exposure to radioactive fallout in the immediate aftermath of Bravo for populations living nearby, including on Rongelap and Utirik, and the long-term exposure to radioactive contamination remaining, for example for people living in Rongelap (1957–86), those living in Utirik following their return three months after Bravo to this day, for Bikinians who lived in Bikini in 1970–78, and—which is ongoing—for those living on Enewetak since 1980 and who might visit contaminated islands in their atoll, including Runit, which is home to the Runit Dome. Those living on many other islands and eating locally grown food that contained radioactivity were never acknowledged by the US government as having suffered radiation exposure. This is despite the findings of a 1955 US study on the Castle Bravo test series (formerly classified secret), which confirms that the islanders were exposed to fallout from Bravo and most of the other tests in the series.[36]

One of the critical markers of short-term exposure to radioactive fallout in the hours and days following a nuclear test is the exposure to the short-lived isotope iodine-131. With a half-life of only eight days, this isotope disappears from the environment in a matter of weeks. In the case of the Bravo explosion, the amount of iodine-131 was very large (1.4 billion curies),[37] leading to the accumulation of this highly radioactive isotope in the thyroid gland of the exposed populations. With the thyroid bioaccumulating iodine-131, the risk of thyroid cancer or other problems with the thyroid is expected to grow; this has been shown to be dose-dependent in children.[38] Although the United States established a project to study the populations exposed to Bravo fallout in Rongelap and Utirik (Project 4.1), that investigation was short-lived (76 days after exposure) and, to this day, the picture of long-term health effects of the exposure to significant radiation in the immediate aftermath of Bravo is limited.[39] Rather than presenting the long-term health outcomes of those locally exposed to Bravo fallout and their descendants, a number of subsequent studies have focused on people in Majuro and Ebeye Islands, where the dose from nuclear testing may have been far smaller than it was in the northern atolls of the country.[40]

Maternal health was impacted dramatically following Bravo – impacts that were not just limited to Rongelap and Utirik Atolls, but which extended to another eight atolls and possibly more. In the early 1990s, Professor Glenn Alcalay studied the maternal health of women on ten atolls in the Marshall Islands and recorded adverse events, including miscarriages and congenital anomalies, before and after the Bravo test.[41] His data attest to

34 WHO, 'Radiation and Health', 7 July 2023, at: https://bit.ly/3P4EfhU.

35 B. C. Davis, H. Jamshed, C. M. Peterson, J. Sabaté, R. D. Harris, R. Koratkar, J. W. Spence, and J. H. Kelly Jr., 'An Intensive Lifestyle Intervention to Treat Type 2 Diabetes in the Republic of the Marshall Islands: Protocol for a Randomized Controlled Trial', *Frontiers in Nutrition*, Vol. 6, Art. 79 (5 June 2019), at: https://bit.ly/3SZr7Mk.

36 A. J. Breslin and M. E. Cassidy, *Radioactive Debris from Operation Castle. Islands of the Mid-Pacific*, Report, US Atomic Energy Commission, New York, 18 January 1955.

37 R. Alvarez, 'The Fallout Never Ended', *Bulletin of the Atomic Scientists,* 1 February 2024, at: https://bit.ly/3uYU42T.

38 L. H. Hempelmann, 'Risk of Thyroid Neoplasms after Irradiation in Childhood', *Science*, Vol. 160, No. 3824 (12 April 1968), 159–63.

39 E. P. Cronkite, V. P. Bond, L. E. Browning, W. H. Chapman, S. H. Cohn, R. A. Conard, C. L. Dunham, R. S. Farr, W. S. Hall, R. Sharp, and N. R. Shulman, 'Study of Response of Human Beings Accidentally Exposed to Significant Fallout Radiation, Operation CASTLE, Final Report Project 4.1', Naval Medical Research Institute, Naval Radiological Defense Laboratory, Report WT-923, Oak Ridge National Laboratory, October 1954.

40 T. Takahashi, S. L. Simon, K. R. Trott, K. Fujimori, N. Nakashima, K. Arisawa, and M. J. Schoemaker, 'A Progress Report of a Marshall Islands Nationwide Thyroid Study: An International Cooperative Scientific Study', *Tohoku Journal of Experimental Medicine*, Vol. 187 (1999), 363–75, at: https://bit.ly/49IqCNS.

41 G. Alcalay, 'Marshall Islands Stands at a New "Crossroads"', Physicians for Social Responsibility Newsletter, V3, 1996.

very low levels of such adverse events across all of the studied atolls before Bravo (ranging from 0–0.1 per woman or about 0.06 per woman, on average), with no geographic pattern to the data for the time period in 1951 and before. His data also suggest a large increase in such adverse effects after Bravo across all of the studied atolls (ranging from 0.4–1.05 per woman or about 0.7 per woman on average), with the number increasing the closer the atoll was to Bikini. In fact, Rongelap and Utirik were found to have the highest number of adverse births per woman, although the effects were large and all far above the levels before Bravo on eight other atolls. Anecdotal evidence with women talking about and describing their miscarriages and 'jellyfish' babies is also abundant.[42]

While the physical health impacts of nuclear testing have been understudied and the affected populations left without adequate support, the picture is even grimmer for studies of mental health impacts and the provision of mental health support to the Marshallese.[43] Pacific populations more generally have been recognized as particularly vulnerable to suicide.[44] In 1987, 21 men and a woman took their own lives in the Marshall Islands, which at the time had a population of 35,000.[45] The use of alcohol and other illicit substances has been implicated in these suicides.[46] Further research into the role that nuclear testing and the resulting societal impacts have had on mental health of people in the Marshall Islands is needed.

The Marshallese social well-being and culture were deeply impacted by nuclear testing and particularly so for populations in the northern Marshall Islands, which suffered due to relocations, loss of land and sustainable practices, and negative health impacts of radiation exposure (see the section above, 'Societal effects and displacement').

### The impact on military personnel

Military personnel involved in the Marshall Islands nuclear testing include veterans present and participating in the nuclear tests in 1946–58. They are recognized by the United States as atomic veterans for the purpose of the Radiation Exposure Compensation Act (RECA), which was enacted in 1990 and which expired at the end of June 2024,[47] before being resuscitated in July 2025.[48] But RECA never covered the US military servicemen who were involved in the Enewetak nuclear clean-up in 1977–80, and it was only in 2021 that US Congress passed legislation making them eligible for Veterans Administration medical care.[49]

Atomic veterans represent one of five categories of RECA claimants, all of which must have or had one of nineteen specific cancers. When RECA expired in 2024, their descendants became no longer eligible for compensation until the scheme was revived in June 2025. In addition to military personnel, civilian contractors were also involved in both the testing programme and the clean-up efforts. They are not included in RECA as potential claimants.

42 'Interviews and Music', Atomic Atolls Archives, at: https://bit.ly/3T9zS6C.
43 G. Johnson, 'US Blocks Release of Mental Health Resources', Radio New Zealand, 16 May 2022, at: https://bit.ly/3P51ybq.
44 S. Mathieu, D. de Leo, Y. W. Koo, S. Leske, B. Goodfellow, and K. Kõlves, 'Suicide and suicide attempts in the Pacific Islands: A Systematic Literature Review', *The Lancet Regional Health – Western Pacific*, 30 September 2021, at: https://bit.ly/48CwUgA.
45 D. C. Scott, 'Pacific Islands Battle High Suicide Rates Among Youth', *Christian Science Monitor*, 18 May 1989, at: https://bit.ly/3uSimvr.
46 V. A. Seaton, T. A. Dickey, M. L. Balli, B. E. Briggs, J. D. Baker, and J. S. Hudson, 'Rate of positive depression screenings among Marshallese patients with diabetes in Northwest Arkansas', *Mental Health Clinician*, Vol. 9, No. 1 (4 January 2019), 36–40.
47 US Department of Justice, Civil Division, 'Radiation Exposure Compensation Act', Updated 1 March 2024, at: https://bit.ly/3JZEB7O.
48 See, e.g., F. Guillen, 'More Americans can get compensated for nuclear poisoning. But there's a catch', *Missouri Independent,* 28 July 2025, at: https://bit.ly/46DejUj.
49 Email from Giff Johnson, 17 May 2024. See: https://bit.ly/3QQ2Asy.

### Transgenerational human effects

Whether transgenerational effects of radiation exposure via genetic changes and subsequent predisposition to diseases caused by radiation exist continues to be a subject of scientific contestation in some quarters.[50] What is undeniable, particularly for the Marshall Islands, is that the descendants of those who were originally moved from their lands or exposed to short- or long-term radiation contamination or both, have a range of health consequences, including some that simply arise from forced relocation and loss of home and sustainable practices, such as high rates of diabetes.

## Victim assistance

Ongoing victim assistance needs in the Marshall Islands range from medical assistance for health issues resulting directly and indirectly from nuclear testing, socio-economic inclusion for victims and their descendants, and the need for a nationwide, comprehensive epidemiological radiological survey. Based on limited knowledge, remediation needs persist for atolls that have already been found to still contain high levels of radioactive fallout. The environmental survey and remediation needs blend in with victim needs because they could prevent further victimization and potentially allow populations that have been away from their islands for decades to finally return home.

Victim assistance efforts during and in the decades following the US nuclear weapon testing programme in the Marshall Islands were virtually non-existent and limited to modest medical assistance for the population exposed to Bravo on Rongelap Atoll, whereby the Marshallese victims travelled to Brookhaven National Laboratory for evaluation and treatment.[51]

The situation changed somewhat when the people of Enewetak, Bikini, Rongelap and Utirik Atolls and other Marshall Islanders initiated lawsuits in United States courts in the 1980s against the United States for property damages and other harms arising from the nuclear tests. The damages claimed in these lawsuits amounted to more than $5 billion.[52] At that time, the United States and the Marshall Islands signed the Compact of Free Association (COFA).[53] COFA defined the relationship between the two States and provided financial assistance to the Marshall Islands, initially for the period 1986–2003. This was followed by an amended COFA, which provided financial assistance through to 2023. The initial COFA included an additional Section 177 Agreement, as part of which, a $150 million Nuclear Fund was established. Income from this fund was designated for the people of Bikini, Enewetak, Rongelap, and Utirik Atolls as 'a means to address past, present and future consequences of the Nuclear Testing Program'. Income was also earmarked to fund a Nuclear Claims Tribunal to be established with 'jurisdiction to render final determination upon all claims past, present and future, of the Government, citizens and nationals of the Marshall Islands which are based on, arise out of, or are in any way related to the Nuclear Testing Program'. The Section 177 Agreement also states that it constitutes the full settlement of all claims, 'past, present and future', of Marshall Islanders and their government against the United States arising from the testing programme. Another section of COFA provides that all such claims pending in US courts are to be dismissed (an espousal clause also prohibits the Marshall Islands from suing the United States).

50 T. Nomura, 'Transgenerational effects of radiation and chemicals in mice and humans', *Journal of Radiation Research*, Vol. 47, Suppl. (2006), B83–B97.
51 R. A. Conard, W. W. Sutow, H. Eugene MacDonald, D. Karnofsky, Leo M. Meyer, A. A. Jaffe, S. Cohn, and E. Riklon, 'Medical Survey of Rongelap People Seven Years After Exposure to Fallout', BNL 727 (T-26), Atomic Energy Commission, United States, 1962, at: https://bit.ly/3ILN8cR.
52 D. Pevec, 'The Marshall Islands Nuclear Claims Tribunal: The Claims of the Enewetak People', *Denver Journal of International Law and Policy*, Vol. 35 (2006), 3221.
53 US Department of Interior, Office of Insular Affairs, 'Compacts of Free Association', Updated 5 March 2024, at: https://on.doi.gov/4bWCNYV.

COFA was renegotiated prior to its 2023 expiration. At the time of writing, Congress was yet to pass legislation that would enable disbursement of the funding.[54] The renegotiated agreement was supposed to have provisions to address the nuclear legacy[55] but the US Department of State prohibited any reference to 'nuclear' in the revised Compact funding agreements. It had also been hoped that there would be a reference in the new compact to an expansion of definition of affected atolls beyond the four that were designated in earlier versions of the agreement.

The United States enacted RECA in 1990, as described in the subsection above, 'The impact on military personnel'. This law, which had expired at the end of June 2024, but which was renewed in July 2025, has provided compensation to victims of nuclear weapon testing and development, as well as their descendants, including people living downwind of the Nevada test site. While military personnel who participated in the Marshall Islands testing have been covered by RECA, Marshallese people who were downwind of Bravo and other tests were never included.

On 10 October 2024, the United Nations Human Rights Council adopted Resolution 57/26: 'Technical assistance and capacity-building to address the human rights implications of the nuclear legacy in the Marshall Islands' without a vote. The resolution urged 'States, all relevant United Nations agencies, as one United Nations, and other stakeholders to support the Government of the Marshall Islands in its efforts to improve the health of its people and environment' and asked the Office of the UN High Commissioner for Human Rights (OHCHR) to provide 'technical assistance and capacity-building to the National Nuclear Commission of the Marshall Islands in advancing its national strategy for nuclear justice'.[56]

## Environmental contamination

A small group from Columbia University (that included one of the authors of the present case study, Ivana Nikolić Hughes) was able to visit four atolls in the northern Marshall Islands (Bikini, Enewetak, Rongelap, and Utirik) in 2015, 2017, and 2018. On these trips, the group measured external gamma radiation, activity concentrations of various isotopes in the soil and ocean sediment, and activity concentrations of caesium-137 in food. An independent study, looking at radiological signatures of human-made isotopes in green sea turtles, and soil, has indicated that radiological contamination in the northern Marshall Islands persists.[57] Two areas of future work are suggested: a comprehensive nationwide survey of radiological conditions; and remediation efforts for areas found to have contamination levels beyond those safe for a multigenerational community to be living in full time.

The picture of the radiological conditions in the Marshall Islands, painted by the scientific research, is complex. It is one that is deeply intertwined with the histories of the different atolls, but also impacted by predicted and predictable weather and other patterns, as well as random effects. In summary, the Columbia research team found high external gamma radiation on Bikini Island in Bikini Atoll and on Naen Island in Rongelap Atoll, as well as elevated levels on Enjebi Island in Enewetak Atoll. The team also found high levels of different isotopes (caesium-137, americium-241, plutonium-238, plutonium-239, and plutonium-241) in the soil samples from Naen Island, Runit Island in Enewetak Atoll, and Enjebi Island in Enewetak Atoll.[58]

54 N. Maclellan, 'RMI President questions US commitment on COFA funding', *Island Business*, March 2024, at: https://bit.ly/3uZZ6fw.
55 J. Niedenthal, 'For the Marshall Islands, Nuclear Remembrance Day is a Painful Reminder', US Institute of Peace, March 2024, at https://bit.ly/3Ipti6J.
56 Human Rights Council Resolution 57/26; adopted without a vote on 10 October 2024, at: https://bit.ly/3Z1TpIY, operative paras. 2 and 3.
57 C. Conrad *et al.*, 'Anthropogenic uranium signatures in turtles, tortoises, and sea turtles from nuclear sites', *PNAS Nexus*, Vol. 2, No. 8 (August 2023), at: https://bit.ly/4mlWbTj.
58 Bordner *et al.*, 'Measurement of background gamma radiation in the northern Marshall Islands'.

A study of the presence of caesium-137 revealed high levels of contamination in the fruit from Bikini Island (primarily coconuts, breadfruit, and pandanus), some of which violate even the most permissive standards for this isotope in the food (the US Food and Drug Administration sets the limit at 1,200 Bq/kg), while food in a few other islands (Enyu Island in Bikini Atoll and Naen and Rongelap Islands in Rongelap Atoll) had levels of this isotope that violated the Japanese limit on the presence of this isotope in food. A study of ocean sediment revealed that the bomb craters, including the crater created by the Bravo test, have sediment contaminated by caesium-137, americium-241, plutonium-238, plutonium-239, and plutonium-241. The presence of high levels of strontium-90 in the ocean sediment suggests that the presence of this isotope should be further investigated in the food.[59]

## Environmental remediation

The most robust results from the Columbia studies pertain to Bikini Island and Bikini Atoll, where, absent serious remediation efforts, a multigenerational community should not live full-time. Radiological contamination is present in inner parts of the island and tapers off towards the beaches. Careful consideration of remediation methods should be undertaken to decide on the best strategies to finally clean Bikini Island and Bikini Atoll and to return it to the Bikinians who have been in exile for 78 years.[60]

Further research into the conditions on Enewetak, Rongelap, Utirik, and elsewhere is of critical importance. Regarding Enewetak, the structural integrity of the Runit Dome must be investigated further and consideration given to the possibility of moving the nuclear waste away from Runit and the Enewetak Atoll. There are currently no planned environmental remediation efforts. In 2024, however, OHCHR released a report urging the United States to

> Assist, upon the invitation of the Government of the Marshall Islands, in improving local capacity to respect, protect and fulfil all human rights affected by the nuclear legacy and implementing the nuclear justice strategy, including through monitoring, repairing and remediating all contaminated sites in the Marshall Islands.[61]

Further, the report recommended that the international community more broadly should 'complement the pursuit of transitional justice by strengthening local capacities in the Marshall Islands for victim assistance and environmental remediation'.[62]

## The impact of climate change[63]

The Marshall Islands face a diverse set of risks from climate change but data and reliable model projections are lacking. The World Bank adaption project in the Marshall Islands included the development of interactive mapping to highlight different sea level rise scenarios, although it covered only Majuro and Ebeye and did not refer to legacy issues from nuclear tests.[64] Bikini is one of the highest lying islands in the Marshall Islands, but cannot provide refuge because it is still too contaminated.

59 Ibid.
60 H. Rapaport, and I. Nikolić-Hughes, 'After 75 years, it's time to clean Bikini', *Bulletin of the Atomic Scientists*, March 2021, at https://bit.ly/3v7XiB3.
61 'Addressing the challenges and barriers to the full realization and enjoyment of the human rights of the people of the Marshall Islands, stemming from the State's nuclear legacy', OHCHR Report, UN doc. A/HRC/57/77, 24 September 2024, para. 74(b)(iv).
62 Ibid.
63 This section was contributed by Linsey Cottrell.
64 The World Bank, 'Adapting to rising sea levels in Marshall Islands', 2021, at: https://bit.ly/48MnY8g.

The DoE has highlighted the impact of rising sea levels on the Runit dome, and risk from the physical effects of storm surges and wave-driven flooding, noting in 2020 that the proposed groundwater radiochemical analysis programme is designed to evaluate the possible effects of changes in groundwater quality and the long-term consequences.[65] This could include an increase in radionuclide uptake into marine biota, placing consumers of marine foods at potentially elevated risk. An understanding of the mechanisms and attempt to quantify radiation exposure levels was reported as essential, although anticipated to equate to a 'very low added risk' to human health.[66]

A summary of trends and potential climate-related impacts is given in Table 1.

**Table 1: Summary of key climate trends and impacts, the Marshall Islands**[67, 68]

<table>
<tr><th>Climate system/ hazard</th><th>Historic trends</th><th>Projected trends</th><th>Possible impact on risk components</th></tr>
<tr><td>Temperature</td><td>Increasing</td><td>Localised temperature increases are expected</td><td rowspan="5">Source: changes in physico-chemical behaviour and leaching, affecting mechanisms by which contaminants may be released. Includes physical landform changes and erosion caused by sea-level rise, storms, high winds, or wave action<br><br>Pathway: changes in water infiltration, water tables/sea-levels, flow rates, and ocean currents<br><br>Receptor: changes in species assemblages and/ or sensitivity to contaminants. Shift in people's proximity/exposure routes to sources</td></tr>
<tr><td>Precipitation</td><td>Little change</td><td>Long-term average is likely to be wetter, yet uncertain regarding short- and medium term. An increase in the frequency and intensity of extreme rainfall events likely</td></tr>
<tr><td>Drought</td><td>Drought conditions in recent years (2013 and 2015)</td><td>Uncertain, but expected to decrease*</td></tr>
<tr><td>Sea level rise</td><td>Sea level rise impacting low-lying islands</td><td>Sea-level rise threatens long-term encroachment on coastal areas and a projected increase in the frequency of extreme sea-level events</td></tr>
<tr><td>Flood, cyclones, and storm surge</td><td>Cyclones have historically affected the Marshall Islands, with 18% (in 1977–2011) recorded as severe events</td><td>Frequency of cyclones may decline, yet sea-level rise may enhance cyclone-induced storm damage, and wind speeds and precipitation intensity may increase*</td></tr>
</table>

* Projections uncertain

## Legal issues

### Individual compensation schemes

The Nuclear Claims Tribunal, established following the initial COFA between the United States and the Republic of the Marshall Islands in 1986, made awards of more than $2.3 billion, which included funds for loss of use, cost to restore, and hardship for communities of Bikini, Enewetak, Rongelap, and Utirik Atolls. These funds included both compensation for individuals, as well as for the atoll communities as a whole, but were

65 US Department of Energy, 'Report on the Status of the Runit Dome in the Marshall Islands', Report to Congress, June 2020, at: https://bit.ly/3ugLDL5.

66 T. Hamilton, 'Marshall Islands Dose Assessment and Radioecology Program', Report, Lawrence Livermore National Laboratory, December 2021, at: https://bit.ly/3TqE0jl.

67 Climate Risk Country Profile: Marshall Islands, The World Bank Group, 2021, at: https://bit.ly/3TuthF9.

68 ThinkHazard! High-level hazard profile for the Marshall Islands, at: https://bit.ly/48PQSo5.

only paid in part. By the time that the Tribunal stopped paying awards (2006), it had approved US$91,402,000 in individual personal injury awards, but it only had the funds to make partial payments totalling $73,261,198, leaving an unpaid balance of $18,140,802.[69]

Prior to the Marshall Islands' independence, the US government had made *ex gratia* compensation payments to communities on the 'Four Atolls' (Bikini, Enewetak, Rongelap, and Utirik), which it considered as those affected by its atmospheric nuclear test programme. But the payments were wholly inadequate to address the long-term humanitarian impact. As a result, the Marshall Islands has sought to address the ongoing nuclear legacies through its Compacts of Free Association (COFA) with the United States. The 1986 COFA set up a trust fund of $150 million to pay claims relating to the impact of the test programme, ostensibly releasing the United States from further liability. The United States did not apologize for the harm caused by the nuclear tests, framing this compensation as a recognition of the 'contributions and sacrifices made by the people of the Marshall Islands', rather than as reparation for any wrongdoing. It also limited eligibility for such compensation to the Four Atolls.[70] Responsibility for assessing applications for compensation for medical and property damage caused by nuclear testing was entrusted with a Marshallese institution, the Nuclear Claims Tribunal.[71]

However, post-Cold War declassification of previously secret documents revealed more extensive nuclear test impacts than Marshallese leaders understood during the first COFA negotiations[72] and US-sponsored environmental remediation of affected atolls has proceeded very slowly.[73] The Nuclear Claims Tribunal eventually found approximately US$4 billion in valid claims from individuals and communities from the Four Atolls against the United States.[74] According to the US Congressional Research Service, the US has provided 'roughly $600 million for damages, environmental clean-up and restoration, resettlement, and health and medical programs'.[75] The Marshall Islands also asserts that more recently declassified documents demonstrate that the humanitarian impact of atmospheric testing extended far beyond the Four Atolls. The recent addition of Guam, a US territory in the Pacific, to the list of areas considered eligible for RECA compensation suggests the United States acknowledges that the fallout from tests in the Marshall Islands was more widespread than earlier admitted.[76] Nevertheless, the US government continues to assert that it has made a 'full and final settlement of all claims relating to the nuclear testing program' in the Marshall Islands.[77]

While not explicitly acknowledged as such by the United States,[78] the 2023 COFA includes a US$700 million trust fund that the RMI government declares will be used to address the needs of those affected by the nuclear testing programme.[79] Nevertheless, a great shortfall still exists between the scale of the impact identified by the Nuclear Claims Tribunal and the compensation and assistance provided by the United States. This is consistent with findings of other studies of efforts to address environmental pollution through a legalistic

69 Nuclear Claims Tribunal, Republic of the Marshall Islands, Last updated 2007, at: https://bit.ly/3V43xjC .
70 'Agreement Between the Government of the United States and the Government of the Marshall Islands for the Implementation of Section 177 of the Compact of Free Association', available at: https://bit.ly/3Is37w8.
71 Ibid.
72 'Statement of Muller, Phillip, Minister of Foreign Affairs and Trade, Republic of the Marshall Islands', 1998, *Joint Oversight Hearing before the Committee on Resources and Subcommittee on Asia and the Pacific of the Committee on International Relations: House of Representatives: One Hundred Fifth Congress: Second Session*, Serial No. 105–117, US Government Printing Office, Washington, DC, at: https://bit.ly/3IpRaHz, 39.
73 B. R. Johnston and B. Takala, 'Environmental Disaster and Resilience: The Marshall Islands Experience Continues to Unfold', *Cultural Survival*, 20 September 2016, at: https://bit.ly/3PtQiWr.
74 Republic of the Marshall Islands, 'First Committee, 26th plenary meeting - General Assembly, 78th session', 2023, Video 47:46 to 52:44; and D. G. Kimball, 'U.S., Marshall Islands Sign Deal on Nuclear Testing Impacts', *Arms Control Today*, March 2023, at: https://bit.ly/49DZzmy.
75 Congressional Research Service, 'The Compacts of Free Association', In Focus, Washington, DC, Updated 13 November 2023, at: https://bit.ly/3uSMqah, 2.
76 Johnson, 'Marshall Islands reacts to US expansion of nuclear compensation'.
77 US Mission to International Organizations in Geneva, 'U.S. Explanation of Position on the Marshall Islands' Nuclear Legacy Resolution', 7 October 2022, at: https://bit.ly/3P5xJrl.
78 K. Hawkins, 'Marshall Islands signs Compact III with the United States', *RNZ Pacific*, 18 October 2023, at: https://bit.ly/49Cr53Y.
79 Congressional Research Service, 'The Compacts of Free Association', 2.

model of liability. While such schemes can be helpful, without independent recourse the perpetrators of harm often dictate the extent of their liability.[80]

### Court judgments

As described in the section on Victim Assistance, the Section 177 Agreement of the Compact of Free Association negotiated between the United States and the Republic of the Marshall Islands in 1986 prevented any further claims being made in US courts regarding the nuclear weapon testing programme. There have been no further legal cases or judgments besides the awards made by the Nuclear Claims Tribunal (see previous subsection on Individual compensation schemes).

### Intergovernmental compensation and reparation

In 2017, the Government of the Marshall Islands established a National Nuclear Commission to further claims for accountability and to address the harms caused by the US nuclear testing. In 2020, the Commission published its nuclear justice strategy with the following five goals:

**Goal 1:** All unpaid and partially paid personal injury and property damage awards issued by the Tribunal be fully paid, and funding be provided to support future claims.

**Goal 2:** All Marshallese have access to quality healthcare, wherever they reside, not just in the Marshall Islands.

**Goal 3:** To support comprehensive and holistic research throughout the Marshall Islands to inform communities on the levels of radioactive contamination and toxins in their environment and empower decision-makers to take necessary and appropriate action.

**Goal 4:** The Marshall Islands possesses the national capacity to collect, analyse, and act on information regarding levels of radiation and toxic contaminants, and their impacts to human health and the environment.

**Goal 5:** Present and future generations of Marshallese possess strong awareness of all aspects of the US nuclear testing programme in the Marshall Islands.[81]

Human Rights Council Resolution 51/35, adopted in 2022, may have the potential to spur intergovernmental compensation and reparation and satisfaction of at least some of these nuclear justice goals. In its report of 24 September 2024 in accordance with Resolution 51/35, OHCHR concluded that:

> The Government of the United States, which has itself acknowledged responsibility for the impacts of the nuclear tests and taken measures to address them, should take further measures necessary to provide full and effective remedies. To effectively address its impacts, a greater understanding of how the nuclear legacy has hindered the full realization of all human rights, and concomitant remedial action, are needed.[82]

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80 B. K. Marshall, J. S. Picou and J. R. Schlictmann, 'Technological Disasters, Litigation Stress, and the Use of Alternative Dispute Resolution Mechanisms', *Law & Policy*, Vol. 26, No. 2 (2004), 289–307.

81 The Marshall Islands National Nuclear Commission, *Nuclear Justice for the Marshall Islands: A Strategy for Coordinated Action, FY2020–FY2023*, at: https://bit.ly/4c1CvzW.

82 'Addressing the challenges and barriers to the full realization and enjoyment of the human rights of the people of the Marshall Islands, stemming from the State's nuclear legacy', OHCHR Report, para. 72.

Chapter 17:

# Addressing the Impact of Testing by the United Kingdom and United States in Kiribati

Becky Alexis-Martin, Oemwa Johnson, and Qurat Ul Ain

**Limited Healthcare Access:** Inhabitants of Bakaka village in Tamana, Kiribati receive free medical services from a Chinese medical team that visited remote Kiribati islands on 12 September 2023. Photograph © Handout via Xinhua/NTB.

## Key Facts about Nuclear Testing in Kiribati

**Testing States:** United Kingdom and United States

**Testing period:** 1957–62

**Number of tests:** 33 atmospheric nuclear tests (9 UK tests and 24 US tests)

**Test locations:** Kiritimati Island and Malden Island

**Scale of exposure:** Approximately 40,700 people were affected in some manner by nuclear weapon testing in Kiribati, including I-Kiribati people, British and allied military forces, and US personnel.

**Lack of scientific assessment:** No large-scale, statistically robust environmental or health studies have been conducted. Existing assessments are fragmented, outdated, or inaccessible.

**Health effects:** Survivors and descendants report widespread cancer, heart disease, congenital anomalies, and mental trauma.

**Indigenous Peoples affected:** In addition to exposure to fallout, I-Kiribati people experienced forced displacement, cultural disruption, and a lasting sense of abandonment.

**Lack of victim assistance:** No formal support has been provided by the United Kingdom or United States to I-Kiribati survivors. Needs include medical care, geriatric support, and historical recognition.

**Environmental damage:** Fallout and contamination affected land, sea, and biodiversity. The UK has stated it considers its cleanup 'complete'.

**Climate-related hazards:** Sea-level rise, erosion, and increased storms may mobilise radioactive contaminants buried or scattered on Kiritimati, compounding the risk of exposure for current and future generations.

**Legal barriers:** The UK and US governments had, at the time of writing, paid no compensation either to individuals in Kiribati or to the Government of Kiribati.

> The Nuclear-Weapon States, which conducted the tests, dispatched their own scientists to study the humanitarian, medical and environmental impacts of these tests. Many of these scientific studies remain classified and restricted to the public, including to the victims and their families, as well as atomic veterans who participated in the tests.
>
> Ambassador Teburoro Tito of Kiribati, in a statement in the UN General Assembly (2024)[1]

## History of testing in Kiribati

The Republic of Kiribati is a Pacific Small Island Developing State (PSIDS) that was exposed to nuclear weapon testing by the United Kingdom (UK) and United States (US) during the Cold War. Kiritimati, a coral atoll that forms part of the archipelago of Kiribati, was selected by the two States as a focus of their hydrogen bomb testing, with thirty-three nuclear explosive devices detonated between 1957 and 1962. Kiribati was under British colonial control until 12 July 1979. This chapter details the history of these nuclear tests on Kiritimati and their humanitarian and environmental impact.

### UK testing over Kiribati

The United Kingdom was the third nation to develop nuclear weapons. In 1946, the McMahon Bill banned the sharing of US nuclear information with foreign powers.[2] This action precipitated the UK's first independent nuclear weapon development programme, code-named 'High Explosives Research' and run by former Los Alamos scientist William Penney.[3] Under Penney's oversight, a new radioactive research facility, the Atomic Weapons Research Establishment (AWRE), was established at Aldermaston in Britain in April 1950. It was there that a thermonuclear and hydrogen bomb programme began in 1954.[4]

The United Kingdom was motivated to develop nuclear weapons as a route to geopolitical power. UK Ambassador Sir Roger Makins voiced emerging national political anxieties when he described that: 'We have the most to lose from any curtailment of our freedom to conduct nuclear tests, and therefore the most to lose from raising the question of limitation'.[5] Kiritimati and Australia were identified as suitable locations for nuclear weapon testing by the British Government in the early 1950s. Kiritimati was subsequently selected as an open laboratory space for the development and testing of the UK's first thermonuclear weapon. The British nuclear weapon test series on Kiritimati was code-named Operation Grapple. Work was undertaken in secrecy until the authorities were certain of their mastery of hydrogen bomb technology.

1 Joint Statement on behalf of Kiribati and Kazakhstan, delivered by Amb. Teburoro Tito at the First Committee of the UN General Assembly, New York, 18 October 2024, at: https://bit.ly/4oipcRI.

2 G. Spinardi, 'Aldermaston and British Nuclear Weapons Development: Testing the Zuckerman Thesis', *Social Studies of Science*, Vol. 27, No. 4 (1997), 547–82.

3 Ibid.; and W. G. Penney, G. I. Taylor, H. Jones, W. M. Evans, R. M. Davies, J. D. Owen, D. H. Edwards, D. E. Thomas, C. A. Adams, F. P. Bowden, and A. R. Ubbelohde, 'A discussion on detonation', *Proceedings of the Royal Society of London A*, Vol. 204, No. 1076 (1950), 1–33.

4 P. C. Thonemann, 'Controlled thermonuclear research in United Kingdom', *Journal of Nuclear Energy*, Vol. 7, Nos. 3–4 (1958), 271; and J. R. Walker, *British Nuclear Weapons and the Test Ban 1954–1973: Britain, the United States, Weapons Policies and Nuclear Testing: Tensions and Contradictions*, Routledge, Abingdon, 2010.

5 L. Arnold, *A Very Special Relationship*, Her Majesty's Stationery Office, London, 1987.

The island was prepared for nuclear weapon testing from June 1956 by the construction of an airstrip, a military encampment, and scientific bunkers.[6] This preparatory work was predominantly undertaken by British Army Royal Engineers, but Operation Grapple was a cross-forces endeavour that also included other personnel from the Army as well as from the Royal Navy and Royal Air Force, along with scientific and civilian participants. Figure 1 shows the geography of Kiritimati Atoll and situates some of the key military sites developed during nuclear weapon testing. Site A was a scientific facility; Site C was a joint control camp with AWRE laboratories; and Site K was used for balloon testing. Sites L and D were used for nuclear weapon testing and observation bunkers.

**Figure 1:** **US Department of Defense map of Kiritimati (adapted from AWRE archives)**


Operation Grapple included four atomic and hydrogen bomb test series undertaken over the course of 1957 and 1958. The tests were code-named Grapple 1-3, Grapple X, Grapple Y, and Grapple Z. In total, nine nuclear explosive devices were tested by the UK during the Grapple series. The United Kingdom's two first attempts at thermonuclear weapon tests, code-named Short Granite and Orange Herald, were detonated high above Malden Island, near Kiritimati, on 15 May and 19 June 1957.[7] A high-yield fission bomb test was undertaken on 31 May 1957 to demonstrate that Britain had scaled up its atomic bomb technology. Tests were then relocated to the southernmost tip of the island, instead of further away, due to limited time before a tripartite moratorium on testing came into force in late 1958.

The nuclear weapon tests were undertaken in a hurry by the British authorities, which resulted in health, safety, and environment considerations being deprioritized in the name of scientific progress. The tests were undertaken at Kiritimati because of the prior success and the existing facilities there, a fact attested to in

6 N. Maclellan, *Grappling with the Bomb: Britain's Pacific H-bomb tests*, ANU Press, Australia, 2017.
7 N. Maclellan, 'Introduction: Resistance and Survival – The Nuclear Era in the Pacific', *The Journal of Pacific History*, 2024, 1–16.

contemporaneous British diplomatic notes. One diplomat is recorded as having said, 'because time is so short, it has been decided to carry out the November tests off the south-east tip of Christmas Island; it would have taken too long to set up Malden again.'[8] This haste may have led to less cautious and environmentally considerate testing practices.

Britain's first successful hydrogen bomb tests were Grapple X and Grapple Y. Grapple X was undertaken on 8 November 1957 followed by Grapple Y on 28 April 1958. A final Grapple Z series of nuclear weapon tests was completed before the joint US/Soviet Union/UK test moratorium came into force on 31 October 1958.[9] The nine test detonations during Operation Grapple cemented the Mutual Defence Agreement and led to the United Kingdom becoming the world's third nuclear weapon possessor State.

### US testing over Kiribati

A further 24 nuclear weapon tests were undertaken on Christmas Island (Kiritimati) by the United States after the moratorium ended in 1962. These tests were part of Operation Dominic, which was the last series of atmospheric nuclear tests conducted by the United States.[10] Most of the tests involved free-fall bombs dropped from B-52 bombers. The objectives were to test new weapons designs, weapons effects, and to confirm the reliability of existing weapons.[11] Following the signature of the 1963 Partial Test-Ban Treaty, both US and UK troops withdrew from Christmas Island.

A 1983 US Department of Defense review stated that 25,399 of the 28,000 personnel involved in Operation Dominic I were issued with film badges 'for extended periods'. It claimed that: 'Because all but one of the shots were airbursts, there was little or no fallout problem and no residual radiation area around the surface zero.' Nevertheless, the film badges indicated that 56 people (2 Army, 4 Navy and Navy civilians, 49 Air Force, and 1 other civilian) were exposed to more than 3.0 roentgens (29 mSV), the 'established JTF 8 Maximum Permissible Exposure'.[12] The review barely mentions the Gilbertese civilian population on Christmas Island.[13]

### Those affected by the tests

Approximately 40,700 people were affected in some manner by nuclear weapon testing in Kiribati. Those affected included military personnel, civilians from other British colonies, and local I-Kiribati people.[14] The breakdown of affected groups by estimated number at each test series is described in Table 1 overleaf. They experienced a range of negative physical, psycho-social, and cultural impacts as a consequence of the tests.

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8 P. Rogers, Secretary of State for the Colonies, Letter dated 20 September 1957, originally classified Top Secret, in the Colonial Office archives reference CO1036/283.

9 M. W. Carter and A. A. Moghissi, 'Three decades of nuclear testing', *Health Physics*, Vol. 33, No. 1 (1977), 55–71; and D. Hawkings, *Keeping the Peace: The Aldermaston Story*, Pen and Sword, Barnsley, United Kingdom, 2000.

10 USS Taylor (DD/DDE 468), 'Operation Dominic I', 2025, at: https://bit.ly/4fk3MiS.

11 Ibid.

12 US Defense Nuclear Agency, 'Operation Dominic I 1962: United States Atmospheric Nuclear Weapons Tests: Nuclear Test Personnel Review', Department of Defense, Washington, DC, 1983, at: https://bit.ly/4mwKxVW, pp. 3–4.

13 'Addressing Humanitarian and Environmental Harm from Nuclear Weapons. Kiritimati (Christmas) and Malden Islands Republic of Kiribati', at: https://bit.ly/4omyex5, pp. 6–7.

14 The specific affected groups during Operation Grapple were I-Kiribati residents, personnel from the Women's Royal Voluntary Service, the British Navy, the British Army, and the Royal Air Force, the New Zealand Navy, and the Fijian Navy and Army, as well as AWRE workers and a small number of visitors and observers. The affected military and occupational communities during Operation Dominic comprised US Army, Navy, Air Force, and Marine Corps members, Department of Defense agencies, contractors, and visitors, and Soviet monitoring personnel.

**Table 1:** **Populations near nuclear detonations in Kiribati**[15]

| Population | Test Series | Number |
|---|---|---|
| i-Kiribati people | Grapple and Dominic 1 | 500 |
| Royal Navy | Grapple | 3,908 |
| British Army | Grapple | 4,032 |
| Royal Air Force | Grapple | 5,490 |
| UK Women's Royal Voluntary Service | Grapple | 4 |
| UK Atomic Weapons Research Establishment | Grapple | 520 |
| New Zealand Navy | Grapple | 551 |
| Fijian Navy and Army | Grapple | 276 |
| Visiting Spouses (Grapple) | Grapple | 30 |
| Visiting Children (Grapple) | Grapple | 31 |
| Visitors (Grapple) | Grapple | 2 |
| US Grapple military observers | Grapple | Unconfirmed |
| Joint Task Force 8 (JTF8): US Army | Dominic 1 | 628 |
| JTF8: US Navy | Dominic 1 | 16,420 |
| JTF8: US Air Force | Dominic 1 | 2,702 |
| JTF8: US Marine Corps | Dominic 1 | 589 |
| JTF8: Department of Defence agencies | Dominic 1 | 350 |
| JTF8: Contractors | Dominic 1 | 4,620 |
| Visitors (Dominic 1) | Dominic 1 | 65 |
| Soviet Navy and Intelligence | Dominic 1 | Unconfirmed |
| **Total** | | **ca. 40,700** |

## Assessments

Existing assessments have been limited in scope, depth, and reliability. Survey scope has often been limited to small scale or veteran studies and their findings are not always publicly available. One of the challenges pertains to the lack of knowledge around the monitoring needs of the island, which results in an information gap during study design. Study scope has also been affected by colonial and military priorities and interests, particularly in the case of UK Ministry of Defence studies. There are also problems of access to relevant documents from the period.

Several other reasons explain the lack of adequate needs assessment. First, information pertaining to the British and US nuclear weapon test series was classified until after the Cold War, and there is still limited access to archival information relating to dose and exposure. Second, the radiation monitoring and detection methods employed during the nuclear weapon tests were limited and unsophisticated compared to contemporary approaches. The monitoring that took place during the 1960s was insufficient and further research was not conducted until the 2010s. Finally, some studies may not be impartial, as they have been undertaken by the UK Ministry of Defence without independent oversight.

15 Maclellan, *Grappling with the Bomb: Britain's Pacific H-bomb tests*; US Defense Nuclear Agency Report, 1983, 4.

**Table 2:** **Assessments of Radiological Conditions and Humanitarian Issues across Kiritimati and Malden Islands**[16]

| Author | Date | Survey area | Type of Study | Findings | Open access? | Limitations |
|---|---|---|---|---|---|---|
| University of Washington Radiation Biology Lab | 1962 | Unknown areas of Kiritimati, Fanning and Washington Islands | Samples of soil, foodstuffs, and water | Low levels of radioactive elements detected | No. Summarised in Defence Nuclear Agency Report (1983, pp. 38-29)[17] | Prior to US tests. Full scope unknown |
| UK Government | 1964 | Unknown sampling strategy, Kiritimati | Unknown | 'There were no areas presenting significant radiation or radioactivity hazards' | No. Summarised in MacEwan *et al.* (1981 pp. 1-2)[18] | Little known about study, but did not survey Malden Island |
| Operation Hard Look | 1970s | Unknown, Kiritimati | Unknown | No cause for concern reported | No. Referenced in Resture, 2013[19]) | Little known about study but did not survey Malden Island |
| US Government for NASDA[20] | 1975 | Unknown, Kiritimati | Unknown | Low radioactivity levels | No | Did not survey Malden Island |
| University of Washington Radiation Biology Lab | 1977 | Unknown, Kiritimati | | Trace quantities of 11 fallout radionuclides, including Cs-137 | No | Did not survey Malden Island |
| University of the South Pacific | 1978 | Unknown, Kiritimati | Unknown | Cause for concern about radiological hazard risk | No | Unavailable |
| NZ National Radiological Lab | 1981 | Inhabited areas of Kiritimati | Fish, soil, seawater | Traces of contamination. Cs-137 and Pu-239. Fallout at global background levels | Yes | Did not survey Malden Island. Wide-interval gamma sampling. Crustacean sampling limited |
| SPREP[21] | 1992 | Literature review and qualitative data | Unknown | Raised concerns that harms will not show up for years | Yes. Thaman and Neema-Mackenzie (1992)[22] | Not a technical survey |
| Aspinwall and Enviros[23] | 1998 and 2004 | Former military areas. Spot checks | Soil, vegetation, water, fish, land crabs | Traces of Pu-239 and Pu-240 at southernmost tip of Kiritimati | No. | Did not survey Malden Island |
| Maclellan | 2015, 2017 | Kiritimati | Oral histories, social study | Historical impacts recorded to veterans and islanders | Yes. See Grappling with the Bomb | Not technical survey |
| Pace University Disarmament Institute | 2018 | Kiritimati | Oral histories, social study | Historical impacts recorded to veterans and islanders | Yes. See Disarmament institute website | Small cohort study |
| Alexis-Martin *et al.* | 2017, 2018, 2023 | Kiritimati | Social study, environmental health | Historical impacts recorded to veterans, islanders, and environment | Yes, open access publishing | Small cohort study. 2023 data in press |

16 Updated from a table prepared by Matthew Breay Bolton; see Maclellan, *Grappling with the Bomb*, 2017.
17 At: https://bit.ly/3wpWAiV.
18 A. C. McEwan, K. M. Matthews, and L. P. Gregory, 'An environmental radiation survey of Christmas Island, Kiribati', Report No. 1981/9, National Radiation Laboratory, Christchurch, New Zealand, 1981.
19 J. Resture, 'The Story of Blackbirding in the South Seas–Part 2', 2013.
20 National Association of State Departments of Agriculture (NASDA).
21 Secretariat of the Pacific Regional Environment Program.
22 At: https://bit.ly/3Ib6oQA.
23 At: https://envirosgroup.com/.

The understanding and documentation of health and environmental issues are limited – no study adequately explores health and related issues and there was no large-scale environmental monitoring programme. To date, no large-scale, statistically robust environmental monitoring programme has been mounted for gamma radiation, radionuclides, persistent organic pollutants, petrochemicals, and transition metal residues. This is despite such contaminants being commonplace at sites of former nuclear tests and military activity. It is also important to note that no recognized environmental standards have been documented as having been upheld during the limited environmental monitoring that did take place. A scientific study of the people of Kiritimati that explores genetic, public health, or medical issues is still to be conducted.

There are ongoing perceptions of risk and uncertainties around the long-term health and environmental impacts of the tests. While US, British, New Zealand, and Fijian military personnel and civilian workers returned to their own countries after the nuclear weapon tests, the 500 I-Kiribati people remained in place, and there are now three generations of affected people on the island.

Table 2 above summarizes the nature of assessments on the island and highlights the limited replication and ongoing monitoring. It also highlights the limited sampling strategies employed.

## Human effects

### Impacts on Indigenous populations

Many local accounts describe the suffering of the community during the nuclear weapon tests. For example, islander Teeua Tetua described being loaded onto a ship and taken offshore before the tests and being too frightened to talk. She said: 'It was very crowded; it was meant for cargo and there was no room for children like me to play. There was no space, we were treated like animals'.[24]

Indigenous communities have since reported long-term health, social, and cultural consequences. The Kiritimati Association of Cancer Patients Affected by the British and American Bomb Tests has noted numerous health problems that are attributed to the testing. As of 2023, this Association had identified at least 40 survivors in Kiribati who experienced the tests first-hand along with 800 descendants.[25] Survivors have health problems consistent with exposure to radiation, including blindness, hearing problems, cancers, heart disease, and reproductive difficulties. They report that their children and grandchildren have suffered similar illnesses and other intergenerational effects, including mental trauma. The terror that first-generation survivors experienced through the nuclear explosions has caused some of them to feel persistent anxiety and uncertainty about their own futures and that of their descendants.[26]

In 2015, Kiribati's then Permanent Representative to the United Nations, Ambassador Makurita Baaro, stated: 'Today, our communities still suffer from the long-term impacts of the tests, experiencing higher rates of cancer, particularly thyroid cancer, due to exposure to radiation'. Furthermore, in Kiribati, 'no studies have been done on the effects of these nuclear tests on our people – we do not have the medical facilities nor the capacity to do this'.[27]

24 B. Alexis-Martin, 'The atomic history of Kiritimati – a tiny island where humanity realised its most lethal potential', The Conversation, 2019, at: https://bit.ly/49KsZ20.

25 B. Alexis-Martin, Kiritimati field notes, ICAN research scholarship, 2023.

26 Ibid.

27 B. Alexis-Martin, M. B. Bolton, D. Hawkins, S. Tisch, and T. L. Mangioni, 'Addressing the humanitarian and environmental consequences of atmospheric nuclear weapon tests: A case study of UK and US test programs at Kiritimati (Christmas) and Malden Islands, Republic of Kiribati', *Global Policy*, Vol. 12, No. 1 (2021), 106–21.

### Impacts on military personnel

The experiences of the service members posted to Kiritimati were shaped by the conditions, risks, and consequences of military life. Although many nuclear test veterans believe that it was nuclear weapons that posed the greatest risk to their health, their work presented many other hazards, including sunburn, sunstroke, accident, exposure to carcinogenic DDT (an insecticide developed in the 1940s and no longer used because of its public health consequences), poor sanitation, dysentery, and inadequate rations.

Veteran descriptions of minimal protective clothing and radiation sampling provide a vivid narrative of the realities of their work on Kiritimati. For example, British nuclear test veteran Terry Quinlan described living in tents in intense heat and being 'eaten alive' by mosquitoes. 'People caught ringworm, some swelled up like balloons', he said. Morale among the troops was consequently low with some reported to have committed suicide while on tour.[28]

There are ongoing impacts to nuclear test veteran families, as nuclear test veterans and their descendants report. They experience somatic and unmedicalized illnesses and higher rates of disability in comparison to the general population.[29] These disabilities include congenital deformities, tooth and bone malformations, cleft lips, and learning disabilities. Ongoing study of UK nuclear test veterans has revealed slightly elevated rates of mortality, leukaemia, solid cancers, and cerebrovascular disease.[30]

A study into exposed servicemen conducted by the University of Dundee found increased frequencies of cataracts, arthritis, gastrointestinal disorders, respiratory diseases, and cancer among exposed servicemen, as well as a high incidence of congenital malformations in their offspring.[31] The study revealed that these conditions and issues arose more commonly among nuclear test veterans and their families than in the general population.[32]

### Transgenerational human effects

Both nuclear test veteran and local communities have self-reported physical and psycho-social transgenerational effects in studies.[33, 34] A genetic study of fifty British nuclear test veteran families by Brunel University found no hereditary issues due to inherited genetic aberrations from fathers among nuclear test veteran families.[35] A further study published in 2022 showed no evidence of increased mutations in the germ line among nuclear test veteran families.[36] There has been, however, no equivalent genetic, medical, or public health research into any transgenerational effects among Kiritimati islanders.

28 Alexis-Martin *et al.*, 'Addressing the humanitarian and environmental consequences of atmospheric nuclear weapon tests: A case study of UK and US test programs at Kiritimati (Christmas) and Malden Islands, Republic of Kiribati'.

29 S. C. Darby, G. M. Kendall, T. P. Fell, J. A. O'Hagan, C. R. Muirhead, J. R. Ennis, A. M. Ball, J. A. Dennis, and R. Doll, 'A summary of mortality and incidence of cancer in men from the United Kingdom who participated in the United Kingdom's atmospheric nuclear weapon tests and experimental programmes', *British Medical Journal (Clinical Research Edition)*, Vol. 296, No. 6618 (1988), 332–38.

30 M. Gillies and R. G. Haylock, 'Mortality and cancer incidence 1952–2017 in United Kingdom participants in the United Kingdom's atmospheric nuclear weapon tests and experimental programmes', *Journal of Radiological Protection*, Vol. 42, No. 2 (2022), 021507.

31 C. Busby and M. E. de Messieres, 'Miscarriages and congenital conditions in offspring of veterans of the British Nuclear Atmospheric Test Programme', *Epidemiology* (sunnyvale), Vol. 4, No. 4 (2014), 172.

32 C. Busby, 'Bomb test veterans' grandchildren suffer health impacts', The Ecologist, 2014.

33 B. Alexis-Martin, E. Waight, and M. Blell, 'Nuclear Families: A Social Study of British Nuclear Test Veteran Community Families', Report, University of Southampton, Southampton, 2019; C. Trundle and B. I. Scott, 'Elusive genes: Nuclear test veterans' experiences of genetic citizenship and biomedical refusal', *Medical Anthropology*, Vol. 32, No. 6 (2013), 501–17; and Alexis-Martin *et al.*, 'Addressing the humanitarian and environmental consequences of atmospheric nuclear weapon tests: A case study of UK and US test programs at Kiritimati (Christmas) and Malden Islands, Republic of Kiribati'.

34 S. R. Roff and D. Holdstock, 'Mortality and morbidity of members of the British Nuclear Tests Veterans Association and the New Zealand Nuclear Tests Veterans Association and their families', *Medicine, Conflict and Survival*, Vol. 15, Su1, (July–September 1999), i–ix, 1–51.

35 C. Rake, C. Gilham, M. Scholze, L. Bukasa, J. Stephens, J. Simpson, J. Peto, and R. Anderson, 'British nuclear test veteran family trios for the study of genetic risk', *Journal of Radiological Protection*, Vol. 42, No. 2 (2022), 021528.

36 A. J. Moorhouse, M. Scholze, N. Sylvius, C. Gillham, C. Rake, J. Peto, R. Anderson, and Y. E. Dubrova, 'No evidence of increased mutations in the germline of a group of British nuclear test veterans', *Scientific Reports*, Vol. 12, No. 1 (2022), 10830.

## Societal effects and displacement

Social effects for Kiribati people were pronounced. Co-author Oemwa Johnson describes the impacts through her lived familial experience:

> One of the most significant societal effects of these tests has been the displacement of the Indigenous communities residing on Christmas Island. The immediate rupture was stark. Families living closest to the detonation zones were unceremoniously uprooted, forced to abandon generations-old villages and seek refuge deeper inland or on neighbouring islands such as Canton Island and Fanning Island. The tests required the evacuation of the island's inhabitants, disrupting their way of life and severing their connection to their ancestral lands. Families were uprooted from their homes, and the physical and emotional toll of displacement was immense. The loss of their homelands resulted in a deep sense of cultural loss and dislocation as communities were forced to rebuild their lives elsewhere. Once teeming with life, fishing grounds became desolate wastelands, poisoned by lingering radiation. Fear of the invisible contaminant permeated every facet of daily life, fracturing once-supportive communities and casting a long shadow of suspicion.
>
> Beyond the physical displacement, the tests ripped open festering wounds of cultural disruption. Traditional practices, deeply intertwined with the land and its cycles, were deemed incompatible with the sterile new reality of radioactive contamination. Ancestral burial grounds were declared unsafe, the spirits of their ancestors disturbed by the violent tremors of the nuclear explosions. The delicate equilibrium between people and their environment, nurtured for centuries, lay shattered, replaced by a gnawing uncertainty about the future of their cultural heritage.

Relevant sites affected by the testing programme include the cemetery near Ronton on Kiritimati, which is of great importance to the local community due to their strong Christian faith. It is clear from Oemwa's description of impacts to island life, which reflects the narrative of other descendants, that societal effects and displacement continue to negatively impact the people of Kiritimati.

## Victim assistance

Victim assistance needs are currently unaddressed among both nuclear test veteran and local communities. These needs span healthcare, geriatric care, education, and development. An atomic epistemic justice study funded by the International Campaign to Abolish Nuclear Weapons (ICAN) and led by chapter co-author Alexis-Martin investigated the needs of Kiritimati people through their own words. The six research workshops conducted with 175 people on the island revealed that local priorities included a secure supported living environment or dedicated home for older people affected by nuclear weapon testing, along with better medical care and support for those affected, accurate historical documentation of events in I-Kiribati and by Kiribati people, a peace museum and a memorial to the affected local communities (not veterans). There were also calls for an atomic heritage trail across the island and better access to education and opportunities for engagement with global policy.[37]

The Treaty on the Prohibition of Nuclear Weapons (TPNW)'s positive obligations on victim assistance, environmental remediation, and international cooperation and assistance (Articles 6 and 7) offer an opportunity to focus global and national policy attention on the ongoing suffering caused by the nuclear tests in Kiribati, as well as the need for renewed assessment and monitoring of potential radiological and other environmental hazards arising due to nuclear weapon testing. Article 6 obligates Kiribati to assess the scope of environmental

37 B. Alexis-Martin, 'Kiritimati people's engagement in TPNW implementation processes', ICAN Report and academic paper, 2023.

contamination of Kiritimati and Malden Islands and to engage in appropriate remediation activities. It also obligates Kiribati, New Zealand, and Fiji to provide appropriate victim assistance to military and civilian survivors of the nuclear tests under their jurisdiction. Under Article 7 of the TPNW, all States Parties should provide international cooperation and assistance. This should encompass not only financial resources, but also scientific expertise, access to archival records, diplomatic support, and acknowledgement of the situation of communities affected by the nuclear weapon testing.

In May 2024, Kiribati told the other UN Member States that a common theme across all interviews conducted with test survivors is 'the absence of adequate assistance or compensation from the States responsible for the nuclear tests. Despite the profound health impacts and environmental degradation, none of the interviewees reported receiving any form of international support from these States. This lack of assistance exacerbates their suffering and leaves them struggling to manage the severe health issues caused by the nuclear fallout.'[38] As a result of the legacy of nuclear tests, Kiribati called on the international community to convene a symposium on victim assistance and environmental remediation in New York. 'This symposium could provide a forum, where survivors and affected States can share their testimonies on the humanitarian and environmental impacts of nuclear weapons and their requests for the international community to provide critical support.'[39]

## Environmental contamination

The environmental impacts of the nuclear tests have not been adequately assessed according to contemporary standards. While there is extensive evidence of ongoing environmental impacts to land, air, sea, and local species, no large-scale, independent environmental impact assessment has been undertaken since the nuclear test detonations.[40] Several environmental studies have been conducted, but these have varied in scope and conclusions, as Table 2 on page 211 illustrated. Some have found traces of radioisotopes that would have been generated by nuclear testing, notably plutonium-239, plutonium-240, and caesium-137.

The UK Ministry of Defence, however, claims that environmental monitoring was both appropriate and adequate and argues that 'levels of radioactivity on land and sea were negligible and not a danger'.[41] But the monitoring approaches the Ministry employed during the testing programme lack the detail and sophistication of modern methods. Approaches included pumped air, sticky paper, rainwater collection, and fish sampling within 2,500 kilometres of Kiritimati.[42] Despite the shortcomings of earlier studies, the UK government affirms, improbably, that no contamination arose due to nuclear weapon testing, claiming that any pollution is due to other nuclear weapon tests in the region at the time:

> During and following the Grapple trials on Christmas Island, environmental monitoring showed that no significant fallout had occurred on the island. The fallout measured was due to the nuclear weapon testing programme of all the nuclear weapon states which had caused global pollution.[43]

It is important to note that environmental contamination is not just about radioactive contamination of the soil or water. Official reports by military observers and other bystanders at the time of the tests note that dead birds

38 The Republic of Kiribati's Submission in Accordance with UN General Assembly Resolution 78/240 entitled Addressing the Legacy of Nuclear Weapons, 31 May 2024, at: https://bit.ly/3XpkplY, 5.
39 Ibid., 6.
40 Alexis-Martin, 'Kiritimati people's engagement in TPNW implementation processes'.
41 Alexis-Martin *et al.*, 'Addressing the humanitarian and environmental consequences of atmospheric nuclear weapon tests: A case study of UK and US test programs at Kiritimati (Christmas) and Malden Islands'.
42 AWRE archival data available in the British Archives.
43 UK government, 'UK atmospheric nuclear weapons tests', Factsheet 1, at: https://bit.ly/49ukuss.

and marine life washed ashore after the nuclear weapon tests, and film footage depicted scorched vegetation.[44] Fijian veteran Anare Bakale recalled visiting the south-eastern point two weeks after a test:

> The whole place look[ed] dry and black. Dead fish were floating in the sea. It was so horrifying. ... The plants were ... withered as if they had been watered with boiling water. Nothing was left. Everything from the stem to the leaves disappeared. Only the sand was left.[45]

The military presence in Kiritimati and Malden Island left other harmful legacies. The British military sprayed the island with DDT, and at the end of their deployment, vehicles, equipment, waste, and toxic chemicals were abandoned across the island and its reefs. There is also unexploded ordnance in areas of former firing ranges. In 2012, the company Mayer Environmental was commissioned by the UK Ministry of Defence to clean up Kiritimati: 'Waste discovered on the island ranged from asbestos, bitumen, metals and radioactive sources (mostly as luminous radium dials) to rusting hulks of vehicles, coral crushers and tarmac plants.'[46] Visual inspection of the island in 2023 revealed that military contamination was still present across the uninhabited areas to the south of the island in the form of spoil heaps and concrete.[47]

## Environmental remediation

No environmental remediation efforts were being undertaken or were planned at the time of writing. In May 2024, the UK government told UN Member States that it 'considers its remediation efforts on Kiritimati to have been completed'.[48]

## The impact of climate change[49]

Kiribati faces a diverse set of risks from climate change, but data and reliable model projections are lacking. There is a long-term threat of permanent inundation, with some studies indicating that many low-lying islands will become uninhabitable. A summary of trends and potential climate-related impacts is given in Table 3 opposite.

## Legal issues

In the years since the tests, there have been repeated calls for compensation and recognition of British, US, New Zealander, and Fijian nuclear test veterans' service and the health impacts that they have encountered. The UK government has taken limited steps to address this issue. The British Government offers no formal admission of liability for harm to British nuclear test veterans or local people. The UK and US governments have provided no individual compensation and no intergovernmental compensation and reparations to the people of Kiribati at the time of writing.

44 Maclellan, *Grappling with the Bomb: Britain's Pacific H-bomb tests*.
45 Ibid.
46 Mayer, 'Grappling with waste on Christmas Island', 2023, at: https://bit.ly/3T6lvkm.
47 B. Alexis-Martin, Notes on fieldwork in Kiritimati in July and August 2023, ICAN, 2023.
48 Document submitted by the United Kingdom on the Secretary General's Report on A/RES/78/240, 31 May 2024, at: https://bit.ly/3Xaen7F, 1.
49 This section was contributed by Linsey Cottrell.

**Table 3: Summary of key climate trends and impacts, Kiribati[50, 51]**

| Climate system/ hazard | Historic trends | Projected trends | Possible impact on risk components |
|---|---|---|---|
| Temperature | Increasing | Warming likely to take place at a rate slightly lower than global average* | Source: changes in physico-chemical behaviour and leaching, affecting mechanisms by which contaminants may be released. Includes physical landform changes and erosion caused by sea-level rise, storms, high winds, or wave action<br><br>Pathway: changes in water infiltration, water tables/sea-levels, flow rates and ocean currents<br><br>Receptor: changes in species assemblages and/or sensitivity to contaminants. Shift in people's proximity/exposure routes to sources |
| Precipitation | Significant increase in annual rainfall between 1946 and 2013 | Models broadly suggest increases in average monthly precipitation, though a minority of models indicate an annual decrease* | |
| Drought | Severe drought at sporadic intervals | Uncertain, but little change a possibility* | |
| Sea level rise | Sea level rise impacting low-lying islands and inhabitants relocated | Sea-level rise threatens long-term encroachment on coastal areas and a projected increase in the frequency of extreme sea-level events | |
| Floods, cyclones, tsunamis, and storm surges | Typically sheltered from direct impact of cyclones | Uncertain, but sea-level rise may enhance cyclone-induced storm damage, and wind speeds and precipitation intensity may increase. A 40% chance of a potentially damaging tsunami occurring in the next 50 years* | |

* Projections uncertain

## Individual compensation schemes

In 2016, the UK Department of Veterans Affairs launched a stream of the Aged Veteran's Fund called the Nuclear Communities Charity Fund.[52] The fund is explicitly described as a benevolent fund rather than compensation (which would imply liability). It was supposed to provide research funding and to support nuclear test veterans in hardship. However, the fund is means-tested and only provides very small grants to veterans.

In the United States, compensation is available to veterans of Operation Dominic who have any one of 19 cancers that are traceable to radiation exposure – these men have been entitled to a one-time award of up to $75,000 or a monthly disability payment from the Department of Veteran Affairs (Radiation Exposure Compensation Act).[53] Concerns about access to this scheme persist: it is difficult to verify records of service and there is no formal discharge form for US atomic veterans. While the United States' DD-214 discharge form does not mention atomic weapons testing, it is widely known that this signifies work undertaken on atomic weapons. The scheme ended in June 2024 but was resuscitated in July 2025.[54]

In addition, those from the United States and the United Kingdom who were involved in the clean-up operations after the tests (as opposed to being present during the tests themselves) are in limbo as they have not been formally recognized as atomic veterans in the same way as those men who participated directly. While the British Government has refused to issue compensation to those who believe their health conditions have been

50 Climate Risk Country Profile: Kiribati, The World Bank Group, 2021, at: https://bit.ly/48ORj22.
51 ThinkHazard! High-level hazard profile for Kiribati, at: https://bit.ly/3IwyqWK.
52 Nuclear Communities Charity Fund, at: https://thenccf.org/.
53 Radiation Exposure Compensation Act, at: https://bit.ly/3JZEB7O.
54 See, e.g., F. Guillen, 'More Americans can get compensated for nuclear poisoning. But there's a catch', *Missouri Independent*, 28 July 2025, at: https://bit.ly/46DejUj.

caused by participation in the tests, other governments, such as those of Fiji, Australia, and New Zealand, have supported their own veterans. Fijian soldiers and sailors have gained compensation from their own government in 2015, each of the 24 survivors who attended the State compensation ceremony received Fiji $9,855.[55]

### Court judgments

Action has been taken against the British Government by test veterans, but the UK legal system has rejected formal liability. The UK Supreme Court has held that requests for compensation have come too late for victims to prove that their health challenges originate from exposure to ionizing radiation in the 1950s and 1960s.[56] In 2010, a group of 1,011 service veterans and civilians from the United Kingdom, Fiji, and New Zealand sought to obtain a compensation hearing against the UK Ministry of Defence relating to alleged illnesses caused by exposure to radiation in nuclear weapon tests during the 1950s.[57] In 2010, the UK Court of Appeal upheld a Ministry of Defence request to overturn a previous judgment waiving limitation requirements for a group of lead cases. In 2011, the Supreme Court agreed to consider an appeal of this decision, but in 2012 it ruled against the Atomic Veterans' case proceeding. In light of this ruling, the UK government has no plans to pay compensation to those who suffered in the cause of its nuclear weapon programme.[58]

### Intergovernmental compensation and reparation

No intergovernmental compensation or reparation has been provided by either the United Kingdom or the United States to the Republic of Kiribati and the affected communities for the nuclear tests conducted on their territory. Kiribati led the call for intergovernmental victim assistance and environmental remediation in conjunction with Kazakhstan at the Second and Third Meetings of States Parties for the Treaty on the Prohibition of Nuclear Weapons (TPNW). Articles 6 and 7 of the Treaty offer future opportunities for intergovernmental compensation and reparation through the creation of a multi-national contribution towards environmental and humanitarian assistance and support to affected member States, including Kiribati. The intergovernmental compensation and reparation implementation framework, format, and outcomes of Articles 6 and 7 were in development at the time of writing.[59]

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55 Agence France-Presse, 'Fiji compensates its veterans of British nuclear tests in the Pacific', *The Guardian*, 30 January 2015, at: https://bit.ly/48m4s29.

56 P. Richards, 'Nuclear test veterans – compensation', Standard Note: SNSC-05145, House of Commons Library, updated 31 January 2013, at: https://bit.ly/3hMxa4b.

57 P. Richards, 'Nuclear test veterans – compensation', Research Briefing, House of Commons Library, 1 February 2013, at: https://bit.ly/3T4JUXI.

58 Ibid.

59 UN doc. TPNW/MSP/2023/14, at: https://bit.ly/3OSBfF4.

Chapter 18:

# Addressing the Impact of Soviet Nuclear Testing in Kazakhstan

Magdalena E. Stawkowski and Dana Yermolyonok

**Lasting Impact:** It has been more than 35 years since the last Soviet nuclear test on the Semipalatinsk Test Site (STS) in Kazakhstan. The victims, now in their fourth generation, continue to pay the price for the Soviet nuclear programme. The picture shows an educational trip to the STS, organized by the Center for International Security and Policy (CISP) for young diplomats and interns. Photograph © Oleg Butenko.

## Key Facts about Nuclear Testing in Kazakhstan

**Testing State:** Soviet Union

**Testing period:** 1949–89

**Number of tests:** 489

**Test locations:** 456 of the tests (116 atmospheric and 340 underground) took place at the Semipalatinsk Test Site (STS) and 33 at various locations in Kazakhstan outside the STS. The tests at the STS involved 616 nuclear explosive devices with a collective explosive yield equivalent to more than 1,100 Hiroshima bombs.

**Mass exposure:** More than one million people lived within 160 kilometres of the STS, and around 3 million were exposed to radiation. Communities as well as military personnel near the test sites and in the path of radioactive fallout hundreds of kilometres away were affected. Indigenous communities were disproportionately affected by nuclear fallout.

**Health impact:** Fallout from atmospheric tests caused widespread health damage, including congenital disorders and cancers as well as psychological effects.

**Indigenous Peoples affected:** The Indigenous Kazakhs living near the STS in both cities and villages received very high doses of radiation. High rates of babies born with serious physical and intellectual anomalies continue to occur.

**Environmental contamination:** 9,000 square kilometres of the STS is estimated to be still radioactively contaminated. Hazardous radionuclides persist in soil and water, impacting livestock and food chains.

**Assessment and remediation:** Kazakhstan has reported being the first nation to conduct a full-scale assessment of the radiation situation on the territory of a former test site. Remediation efforts from 2008 to 2021 involved soil removal, containment structures, and long-term monitoring.

**Victim assistance and compensation:** While cash compensation and healthcare benefits exist, they are limited and inconsistently distributed. Many citizens struggle to access benefits.

**Lack of trust:** Long-standing mistrust of officials on all matters related to the STS persists, as people lived many years in psychological stress, experiencing health risks and lacking proper information about the causes.

**Lack of Russian accountability:** The Russian Federation accepts no responsibility for nuclear testing in Kazakhstan.

Kazakhstan has suffered terribly from past nuclear weapons testing, so we understand very clearly the dangers of escalating tensions between nuclear powers. For this reason, nuclear disarmament has become a key part of Kazakh foreign policy and we will be continuously struggling for a world free of nuclear arsenals.

Kazakhstan's President Kassym-Jomart Tokayev (2022)[1]

## History of testing in the Soviet Union

The Soviet Union conducted nuclear testing in two main areas: the southern Semipalatinsk Test Site in Kazakhstan and the northern Novaya Zemlya Arctic Archipelago (part of the Russian Federation). In the course of the testing programme, which ran from 1949 to 1990, the Soviet Union conducted 715 nuclear tests and 'peaceful nuclear explosions' involving detonation of an estimated total of 969 nuclear devices.[2] The tests encompassed atmospheric detonations, including high-altitude tests, as well as detonations in outer space, underwater, and underground (in boreholes and tunnels or adits – horizontal tunnels with one opening). A total of 129 tests occurred outside designated nuclear test sites, across various regions of Russia (91), in Ukraine (2), in Kazakhstan (33), in Uzbekistan (2), and in Turkmenistan (1).[3]

As was the case with the United States, tests were carried out both for military and peaceful purposes. The total energy yield of the known Soviet tests equates to 285 megatons (Mt) of TNT, of which 247 Mt (or the equivalent of 16,500 Hiroshima bombs) was released in above-ground (atmospheric) detonations.[4] The Soviet Union conducted 35 per cent of the world's total number of nuclear tests, with two-thirds of their tests conducted at the test site in Kazakhstan.[5]

### The Semipalatinsk Test Site in Kazakhstan

Established in 1947, the Semipalatinsk Test Site (STS) in Kazakhstan, known locally as the Polygon (the Russian word for any military firing range), was most likely selected for strategic reasons because of the perception that

1 Speech by the President of Kazakhstan, Kassym-Jomart Tokayev, at the General Debate of the 77th UN General Assembly, New York, 2022, at: https://bit.ly/45wd0VZ.

2 The numbers of tests are estimates because some data remains classified or is unavailable due to lack of record keeping. Many Soviet tests also involved multiple nuclear devices detonated within milliseconds to seconds (salvo explosions), resulting in higher count of nuclear charges compared to the number of tests. For an official summary table of Soviet tests see V. N. Mikhailov (ed.), *USSR Nuclear Weapons Tests and Peaceful Nuclear Explosions, 1949 through 1990,* Ministry of Atomic Energy and Ministry of Defence of the Russian Federation, Moscow, 1996; R. S. Norris and T. B. Cochran, 'Nuclear Weapons Tests and Peaceful Nuclear Explosions by the Soviet Union, August 29, 1949 to October 24, 1990', Draft, Natural Resource Defense Council, Washington, DC, 1996, at: https://bit.ly/4devtHi; P. Podvig (ed.), Russian Strategic Nuclear Forces, MIT Press, Boston, MA, 2001. Some sources list a total of 742 nuclear tests and approximately 969 nuclear charges. See V. V. Adushkin and W. Leith, *The Containment of Soviet Underground Nuclear Explosions,* United States Geological Survey Open File Report 01-312, September 2001, at: https://bit.ly/3OqyuuJ.

3 V. N. Mikhailov *et al.*, 'USSR Nuclear Weapons Tests and Peaceful Nuclear Explosions, 1949 through 1990', Russian Federal Nuclear Center, Sarov, 1996. 10.

4 V. N. Mikhailov (ed.), *Catalog of Worldwide Nuclear Testing,* Ministry of Atomic Energy of the Russian Federation, Begell-Atom, New York, 1999.

5 R. Prăvălie, 'Nuclear weapons tests and environmental consequences: a global perspective', *Ambio,* Vol. 43, No. 6 (2014), 729–44. Some authorities assert that 70 per cent of tests were conducted at STS. See S. B. Balmukhanov, 'Medical Effects and Dosimetric Data from Nuclear Tests at the Semipalatinsk Test Site', Defense Threat Reduction Agency, Fort Belvoir, VA, 2006, p. 5.

the region had a sparse population density (even though it was inhabited mainly by Kazakhs), in addition to its close proximity to the South Urals' military-industrial complex.[6] Additionally, the site benefitted from a well-developed railway infrastructure and provided access to the Irtysh river.[7] The STS, which spanned three oblasts (provinces)—Semipalatinsk (now Abay Oblast), Pavlodar, and Karaganda—covered a total area of 18,300 square kilometres (comparable in extent to the size of Slovenia).

Between 1949 and 1989, 456 total nuclear tests were carried out at the STS involving 616 nuclear devices that yielded 17.4 Mt (the equivalent of more than 1,100 Hiroshima bombs).[8] The tests comprised 116 atmospheric detonations with the remaining 340 underground.[9] Testing occurred in four main areas within the STS. In 1949–62, 116 tests were conducted at Opytnoye Pole (Experimental Field), also known as Site 'P'.[10] Bombs were dropped from planes and platforms in order to analyse the impact of blasts on infrastructure and transportation vehicles (planes, trucks, and tanks) as well as on animals, including livestock.[11] After the adoption of the Partial Test-Ban Treaty, which prohibited atmospheric testing, 209 underground tests were conducted in adits in the Degelen mountain range. The test site further expanded to include Balapan (105 tests) and Sary-Uzen (24 tests), where underground explosions were conducted in wells. In 2002, Soviet officials made it known that radiological weapons were also tested on the STS until 1955.[12] These tests involved the use of radioactive waste, which was either dropped from a plane or detonated using explosives. A thermal neutron reactor and related facilities were built in 1961.[13]

In the broader histories of testing at the STS, several tests stand out. Nuclear testing there began with a surface test of the RDS-1 plutonium bomb (a near replica of the US bomb dropped on Nagasaki) with a yield of 22 kt on 29 August 1949.[14] Other significant tests include the first bomb dropped from the air, a 42 kt device, on 18 October 1951, and the first thermonuclear device, which was detonated on 12 August 1953 with the release of 400 kt of energy. The highest yield nuclear explosion at the STS was a 1.6 Mt atmospheric detonation on 22 November 1955. In January 1965, an underground peaceful nuclear explosion aimed to create an artificial lake (Chagan—'Atomic'—lake) 400 metres in diameter and 100 metres deep.[15] This was the first (and largest) of the 124 'peaceful' nuclear explosions by the Soviet Union, releasing 140 kt of energy.

In the mid-1980s, with the unveiling of Mikhail Gorbachev's *glasnost* (openness) policies, the newly formed Nevada-Semipalatinsk anti-nuclear movement in Soviet Kazakhstan called for the closure of the STS. In August 1991, four months before Kazakhstan's formal independence, President Nursultan Nazarbayev

6 The region is described in official publications as 'abandoned and waterless steppe with abandoned and dry wells' characterized by harsh continental climate. See V. Logachev (ed.), *Nuclear Tests of the USSR. Semipalatinsk Test Site: Facts, Evidence, Memories. Ensuring General and Radiation Safety of Nuclear Tests [in Russian: Yadernyye Ispitaniya SSSR: Semipalatinskiy Poligon. Fakty, Svidetel'stva, Vospominaniya, Obespecheniye Obshchey I Radiatsionnoy Bezopasnosti Yadernykh Ispitaniy]*, IGEM RAN, Moscow, 1997, 18; See also D. Holloway, *Stalin and the Bomb: The Soviet Union and Atomic Energy, 1939–1956*, Yale University Press, New Haven, 1994.

7 Balmukhanov, 'Medical Effects and Dosimetric Data from Nuclear Tests at the Semipalatinsk Test Site', p. 5.

8 Logachev (ed.), *Nuclear Tests of the USSR. Semipalatinsk Test Stie: Facts, Evidence, Memories. Ensuring General and Radiation Safety of Nuclear Tests*, 33. There is no agreement on the number of above ground tests and some sources list 527 tests in total with 126 (or 118) tests above ground. See Balmukhanov, 'Medical Effects and Dosimetric Data from Nuclear Tests at the Semipalatinsk Test Site', p. 5; A. M. Matushenko *et al.*, 'Chronological list of nuclear tests at the Semipalatinsk Test Site and their radiation effects', in C.S. Shapiro *et al.* (eds.), *Nuclear Tests. NATO ASI Series, Vol. 36,* Springer, Berlin/Heidelberg, 1998, 90.

9 Logachev (ed.), *Nuclear Tests of the USSR. Semipalatinsk Test Site: Facts, Evidence, Memories. Ensuring General and Radiation Safety of Nuclear Tests*, 33.

10 Ibid., 4.

11 The period between 1949 and 1957 saw the most intensive medical-biological studies conducted on animals, including mice, dogs, and camels. See V. A. Logachev and L. A. Mikhalikhina, 'Animal Effects from Soviet Atmospheric Nuclear Tests', Defense Threat Reduction Agency, Fort Belvoir, VA, 2008, p. 2.

12 Nuclear Threat Initiative, 'Semipalatinsk Test Site', updated 24 October 2021, at: https://bit.ly/49cAazS.

13 E. G. Batyrbekov and S. N. Lukashenko (eds.), *Semipalatinsk Test Site: Present State*, Kazakhstan National Nuclear Centre Institute of Radiation Safety and Ecology Press House, Pavlodar (KZ), 2017, 5.

14 Mikhailov (ed.), 'USSR Nuclear Weapons Tests and Peaceful Nuclear Explosions, 1949 through 1990', 12.

15 Ibid.

closed the site. Having inherited part of the Soviet nuclear weapon arsenal,[16] Kazakhstan subsequently worked with the United States and Russia to return to Russia more than 1,000 nuclear warheads[17] and played a pivotal role in establishing the Central Asian nuclear-weapon-free zone. Kazakhstan ratified the NPT in 1994 and the CTBT in 2002. In 2017, Kazakhstan supported and actively engaged in the elaboration of the TPNW, ratifying the treaty in August 2019 on the twenty-eighth anniversary of the closure of the STS.

Holding some of the world's largest uranium reserves, Kazakhstan has been the leading uranium exporter since 2019, contributing 43 per cent to global production.[18] The world's first International Atomic Energy Agency (IAEA) nuclear Low Enriched Uranium (LEU) Bank stocks 90 metric tons of LEU hexafluoride in Oskemen (formerly the city of Ust-Kamenogorsk).[19] Four small research reactors—three at the STS and one in the south of the country—operate in Kazakhstan. There are also plans to build a nuclear power station on the shores of Lake Balkhash.[20]

## Assessments

A series of assessments have been conducted by national and international agencies at the STS since its closure in 1991. The most significant investigations by Kazakhstan's National Nuclear Centre (NNC) and its Institute of Radiation Safety and Ecology (IRSE) were carried out between 2008 and 2021 during the 'comprehensive environmental survey'. This survey, which is considered 'complete', has served as the basis for the government's decision on further land use and economic activities at the Site, as well as the legal regime that has been adopted. The NNC will continue research at the Site as part of its mandate.

One of the early investigations includes an IAEA assessment, which concluded that the Opytnoye Polye (Experimental Field) and Lake Balapan are heavily contaminated (annual exposures of 100 millisievert (mSv) per year), whereas most of the test site has little or no residual radioactivity, with a dose rate very close to the global average from fallout (a total effective dose of 2.5 mSv per year). The IAEA has recommended restricting access to the contaminated sites until remediation is carried out. Interventions to reduce radiation exposure to individuals outside the STS were not considered justified due to the low risk levels.[21]

National radiation thresholds are established in the Rules of 'Sanitary and Epidemiological Requirements to Ensure Radiation Safety' of 15 December 2020.[22] According to Article 236 of the Rules, assessment of the population's radiation safety level is determined based on effective doses from natural sources of radiation. When the annual exposure is below 2 mSv, radiation exposure is deemed to remain within the average range for the population. Exposure from 2 to 5 mSv per year suggests elevated exposure, while values exceeding 5 mSv per year indicate a high level of exposure.[23]

At the STS, perceptions of the reliability of assessments vary. While experts accept the assessment results, doubts linger among communities regarding the official statements on radiation safety. At the STS, the lack of

16 T. Kassenova, *Atomic Steppe: How Kazakhstan Gave Up the Bomb,* Stanford University Press, Stanford, CA, 2022.
17 Ibid.
18 https://world-nuclear.org/.
19 IAEA, 'IAEA Low Enriched Uranium (LEU) Bank', 2023, at: https://bit.ly/42nNY8g.
20 A. Satubaldina, Nuclear power plant in Kazakhstan: What's Next', *Astana Times.* 18 August 2023, available at: https://bit.ly/3uemdT6.
21 'In most areas, external radiation dose rates and soil activity are the same, or close to, typical levels in other regions and countries where no nuclear weapon testing has been carried out. The estimated annual effective dose to persons outside the nuclear test site from residual radioactivity is at most 0.1 mSv (giving a total effective annual dose of 2.5 mSv when exposure to natural sources of radiation is included). Actual exposures are more likely to be of the order of a few microsieverts per year, a dose rate which is very close to the global average from fallout. On the basis of this evidence, intervention to reduce the radiation exposure of persons outside the Semipalatinsk test site is not considered to be justified.' IAEA, 'Radiological Conditions at the Semipalatinsk Test Site, Kazakhstan: Preliminary Assessment and Recommendations for Further Study', Vienna, 1998, at: https://bit.ly/49hFL8e.
22 No. KR DSM-275/2020.
23 Rules available at: https://bit.ly/3UfnqUW. The English version is available at: https://bit.ly/3U92UVo.

a targeted communication campaign by the government has led to mistrust and fear among local communities. These communities live in a state of uncertainty as radioactivity cannot be seen and, for many people, is a challenging notion to grasp. Concern that particles from contaminated regions may be dispersed to other areas and that water sources may not be safe remains. In addition, apprehension surrounds ongoing coal mining at the former STS, specifically the Karazhyra open-pit mine, and the potential risk of groundwater contamination due to current and planned mining.[24]

Long-standing mistrust of officials on all matters related to the STS persists, as people lived many years in psychological stress, experiencing health risks and lacking proper information about the causes.[25] Even the past delineation of the STS borders is met with scepticism, as Sarzhal village appears to have been artificially cut out from the site, seemingly to avoid the relocation of people and associated expenses. Similarly, it is feared that reports may be tainted by the desire to avoid having to make social welfare payments, raising doubts as to their credibility. Unlike at the STS, health studies of other populations exposed to radiation by atmospheric testing are lacking despite local concerns about the safety of water sources and locally obtained food products.

## Human effects

The Soviet Union conducted nuclear tests with little regard to nuclear safety or human health. Direct human casualties, both fatal and non-fatal, have been confirmed from Soviet nuclear tests at the STS.[26] Yet for decades, the authorities denied any harmful effects of radiation from atomic weapons testing, accidents, or the dumping of radioactive waste. Relatively few scientists took the path of the Soviet nuclear physicist and 'father' of the Soviet hydrogen bomb, Andrei Sakharov, who spoke out against nuclear proliferation and human rights abuses in the Soviet Union.[27] The public, however, were not made aware of the dangers of nuclear testing due to the culture of secrecy surrounding the nuclear testing programme.

Naturally, those living near the proving grounds were among those most at risk. Civilian communities as well as military personnel living near the test sites and in the path of radioactive fallout hundreds of kilometres away were all affected. But local communities were disproportionately affected by nuclear fallout. Indeed, the testing sites were selected because they were perceived as 'empty' of important human populations and public discussions of radiation or its effects on human health were prohibited.[28]

### The impact on Indigenous populations

The STS and its military command centre, later named Kurchatov after the Soviet physicist Igor Kurchatov, were installations that were classified secret (in the early years), off publicly available maps, and under a strict

24 https://polygon.vlast.kz/kalmykov.

25 R. Vakulchuk and K. Gjerde with T. Belikhina and K. Apsalikov, 'Semipalatinsk Nuclear Testing: The Humanitarian Consequences', Report, Norwegian Institute of International Affairs, Oslo, 2014, at: https://bit.ly/47WBKov.

26 Balmukhanov, 'Medical Effects and Dosimetric Data from Nuclear Tests at the Semipalatinsk Test Site'. See also B. Grosche *et al.*, 'Studies of health effects from nuclear testing near Semipalatinsk Nuclear Test Site, Kazakhstan', *Central Asian Journal of Global Health,* Vol. 4, No. 1 (2015), 147; C. Becker *et al.*, *Brighter than a Million Suns: Contemporary Health Consequences of Atomic Testing in the Semipalatinsk Nuclear Polygon,* University of Central Asia, Bishkek, 2022, at: https://bit.ly/4bgqTsl; W. Yan, 'The nuclear sins of the Soviet Union live on in Kazakhstan', *Nature,* 2019, available at: https://bit.ly/3Ou0v4r; Y. Dubrova *et al.*, 'Nuclear weapons tests and human germline mutation rate', *Science,* Vol. 295, No. 5557, 1037; Institute of Biophysics of the USSR Academy of Medical Sciences, 'Vypiska is otchota resul'taty nauchenениya vozdeystviya radioaktivnykh osadkov na ob'yekty vneshney sredy is sostayene zdrov'ya nasleniya itogi', 1958. Archive in Semey Scientific Research Institute for Radiation Medicine and Ecology.

27 A. Sakharov, 'Here and there: the threat of nuclear war', *American Scientist,* Vol. 57, No. 1 (1969), 167–71.

28 C. Werner and K. Purvis-Roberts, 'Unravelling the secrets of the past: contested versions of nuclear testing in the Soviet Republic of Kazakhstan', in B. Rose-Johnston (ed.), *Half-Lives and Half Truths: Confronting the Radioactive Legacies of the Cold War*, School for Advanced Research Press, Santa Fe, NM, 2007, 277–98. See also K. Brown, *Plutopia: Nuclear Families, Atomic Cities, and the Great Soviet and American Plutonium Disasters*, Oxford University Press, Oxford, 2013.

control regime throughout the Soviet era until *glasnost*.[29] Since many classified records were destroyed, while other files remain stored in the Russian Federation and are inaccessible to the public, the official STS files contain only partial records of impacts on Indigenous Kazakh populations, with much of what we know about the site reconstructed from available official sources and oral histories.[30] At the time of testing, well over a million people lived within 160 kilometres of the STS.[31] The site is located 140 kilometres north-west of the city of Semipalatinsk (now Semey) and several dozen winter pastures were located within today's official site borders. Dozens of villages and smaller towns (inhabited primarily by Indigenous Kazakhs and ethnic Russians), including Kurchatov, lay just outside the test area.[32] Approximately three million people have been affected by radiation, divided between citizens of what is now Kazakhstan and the neighbouring Altai region of Russia.[33] The population living in the vicinity of STS received a dose between 20 and 4,000 mSv.[34]

Indigenous Kazakhs living in and around the STS raised cows, goats, sheep, and horses, or worked on industrial-scale farms growing wheat. They were not informed about the potential risks associated with nuclear tests until the mid 1980s. This is despite the fact that atmospheric detonations accounted for the primary contamination of the environment and subsequent radiation exposure (both internal and external) to the public, contributing to approximately 95 per cent of the total dose.[35] Evidence suggests that Soviet authorities intentionally exposed local populations to fallout from above-ground tests to collect scientific data on human and environmental effects.[36] The tests with the most significant impacts on human health were those that occurred on 29 August 1949 (22 kt), 24 September 1951 (38 kt), 12 August 1953 (400 kt), and 24 August 1956 (27 kt).[37]

The first test conducted in 1949 is believed to have exposed some 25,000 people to average doses exceeding 130 mSv.[38] The somatic effects were extreme. Several thousand among them received 1 sievert (Sv), a dose known to induce radiation sickness, leading to symptoms like nausea, vomiting, and haemorrhaging. The 1953 thermonuclear test resulted in significant fallout, dispersing a cloud up to 1,000 kilometres from the STS and reaching as far as Russia's Altai region.[39] In the city of Ust-Kamenogorsk in Kazakhstan, more than 600 people were admitted to the hospital with radiation sickness.[40]

The fallout from the 1953 thermonuclear test led to systematic yet clandestine studies of population health. Between 1956 and 1960, six research expeditions were conducted under the direction of the Moscow Institute of Biophysics of the Soviet Union Academy of Medical Sciences and the Institute of Regional Pathology, Kazakh Academy of Sciences, in order to gather data on human health.[41] Kazakh researchers Bakhiya Atchabarov and

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29 Holloway, *Stalin and the Bomb: The Soviet Union and Atomic Energy, 1939–1956*, 213. The STS was known by several code names, including Training Ground No. 2, Semipalatinsk-21, Ploshad M (Site M), Bereg (riverbank), and Konechnaia (terminus). See S. Balmukhanov *et al.*, *Three Generations of the Semipalatinsk Affected to the Radiation*, Sakshy Press, Almaty, 2002, 5; C. Alexander, 'A Chronotope of Expansion: Resisting Spatio-temporal Limits in a Kazakh Nuclear Town', *Ethnos*, Vol. 88, No. 3 (2023), 467–90, at p. 473; Logachev (ed.), *Nuclear Tests of the USSSR: Semipalatinsk Test Site Facts, Evidence, Memories. Ensuring General and Radiation Safety of Nuclear Tests,* 17.

30 Balmukhanov, 'Medical Effects and Dosimetric Data from Nuclear Tests at the Semipalatinsk Test Site', p. 7.

31 T. Carlsen *et al.*, 'Radionuclide contamination at Kazakhstan's Semipalatinsk test site: implications on human and ecological health', *Human and Ecological Risk Assessment,* Vol. 7 No. 4 (June 2001), 943–55.

32 M. Stawkowski, 'I am a radioactive mutant: emergent biological subjectivities at Kazakhstan's Semipalatinsk Nuclear Test Site', *American Ethnologist,* Vol. 43 No. 1 (2016), 144–57, at: https://bit.ly/3ubNBkP; Werner and Purvis-Roberts, 'After the Cold War: international politics, domestic policy and the nuclear legacy in Kazakhstan', 465.

33 Balmukhanov, 'Medical Effects and Dosimetric Data from Nuclear Tests at the Semipalatinsk Test Site', p. 5.

34 Four decades of nuclear testing: the legacy of Semipalatinsk', *EClinicalMedicine*, Vol. 13 (2019), at: https://bit.ly/42jzKFI.

35 B. Grosche, 'Semipalatinsk Test Site: introduction', *Radiation and Environmental Biophysics,* Vol. 41, No. 1 (2002), 53.

36 C. Werner and K. Purvis Roberts, 'After the Cold War: international politics, domestic policy and the nuclear legacy in Kazakhstan', *Central Asian Survey,* Vol. 24, No. 4 (2006), 461–80.

37 Grosche *et al.*, 'Studies of health effects from nuclear testing near Semipalatinsk Nuclear Test Site, Kazakhstan', p. 147.

38 M. Godman, 'The Russian radiation legacy: its integrated impact and lessons', *Environmental Health Perspectives,* Vol. 105, No. 6 (1997), 1389.

39 Balmukhanov, 'Medical Effects and Dosimetric Data from Nuclear Tests at the Semipalatinsk Test Site', p. 6.

40 W. Yan, 'The nuclear sins of the Soviet Union live on in Kazakhstan', *Nature,* 2019, available at: https://bit.ly/3Ou0v4r.

41 Logachev (ed.), *Nuclear Tests of the USSR. Semipalatinsk Test Stie: Facts, Evidence, Memories. Ensuring General and Radiation Safety of Nuclear Tests,* 183–87; S. Bauer *et al.*, 'The legacies of Soviet nuclear testing in Kazakhstan: fallout, public health and societal issues', in D. Oughton and S. O. Hansson (eds.), *Social and Ethical Aspects of Radiation and Risk Management*, Elsevier Science, 2013, 239–58.

Saim Balmukhanov raised the alarm with Soviet authorities about radiation sickness among the exposed residents, but their concerns were dismissed and silenced. In 1960, a historical cohort of some 20,000 inhabitants of exposed and non-exposed villages was established and people's health was longitudinally monitored. The historical cohort data was collected until 1990 at a secret clinic established by the Soviet Ministry of Health in 1957, operating under the pseudonym of Anti-Brucellosis Dispensary No. 4. The individuals exposed to radiation were never provided with any information about what had happened to them or offered meaningful medical care. Congenital malformations, cancers, and other health issues among exposed populations have been reported.[42]

Although there are only scattered data on how radiation from the STS has impacted human health, the most recent report found 'exceptionally large consequences for a wide range of health conditions many decades after the explosions ceased'.[43] Local residents who lived through the tests recall bright flashes, thundering booms, the earth rumbling under their feet, and damaged houses with blown-out windows and cracked walls.[44]

### The impact on military personnel

By 1950, approximately 700,000 people participated in the Soviet atomic project, more than half of whom were prisoners.[45] Thousands were involved in building administrative and logistical centres (Kurchatov, Belushya, and others) with the establishment of the STS (and the test site in Novaya Zemlya, NZTS), as well as living quarters for military employees and their families. In the early days of construction, soldiers and prisoners worked with little available machinery and lived in tents through brutal winter months. Once construction was completed, soldiers, officers, and their families inhabited exclusive, albeit restricted, communities. Within these nuclear enclaves, they enjoyed access to food products not found elsewhere in the Soviet Union, as well as many amenities such as parks, kindergartens, schools, well-stocked stores, and various other privileges.[46] There are no detailed studies of accidents, illnesses, deaths, or the incidence of cancers among military participants in the Soviet nuclear tests. Although accidents were common and there was virtually no regard for nuclear safety, very little information about the impact of nuclear testing on military personnel working at STS and NZTS from both official and unofficial sources is available.[47] A few cases, however, stand out.

It was commonplace for the Soviet Army to conduct tests involving the dropping of bombs from aircraft and platforms at the STS. Personal accounts suggest that individuals involved in these tests were affected by nuclear fallout.[48] Several above-ground tests did not go as planned when the weather conditions changed, leading the nuclear cloud to pass over military garrisons. Additionally, accidents from underground tests and in adits have resulted in the release of radioactive gases into the air.[49]

42 Grosche *et al.*, 'Studies of health effects from nuclear testing near Semipalatinsk Nuclear Test Site, Kazakhstan', 147.

43 C. Becker *et al.*, *Brighter than a Million Suns: Contemporary Health Consequences of Atomic Testing in the Semipalatinsk Nuclear Polygon,* University of Central Asia, Bishkek, 2022, at: https://bit.ly/4bgqTsl, 1.

44 W. Yan, 'The nuclear sins of the Soviet Union live on in Kazakhstan', *Nature,* 2019, available at: https://bit.ly/3Ou0v4r; See also Stawkowski, 'I am a radioactive mutant: emergent biological subjectivities at Kazakhstan's Semipalatinsk Nuclear Test Site'.

45 Z. Medvedev, 'Stalin and the Atomic bomb', 1999, accessed 1 December 2023 at: https://bit.ly/3HL7FgM, 61.

46 Brown, *Plutopia: Nuclear Families, Atomic Cities, and the Great Soviet and American Plutonium Disasters.*

47 Ibid. See also the Totskoye nuclear exercise in 1954 where 45,000 soldiers marched through an area where a 40 kt bomb had exploded minutes earlier. See M. Goldman, 'The Russian radiation legacy: its integrated impact and lessons', *Environmental Health Perspectives,* Vol. 105, No. 6 (1997), 1385–91.

48 Batyrbekov and Lukashenko (eds.), *Semipalatinsk Test Site: Present State.*

49 Ibid.

### Transgenerational human effects

Radiation exposure has been shown to cause an increase in intergenerational genetic disease in animals.[50] Studies in Kazakhstan show intergenerational damage in the germline (the population of cells that pass on genetic material to offspring), although it remains uncertain if this damage translates to negative health outcomes in children.[51] Research on population health in and around the STS is partial and scattered. The historical record established in 1960 shows significantly higher rates of thyroid, breast, oesophagus, and other cancers, cardiovascular diseases, and cognitive and other disorders.[52] In the STS region, children are nine times more likely than the control group to develop digestive system diseases, 1.4 times more likely to develop skin diseases, and eight times more likely to develop chronic blood pathologies, as well as other disorders.[53] Additionally, 'elevated risks range from pregnancy complications to a range of immune disorders to circulatory illnesses to muscular-skeletal conditions and deformities'.[54]

## Societal effects and displacement

In the 1920s and 1930s, Kazakhs and non-Indigenous populations in Soviet Central Asia were forcibly settled on collective farms. When nuclear testing began in 1949, the internal passport system adopted throughout the Soviet Union effectively kept people in place. Thus, the population living in the shadow of the STS was repeatedly exposed to radioactive fallout, especially during the period of atmospheric testing. When the Soviet Union collapsed in 1991, the STS was no longer patrolled. Few warning signs remained and anyone could enter the site despite lingering, uneven contamination.[55] Nuclear testing at the STS had serious negative consequences for people's health and the environment. Among other activities, Kazakhs continue to pasture animals on the STS and there is no State agency in charge of radiation monitoring of the animals which are frequently sold in open-air markets. People's claims of ill-health are frequently dismissed by government authorities as symptomatic of 'radiophobia' – an irrational fear of radiation.[56] Moreover, the legacy of nuclear testing and the attention it has garnered have stigmatized local populations, who are often perceived by outsiders as genetically corrupted.[57]

## Victim assistance

At the STS, and despite research carried out by the NNC which indicated a low risk of product contamination, the absence of monitoring leaves local communities vulnerable. Establishing a comprehensive monitoring system for product sampling, especially meat, and the implementation of necessary mitigation measures is therefore necessary. Moreover, a monitoring programme for drinking water is essential for assessing the migration of radionuclides from underground tests. Restricting agricultural activities and livestock breeding in

50 Data for humans are ambiguous. See H. Weinbert *et al.*, 'Very high mutation rate in offspring of Chernobyl accident liquidators', *Proceedings of the Royal Society B,* Vol. 268, No. 1471 (2001), 1471–2954; M. Yeager *et al.*, 'Lack of transgenerational effects of ionizing radiation exposure from Chernobyl accident', *Science*, Vol. 375, No. 6543 (2021), 725–29.

51 Y. Dubrova *et al.*, 'Nuclear weapons tests and human germline mutation rate', *Science*, Vol. 295, No. 5557 (2002), 1037.

52 Becker *et al.*, *Brighter than a Million Suns: Contemporary Health Consequences of Atomic Testing in the Semipalatinsk Nuclear Polygon,* 11–14.

53 A. Kuzgibekova *et al.*, 'The state of health of children living in adverse environmental conditions', *Australasian Medical Journal,* Vol. 9, No. 12 (2016), 474–80; See also A. Markabayeva *et al.*, 'Increased prevalence of essential hypertension in areas previously exposed to fallout due to nuclear weapon testing at the Semipalatinsk Test Site, Kazakhstan', *Environmental Research,* Vol. 167 (2018), 129–35; Y. Semenova *et al.*, 'Mental distress in rural Kazakhstani population exposed and non-exposed to radiation from the Semipalatinsk Nuclear Test Site', *Journal of Environmental Radioactivity,* Vol. 203 (2019), 39–47.

54 Becker *et al.*, *Brighter than a Million Suns: Contemporary Health Consequences of Atomic Testing in the Semipalatinsk Nuclear Polygon,* 7.

55 Stawkowski, 'I am a radioactive mutant: emergent biological subjectivities at Kazakhstan's Semipalatinsk Nuclear Test Site'.

56 M. Stawkowski, 'Radiophobia had to be reinvented', *Culture, Theory and Critique,* Vol. 58, No. 4 (2017), 357–74.

57 Stawkowski, 'I am a radioactive mutant: emergent biological subjectivities at Kazakhstan's Semipalatinsk Nuclear Test Site', 185.

contaminated areas is especially important, particularly in regions where the Shagan river (containing tritium) is used for livestock watering. A transparent return to economic use of lands deemed 'uncontaminated' is needed; an inclusive process should allow local communities to engage in the decision-making process. Moreover, continued medical examinations are critical to assess the health of individuals exposed to past and present radioactive contamination. Improving the method of determining victim status is key for facilitating compensation payments, providing much needed benefits to all affected citizens, regardless of their current residence.

The Kazakh government continues registration of people eligible for recognition as victims and compensation schemes.[58] Assistance to victims is limited to the official compensation schemes and additional medical support via the Institute of Radiation Medicine and Ecology (IRME), formerly Dispensary No. 4, located in Semey. IRME conducts studies of the health consequences of radiation impacts and provides medical assistance to victims in its clinic. IRME also serves as the Regional Interdepartmental Expert Council, which carries out expert examination of the causal relationship of diseases and mortality with exposure to radiation. The conclusion of the Expert Council is the basis for the affected individuals to apply for social benefits. The State Scientific Automated Register of Victims of Nuclear Tests, compiled by IRME, has 367,950 entries and complete files for 232,580 people. According to its director, Talgat Moldagaliyev, 135,370 people are recorded as having died as a result of exposure to radiation.[59]

## Environmental contamination

Kazakhstan reports that it was 'the first country in the world to conduct a full-scale assessment of the radiation situation on the territory of a former test site'. It told UN Member States in 2024 that a 'comprehensive environmental survey of the Semipalatinsk test site was carried out from 2008 to 2021'.[60] According to the latest NNC data, the STS area can be conditionally divided into two zones: 1) the territory with increased values of dose loads (more than 0.3 mSv per year), which includes the actual testing areas and the pathways of radioactive fallout plumes; and 2) the remaining territory with dose values less than 0.3 mSv.[61] According to the NNC 2018 report, the areas discussed below are all contaminated.[62]

### Contamination at Opytnoye Pole (Experimental Field)

The site has uneven radioactive contamination, concentrated in specific areas – epicentres and fallout traces from tests. Some spots show dose rates exceeding 40 picosieverts (pSv)/h. Radioactive traces extend beyond STS borders. Testing localities vary: a) high-energy release with abundant decay products (caesium-137, strontium-90); b) minimal or no energy release, with high concentrations of nuclear charge material (plutonium-239 and plutonium-240, americium-241); c) intense neutron fluxes, yielding activated products (cobalt-60, Europium isotopes, hydrogen-3 (better known as tritium), and others).

58 https://bit.ly/42lcEhS, E-government web-portal of the Republic of Kazakhstan, accessed on 24 January 2024.
59 Interview with *Caravan* newspaper on 24 June 2019, accessed on 24 January 2024, at: https://bit.ly/3SANKrf.
60 Report of Kazakhstan pursuant to operative paragraph 4 of resolution 78/240 entitled 'Addressing the legacy of nuclear weapons: providing victim assistance and environmental remediation to Member States affected by the use or testing of nuclear weapons', 2024, at: https://bit.ly/3T7N4JF, para. 8.
61 'Human, Energy, Atom', *Scientific Journal of the NNC*, Vol. 35, No. 1 (2021), at: https://bit.ly/3ubNLZt.
62 E. G. Batyrbekov and S. N. Lukashenko (eds.), *Semipalatinsk Test Site: Modern State*, 3rd Edn, IRSE NNC, 2018, at: https://bit.ly/3OkD2T5.

### Contamination at Balapan and Sary-Uzen

Radioactive contamination of the surface soil near the wells can reach the following maximal specific activity values: americium-241 – from 1 to n x $10^2$ Bq/kg, caesium-137 – from 1 to n x $10^2$ Bq/kg, strontium-90 - from 10 to n x $10^2$ Bq/kg, Europium-152 – from 2 to n x $10^3$ Bq/kg. The total contaminated area of the nearby lands comprises about 10 per cent of the total site area.[63]

### Contamination at Degelen

The most contaminated areas at the Degelen site are the near-portal sections of the adits where water flows from the tunnels. The maximum specific activities of radionuclides in water from various adits are as follows: caesium-137 – 820 Bq/l, strontium-90 – 2,100 Bq/l, plutonium-239 and plutonium-240 – 6.4 Bq/l, americium-241 – 2.6 Bq/l, andtritium – 9.9 x $10^5$ Bq/l.[64]

### Contamination at excavation blasts at Chagan, Sary-Uzen, Telkem-1, and Telkem-2

Currently, most of these cavities (craters) are periodically filled with water. The highest radionuclide concentrations occur in the Chagan (Atomic Lake) debris heap areas, reaching maximum effective dose values of 7 pSv/h. Max specific activity can be nx$10^4$ Bq/kg for caesium-137, nx$10^3$ Bq/kg for strontium-90, and nx$10^4$ Bq/kg for plutonium-239 and plutonium-240. Water contamination includes tritium and strontium-90 at concentrations as high as 20,000 Bq/kg and 700 Bq/kg, respectively.

### Contamination at radiological warfare sites 4a and 4

From 1953 to 1957, the sites were used for testing combatant radioactive substances (CRS), created from radiochemical wastes or by irradiating special substances with neutrons in a nuclear reactor. The primary contaminant is strontium-90, with a maximum specific activity in soil cover reaching 5x$10^8$ Bq/kg, classifying it as intermediate-level radioactive waste. Other radionuclides like plutonium-239 and plutonium-240, Europium-152 and Europium-154, caesium-137, americium-241, and coblat-60 are present in smaller amounts (nx$10^3$-$10^6$ Bq/kg). Radioactively contaminated spots can range from several hundred to several hundred thousand square metres, with some spanning a square kilometre. Vegetation in these spots exhibits higher radionuclide accumulation coefficients. The elevated strontium-90 levels in soil make these testing grounds the most radiologically hazardous among the STS objects, posing a significant threat to people and local animals.

### Contamination outside the main testing areas at the STS

Trace of radioactive fallouts outside the STS includes areas of radioactive deposition from fallout plume from surface nuclear tests extending from the Opytnoye Polye almost to the STS boundaries, with a width of up to 15 kilometres and a length exceeding 100 kilometres. These traces contain caesium-137, strontium-90, plutonium-239 and plutonium-240, americium-241, cobalt-60, and europium isotopes – with maximum amounts reaching thousands of Bq/kg, observed about 40 kilometres from the testing ground's epicentre (P-1 site). Contamination gradually reduces along the fallout plume pathways. The Shagan river's radioactivity stems from

63 Ibid.
64 Ibid.

a thermonuclear explosion at the Balapan site, which led to the creation of the Atomic Lake. Contamination includes tritium, strontium-90, and plutonium-239 and plutonium-240.

Downstream of the Atomic Lake, levels of strontium-90 and plutonium-239 and plutonium-240 were found at 0.03 Bq/kg and 0.002 Bq/kg, respectively. Tritium concentrations range from 100 to 350,000 Bq/kg. Livestock watering in the Shagan River leads to tritium intake, impacting agricultural products like meat and milk. Tritium levels in the river water exceed the intervention level of 7,600 Bq/kg under sanitary rules by between fivefold and fiftyfold. These elevated tritium concentrations extend about 25 kilometres beyond the STS border.

## Environmental remediation

Approximately half of the STS—9,000 of the total of 18,300 square kilometres—is estimated to be radioactively contaminated. NNC reports claim that comprehensive remediation and safety measures have been undertaken, but 2018 data indicate significant strontium-90 levels in radioactive substance testing grounds. Currently, access to the sites (4a and 4) for people and animals is restricted by trenches and radiation warning signs. Nevertheless, these lands, estimated to cover 1.1 square kilometres, are near areas planned for future economic use. Instead, they need remediation.[65] Contamination extends beyond the STS borders, affecting locations like the Chagan River from Balapan Lake (Atomic Lake), which is contaminated as a result of tritium migration.[66] Remediation efforts within STS borders have been made, but plans for external contaminated areas were not deemed necessary, although isolated hotspots may persist.

NNC reports on wildlife and vegetation sampling from 2008 to 2021 claim radionuclide levels in meat within and beyond STS are below detection limits. The radiation state of flora is deemed safe,[67] but limited research into radioactive and chemical contamination in biota raises questions about actual remediation needs.[68]

After the closure of the STS, several phases of remediation works have been conducted under the overall coordination of the NNC and its IRSE. This encompassed remediation efforts at the Degelen, Aktan-Berli (used for experiments with incomplete chain reactions), and Opytnoye Polye testing sites.

By 2000, all adits and wells (181) intended for underground nuclear explosions at the Degelen mountains had been rendered unusable for their initial purpose. A further thirteen unused wells were closed at the Balapan site.[69] In 2021, construction of additional elements of engineering barriers took place at the Aktan-Berli testing site, and a security and remote monitoring system was installed.[70] Nevertheless, a significant portion of the remediation efforts was dedicated to the Opytnoye Polye. Research began in 2012, involving over three million spectrometric measurements and analysis of more than five thousand collected samples. Subsequent remediation was completed in 2020.[71]

The site was rehabilitated by removing the topsoil containing high concentrations of nuclear waste. The reprocessed nuclear waste from the site was transported for long-term storage at the Baikal-1 research reactor complex, under IAEA safeguards. In areas where reclamation was not feasible due to personnel safety concerns, protective concrete structures were constructed. The NNC established security systems at both the Degelen

65 Batyrbekov and Lukashenko (eds.), *Semipalatinsk Test Site: Modern State*.
66 Ibid.
67 'Human, Energy, Atom', *Scientific Journal of the NNC*.
68 S. Geraskin, K. Minkenova, A. Perevolotsky, Z. Baigazinov, and T. Perevolotskaya, 'Threshold dose rates for the cytogenetic effects in crested hairgrass populations from the Semipalatinsk nuclear test site, Kazakhstan', *Journal of Hazardous Materials*, Vol. 416 (15 August 2021), 125817, at: https://bit.ly/49iCBAL.
69 Publication by the NNC on 29 August 2019, at: https://bit.ly/4bb6818.
70 Publication by the NNC on 21 December 2021, at: https://bit.ly/3SGhP8I.
71 'Human, Energy, Atom', at: https://bit.ly/3ubNLZt.

and Opytnoye Polye sites, though local populations continue to travel through ground zero. Remediation works were carried out in accordance with the 'Protocol on Functions and Obligations between the NNC RK and the US Department of Defense Threat Reduction Agency for the security and long-term activities at the former STS', which was signed in December 2018.[72]

## The impact of climate change[73]

The Semipalatinsk test site in Kazakhstan lies southwest of the Irtysh River that flows from China and passes close to the test site boundary. Climate profiles indicate an increase in the frequency of extremely high flows for the Irtysh River, with a one in a century river flow projected to become a one in forty-year event. Drought and wildfires are also predicted to increase. The area is also vulnerable to earthquakes. A summary of trends and potential climate-related impacts is given in Table 1.

**Table 1: Summary of key climate trends and impacts, Kazakhstan**[74, 75]

<table>
<tr><th>Climate system/ hazard</th><th>Historic trends</th><th>Projected trends</th><th>Possible impact on risk components</th></tr>
<tr><td>Temperature</td><td>Rise in average annual temperatures</td><td>Average annual temperatures expected to rise significantly</td><td rowspan="5">Source: changes in physico-chemical behaviour affecting mechanisms by which contaminants may be released. Includes physical landforms changes caused by soil desiccation, erosion, and wildfires.<br><br>Pathway: potential changes in water infiltration, water tables, dilution, and flow rates. Changes to release of airborne contaminants, including from wildfires.*<br><br>Receptor: changes in species assemblages and/or sensitivity to contaminants, water abstraction/dependency and exposure routes for people.</td></tr>
<tr><td>Precipitation</td><td>Not clear</td><td>Increases in average annual precipitation, and the intensity of sub-daily extreme rainfall events appears to also increase with temperature</td></tr>
<tr><td>Drought</td><td>Droughts regularly occurring between 1986 and 2006</td><td>Severe droughts are expected to occur more frequently</td></tr>
<tr><td>Flood</td><td>Flooding more prevalent in southern and eastern parts of Kazakhstan</td><td>Irtysh River, with a 1 in 100-year river flow is projected to become a 1 in 40-year event</td></tr>
<tr><td>Wildfires</td><td>High chance of encountering weather that could support a significant wildfire</td><td>Expected to become more frequent in steppe and forest areas, driven by higher temperatures and more frequent droughts</td></tr>
</table>

* Includes soil-bound radionuclides or radionuclides taken up by plants

## Legal issues

### Individual compensation schemes

A range of compensation schemes have been created in the STS areas, largely following pressure from the public in Kazakhstan. The Russian Federation, which upon the dissolution of the Soviet Union took over the USSR's

72 Publication by the NNC on 3 May 2023, at: https://bit.ly/4bhRQvO.
73 This section was contributed by Linsey Cottrell.
74 Climate Risk Country Profile: Kazakhstan, The World Bank Group and the Asian Development Bank, 2021, at: https://bit.ly/3v5QS5A.
75 ThinkHazard! High-level hazard profile for Abay, at: https://bit.ly/3V7OFkz; for Beskaragay, at: https://bit.ly/3TujE9i; for Borodulikha, at: https://bit.ly/3Vb9zzn; and for Semey, at: https://bit.ly/3P9q9M3.

permanent seat on the UN Security Council and its status under the NPT as a 'nuclear-weapon State', has not provided additional funding. A State system for compensation schemes for affected communities was introduced in 1992, regulated by the law 'On social protection of citizens affected by nuclear tests at the Semipalatinsk Nuclear Test Site, N 1787-XII'. The law defines five groups of the population eligible for compensation, depending on the areas adjacent to the STS where people lived during different periods of nuclear testing.

As of 2005, 1,323,000 people were recognized as victims of nuclear tests, but only 1,057,000 people received certificates confirming their victimhood status – the so-called 'Polygon IDs'.[76] The number of people with confirmed status cannot be found in open sources, and registration of those eligible for recognition as victims was still ongoing at the time of writing.[77] Moreover, since the main criteria for eligibility for compensation were only the residence of people and their period of residence, the actual number of people affected by the tests is unknown.

Kazakhstan reported in 2024 that a total of more than 1.1 million citizens had received 'one-time cash compensation'.[78] Persons with disabilities associated with radiation exposure during nuclear tests and their consequences are entitled to monthly disability allowances. Recipients are divided into three groups (severe disability, less severe disability, and moderate disability) and entitled to monthly payments of 113,993 tenge, 97,361 tenge and 81,540 tenge, respectively. The value of the payments is linked to minimum living wage and reviewed annually. Family members of those who died as a result of radiation-related diseases or consequences of nuclear tests are also entitled to allowances.[79]

According to the aforementioned law (Chapter 4 on social protection), individuals with confirmed status are entitled to the following social support measures, with the amounts depending on their residence:

I. Lump-sum monetary compensation for damages
II. Pension top-up (only for two categories of victims)
III. Salary top-up (currently only for those who continue living in the radiation risk areas)
IV. Annual additional paid leave (currently only for those who continue living in the radiation risk areas)
V. Additional maternity leave
VI. Free treatment (medically justified) in sanatoriums and recreational facilities; and
VII. Servicemen and employees of military service and special State bodies are entitled to the same rights and benefits while performing their services in contaminated territories.

An additional form of compensation is based on individual health conditions caused by exposure to radiation, determined by the decisions of the 'Interdepartmental expert councils responsible for establishing the causal relationship of diseases in persons affected by nuclear tests, Chernobyl, and other radiation accidents'. However, accessing the expert councils for people living in remote rural areas has been difficult due to financial and social reasons. Citizens also lack trust in the procedures applied by the councils.[80]

Lump-sum compensations were paid only for the period of residence from 1949 to 1965. The amounts of the lump-sum monetary compensations were very small due to the economic situation in the 1990s. There were also years of delays in making the payments. As well, people complain that 'Polygon IDs' are only valid in the East Kazakhstan region (now Abay) and that social support measures such as salary top-ups and additional

76 Data provided by the Parliament of Kazakhstan on 24 June 2005 during the parliamentary hearings 'On health care and social protection of the population living in the zone of influence of the former Semipalatinsk Nuclear Test Site'.
77 E-government web-portal of the Republic of Kazakhstan accessed 24 January 2024, at: https://bit.ly/42lcEhS.
78 Report of Kazakhstan pursuant to operative paragraph 4 of UN General Assembly Resolution 78/240, 2024, para. 43.
79 Ibid., paras. 46 and 47.
80 I. Gumyrkina and O. Loginova, in *Vlast* (newspaper), at: https://bit.ly/3w4oJMa.

paid leave are only available for government employees.[81] No social benefits related to the STS are available for people who moved to adjacent areas after 1990.

### Court judgments

Court judgments on compensations related to the STS are taking place in Kazakhstan and Russia. In Kazakhstan, one of the problems is for people living outside the former East Kazakhstan region to get social support such as salary top-ups and additional paid leave. In Russia, individuals who moved from the STS areas also apply to courts for similar social benefits, but through the Russian Federation. Information on such court judgments is not systematized, with scattered cases found in open sources.

In 2017, the Legal Monitoring Center of the Institute of Legislation conducted an analysis of the law on the social protection of victims and concluded that 'the legal norms concerning individuals affected by the nuclear test site are not fully effective in the territory of the Republic of Kazakhstan'. The researchers highlighted the normative conflicts between this law and others.[82]

### Intergovernmental compensation and reparation

The Russian Federation accepts no responsibility for nuclear testing in Kazakhstan.

81 *Caravan* (newspaper) 11 February 2019, at: https://bit.ly/4bhSnhi.
82 I. Gumyrkina and O. Loginova, in *Vlast*.

Chapter 19:

# Addressing the Impact of Soviet Nuclear Testing in Novaya Zemlya

Magdalena E. Stawkowski and Dana Yermolyonok

**Tsar Bomba:** In 1961, Novaya Zemlya was the site of the largest nuclear explosion in history – the 50 Mt Tsar Bomba test. The explosion produced a 67-kilometre-high mushroom cloud with a diameter of more than 90 kilometres. The infrasound wave from the explosion travelled around the globe three times. Photograph © Federal Agency on Atomic Energy (Rosatom)/NTB.

## Key Facts about Nuclear Testing in Novaya Zemlya

**Testing State:** Soviet Union

**Testing period:** 1955–90

**Number of tests:** 130 (91 atmospheric and 39 underground) involving the detonation of 224 nuclear explosive devices with a total yield of 265 Mt – nearly half of the global total from all nuclear tests.

**Test location:** Novaya Zemlya Test Site (NZTS)

**Indigenous Peoples affected:** Indigenous Nenets people were forcibly removed from the islands in the 1950s. Increased health issues were reported but not formally studied in the communities that relied on reindeer meat and lichen.

**Military accidents:** At least three serious radiation accidents during underground nuclear tests resulted in hundreds of military personnel receiving significant radiation doses, with many cases of confirmed radiation sickness.

**Lack of support:** There are no court judgments, no compensation schemes, and no public health programmes for affected Indigenous populations or military personnel.

**Radiation studies:** Scientific expeditions from Russia, Norway, and the International Atomic Energy Agency (IAEA) confirmed widespread contamination. Attribution of specific radiation sources is complex due to overlapping fallout from Chernobyl, global testing, and industrial discharges.

**Climate change:** Arctic warming and glacial melting on Novaya Zemlya may increase the risk of the spread of radiation.

**Ongoing secrecy:** The NZTS remains a highly restricted military site with limited public access or transparency. While some radiation monitoring continues, no comprehensive cleanup has been undertaken, and there is a fear that testing may be resumed.

A fire-red ball of enormous size rose and grew. It grew larger and larger, and when it reached enormous size, it went up. Behind it, like a funnel, the whole earth seemed to be drawn in.

Vladimir Afanasyev,
quoted in Vladimir Suvorov's book *Strana Limoniya* (1989)[1]

## History of testing in Novaya Zemlya

Until 1955, all Soviet nuclear tests were conducted above ground at the Semipalatinsk Test Site (STS) in Kazakhstan. At that point, the Soviet military searched for a coastal site to test its first nuclear torpedo, the T-5.[2] The Novaya Zemlya Test Site (NZTS)—Novaya Zemlya meaning 'New Land' in Russian—and referred to in official sources as Object-700, was chosen in 1954 for this underwater test, with the detonation of a 3.5 kiloton (kt) device on 21 September 1955.[3] The Novaya Zemlya archipelago is made up of two islands (North and South) located approximately 450 kilometres north of the Arctic Circle, between the Barents and Kara seas. The mountainous islands, which stretch over 800 kilometres in length and 100 kilometres in width, are separated by the narrow Matochkin Shar (strait) which is less than three kilometres wide. The NZTS (which is part of Archangelsk oblast), is, like the island, divided into North and South areas.

The 1.6 megaton (Mt) test at the STS in November 1955 had made it clear to Soviet leaders that radioactive fallout from larger detonations made the site unsuitable for extensive atmospheric testing.[4] Consequently, in 1957, despite the harsh Arctic environment (a zone of continuous permafrost) as well as the area's proximity to Russia and Western Europe, the NZTS was chosen as the site for multi-megaton atmospheric, underwater, and underground tests. Combined, the NZTS tests account for nearly half of the total yield of all nuclear tests worldwide. As with the STS, the broader public learned about NZTS activities only in the middle of the 1980s following the introduction of *glasnost*.[5]

Between 1955 and 1990, 130 nuclear tests were carried out at the NZTS involving 224 explosive devices with a total yield of 265 Mt.[6] These comprised eighty-five atmospheric tests; six underwater, above water, and surface tests; and thirty-nine underground tests (including in tunnels or adits and in deep boreholes).[7] Testing occurred in three main zones: Zone A (Chernaya Guba), Zone B (Matochkin Shar), and Zone C (Sukhoy Nos).[8] From 1957 to 1962, Zone C was reserved for the most powerful atmospheric tests. On 30 October 1961, the Soviet Union detonated the most powerful hydrogen bomb in history. Dubbed the 'Tsar Bomba', the 50 (or possibly 58) Mt weapon, which was dropped from a plane, exploded four kilometres above the ground, producing a sixty-seven-

1 At: https://bit.ly/456wAbr.
2 V. Khalturin *et al.*, 'A review of nuclear testing by the Soviet Union at Novaya Zemlya, 1955–1990', *Science and Global Security*, Vol. 13 (2005), 1–42.
3 In 1958, the test site became known as the Sixth State Test Site of the Ministry of Defense. Ibid., pp. 10–11.
4 Ibid., p. 5.
5 Khalturin *et al.*, 'A review of nuclear testing by the Soviet Union at Novaya Zemlya, 1955–1990', p. 42.
6 Ibid, p. 1.
7 Ibid., pp. 1 and 15–19. Others list a total of 133 tests: 88 atmospheric tests, 3 underwater tests, and 42 underground tests (36 in tunnels or adits and 6 in deep boreholes). See V. V. Adushkin and W. Leith, 'The Containment of Soviet Underground Nuclear Explosions', United States Geological Survey Open File Report 01-312, September 2001, at: https://bit.ly/3OqyuuJ, p. 7.
8 Khalturin *et al.*, 'A review of nuclear testing by the Soviet Union at Novaya Zemlya, 1955–1990', p. 13.

kilometre-high mushroom cloud with a diameter of more than ninety kilometres. The infrasound wave from the explosion travelled around the globe three times.[9]

The last nuclear test detonation was in 1990, but the site remains a highly restricted military installation. Recent reports have suggested that Russia might be preparing to resume nuclear testing at the NZTS.[10]

## Assessments

Since 1990, a number of assessments have been conducted by national and international organizations on and in the vicinity of the NZTS.[11] Initial studies used satellite imagery to examine occurrences such as rockfalls and large-scale rock slides alongside other geological changes resulting from the underground tests.[12] A first assessment of radioactive contamination in 1991 focused on the Barents Sea and Kara Sea, in response to reports of radioactive waste disposal in and around the NZTS.[13] This research was followed by joint Russian-Norwegian expeditions to collect information on the level of contamination in the Kara sea.[14] Following official acknowledgement in 1993 of the dumping of radioactive waste in the shallow and deep waters off the NZTS (a violation of international norms), a series of further scientific expeditions were launched.[15] Among others, joint efforts involving scientists from Russia, Norway, and the IAEA Marine Environmental Laboratory in Monaco made four trips to assess contamination from the disposal of radioactive waste in the Kara and Barents seas. The main aim of the studies was to measure levels of radioactivity in the environment. During these early assessments, scientists recorded the locations of a range of relevant items, including tankers containing solid waste, nuclear submarines, nuclear reactors, and containers with radioactive waste and spent fuel.[16]

In the 1990s, official investigations of radiation contamination of the NZTS included analysis of atmospheric fallout, and contamination of water, soil, flora, and fauna with caesium-137, which demonstrated a consistent decrease in contamination since the end of atmospheric testing. Authorities suggest that underground testing 'did not make a noticeable contribution to the radioactive contamination of the archipelago territory against the existing background'.[17] As the test site remains a military facility, ongoing assessments primarily focus on monitoring environmental contamination of Kara and Barents seas, as well as the shallow bays of Novaya Zemlya.[18] Challenges remain in tracking radioactivity at the NZTS due to multiple sources of contamination, including the historical nuclear testing with concentrated fallout in Arctic regions, the Chernobyl disaster, discharges from the Sellafield nuclear fuel reprocessing plant, and the dumping of radioactive waste in and around the NZTS. The complexity of these intertwined radioactive discharges makes it difficult to isolate individual sources.

9 A. Wellerstein, 'An unearthly spectacle: the untold true story of the world's biggest nuclear bomb', *Bulletin of the Atomic Scientists,* 29 October 2021, at: https://bit.ly/3uiubL1.

10 M. Giveh, 'Concerns mount over possible new nuclear tests', *Arms Control Today*, October 2023, at: https://bit.ly/3Oksgws.

11 P. Povinec, I. Osvath, and M. Baxter, 'Marine scientists on the Arctic Seas: documenting the radiological record', *IAEA Bulletin,* No. 2 (1995), 31–35.

12 J. Skorve and J. Skogan, 'The NUPI Satellite Study of the northern underground Nuclear Test Area on Novaya Zemlya', *NUPI Research Report*, Norwegian Institute of International Affairs (NUPI), Oslo, 1992.

13 A. Zolotkov, 'On the dumping of radioactive waste at sea near Novaya Zemlya', *Greenpeace Nuclear Free Seas Campaign, Russian Information Agency Seminar: Violent Peace-Deadly Legacy.* Greenpeace, Moscow, 1991.

14 Joint Russian-Norwegian Expert Group for Investigation of Radioactive Contamination in the Northern Seas, *A Survey of Artificial Radionuclides in the Kara Sea. Results from the Russian-Norwegian 1992 Expedition to the Barents and Kara Seas,* Norwegian Radiation Protection Authority (NRPA), Østerås, Norway, 1993; see also *Radioactive Contamination at Dumping Sites for Nuclear Waste in the Kara Sea: Results from the Russian-Norwegian 1993 Expedition to the Kara Sea*, NRPA, 1994.

15 A. Yablokov *et al.*, *Facts and problems related to radioactive waste disposal in seas adjacent to the territory of the Russian Federation*, Office of the President of the Russian Federation, Moscow, 1993.

16 R. Bergman and A. Baklanov, *Radioactive Sources of Main Radiological Concern in the Kola-Barents Region*, Swedish Council for Planning and Coordination of Research, Stockholm, 1998.

17 *Nuclear Explosions in the USSR: The North Test Site Reference Material*, IAEA, Vienna, 2004, 64.

18 A. Travkina *et al.*, 'Monitoring the environmental contamination of Kara Sea and shallow bays of Novaya Zemlya', *Journal of Radioanalytical and Nuclear Chemistry*, Vol. 311 (2017), 1673–80.

In compliance with national radiation safety standards of the Russian Federation, the annual allowable exposure dose for individuals directly involved in nuclear tests should not exceed 50 millisievert (mSv).[19] For military personnel and their families stationed at the test site, the limit is set at 5 mSv, and for the public 1 mSv, aligning with the guidelines provided by international and national commissions on radiation protection, including the International Commission on Radiological Protection and the United States' National Council on Radiation Protection and Measurements.[20]

With respect to the NZTS, perceptions of the reliability of assessments vary. While experts accept the assessment results, doubts linger among communities regarding the official statements on radiation safety. Health studies of populations exposed to radiation during atmospheric testing are lacking despite local concerns about the safety of water sources and locally obtained food products.

## Human effects

The Soviet Union conducted nuclear tests with little regard to nuclear safety or human health. Both Indigenous and non-Indigenous communities, as well as military personnel living near the test sites and in the path of radioactive fallout hundreds of kilometres away, were all affected. But Indigenous communities were disproportionately impacted by nuclear fallout. Indeed, the testing sites were selected because they were perceived as 'empty' of important human populations and public discussions of radiation or its effects on human health were prohibited.[21]

### The impact on Indigenous populations

The NZTS was a highly classified military installation with an administrative and scientific centre constructed on the island at Belushya, with other settlements scattered throughout the test site.[22] Like the STS, the NZTS was under strict control throughout the Soviet era and remains so today. It is estimated that more than 12,000 officers and their families lived on the island at the height of nuclear testing.[23] One of the reasons for choosing the archipelago was its isolation, with the nearest village, Amderma, located 280 kilometres away, and a larger inhabited town of Arkhangelsk 1,000 kilometres away, with several villages in between.[24] Norway, though, is only some 900 kilometres from the NZTS.

The islands were originally inhabited by the Nenets peoples who relied on subsistence fishing, trapping, and reindeer herding. Other Indigenous populations who inhabited the Arctic regions during the period of nuclear testing included the Vepsians, Chukchi, Evenk, Khanty, Karelians, and Komi communities along the Northern coast of Russia, as well as the semi-nomadic Sámi reindeer herders in the northern parts of Finland, Sweden, Norway, and the Kola peninsula in Russia. There is very little information on the impact of nuclear testing at the NZTS on Indigenous populations living in the far north (the lack of data includes information about external and internal radiation doses). It is argued that because tests conducted in the atmosphere at the NZTS were at high altitude and not on the surface, there was little impact on local populations living outside

19 IAEA, *Nuclear Explosions in the USSR: The North Test Site Reference Material*, 32.
20 Ibid.
21 C. Werner and K. Purvis-Roberts, 'Unravelling the secrets of the past: contested versions of nuclear testing in the Soviet Republic of Kazakhstan', in B. Rose-Johnston (ed.), *Half-Lives and Half Truths: Confronting the Radioactive Legacies of the Cold War*, School for Advanced Research Press, Santa Fe, NM, 2007, 277–98. See also K. Brown, *Plutopia: Nuclear Families, Atomic Cities, and the Great Soviet and American Plutonium Disasters*, Oxford University Press, Oxford, 2013.
22 Ibid., 12.
23 Ibid.
24 *Radioactive Heaven and Earth. The Health and Environmental Effects of Nuclear weapon testing in, on, and above the Earth*, Zed, London, 1991, 101.

of the archipelago.[25] This meant that nuclear debris reached the stratosphere and was dispersed globally, not locally.[26] At the same time, there is evidence that Indigenous Arctic communities are 'one of the most heavily exposed populations from the global fallout from atmospheric atomic bomb testing of the 1950s and 1960s due to their diet rich in reindeer meat in which radionuclides accumulate'.[27]

In 1962, a Soviet scientific expedition collecting data on the impact of the Tsar Bomba test found increased levels of caesium-137, cobalt-60, polonium-210, strontium-90, and other radioisotopes in tundra grasses, lichens, snow, and reindeer meat (which is the mainstay of the local diet).[28] The 'lichen-reindeer-human' food chain studies suggest that Indigenous Nenets and other Arctic communities have been continuously exposed to strontium-90 and other radioisotopes internally.[29] Locals refer to the NZTS as the 'archipelago of death', with many inhabitants reporting higher rates of cancers and other illnesses that they link to past and present radiation exposure.[30]

### The impact on military personnel

Risks of exposure also came from underground tests at NZTS. Three accidental releases of radioactivity and their impact on military personnel are reported in official sources.[31] The first accident of venting of gases from two 540 kt underground nuclear detonations on 14 October 1969. Radiation levels reached several sieverts (Sv) per hour for about 50 minutes. Test personnel were exposed to a dose of between 0.4 and 0.8 Sv, with 344 people suffering from radiation sickness.[32] Since no emergency plan was in place, affected test personnel were abandoned by the leadership (who left the island) and the test personnel were only taken off the island an hour afterwards. The second accident occurred on 27 September 1973.[33] A 120-kt borehole test vented a radioactive gas 20 minutes after the explosion, but there are no reports of casualties. The third accident was on 2 August 1987, one minute after the explosion.[34] The 150-kt test vented radiation into the air. All the staff were evacuated, and no radiation sickness was reported.

### Transgenerational human effects

No epidemiological studies have been conducted of the situation in populations living near the NZTS.

25 S. Simon and A. Bouville, 'Radiation doses to local populations near nuclear weapons test sites worldwide', *Health Physics*, Vol. 82, No. 5 (2002), 717.
26 Prăvălie, 'Nuclear weapons tests and environmental consequences: a global perspective'.
27 P. Kurttio *et al.*, 'Radiation doses from global fallout and cancer incidence among reindeer herders and Sami in Northern Finland', *Occupational Environmental Medicine,* Vol. 67 (2010), 737.
28 V. Chugunov and P. Ramzaev, 'The radiological consequences after explosion of the most powerful atomic bomb on Novaya Zemlya', at: https://bit.ly/42Bzxhn.
29 L. Osipova *et al.*, 'Epidemiological studies for the assessment of risks from environmental radiation on tundra Nentsi population' in: C. Baumstark-Khan *et al.*, (eds.), *Fundamentals for the Assessment of Risks and Environmental Radiation.* NATO Science Series, Vol. 55, Springer, Dordrecht, 35.
30 Available at: https://bit.ly/3HHzlTQ; see also Simon and Bouville, 'Radiation doses to local populations near nuclear weapons test sites worldwide'.
31 Khalturin *et al.*, 'A review of nuclear testing by the Soviet Union at Novaya Zemlya, 1955–1990', p. 26.
32 Ibid.
33 Ibid., p. 27.
34 Ibid.

## Societal effects and displacement

Between 1955 and 1957, 536 Indigenous Nenets were forcibly resettled on the mainland from the Novaya Zemlya archipelago. Although no information on doses from external and internal exposure are available, it is believed reindeer herders received much higher internal doses than people who rarely consume reindeer meat.[35] Besides nuclear testing, large quantities of highly radioactive nuclear waste have been dumped in and around the islands, posing serious risks to human health and biodiversity. There have been no serious efforts to conduct population health studies or to clean up the contamination.

## Victim assistance

The needs for victim assistance among affected Indigenous populations and concerned military personnel have not been quantified. No studies have concluded with a clear exposition of victim assistance needs. There is no information on any ongoing or planned victim assistance efforts at the NZTS.

## Environmental contamination

Contamination at the NZTS is diverse and uneven. Numerous tests, especially ground or underwater nuclear explosions, have led to pollution of the archipelago. For instance, the surface explosion on 7 September 1957 involved a 32 kt charge dropped from a 15-metre tower, creating a crater 80 metres in diameter and 15 metres deep.[36] This test produced substantial radioactive contamination, measuring 400 Sv per hour near the epicentre. An above-water explosion on 27 October 1961 contaminated another area, Guba Chernaya Bay, as a result of fallout that polluted a 100 square kilometre area with plutonium-239, caesium-137, and cobalt-60.[37]

Radioactive waste dumped into the Kara and Barents Seas between the late 1950s and 1992 continues to pose a radiological threat.[38] Significantly, major dumping sites in NZTS bays showed especially heightened concentrations of caesium-137 and cobalt-60, suggesting contamination resulting from leakage from disposed wastes.[39] There is evidence that the NZTS contains localized contamination from underground tests, many of which vented radiation, but little is known about their impact on the local and regional environment.[40] It is believed that atmospheric testing at the NZTS contributed to greater fallout in Norway and globally compared to local fallout. At the same time, underground testing resulted in frequent leakage of radioactivity into the local environment.[41] The 1993 Yablokov Report (also known as the White Book), estimated that since the 1960s, the Soviet Union dumped 92.5 quadrillion Bq of radioactive waste in and around the NZTS.[42]

There are other clear indications of serious contamination. For example, in 1962, the highest deposition of beta radioactivity measured at Naryan Mar near Archangelsk, roughly 1,000 kilometres away, exceeded 1,300 MBq/km$^2$, representing a peak approximately 460 times greater than that recorded in 1988.[43] Similarly, peak

35 Simon and Bouville, 'Radiation doses to local populations near nuclear weapons test sites worldwide', p. 717.
36 Khalturin *et al.*, 'A review of nuclear testing by the Soviet Union at Novaya Zemlya, 1955–1990', p. 16.
37 Ibid.
38 A. Travkina *et al.*, 'Monitoring the environmental contamination of Kara Sea and shallow bays of Novaya Zemlya', *Journal of Radioanalytical and Nuclear Chemistry,* Vol. 311 (2017), 1673–80.
39 Povinec, Osvath, and Baxter, 'Marine scientists on the Arctic Seas: documenting the radiological record', 33.
40 *Nuclear Wastes in the Arctic: An Analysis of Arctic and Other Regional Impacts from Soviet Nuclear Contamination*, OTA-ENG-623, US Government Printing Office, Washington, DC, 1995.
41 N. Bøhmer *et al.*, 'The Arctic Nuclear Challenge', Report, Vol. 3 (2001), Bellona, Oslo.
42 Yablokov *et al.*, *Facts and problems related to radioactive waste disposal in seas adjacent to the territory of the Russian Federation.*
43 A. Makhijami, 'The Soviet nuclear weapons tests at Novaya Zemlya', in *The Devastating Consequences of Nuclear Testing: Effects of Nuclear weapon testing on Health and the Environment,* ICAN and IPPNW Germany, Berlin, 2023, 55.

deposition levels in Amderma village surpassed those at Naryan Mar by over 20 times.[44] Additionally, in the 1980s, iodine-131, known to cause thyroid cancer, was detected in both the air and milk samples. It is believed that the total fallout of strontium-90 and caesium-137 from testing conducted at the NZTS is 266,000 TBq and that 426,000 TBq were dispersed across a vast region, while concentrations of strontium-90 in Kara Sea were as high as 39 Bq/m$^3$ in the 1960s.[45] As of 2020, the estimated total of strontium-90 and caesium-137 is approximately 40,000 TBq and 70,000 TBq, respectively. Background radiation levels at the NZTS still exceed the norm, and the seabed along the coastline is contaminated with caesium and plutonium.[46]

## Environmental remediation

The NZTS remains a closed military zone. A primary concern is the significant contamination of the Kara and Barents seas resulting from nuclear waste dumping, posing a continuous risk of potential leakage. The contamination jeopardizes the marine ecosystems and threatens human health and livelihoods of communities dependent on fishing. A comprehensive clean-up effort to mitigate potential health hazards is needed.

## The impact of climate change[47]

For Novaya Zemlya, warming across Arctic Russia has also already caused accelerated glacier and ice loss, with the potential for 'future dynamic regime changes and enhanced mechanisms of ice loss'.[48] This rapid thawing has the potential to increase the mobility and transportation of radionuclides, yet the full impact is unquantified.[49] Similarly, research on glaciers in Arctic Sweden indicates the accumulation of fallout radionuclides. That said, the environmental impact from glacier retreat, the downstream transport of meltwater and sediment, and the release of legacy contaminants trapped in snow, ice, and cryoconite[50] is not yet known.[51] For Novaya Zemlya, a summary of trends and potential climate-related impacts is given in Table 1 opposite.

44 Makhijami, 'The Soviet nuclear weapons tests at Novaya Zemlya', 56.
45 Ibid.
46 A. Nikitin and A. Shchukin, *Remediation of Nuclear and Radiation Legacy Sites in Russia's Northwest: An Overview of Projects Carried Out as Part of International Cooperation*, Bellona, St. Petersburg, 2014.
47 This section was contributed by Linsey Cottrell.
48 At: https://bit.ly/48LJaLF.
49 K. R. Miner, J. D'Andrilli, R. Mackelprang, *et al.*, 'Emergent biogeochemical risks from Arctic permafrost degradation', *Natural Climate Change*, Vol. 11 (2021), 809–19, at: https://bit.ly/49PspAz.
50 Cryoconite is a mixture of material found on the surface of glaciers.
51 C. C. Clason, W. H. Blake, N. Selmes, A. Taylor, P. Boeckx, J. Kitch, S. C. Mills, G. Baccolo, and G. E. Millward, 'Accumulation of legacy fallout radionuclides in cryoconite on Isfallsglaciären (Arctic Sweden) and their downstream spatial distribution', *The Cryosphere*, Vol. 15 (2021), 5151–68, at: https://bit.ly/48SZxG9.

**Table 1:** **Summary of key climate trends and impacts, Novaya Zemlya** [52]

| Climate system/ hazard | Historic trends | Projected trends | Possible impact on risk components |
|---|---|---|---|
| Glacial/ice loss | Significant losses between 2010 and 2018 | Potential for dynamic regime changes and enhanced mechanisms of ice loss | Source: changes in physico-chemical behaviour affecting mechanisms by which contaminants may be released. Includes physical landform changes caused by permafrost melt and erosion<br><br>Pathway: potential changes in water infiltration, water tables, dilution, flow rates and ocean currents<br><br>Receptor: changes in species assemblages and/ or sensitivity to contaminants. Shift in people's proximity/exposure routes to sources |
| Coastal flooding | Not given | Potentially damaging waves are expected to flood the coast at least once in the next 10 years | |

## Legal issues

There are no court judgments on compensation related to past activities in the NZTS. There are also no individual compensation schemes at the NZTS.

52 P. Tepes, P. Nienow, and N. Gourmelen, 'Accelerating ice mass loss across Arctic Russia in response to atmospheric warming, sea ice decline, and Atlantification of the Eurasian Arctic Shelf Seas', *Journal of Geophysical Research: Earth Surface*, Vol. 126, No. 7 (July 2021), at: https://bit.ly/48LJaLF; ThinkHazard! High-level hazard profile for Nenetskiy Okrug, Russian Federation, at: https://bit.ly/3lxSZ5j.

Chapter 20:

# Addressing the Impact of Nuclear Testing by the United Kingdom in Australia

Tilman Ruff, Karina Lester, and Stuart Casey-Maslen

**Survivor and Activist:** James Yami Lester OAM survived nuclear testing in outback Australia and went on to become a prominent anti-nuclear and Indigenous rights advocate. He passed away in 2017. Photograph © Jesse Boylan.

## Key Facts about Nuclear Testing in Australia

**Testing States:** United Kingdom

**Testing period:** 1952–63

**Number of tests**: 24 (12 atmospheric detonations of nuclear explosive devices and 12 'safety tests'). Hundreds of further 'minor trials' were also conducted.

**Testing locations:** Monte Bello Islands, Emu Field, and Maralinga.

**Indigenous Peoples affected:** Aboriginal communities experienced displacement; health problems, including acute radiation sickness after the Totem 1 test; distress, and cultural disruption.

**Environmental contamination:** Large areas were contaminated with radioactive materials, especially plutonium from the Vixen B safety tests and the minor trials.

**Incomplete remediation:** Multiple clean-up efforts have been undertaken, but some further work and long-term monitoring are needed.

**Climate risks:** Climate change will likely worsen radioactive risks at contaminated sites through wildfires, drought, erosion, sea level rise, and extreme weather, but this is not yet addressed in Australia's national preparedness strategies.

**Legal and political struggles:** Only one lawsuit against the Australian government for its failings has ever been successful. In 1994, the Australian government provided a settlement of A$13.5 million to the Indigenous Peoples in and around Maralinga. The Spinifex Indigenous Peoples in Western Australia successfully negotiated a compensation package for their economic and cultural loss.

> When I was a young boy living in the desert, the ground shook and a black mist came up from the south and covered our camp. The older people said they had never seen anything like it before, and in the months that followed many people were sick and many died. I don't like to think about it now, but one of those people was my uncle, and he was very sick before he died. People had sore eyes too. I was one of those people, and later I lost my sight, and my life changed forever.
>
> Yami Lester (1941–2017)
> *Yami, the autobiography of Yami Lester*

## History of testing in Australia

The United Kingdom conducted nuclear testing in Australia over the course of six years in the 1950s, with 'minor trials' continuing until 1963. Twelve nuclear explosive devices were test-detonated with explosive yields ranging between 0.9 and 60 kilotons (kt)[1] (or possibly more).[2] The tests had a collective yield equating to at least 216 kt of TNT. All but one were conducted in the atmosphere. The exception was the first of the twelve detonations – a 25 kt plutonium implosion device placed in the hold of a warship 2.7 metres below the waterline.[3] One of the resultant weapons, 'Blue Danube', would become the United Kingdom's first operationally deployed nuclear weapon in 1956, designed to be dropped by the Royal Air Force's strategic bomber force.[4] 'Red Beard', a second-generation fission weapon, would enter operational service in 1961.[5]

In five major series of tests between 3 October 1952 and 9 October 1957, the United Kingdom detonated the twelve nuclear explosive devices at three separate locations in Western and South Australia. The first and third series of tests (code-named Operation Hurricane and Operation Mosaic) were conducted on the Monte Bello Islands off the coast of Western Australia, in October 1952 and October 1956, respectively. The last Monte Bello test, Operation Mosaic G2, was the largest of the Australian test explosions. It was a precursor to British thermonuclear testing at Christmas Island (Kiritimati), and was 'boosted' by lithium-deuteride, increasing both the explosive yield and the formation of high mass actinides.[6] The second series of tests, under Operation Totem, took place in October 1953 at 'Emu Field' (site X200) in South Australia. These two tests were designed to assess whether, instead of plutonium-239, plutonium-240 could be used. The fourth and fifth series of tests (Operation Buffalo and Operation Antler) were held at Maralinga (site X300), also in South Australia, from September to October 1956 and September to October 1957, respectively.

1 United Kingdom (UK) government, 'UK atmospheric nuclear weapons tests', Factsheet 5: UK programme, at: https://bit.ly/3QkXHa3, p. 4.
2 Some claim that the device was in fact equivalent to 98 kt. See E. Tynan, *Atomic Thunder: British Nuclear Testing in Australia*, Pen & Sword Military, United Kingdom (UK), 2018, 87, 158.
3 Tynan, *Atomic Thunder: British Nuclear Testing in Australia*, 70.
4 UK Ministry of Defence and Foreign and Commonwealth Office, 'The History of the UK's Nuclear Weapons Programme', Fact Sheet 5, undated but accessed 1 November 2023 at: https://bit.ly/3SFGqLF.
5 Atomic Archive, 'Britain's Nuclear Weapons: History of the British Nuclear Arsenal', Last amended 30 April 2002, at: https://bit.ly/46Ro7ar.
6 M. Williams-Hoffman, P. Johansen, P. Larcombe, D. P. Child, M. A. C. Hotchkis, O. Serrano, P. S. Lavery, S. Thiruvoth, and P. Masqué, 'Montebello Islands marine sediment retains nuclear weapons-derived radionuclide contamination 70 years after detonations', *Marine Pollution Bulletin*, Vol. 219 (October 2025), 118280; and references therein.

In addition to these nuclear tests, the United Kingdom conducted about 600 other 'minor trials' between September 1953 and April 1963. These were essentially developmental experiments to investigate the performance of various nuclear weapon components, separately and in combination, including when exposed to fire, impact or explosion. Almost all involved radioactive materials in conjunction with conventional high explosives.[7] No Australians were present at any of the minor trials, and their nature and the extent of contamination they caused were barely publicly known until a Royal Commission examined the nuclear tests in 1985.

The first five 'Kittens' trials were conducted at Emu in 1953; all the other minor trials were carried out at Maralinga between 1955 and 1963. The minor trials involved neutron initiator development trials using polonium-210 and beryllium (code-named Kittens); fissile material compression tests involving uranium, plutonium, beryllium and intense gamma sources (Tims and Rats); burning trials on rods of plutonium, uranium, and beryllium, involving combustion and dispersion, and explosive dispersion of plutonium (Vixen A); and twelve safety and development trials including detonations and subjecting nuclear weapons components and subassemblies to impacts, fire and other accidents (Vixen B), in part to assess the impact of a 'Broken Arrow' scenario, such as if a plane with nuclear bombs on board were to crash after take-off. The data from the trials have still not been released publicly by the United Kingdom.[8]

The Vixen B trials also involved limited nuclear fission, with varying nuclear yields ranging up to 300 but averaging about 3 grams of TNT equivalent.[9] They also involved burning and high-explosive detonations, which released sufficient energy from a vertical jet firing upwards from the test device to lift plutonium-contaminated debris high into the air.[10] In an official report, Burns and others described that 'the plutonium melted and burned as it was ejected vertically to heights of up to 800 m and dispersed by the prevailing winds'.[11] Plutonium is highly pyrophoric – even tens of microns-sized particles spontaneously ignite in air.

The minor trials are assessed to have used the following radioactive and toxic materials:[12]

- 24.2 kg of plutonium, the great majority plutonium-239, the rest mostly plutonium-240
- 15,900 kg of natural uranium/uranium-238
- 24 kg of enriched uranium
- 144 kg of beryllium
- 225 TBq of polonium-210
- 78.7 TBq of scandium-46
- 4.4 TBq of lead-212
- 5 MBq of actinium-227

As a consequence, plutonium and other radioactive substances as well as hazardous chemicals were dispersed across South Australia and beyond. The Vixen trials pose the greatest long-term contamination hazard because they involved high-explosive detonations scattering a total of 22 kilograms of plutonium over distances of hundreds of kilometres, as well as some nuclear fission products.

7 Maralinga Rehabilitation Technical Advisory Committee (MARTAC), 'Rehabilitation of former nuclear test sites at Emu and Maralinga (Australia)', Commonwealth of Australia Department of Education, Science and Training, Canberra, 2003, at: https://bit.ly/4fkkleD, pp. 10–13.

8 Tynan, *Atomic Thunder: British Nuclear Testing in Australia*, 119, 122.

9 MARTAC, 'Rehabilitation of former nuclear test sites at Emu and Maralinga (Australia)', p. 10.

10 P. A. Burns, M. B. Cooper, P. N. Johnston, L. J. Martin, and G.A. Williams, 'Determination of the ratios of 239Pu and 240Pu to 241Am for nuclear weapons test sites in Australia', *Health Physics*, Vol. 67 (1994), 226e232.

11 P. A. Burns, M. B. Cooper, G. A. Williams, and P. N. Johnston, 'Properties of Plutonium-Contaminated Particles Resulting from British Vixen B Trials at Maralinga', Australian Radiation Laboratory, Department of Health, Housing & Community Services, Report ARL-TR–086, 1990.

12 MARTAC, 'Rehabilitation of former nuclear test sites at Emu and Maralinga (Australia)', p. 13.

**Figure 1:** **The location of nuclear tests in Australia**


Following their early post-war exclusion from continuing nuclear weapons development and testing in the United States under the 1946 US Atomic Energy Act (McMahon Act), the UK government was determined to embark on its own nuclear weapons programme. UK Foreign Secretary Ernest Bevin stated: 'We've got to have this thing over here whatever it costs… We've got to have a bloody Union Jack flying on top of it.'[13] The twelve nuclear tests were personally authorised by the Prime Minister of Australia of the time, Robert Menzies, without formally consulting his Cabinet, many of whom were not even informed about the decision, let alone the parliament.[14] The Royal Commission concluded that the decision was taken 'without the benefit of any scientific knowledge of the hazards that would be involved.'[15] Later, Prime Minister Menzies would argue in his weekly public broadcast on the radio in October 1953 that the tests were necessary to address 'aggressive Communist-Imperialism'.[16]

It was later admitted during the Royal Commission by Noah Pearce, a British scientist prominent in both the major and minor trials, that radioactive contamination was considered politically acceptable for Australia but not for the United Kingdom.[17] When it was suggested by Counsel assisting the Royal Commission to Lieutenant Colonel K. Stewart from the UK Atomic Weapons Research Establishment (AWRE), that appropriate places for the minor trials might have been found in remote parts of Scotland, his response was: 'I doubt if the people owning the estates in Scotland would look on that with very great favour. They are interested in pheasants and deer in Scotland.'[18]

The Royal Commission stated that the 1963 minor trials 'brought to an end a drama characterised by persistent deception and paranoid secrecy. In their desire to avoid international repercussions, the British authorities embarked on a course of determined concealment of information from the Australian Government' and that 'the

13 Grace., P. *Operation Hurricane*. Sydney; Hachette Australia, 2023, 6; Symonds J. L. *A History of British Atomic tests in Australia*, Australian Government Printing Service, Canberra, 1985, 31.
14 Justice J. McClelland, *Royal Commission into British nuclear tests in Australia*, Vol. 1, 1985, §2.1.12; Tynan, *Atomic Thunder: British Nuclear Testing in Australia*, 3, 68.
15 J. McClelland, *Royal Commission into British nuclear tests in Australia*, 1985, Conclusions 1 and 2, p. 7.
16 'Man-to-Man', radio broadcast in October 1953, cited by Tynan, *Atomic Thunder: British Nuclear Testing in Australia*, 79.
17 Justice J. McClelland, *Royal Commission into British nuclear tests in Australia*, Vol. 2, 1985, pp. 404–05; Tynan, *Atomic Thunder*, 117.
18 J. McClelland, *Royal Commission into British nuclear tests in Australia*, Vol. 2, 1985, p. 405.

Vixen series should never have been conducted at Maralinga.'[19] This deception and secrecy was in part driven by the fact that the trials evidenced bad faith by the UK government in violating the spirit and, in the case of the Vixen B trials, likely the letter of an international moratorium on nuclear test explosions it had supported.[20] In 1958, while 'Tims' and 'Rats' minor trials continued, US President Eisenhower pledged a one-year moratorium on weapons testing, and the Soviet Union reciprocated, while the Conference for the Discontinuation of Nuclear Tests in Geneva negotiated towards a test ban. The moratorium in fact continued until September 1961, and was followed by the largest ever spike in US and USSR testing before in 1963 the Partial Test-Ban Treaty, banning nuclear test explosions in all environments except underground, came into effect. The Vixen B assemblies were intended to fit a unilateral UK definition, not ratified by the test ban negotiating conference, of a nuclear fission reaction equivalent to not more than 10 tons of TNT, which if exceeded, could be discounted as 'accidental'.

Based on national authority data only, most nuclear test records cite 21 atmospheric nuclear tests conducted by the United Kingdom – nine in Kiribati and twelve in Australia. However, consistent with the 2000 UNSCEAR report and the 1999 SCOPE 59 report, this report classifies the 12 Vixen B tests carried out in Australia as safety tests and thus as nuclear tests, thereby increasing the total number of UK atmospheric nuclear tests to 33.[21]

The United Kingdom had previously sought approval from Canada to test-detonate nuclear explosive devices on its territory, but the request was denied by the Canadian government.[22] As the Australian government would explicitly prohibit the detonation of a hydrogen device on its territory,[23] in May 1957, the United Kingdom would drop its first fusion bomb off the coast of Christmas Island (Kiritimati), now part of Kiribati.[24]

Australia has the world's largest deposits of uranium – equating to almost one third of the global total today.[25] According to Tynan, these deposits made the proposal for UK testing attractive to Australia as it could 'maximise the value of the country's newly discovered and extensive uranium resources'.[26] For Cross, the temptation on the part of Menzies to feel of use to the 'mother country' was also a contributing factor in his readiness to allow Australian territory to be used for nuclear testing.[27] But in the words of the famed Australian nuclear physicist Mark Oliphant, who played an influential role in the development of nuclear weapons in the Manhattan Project, 'a few—a very few—tests are essential. The remainder are completely unjustified except as gestures and as fun for the boys.'[28] In 2022, Australia was the world's fourth largest producer of uranium (at 8 per cent of the global total) after Kazakhstan, Canada, and Namibia.[29]

During the British nuclear testing programme in Australia in the 1950s through at least until 1972 and the advent of the Whitlam Labor government, Australian governments actively pursued options for acquiring nuclear weapons, first through attempted procurement and then by developing their own capacity.[30] While long-serving Prime Minister Menzies (1939–41 and 1949–66) believed that nuclear weapons could be a stabilizing force for global order and serve Australia's interests if wielded by responsible great power allies on which he was willing

19 Ibid., pp. 414–15.

20 Useful accounts of this can be found in ibid., pp. 402–15, and Tynan's *Atomic Thunder,* 121, 125-6, 129, 132-6, 250-3.

21 UNSCEAR, 'Exposures to the public from man-made sources of radiation', Annex C, Table 22; Warner and Kirchmann (eds.), SCOPE 59, pp. 30–31.

22 Tynan, *Atomic Thunder: British Nuclear Testing in Australia*, 5.

23 This was set out in the agreement between the Australian and UK governments signed on 7 March 1956 which concerned the Maralinga testing site. Tynan, *Atomic Thunder: British Nuclear Testing in Australia*, 93.

24 Royal Signals Museum, 'On the 15th of May 1957 Britain's first H-bomb was exploded', 2023, at: https://bit.ly/45PmicI.

25 World Nuclear Association, 'Australia's Uranium', Updated August 2023, at: https://bit.ly/46RQl4K.

26 Tynan, *Atomic Thunder: British Nuclear Testing in Australia*, 6.

27 R. Cross, *Fallout: Hedley Marston and the British Bomb Tests in Australia*, Read How you Want, 2010, 1.

28 Letter to Hedley Marston, 11 September 1956; see Cross, *Fallout: Hedley Marston and the British Bomb Tests in Australia*, 66.

29 World Nuclear Association, 'Uranium Production Figures, 2013–2022', Updated August 2023, at: https://bit.ly/47ckI5E.

30 L. Clohesy and P. Deery, 'The prime minister and the bomb: John Gorton, W. C. Wentworth and the quest for an atomic Australia', *Australian Journal of Politics and History*, Vol. 61, No. 2, (2015), 217–32; J. Walsh, 'Surprise Down Under: The Secret History of Australia's Nuclear Ambitions', *The Nonproliferation Review*, Vol. 5 (Fall 1997), 1–20.

to depend, others such as later Prime Minister John Gorton (1967–71) believed that only Australian nuclear weapons could be relied upon to serve Australian interests. Through much of the 1950s and 1960s, government agencies were divided, with the Australian Atomic Energy Commission and the military generally supportive, and External Affairs and Treasury generally opposed.[31] Concerted US government pressure was needed for Australia to sign the 1968 Treaty on the Non-Proliferation of Nuclear Weapons (NPT).[32]

## Assessments

A detailed study of the deaths and the incidence of cancers among Australian participants in the British nuclear tests was published in May 2006.[33] The study population was based on the nominal roll of test participants compiled by the Australian Government Department of Veterans' Affairs (DVA). The study population comprised 10,983 male subjects, of whom 7,116 were military participants and 3,867 were civilians. Subjects were followed to a cut-off date of 31 December 2001, when 5,494 subjects (50 per cent) were confirmed living, and 4,427 subjects (40 per cent) were confirmed deceased.[34]

The study found that the overall death rate in test participants was similar to that of the general population (4,233 deaths compared with 4,150 expected from the general population). The most common cause of death in test participants was cancer, with this cause of death 18 per cent greater in test participants than would be expected in the general population. Deaths from other causes were generally fewer than expected in test participants compared with the general population. The cancer incidence study showed an overall increase in the number of cancers in test participants (2,456), which was 23 per cent higher than expected. No relationship could be found between overall cancer incidence or mortality and estimated exposure to radiation, but the excess of non-chronic lymphatic leukaemia remains 'unexplained'.[35] One of the committee members responsible for the study, Ms Ann Munslow-Davies, refused to endorse the report.

## Human effects

No direct human casualties from the UK nuclear tests in Australia have ever been confirmed.[36] There is, however, strong evidence of both fatal and non-fatal victims as an indirect result of the test detonations, both among Aboriginal and other Indigenous communities living or travelling in their vicinity and by the military personnel required to witness the tests. This is despite the claim made in the press in 1956 by Howard Beale, Australia's Minister for Supply under whose remit the tests occurred, whereby it was the 'opinion of top scientists' that the coming nuclear test-detonations in 1956 would not 'harm the nation or the population'.[37] In fact, the third and final test conducted on the Monte Bello Islands on 19 June 1956 concerned a 60 kt device that rattled windows and roofs at Marble Bar, a town 400 kilometres to the east and where radioactive fallout was later reported. The device's true explosive yield was kept from the public for almost thirty years.[38]

31 J. E. C. Hymans, 'Isotopes and Identity: Australia and the Nuclear Weapons Option, 1949–1999', *The Nonproliferation Review*, Vol. 7, No. 1 (Spring 2000), 1–23, at: https://bit.ly/3Ug2KLi.

32 Dean Rusk, Secret cable. (Declassified), US Department of State, 6 April 1968, at: https://bit.ly/4oo68kV.

33 M. Carter, F. Robotham, K. Wise, G. Williams, and P. Crouch, 'Australian participants in British nuclear tests in Australia', Report, Australia, May 2006, at: https://bit.ly/4acUFN3.

34 A further 23 participants were known by DVA to be deceased, but corroborating evidence for the death could not be found. Less than 1 per cent of participants (105 participants) were known to be living overseas or to have died overseas. The vital status of 934 subjects (8.5 per cent) on the cut-off date was unknown.

35 M. Carter, F. Robotham, K. Wise, G. Williams, and P. Crouch, 'Australian participants in British nuclear tests in Australia', Vol. 1: Dosimetry, Australia, May 2006, 'Main Findings', v–vi.

36 But see on the issue of alleged deaths from the first test at Emu field: E. Tynan, *The Secret of Emu Field*, NewSouth Publishing, 2022, 123–24.

37 Cross, *Fallout: Hedley Marston and the British Bomb Tests in Australia*, 42.

38 R. Milliken, *No Conceivable Injury*, Penguin, Victoria, 1986, 197–98.

Part of the problem with the testing programme was the lack of concern on the part of scientists and politicians who should have looked after the welfare of the affected populations. Limited warnings were provided to the at-risk populations, but most of the public awareness was about reassurance. The first three test-detonations were not observed by an official Australian watchdog.[39] The population of Adelaide was not even informed that a radioactive cloud had passed over the city.[40] A query to a British scientist involved in the later tests at Maralinga about the fate of Aborigines was said to have met with the response that they were 'a dying race' and were therefore 'dispensable'.[41] In May 1956, Ernest Titterton, the scientist leading Australia's oversight of the testing programme, wrote publicly that a radioactive cloud might render an area 'dangerously radioactive' to distances of 'several hundred miles'.[42] This was intended to explain why Australia had been chosen to host the tests. In fact, there was great variation in fallout trajectories, which included hotspots from rainout events thousands of kilometres away from the test sites. The entire continent, including all the major cities, received test fallout at some time, except for the south-west corner of Western Australia.[43]

### The impact on Indigenous populations

The testing programme caused major displacement, disruption, and distress to Indigenous communities, including the break-up of families, loss of cultural continuity, and disruption of access to important sites, along with the negative social and mental health consequences these impacts engendered. The UK government simply did not consider that there were Aboriginal people living near the Monte Bello Islands whose health would be adversely affected by the Mosaic tests. More than 4,500 Aboriginal people lived on the mainland close to Monte Bello.[44] In evidence to the Australian Royal Commission of 1984–85, Sir William Penney, the British nuclear physicist who led the United Kingdom's development of the atomic bomb, was asked: 'Did you or different people ever consider the prospect of Aborigines living on the north-west coast of Australia before firing the Mosaic explosion?' He responded: 'Not to my knowledge.' He was then asked to 'accept now that the safe position would have been to consider the position with respect to Aborigines before either G1 or G2 [the test detonations on 16 May and 19 June 1956, respectively] was fired?' He responded in the affirmative but added, 'once again, would we not have looked to the Australians for advice?'[45]

With respect to the nuclear tests at Maralinga, concerns occasionally raised about the welfare of local Indigenous People were rebuffed by the Australian government. A senior official even criticized a 'lamentable lack of balance' in 'apparently placing the affairs of a handful of natives above those of the British Commonwealth of Nations'.[46] An epidemic occurred among Indigenous Peoples at Ernabella (now known as Pukatja) in South Australia in March–June 1957, resulting in the deaths of twenty children and two adults. But an ostensible link with radioactive contamination, the subject of speculation in *The Lancet* at the time, was never confirmed.[47] The outbreak occurred after the *Buffalo* series of tests at Maralinga (in September to October 1956) but before the *Antler* series, which began in September 1957. The scheduling of Operation Antler, the last series of tests at Maralinga, coincided with the dingo pup season when it was known that Aboriginal people would be on the move hunting dingoes.[48]

39 Cross, *Fallout: Hedley Marston and the British Bomb Tests in Australia*, 45; Tynan, *The Secret of Emu Field*, 147.
40 Cross, *Fallout: Hedley Marston and the British Bomb Tests in Australia*, 97.
41 Ibid., 44.
42 E. Titterton, 'Why A-Test sites are in Australia', 16 May 1956, cited by Cross, *Fallout: Hedley Marston and the British Bomb Tests in Australia*, 52.
43 See the fallout maps in Chapters 7–9 in McClelland, *Royal Commission into British nuclear tests in Australia*, Vol. 1, 1985.
44 McClelland, *Royal Commission into British nuclear tests in Australia*, Vol. 1, 1985, §5.4.5.
45 Ibid., §7.5.2.
46 Ibid., §8.4.38.
47 Tynan, *Atomic Thunder: British Nuclear Testing in Australia*, 194–95.
48 Ibid., 191.

Official information issued shortly before the Totem tests stated: 'There are no Aborigines in the area.'[49] However, north of Emu Field to the east and the west there were a number of small settlements, pastoral stations and missions, including the Granite Downs settlements of Wallatinna, Mintabie and Mabel Creek, and Indigenous traditional hunting, gathering, and cultural activities in desert environments covered large distances and areas. In the context of Operation Totem at Emu Field, a well-intentioned individual had removed sacred Aboriginal items such as totem poles in the mistaken belief that the sites would lose their sacred status.[50] The British had corresponded internally on the risks to Aboriginal peoples, with the Assistant Under-Secretary for Commonwealth Relations writing in early March 1953 that, 'Needless to say we are assuming that no danger exists of the tests resulting in the death or injury of any Aboriginal inhabitants. But it is for the Australians to make sure of this….'[51]

It is reported that after the first test at Emu Field in October 1953, a black cloud or 'mist' passed over land around Wallantina and Mintabie and deposited material on the Indigenous people in those areas. There was a report of several deaths, as well as vomiting, diarrhoea, skin conditions, and even blindness among the survivors. The existence of the black mist was rejected by British and Australian scientists responsible for the nuclear testing programme.[52] But the British meteorologist advising on the Operation Totem tests had cautioned that firing the nuclear weapon in the prevailing conditions was risky.[53] One possible explanation is the presence of cobalt-60 in the cloud resulting from the presence of cobalt-59 in the steel tower from which the nuclear explosive device was suspended.[54]

The following account of the Totem One test is written from an A<u>n</u>angu perspective by one of the authors of this chapter, Karina Lester, who is a Yankunytjatjara-A<u>n</u>angu woman and a second-generation survivor of the British nuclear tests that took place at Emu Field.

> Totem One, 15th October 1953 and Totem Two, 27th October 1953 were the first two mainland tests conducted on Yankunytjatjara, Matu-Yankunytjatjara Mantangka (on the traditional lands of the Yankunytjatjara and Matu-Yankunytjatjara people), in the far north-west of South Australia.
>
> Walyatjata, Walatina is on Yankunytjatjara Matutjara Country, in the Western Desert region of South Australia. Species of acacia, native grasses, rocky outcrops and sand dunes is what you will see as you travel through this country. Records of our Wapar (Ancestral Stories) that crisscross through country, stories of Ngintaka (perentie), Tjurki (nightjar), Malu (kangaroo), and Kanyala (euro) hold the knowledge of our A<u>n</u>angu Law and Culture. Our rules, our ways, our language, law and culture. These are our intangible cultural heritage, that A<u>n</u>angu are responsible for, that A<u>n</u>angu follow and respect. 'This is sacred land.'
>
> Walyatjata was the outstation of the Granite Downs pastoral lease where pastoralist Mr Tommy Cullinan and his wife managed and ran cattle on Yankunytjatjara Country. A<u>n</u>angu (Yankunytjatjara people) lived on their country, tali-angka (in the sand dunes) and kanku-ngka (in their traditional shelters). A<u>n</u>angu (Aboriginal) men worked as stockmen, assisting Mr Cullinan to run the Station and the women worked as domestics, assisting Mrs Cullinan with washing clothes and dishes, cooking and cleaning. A<u>n</u>angu (Aboriginal) were starting to learn to live two ways, A<u>n</u>angu (traditional) Way and Piyan (whiteman) Way. A<u>n</u>angu were starting to see more and more strangers coming into their traditional lands, speaking a new language, wearing clothes and bringing in new animals, hooved

49 Tynan, *The Secret of Emu Field*, 12.
50 Tynan, *Atomic Thunder: British Nuclear Testing in Australia*, 182.
51 Letter to Ben Cockram, British High Commission in Australia, Ref. AB 16/1743, 2 March 1953, letter in the UK National Archives.
52 Tynan, *Atomic Thunder: British Nuclear Testing in Australia*, 196–97.
53 Tynan, *The Secret of Emu Field*, 121–22.
54 Ibid., 129.

animals. With this shift and gradual change over time, they were witnessing a clash of two very different cultures, two different ways of life.

Walyatjata is also the very country where Irati (poison) contaminated our sacred lands, where a black, toxic smoke of radioactive materials (radiation fallout) fell silently and deadly over our country. This deadly smoke was from the British Nuclear Weapons testing programmes where the first mainland tests were conducted in the south, 150 kilometres away. Walyatjata was where my late father Yami Lester witnessed the ground shake and the black smoke roll over country, silently, oily, and with a toxic smell, contaminating country and people. Leaving its poison, sickness and scars on country and people for generations to come and leaving a trail of mass destruction.

That morning, Thursday 15th October 1953 started like any other morning; at daybreak (first light) the men were getting ready to make their way down to the stockyards to start work on the station, and the women were seeing to their families at the camp before making their way to the homestead. Early that morning at 7am they heard a loud 'boom' that shook the ground and startled A<u>n</u>angu and animals, confusing everyone and everything that heard it and felt it. Come late morning they were witnessing a black smoke, creeping silently towards their camp in the sand dunes, falling heavy over country and leaving a black oily substance that smelt toxic. A<u>n</u>angu were confused and fear was starting to set in. Fear of not knowing what was happening, and what they were witnessing. Panic fell over the camp and many mothers started to dig holes in the sand dunes to protect their children, to hide them from the black smoke. The elderly and weak were the first to feel the impact of this radiation fallout. Many elders by the afternoon were showing signs of new sickness, vomiting, diarrhoea, rashes on their skin and burning eyes and developing bad coughs. By late afternoon many of our loved ones, our knowledge holders and law men and women were dying. A<u>n</u>angu became very sick, and our elders passed because of the 'black smoke'. Our workers (Mums and Dads) were also showing signs of new sickness, sore eyes, skins rashes and bad coughs, because the 'black smoke' fell on their skins. 'No one was protected.' My late father Yami Lester started to develop very sore eyes, like they had been burnt. My father was 12 years of age, when he witnessed the 'black smoke' and the sickness that fell over his people and his Yankunytjatjara Country. By the young age of 16 years his world turned into complete darkness. Taking his vision and his independence away with trauma and pain.

Medical aid was very limited, and the closest doctor would have been at Ernabella Mission some 200 kilometres away, two days walking in a north-west direction or at Oodnadatta another 200 kilometres east of Walyatjata, Walatina, where maybe a nurse was based. Oodnadatta also was the location where The Ghan railway line was and the transport route from Adelaide to Alice Springs. There was no immediate medical assistance for A<u>n</u>angu, and many became very sick and died. A<u>n</u>angu were never told of what was happening south at Emu Field, it was never explained that the Australian government and the British Government were in agreeance to run a nuclear testing programme on the tradition lands of Pitjantjatjara, Yankunytjatjara and Matutjara A<u>n</u>angu-ku mantangka (Aboriginal Land). A<u>n</u>angu never spoke English. They do have memory of a Mr McDougall who was the one patrol officer tasked to inform all living and working around the test site of the nuclear testing programme, one patrol officer covering an estimated 100,000 square kilometres across sand dunes and two-wheel tracks. Mr McDougall didn't get to everyone and many of our family who were out on country that day never returned.

Today the scars are still evident on our country and our people. New sicknesses are developing and A<u>n</u>angu are now faced with the threat of cancers, auto-immune diseases and infant mortality, all around the Nuclear Test sites in South Australia. Those tests impacted not only in South Australia (SA) but into the Northern Territory (NT) and into Western Australia (WA). Around these test sites are remote Aboriginal Communities that are on the A<u>n</u>angu Pitjantjatjara Yankunytjatjara Lands, Oak Valley, Yalata, Koonibba, Coober Pedy and Oodnadatta (SA), Tjuntjuntjara, (WA) and Mutitjulu (NT). All hold the stories of the dark past, the stories passed down from generation to generation of the nuclear testing programme conducted on their traditional lands.

The Spinifex people who live in the Great Victoria Desert in Western Australia, north-west of Maralinga, perhaps the harshest landscape in the most arid continent on earth, lived as nomadic hunter-gatherers without contact with Europeans until the 1950s and 1960s. They witnessed increasing incursions and roads into their country presaging the nuclear test programme, and saw white men who told them their land was to be poisoned by atomic blasts. Over the following decade, they drifted to the shelter of missions hundreds of kilometres away. Between 1954 and 1965, 26 'rescue missions' were conducted by the Australian Aborigines' Evangelical Mission, and most of the 403 people contacted were taken to Cundeelee Mission, or walked, some returning to the desert searching for lost relatives. Some were too afraid to venture from roads graded through their homelands to obtain water and food for fear of being killed by atomic poison. Some died of thirst and starvation in this exodus. Spinifex woman Darlene Stevens told how, at age 12, her family decided to walk the 900 kilometres to Cundeelee. Frightened of the poison in their land, they followed the road. Her mother, father and both brothers died on the journey.[55] In the early 1980s, Cundeelee Mission was forced to close and the Spinifex people returned to their homelands, settling at Tjuntjuntjara. They successfully negotiated a compensation package for their economic and cultural loss and won their Native Title rights in 2000, the first Native Title determination on the Australian mainland.[56]

### The impact on military and civilian test participants

The nuclear test programme was a massive industrial undertaking. Just over 17,000 Australians, both military and civilian, worked on the programme, in addition to British personnel. Permissible radiation dose limits for whole body penetrating radiation for workers from 1950 were 5 millisievert (mSv) per week,[57] compared with current occupational limits averaging 20 mSv per year and 1 mSv per year for the public. Yet measures to comply with even the low standards of the time were frequently deficient. Veterans describe lack of information about the risks they faced and how they might be reduced, lack of protective clothing and equipment, soldiers sent into ground zero to examine and retrieve test objects the same day after a nuclear explosion, servicing of inadequately decontaminated vehicles, and unpressurised aircraft flying through fallout clouds. Facilities for decontamination were often inadequate.[58]

Some radiation exposures were deliberate. At both Monte Bello and Maralinga tests, some personnel were required to stand in the open three kilometres from ground zero, and in trenches even closer. In the *Buffalo* series of tests in September to October 1956, an 'Indoctrinee Force' there to get real experience of nuclear war conditions, consisted of mainly commissioned officers who were positioned less than nine kilometres from ground zero. Of the 283 men, 178 were British (including 6 civilians), 100 were Australian, and the remaining 5 were from New Zealand. Like most Australian personnel, they were dressed in shorts, shirts, and long socks.[59] Pilots who flew pressurised Canberra airplanes through fallout clouds were measured to receive a radiation dose up to 210 mGy during one flight. Crews of unpressurised Lincoln aircraft who flew through mushroom clouds in 1953 were likely to have received even higher doses. The Australian and British crews tasked with flying through the radioactive cloud during the Operation Totem tests were considered to be exposed to only

55 A powerful account of this history is S. Cane, 'The history of the Spinifex people' in J Carty and L. Scholes (eds.), *Sun and shadow. Art of the Spinifex people*, Upswell Publishing, Perth, 2023, 34–51.

56 Ibid., 48–51.

57 McClelland, *Royal Commission into British nuclear tests in Australia*, Vol. 1, 1985, 39–85, especially Table 4.5.1, 78.

58 There are numerous informative eyewitness accounts by test participants. See. e.g., Tynan, *Atomic Thunder* and *The Secret of Emu Field*; F. Walker. *Maralinga*, Hachette Australia, Sydney, 2014; and R. Cross and A. Hudson, *Beyond Belief*, Wakefield Press, Kent Town, 2005.

59 Tynan, *Atomic Thunder*, 102, 104.

negligible radiation and so no detection equipment or personal monitoring devices were provided to them.[60] The failure to do so was described as negligent by the Royal Commission.[61] Lancelot Edwards, a wireless operator on board one of the aircraft, was diagnosed with cancer of the thyroid in 1959; he was compensated in 1981. The code-name for the flights was the ironic Operation Hot Box.[62]

The Royal Commission described 'departures, some serious and some minor, from compliance with the prescribed radiation protection policy and standards'.[63] No more than 4 per cent of Australian veterans had radiation film badge data available (compared with 22.5 per cent of UK personnel). The Royal Commission concluded that test participation had increased the risk of cancer among nuclear veterans, but given inadequate radiation monitoring, was unable to quantify the probable increase in the risk of cancer among the participants in the trial programme.

A belated Australian government-funded mortality and cancer study of test veterans was conducted at the University of Adelaide between 1999 and 2005. The study had two parts – a dosimetry study and a study of mortality and cancer.[64] The studies included close to 11,000 test participants, 65 per cent military and the rest civilians employed by construction companies. They excluded about 7,000 of the estimated 17,000 directly exposed persons. These were Aboriginal and other exposed local residents. These outside the scope of the studies include many of those likely to have suffered the highest radiation exposures. The dosimetry study confirmed that some service personnel had been intentionally exposed to radiation. Using the limited exposure data available (which excluded some external radiation, and more importantly, internal exposures) to estimate radiation exposure levels, only 4 per cent of the test veterans were estimated to have received more than 20 mSv, the current annual occupational exposure limit. Despite the major limitations of this retrospective study, it found statistically significant 23 per cent higher rates of cancer and 18 per cent higher cancer deaths between 1982 (29 years after the first test) and 2001 in test veterans compared with the general population. (Many cancers in veterans would have occurred before and after this time window.) As would be expected, the strongest association was for leukaemia (excluding chronic lymphatic leukaemia). For survivors, time is running out. In 2013, it was estimated that only 2,000 of the 17,000 Australian test participants were still alive.

### Transgenerational human effects

In 2022, details of a study of the risk of genetic and cytogenetic effects in children of individuals exposed to ionizing radiation by the British nuclear testing programme were published. The genetic and cytogenetic family trio (GCFT) study is the first to obtain blood samples from a group of British nuclear test veterans, their partners and one biological child, for the purposes of identifying genetic alterations in offspring as a consequence of historical paternal exposure to ionizing radiation. Complete trio blood samples were received for 43 test and 40 control families. Of the test veterans included, 43 per cent were involved in nuclear testing in Australia (the remainder were at Kiritimati/Christmas Island).[65] Radiation doses were estimated in 3 broad groups, as only around 20 per cent of British test veterans had external exposure measured and internal exposures were not measured. While the study is small, 20 per cent of the test veterans reported at least one congenital anomaly among their children or grandchildren, compared with 5 per cent of control families (p=0.03) and a rate of 2 per cent in the general UK population, warranting further study.

60 Ibid., 82.

61 McClelland, *Royal Commission into British nuclear tests in Australia*, Vol. 1, 1985, §5.5.7.

62 Tynan, *The Secret of Emu Field*, 164, 173.

63 McClelland, *Royal Commission into British nuclear tests in Australia*, Conclusions and Recommendations, 1985, 12.

64 Department of Veterans' Affairs. Australian participants in British nuclear tests in Australia. Vol 1: Dosimetry; Vol 2: Mortality and cancer incidence study. Canberra, Department of Veterans' Affairs, 2006, at: https://bit.ly/47i1zm9.

65 C. Rake *et al.*, 'British nuclear test veteran family trios for the study of genetic risk', *Journal of Radiological Protection*, Vol. 42 (2022), 021528.

Two further reports of results from this study have been published. The first examined de novo germline mutations in 30 test veteran families and 30 control families using whole genome sequencing.[66] The one statistically significant difference observed ($p<0.01$) was an elevated occurrence of single base substitution mutations within mutation signature SBS16, which may be associated with compromised DNA repair, mostly due to a small group of offspring of veterans, disproportionately in the veteran group assigned the highest potential radiation exposure. The finding and its relevance to future health risks warrant further investigation.

The third study thus far reported used Multiplex Fluorescence in situ Hybridisation (M-FISH) to evaluate chromosome aberrations among 48 test and 38 control veterans.[67] While no characteristic cytogenetic evidence of radiation exposure was identified, a higher frequency of complex chromosomal aberrations was observed in a small group of veterans at risk of higher exposures, from being on board ships (mostly at the Monte Bello Mosaic tests) or present at Maralinga, where ongoing internal exposures particularly from plutonium might be present. In addition, a small number of families in both test and control groups showed a relationship between paternal complex chromosome aberrations and germline mutation subtypes. The researchers postulated that this may represent a transgenerational biomarker of paternal exposure and assessed that further investigation is warranted. These findings are in contrast to those in a cohort of 50 New Zealand Kiritimati/Christmas Island test veterans, who observed on average three times as many nuclear tests as their British counterparts, and had a highly statistically significant threefold greater rate of chromosomal translocations compared with 50 carefully matched control NZ veterans.[68]

### Historic research related to nuclear testing

There was an extensive programme of sampling of human bones for strontium-90 in Australia. From 1957 to 1978, hospital pathology services were paid to remove sometimes quite sizeable samples of bone from about 22,000 bodies at autopsy, particularly of infants and children. In the 1950s and 1960s, samples were sent to the United Kingdom or United States (under 'Project Sunshine') for testing. Permission was not sought from families, who were not aware of the programme, or that many remains were kept without their knowledge or consent for decades.[69] There are disturbing reports of families of children who had died who were used for study being denied access to their children's bodies or not being able to bury them after bones had been removed; of foetuses having been discarded; and of children having been buried anonymously.[70]

## Societal effects and displacement

Hundreds of Maralinga Tjarutja people were dispersed by the tests in Maralinga.[71] It was not until 2009 that contamination was considered low enough for 3,000 square kilometres of land to be returned to the Tjarutja.[72] But as Tynan observes, the injury inflicted upon the Indigenous people of Australia by the multiple tests and trials 'cannot be properly measured'.[73] The Royal Commission concluded:

66 A. J. Moorhouse, M. Scholze, N. Sylvius, C. Gillham, C. Rake, J. Peto, R. Anderson and Y. E. Dubrova, 'No evidence of increased mutations in the germline of a group of British nuclear test veterans', *Scientific Reports*, Vol. 12 (2022), 10830.

67 K. J. Lawrence, M. Scholze, J. Seixo, *et al.*, 'M-FISH evaluation of chromosome aberrations to examine for historical exposure to ionising radiation due to participation at British nuclear test sites', *Journal of Radiological Protection*, Vol. 44 (2024), 011501.

68 M. A. Wahab, E. M. Nickless, R. Najar-M'Kacher, C. Parmentier, J. V. Podd, and R. E. Rowland, 'Elevated chromosome translocation frequencies in New Zealand nuclear test veterans', Cytogenetic and Genome Research, Vol. 121 (2008), 79–87.

69 Australian Health Ethics Committee, National Health and Medical Research Council, 'Ethical and Practical Issues Concerning Ashed Bones From the Commonwealth of Australia's Strontium 90 Program, 1957–1978', Advice of the Australian Health Ethics Committee to the Commonwealth Minister for Health and Ageing, Senator the Honourable Kay Patterson, Canberra, March 2002, pp. 4–6.

70 Walker, *Maralinga*, 218–30.

71 Tynan, *Atomic Thunder*, 14.

72 S. Boniface, 'The "Minor" Trials', *Daily Mirror*, 2018, at: https://bit.ly/3Spxrhk.

73 Tynan, *Atomic Thunder*, 306.

186. The traditional owners of the Maralinga lands were denied effective access to these lands for over 30 years as a result of the British nuclear test program. This denial has contributed to their emotional, social and material distress and deprivation.

188. It is appropriate and fair that after the loss of the use of their lands the Aboriginal people be compensated. Effective compensation would enable them, where and as they wish, to re-establish their links with the land as rapidly as possible and with as little hardship as possible.

The Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) declared that if the Tjarutja people were to adopt a 'more European lifestyle' the plutonium dust would be less likely to affect them.[74] The University of Sydney found that they and other groups affected by the tests reported sickness, high rates of miscarriage, and congenital anomalies, but without medical or hospital records have been unable to prove it to the satisfaction of the authorities.[75] Clean-up operations actually made the contamination worse.[76]

### Nuclear colonialism in Australia[77]

Australia's nuclear journey reveals a narrative that is deeply intertwined with settler colonial ambitions. In the early twentieth century, settler colonial ambitions were the driving force behind the pursuit of radioactive minerals. A transformative shift occurred during the 1940s and 1950s when the strategic potential of radium and uranium became apparent. This transformation culminated in British nuclear testing in Australia, showcasing a colonial dynamic where decisions were imposed without regard for local rights, leading to secrecy, disenfranchisement of Aboriginal populations, and limited opposition from the national government.[78] Nuclear colonialism evolved in a manner defined by the perceived exceptionalism of nuclear weapons, which offered an alternative source of power for declining empires.[79]

By the middle of the 1980s, however, the consequences of Australia's nuclear order came to light. Aboriginal political mobilization and resistance played a pivotal role, as highlighted in the Royal Commission into British Nuclear Tests in 1984–85. Testimonies revealed the multifaceted impact of nuclear colonialism, including displacement, dispossession, and unwarranted exposure to danger.[80] This examination underscores the dynamic nature of nuclear colonialism, where settler interests initially aligned with the nuclear order but were later contested by Aboriginal communities and changing societal sentiments.

The legacy of nuclear colonialism persists, as seen in ongoing debates over uranium mining, radioactive waste disposal, missile and weapons testing, and the role of nuclear energy in addressing climate change in the broader context of nuclear colonialism in Australia.[81] The testing at Maralinga in particular stands as a stark example of imperial power dynamics whereby the decision-making process, lack of consultation,[82] and ongoing struggles for recognition and compensation underscore the profound disregard for Indigenous populations and their land during British nuclear testing.[83]

74 S. Boniface, 'The "Minor" Trials', *Daily Mirror*, 2018, at: https://bit.ly/3Spxrhk.
75 Ibid.
76 E. Tynan, 'Maralinga: Sixty years on, the bomb tests remind us not to put security over safety', The Conversation, *ABC News*, 27 September 2016, at: https://bit.ly/3sju9Sg.
77 This section was contributed by Leila Hennaoui.
78 E. Lacovsky, 'Opposing Nuclear weapon testing in the Global South: A Comparative Perspective', *The International Spectator*, Vol. 58, No. 4 (2023), 73–90, at: https://bit.ly/3tYsq5t.
79 Urwin, 'Chain Reactions: Nuclear Colonialism in South Australia', p. 5.
80 Ibid., pp. 197–230.
81 Ibid., p. 308.
82 R. Jacobs, 'Nuclear Conquistadors: Military Colonialism in Nuclear Test Site Selection during the Cold War', *Asian Journal of Peacebuilding*, Vol. 1, No. 2 (November 2013), 157–77, at: https://bit.ly/490hRxH.
83 I. Golding, 'Nuclear Colonialism: The Story of Maralinga', Online article, 15 June 2021, at: https://bit.ly/48F5szk.

## Victim assistance

In 2006, 54 years after the tests began and in response to the test veterans health study, the government announced provision of free care for cancers to all test participants (military, public servant and civilian), and in 2010 military veterans were extended the same benefits as veterans involved in operational service or service recognized as 'hazardous'. In 2017, a Veteran Gold Card supporting comprehensive health care was made available to all Australian participants in British nuclear tests, including certain civilians within limited areas within 10 to 40 kilometres of test sites. This excludes, for example, those subjected to the Black Mist.

While various compensation schemes and pension provision are available, there is still no readily available inclusive compensation for all those exposed. Claimants have faced difficulties getting evidence – Maralinga hospital records are not available and dosage records are grossly incomplete and for reasons not explained, have been removed from the National Archives.[84] The currently available benefits for those exposed to the British nuclear tests, both military and civilian, are summarised by the Department of Veterans Affairs (last updated in 2022).[85] Since 2023, Australians who worked on British nuclear tests can apply to the British Ministry of Defence to receive a Nuclear Test Medal.[86]

The needs for victim assistance today among affected Indigenous populations and concerned military personnel have not been quantified. While some studies of the impact of the nuclear tests and trials are ongoing (see above), none has concluded with a clear exposition of victim assistance needs. The Royal Commission recommended that compensation should cover not only members of the armed forces, but also civilians including Aboriginal people. To assist with this, they recommended the establishment of a national register of nuclear veterans, Indigenous and other persons who may have been exposed to radiation from the tests (Recommendations 1 and 2). Such a register would have assisted distribution of information, data collection and linkage for health and other studies to assess the long-term consequences of their exposures, inform needs assessment and assist provision of services, and other benefits. Unfortunately, such a register was never implemented.

## Environmental contamination

Studies from both fission and non-fission tests at Emu, Maralinga and Monte Bello Islands show that radioactive particles are persistent and numerous in all these environments many decades after they were formed.[87] Their radionuclide content is substantial and can cause external and particularly internal exposure. The larger proportions of fine particles that are present are more consequential for biota, including humans, as they are more easily mobilized and transported by wind and water, and can bring a larger surface area emitting low-penetrating alpha and beta radiation in closer contact with tissues and cells. Particles less than 5 $\mu$m can lodge deep in the lungs and present an ongoing risk both from their direct emissions, as well as leaching of radionuclides into the bloodstream and transport to other parts of the body. Fractures within particles are prevalent, particularly in particles with the highest calcium content, and are likely have a strong role in leaching radionuclides into the environment. In all particles studied, plutonium-239 and plutonium-240 were dominant, and thus both fission test and Vixen B particles emit intense alpha and betea radiation, contrasting with fallout particles from Fukushima (where caesium-137 is dominant) and Chernobyl (where caesium-137 and strontium-90 are present in comparable amounts).

84 Walker, *Maralinga*, 246.

85 Department of Veterans' Affairs, Australian Government, 'Claims for nuclear test of bomb site exposure', 31 May 2022, at: https://bit.ly/3HdLPWU.

86 Ministry of Defence, UK, Nuclear Test Medal - Eligibility Criteria, updated 20 December 2024, at: https://bit.ly/47eH1uL.

87 M. P. Johansen, D. P. Child, R. Collins , M. Cook, J. Davis, M. A. C. Hotchkis, D. L. Howard, N. Howell, A. Ikeda-Ohno, and E. Young, 'Radioactive particles from a range of past nuclear events: Challenges posed by highly varied structure and composition', *Science of the Total Environment*, Vol. 842 (2022), 156755.

### Contamination at Maralinga

The plains of Maralinga are on the edge of the Great Victoria Desert, Australia's largest. Maralinga is 850 kilometres from Adelaide, South Australia's largest city and the fifth most populous in the country.[88] As noted above, in addition to the test detonations, more than 22 kg of plutonium were exploded in the Vixen B tests between April 1960 and September 1963.[89] The tests and trials resulted in vast areas of Australia being repeatedly contaminated, if only lightly, with radioactive materials.[90] Concerns were accentuated by the detection of radioactivity in the thyroid glands of sheep in the town of Alice Springs, more than 1,200 kilometres from Maralinga, and following some tests in Queensland and other areas thousands of kilometres away.[91] In a global study between 1956 and 1958, the highest concentrations of strontium-90 in Australia were recorded in Adelaide and Brisbane, both having been swept by winds bringing radioactive clouds from the atmospheric tests, especially those conducted in 1956 and 1957.[92]

A report by UK physicist Noah Pearce in 1968 (the Pearce report) claimed that only minimal levels of plutonium contamination remained at the site of the trials. Field results reported by the Australian Radiation Laboratory two decades later, however, demonstrated 'an underestimate of the plutonium contamination by about an order of magnitude'.[93] In fact, Vixen B scattered 22.2kg of plutonium-239 in an estimated three million fragments around the Taranaki test site at Maralinga.[94] In 1959, in seeking formal approval for the trials, the UK minister responsible had written to his Australian counterpart, the Minister for Supply, declaring that although the 'experiments are in no sense nuclear tests, it will be desirable to avoid publicity for them in order to remove the risk of their being misrepresented by ignorant or ill-intentioned persons'.[95]

A 2014 study examining plutonium in soils and wildlife at Taranaki (site of the Vixen B trials) outside the remediated area more than 50 years after deposition showed more than 80 per cent of the plutonium was plutonium-239, dispersed by the sub-fission or low nuclear yield trials. This study showed slow migration down into soil: 93 per cent and 62 per cent remained in the top 2 centimetres of soil after twenty-five and fifty years, respectively.[96] In various mammals, reptiles and arthropods (both herbivorous and predatory), over the period from the 1970s to 2012, plutonium uptake did not decrease over nearly thirty years, with a possible increase in reptiles, suggesting continued generation of bioavailable plutonium. The study also identified higher retention of plutonium-containing particles by soils with a biological crust formed by mosses and lichens, compared with bare soils.

Further evaluation of a Taranaki hot particle from the Vixen B sub-critical nuclear tests collected by remediation crews in the 1980s showed the presence of a crystalline plutonium-rich carbide quite stable under ambient conditions for more than 60 years.[97] Slow physical and chemical weathering of such particles over decades may contribute to slow release of radionuclides and explain the persistence

88 The name Maralinga, which means thunder in the Garik dialect of the now-extinct Northern Territory Ilgar language, was chosen by the Chief Scientist of Australia's Department of Supply, William Butement. O. Mazel, 'Returning Parna Wiru: Restitution of the Maralinga Lands to the Traditional owners', in M. Langton *et al.* (eds.), *Settling with Indigenous People: Modern Treaty and Agreement-making in South Australia*, Federation Press, Australia, 2006, 159–80.

89 Tynan, *Atomic Thunder*, 16.

90 Cross, *Fallout: Hedley Marston and the British Bomb Tests in Australia*, 143.

91 Ibid., 144.

92 Ibid., 154, 248.

93 E. Tynan, 'Dig for secrets: the lesson of Maralinga's Vixen B', The Conversation, 25 July 2013, at: https://bit.ly/3QmvNdR.

94 Tynan, *Atomic Thunder*, 122.

95 Ibid., 164.

96 M. P. Johansen, D. P. Child, E. Davis, C. Doering, J. J. Harrison, M. A. C. Hotchkis, T. E. Payne, S. Thiruvoth, J. R. Twining, and M. D. Wood, 'Plutonium in wildlife and soils at the Maralinga legacy site: persistence over decadal time scales', *Journal of Environmental Radioactivity*, Vol. 131 (2014), 72–80.

97 B. Etschmann, O. P. Missen, S. D. Conradson, S. Mills, Y. Liu, and J. Brugger, 'Environmental stability of a uranium-plutonium-carbide phase', *Scientific Reports*, Vol. 14 (2024), 6413, at: https://bit.ly/45CkOpk.

and even increase in levels of plutonium in wildlife over 50 years. These findings reinforce the need for long-term environmental monitoring of contaminated former nuclear test sites and have implications for clean-up. With significant levels of plutonium remaining near the surface in soils and continuing release of bioavailable plutonium over long timeframes, clean-up may still be feasible and warranted even numerous decades after dispersal.

Burial pits and other areas of waste concentration also require regular long-term surveillance and monitoring to ensure their continuing integrity. In 2011, a report obtained under Freedom of Information laws documented that only a decade on, a number of burial pits from the main Maralinga clean-up had been subject to subsidence and erosion, requiring further remediation.[98]

### Contamination at the Monte Bello Islands

Unlike Maralinga, the Monte Bello Islands have been little disturbed since nuclear testing; are devoid of permanent human habitation; and, while many structures were removed and plinths were placed at ground zero locations, no substantive clean-up of residual contamination has been undertaken.[99] Persisting radioactivity in the physical environment and in biota have been recently studied. Levels of plutonium-239 and plutonium-240 in surface marine sediments ranged up to 657 Bq/kg, 4,500 times higher than from other Western Australia coastline areas.[100] The residual fallout burden in Monte Bello sediments is surprisingly high, with plutonium levels in marine sediments similar to those in Bikini, despite only three tests totalling 145 kt in the Monte Bello Islands, compared with twenty-three tests totalling 76.8 megatons (Mt) at Bikini.[101] The level of caesium-137 found in the Monte Bello Islands is higher than at Fangataufa Atoll in Mā'ohi Nui (French Polynesia), despite the explosive yield of atmospheric nuclear tests at the latter being 26 times greater. These data illustrate an important principle that radioactive fallout and residual radioactivity from nuclear tests do not correlate in any simple way with their explosive yield.

There has been little attenuation of plutonium activity in island soils, with similar levels being measured in 1972 and 2015, with ongoing spreading through erosion, island to sea movement and transport by winds and currents. In 2015 samples, low levels of plutonium and other radionuclides were found in all local wildlife tested, with the highest levels in terrestrial arthropods.

### Contamination at 'Emu' Field

Emu Field, where devices with higher proportions of plutonium-240 were incorporated in the warhead,[102] was the subject of limited clean-up as a result of Operation Brumby (discussed further below). In addition to the two nuclear tests, so-called 'Kittens' trials were conducted into the triggers to be used in the Blue Danube weapon. This brought polonium-210 into contact with beryllium.[103] The polonium deposited by the trials has since decayed.

98 P. Dorling, 'Ten Years after the All-Clear, Maralinga is Still Toxic', *Sydney Morning Herald*, 12 November 2011 at: https://bit.ly/454NY09.
99 M. P. Johansen, D. P. Child, T. Cresswell, J. J. Harrison, M. A. C. Hotchkis, N. R. Howell, A. Johansen, S. Sdraulig, S. Thiruvoth, E. Young, and S. D. Whiting, 'Plutonium and other radionuclides persist across marine-to-terrestrial ecotopes in the Montebello Islands sixty years after nuclear tests', Science of the Total Environment, Vol. 691 (2019), 572–83.
100 M. Williams-Hoffman et al., 'Montebello Islands marine sediment retains nuclear weapons-derived radionuclide contamination 70 years after detonations', *Marine Pollution Bulletin*, Vol. 219 (October 2025), 118280.
101 F. Warner and R. J. C. Kirchmann (eds.), *Nuclear Test Explosions: Environmental and Human Impacts*, Scientific Committee on Problems of the Environment (SCOPE) , John Wiley & Sons, New York, 1999, 19–22.
102 Tynan, *The Secret of Emu Field*, 47.
103 Ibid., 85.

The MARTAC Committee which oversaw the 1990s clean-up stated that no remaining contamination was observed from the minor trials at the Operation Kittens sites at Emu Field. However, the major trial sites at Emu are contaminated, and fallout plumes extend northward for Totem 1 and southward for Totem 2, and surface glazing and bead formation are present near ground zero. An aerial survey in the 1990s found levels of americium-241 up to 10 kBq/m$^2$ and caesium-137 levels up to 130 kBq/m$^2$ at Emu. During the 1990s the clean-up programme recommended avoidance of occupancy around the ground zeros and scraping of surface soil with mounding over the ground zeros, however this was rejected by the Maralinga Tjarutja as being unsightly. Track entrances to the two areas were ripped and seeded with local vegetation and boundary markers signs were emplaced. Most of the glazed material was removed in 1967 and follow-up collection occurred as part of the 1990s clean-up.[104] Local Indigenous people believe the removal of remaining contamination at Emu Field remains an urgent priority and continue to advocate this to the Australian government.

## Environmental remediation

In 1984, in its submission to the Australian Royal Commission established to review the nuclear tests, the United Kingdom stated:

> Scientific knowledge is not now, and certainly was not then, sufficiently advanced to enable a complete decontamination of an area in which nuclear explosive tests have taken place.[105]

The United Kingdom launched a series of short-lived and inadequate clean-up operations. In 1964, Operation Hercules conducted a limited clean-up of the site at Taranaki, which included burying contaminated materials that could not be cleaned in pits and fencing off areas with residual contamination. Ploughing plutonium into the topsoil was the wrong approach given the presence of very hard limestone under 7 to 10 centimetres of sand.[106] Indeed, a radiological survey the following year found it was still contaminated, and in 1967, Operation Brumby tried again, this time collecting plutonium found on the surface, burying it in 21 pits covered by 650 tonnes of concrete, and ploughing the soil.[107]

On the incorrect assumptions that there would be no permanent habitation in the Maralinga area and that plutonium was not present as fragments, the testing areas were then declared 'radiologically safe'. This led to a 1968 agreement between the British and Australian governments releasing Britain from liability for any future claims related to its nuclear tests. A 1984 study by the Australian Radiation Laboratory, however, demonstrated far more extensive and severe contamination than previously revealed, proving that the information and hazard assessment on which the agreement was based was unreliable.[108] From 1986, a Technical Assessment Group (TAG) and Maralinga Consultative Group involving Australia, the United Kingdom, and the South Australia and Western Australia authorities and the Maralinga Tjarutja oversaw studies to define risks to Aboriginal people and formulate clean-up options within a budgetary limit.[109]

The criteria TAG recommended for rehabilitation was that the annual risk of fatal cancer should not exceed one in 10,000 by age 50, and an effective action level of 5 mSv/yr.[110] The life expectancy of Aboriginal people in South Australia at that time was around 50 years. Even at the likely underestimated BEIR 7 report population

104 MARTAC , 'Rehabilitation of former nuclear test sites at Emu and Maralinga (Australia)', pp. 23–24, 166–67, and 384.
105 Written Submission of the UK to the Royal Commission into British Nuclear Tests in Australia, 1984.
106 Tynan, *Atomic Thunder: British Nuclear Testing in Australia*, 231, 232.
107 MARTAC , 'Rehabilitation of former nuclear test sites at Emu and Maralinga (Australia), p. 30.
108 McClelland, *Royal Commission into British nuclear tests in Australia*, Vol. 2, 1985, 539-40, 549-52.
109 MARTAC , 'Rehabilitation of former nuclear test sites at Emu and Maralinga (Australia)', pp. 38-46.
110 Ibid., p. 43.

risk of 1 in 20,000 additional lifetime fatal cancer risk per mSv of exposure, the incremental increased risk of fatal cancer from 5 mSv is 1 in 4,000. Exposure at this level over 50 years, totalling 250 mSv, would roughly translate into a 1 in 80 increased risk of fatal cancer. The current recommended maximum permissible non-medical radiation dose for the general public in Australia and most other countries is 1 mSv/year.

TAG considered nine different clean-up options and 26 sub-options, ranging in cost from A$13 million (patrolled fencing) to A$653 million (1988).[111] Agreement was reached on an option which focused on the need for major remedial works at the most plutonium-contaminated sites:

- soil ploughed during operation Brumby would be removed and buried in an engineered trench
- formal debris pits would be stabilized using in situ vitrification
- sorting contents of informal rubbish pits to recover any radioactive objects and re-burying remaining contents at the same site
- the Vixen B plumes would be delineated at the 5 mSv/yr dose contour; and
- for Emu, with simpler rehabilitation requirements, the focus was on removal of debris with souvenir potential.

Engineer Alan Parkinson was appointed in 1994 to oversee the clean-up project, until he was removed for questioning the project's management. In extensive published material, including his book, Parkinson has documented shortcomings, failures, and poor management of the challenging clean-up project. A number of his concerns have been echoed by other knowledgeable scientists.[112] Parkinson emphasizes that the full extent of contamination remains unknown, citing identification of 40 minor trial ground zero sites, whereas UK records indicated 26, with at least three contaminated sites being found by accident during the clean-up.[113]

In 2000, after the clean-up claimed to be world's 'best practice' was completed, Maralinga was again declared 'safe' by the responsible government minister, Nick Minchin. Parkinson writes that, after clean-up, less than 2 per cent of areas contaminated above the clean-up criteria at the Taranaki 'minor trials' site meet the clean-up clearance criteria;[114] and that an estimated 3.3 kilograms of plutonium was collected and buried, leaving 84 per cent of the total plutonium contamination still dispersed.[115] While long-term safety has been significantly improved by the 1995–2000 clean-up, Parkinson notes that the clean-up added only 0.5 square kilometres of land suitable for permanent habitation.

Burial pits and other areas of waste concentration require regular long-term surveillance and monitoring to ensure their continuing integrity. In 2011, a report obtained under Freedom of Information laws documented that only a decade on, significant remediation has been required because of erosion of the massive Taranaki burial trench, and subsidence and erosion had exposed asbestos-contaminated debris at other burial pits.[116]

With respect to the Monte Bello Islands, two relatively minor clean-up operations were conducted.[117] In 1965 (Operation Cool Off), soldiers and sailors spent a week putting up new fences around bomb sites, fixing the fence across Trimouille island and adding one across Alpha island, and replacing missing warning signs. In 1979, a more concerted Operation Capelin was conducted by the Royal Australian Engineers. Pieces of the frigate HMS *Plym* were found by the team, including a large driveshaft containing cobalt-60 (formed by neutron irradiation of steel). The Australian Radiation Laboratory wrote to the British High Commissioner

111 P. N. Johnston, A. C. Collett, and T. J. Gara, 'Aboriginal participation and concerns throughout the rehabilitation of Maralinga', presented at the Third International Symposium on the Protection of the Environment from Ionising Radiation, IAEA, Darwin, 2002, 349–56 in: https://bit.ly/3GXgAiM.
112 A. Albanese, Ministerial Statements: Maralinga: Nuclear test sites, 24 March 2002 at: https://bit.ly/3HAxELB.
113 A. Parkinson, *Maralinga: Australia's Nuclear Waste Cover-up*, ABC Books, Sydney, 2007.
114 Ibid., 231.
115 A. Parkinson, 'Maralinga: The Clean-Up of a Nuclear Test Site', *Medicine & Global Survival*, Vol. 7, No. 2 (2002), 77–81.
116 P. Dorling, 'Ten Years after the All-Clear, Maralinga is Still Toxic', *Sydney Morning Herald*, 12 November 2011, at: https://bit.ly/45kcyu0.
117 P. Grace, *Operation Hurricane,* 2023, 291–92.

about the continuing problems with contaminated debris and black dust, which received the response 'Everyone knows when you explode a nuclear weapon on a ship, the whole ship is vaporised.'[118]

There are no ongoing or planned environmental remediation efforts in Australia. That said, through the 2009 Maralinga Nuclear Test Site Handback Deed—an agreement on the in-perpetuity responsibilities of the Commonwealth, South Australia Government, and Maralinga Tjarutja—the Commonwealth is obligated to ensure Maralinga Lands remain safe for agreed and intended land use.[119] The government claims that since its rehabilitation project between 1995 and 2000, 'dose assessments undertaken every three years have shown contaminated soils are well within the clean-up standards for agreed and intended land use.'[120] Its results have not been made public.

## The impact of climate change[121]

The development of Australia's National Climate Risk Assessment is pending, but a summary of key regional trends and potential climate-related impacts for the Monte Bello Islands is given in Table 1 below, and for Emu Field and Maralinga in Table 2 opposite. Sea-level rise, storm surges, and increased intensity of extreme rainfall events are highlighted as the predominant impact for the Monte Bello Islands, and increased drought, risk of wildfires, intensity of extreme rainfall events, and airborne contaminants as the predominant impact for Emu Field and Maralinga.

The 2020 Royal Commission into National Natural Disaster Arrangements report includes recommendations for preparedness for extreme weather events, but does not specifically address land contamination or legacy nuclear test sites.[122]

**Table 1:** **Summary of key climate trends and impacts, Monte Bello Islands**[123, 124]

| Climate system/ hazard | Historic trends | Projected trends | Possible impact on risk components |
|---|---|---|---|
| Temperature | Increasing | Increasing temperatures and frequency, duration and severity of heat waves* | Source: changes in physico-chemical behaviour and leaching, affecting mechanisms by which contaminants may be released. Includes physical landform changes and erosion caused by sea-level rise, storms, or wave action<br><br>Pathway: changes in water infiltration, water tables/sea-levels, flow rates and ocean currents Changes to release of airborne contaminants, including from wildfires.**<br><br>Receptor: changes in species assemblages and/or sensitivity to contaminants. Shift in people's proximity/exposure routes to sources. |
| Precipitation | Generally increasing in north-western Australia | More intense rainfall events expected* | |
| Sea level rise | Sea level rise impacting low-lying areas | Mean sea-level rise increases, yet low confidence in projected extremes and storm surges events* | |
| Floods, cyclones, tsunami, and storm surges | Cyclones have historically affected the region | Uncertain, but may see a greater incidence of large and strong cyclones. A 40% chance of a potentially damaging tsunami occurring in the next 50 years* | |
| Wildfires | Increase in wildfire size and severity | Increased risk of wildfires* | |

* Projections uncertain ** Includes soil-bound radionuclides or radionuclides taken up by plants

118 Tynan, *Atomic Thunder*, 245, 246.
119 Australia Department of Foreign Affairs and Trade, 'Australia's Submission to the United Nations Secretary-General's Report on Addressing the Legacy of Nuclear Weapons: Providing Victim Assistance and Environmental Remediation to Member States Affected by the Use or Testing of Nuclear Weapons', July 2024, at: https://bit.ly/4e8jigc, para. 10.
120 Ibid, para. 8.
121 This section was contributed by Linsey Cottrell.
122 Royal Commission, 2020, at: https://bit.ly/4a7QWAr.
123 Australia, State of the Environment, 2021, at: https://bit.ly/437DBWJ.
124 ThinkHazard! High-level hazard profile for Roeborne, Western Australia, at: https://bit.ly/3TdqH4K.

**Table 2:** **Summary of key climate trends and impacts, Emu Field and Maralinga**[125, 126]

| Climate system/ hazard | Historic trends | Projected trends | Possible impact on risk components |
|---|---|---|---|
| Temperature | Increasing | Increase in average temperatures, as well as frequency and severity of heat waves | **Source:** changes in physico-chemical behaviour affecting mechanisms by which contaminants may be released. Includes physical landform changes caused by soil desiccation, erosion, wildfires, and high winds<br><br>**Pathway:** changes to release of airborne contaminants, including by wildfires.<br><br>**Receptor:** changes in species assemblages and/ or sensitivity to contaminants, and exposure routes for people. |
| Precipitation | Decreased in southern Australia | Decrease in winter and spring rainfall | |
| Drought | Increasing evaporative demand and worsening droughts | Increase in drought frequency and severity | |
| Wildfires | Increase in wildfire size and severity | Increased risk of wildfires | |

* Includes soil-bound radionuclides or radionuclides taken up by plants

## Legal issues

A range of compensation schemes have been created in the decades since the nuclear tests, largely following pressure from veterans, Aboriginal people, and the wider public in Australia and in parliament. Additional funding, albeit limited, has also been received from the UK government for the clean-up of Maralinga. Only one lawsuit against the Australian government for its failings has ever been successful.

### Individual compensation schemes

In November 1994, the Australian government provided a settlement of A$13.5 million to the Indigenous Peoples in and around Maralinga. They had been granted legal title to their ancestral lands under the 1984 Maralinga Tjarutja Land Rights Act.[127] Administrative payments have also been made by the Australian government to some service personnel, Indigenous people, and civilians, with an average payout calculated as of 2016 at A$126,561.[128] Australia's the 1986 Veterans' Entitlement Act has been broadened, most recently in 2010, to address the health concerns of more nuclear veterans.[129] In 1988, the UK government agreed to pay war pensions to its own service personnel who developed blood cancers after being stationed at Maralinga.[130]

### Court judgments

In 1988, Richard Johnstone was awarded A$679,500 in compensation for the impact on his mental health of service at Maralinga in 1956 during the *Buffalo* series of nuclear tests. He was 22 years of age when he was sent there to serve as a motor mechanic. Johnstone was discharged from the Royal Australian Air Force (RAAF) on medical

125 ThinkHazard! High-level hazard profile for Maralinga Tjarutja, Southern Australia, at: https://bit.ly/3wJ8xQZ.
126 CSIRO, Climate projections for Australia, at: https://bit.ly/4bDg8je.
127 Tynan, *Atomic Thunder: British Nuclear Testing in Australia*, 174.
128 Ibid., 304–05.
129 Ibid., 306.
130 Ibid., 305.

grounds in December 1957. In the months after leaving Maralinga, he was treated in an RAAF hospital for radiation sickness and in a repatriation hospital for anxiety. Mr Johnstone who became the president of the Australian Nuclear Veterans Association (ANVA) established in the 1970s, sued the Commonwealth of Australia in the Supreme Court of New South Wales for the psychological effects of his service. He passed away in 2012. To date, he remains the only successful litigant in Australia to receive damages for the failings of the nuclear testing programme.[131]

### Intergovernmental compensation and reparation

Despite its significant measurement errors, the 1968 Pearce report provided the technical basis for the Australian government to release its British counterpart from any further liability for the Vixen B contamination at the Maralinga site.[132] Mr Pearce had confirmed that the United Kingdom would not 'repatriate' any of the plutonium, leaving the options of either 'burying' it at Maralinga or 'disposing' of it elsewhere in Australia.[133] On 23 September 1968, the Australian government signed a memorandum with the United Kingdom whereby the UK government was 'released from all liabilities and responsibilities'.[134] In 1993, however, following revelations of the UK´s failure to be forthright about the true extent of contamination, Australia called on Britain to pay at least A$75 million (£33 million at the time) to clean up the land at Maralinga with a further A$45 million to compensate the Maralinga Tjarutja, who had been deprived of access to about 3,000 square kilometres of their land as a result of the tests and trials.[135] In fact, the UK government provided £20 million in compensation to support the clean-up.[136] In May 2024, the UK government told UN Member States that it 'considers its remediation efforts in regard to testing conducted in Australia to be complete'.[137]

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131 'Nuclear survivor fought to the end', Obituary, *The Sydney Morning Herald*, 25 February 2012, at: https://bit.ly/46Wq0m3.
132 Tynan, 'Dig for secrets: the lesson of Maralinga's Vixen B'.
133 Tynan, *Atomic Thunder: British Nuclear Testing in Australia*, 137.
134 Ibid., 244.
135 I. Anderson, 'Britain's dirty deeds at Maralinga: Fresh evidence suggests that Britain knew in the 1960s that radioactivity at its former nuclear test site in Australia was worse than first thought. But it did not tell the Australians', *New Scientist*, 12 June 1993, at: https://bit.ly/461sQ8a.
136 Tynan, *Atomic Thunder: British Nuclear Testing in Australia*, 286.
137 Document submitted by the United Kingdom on the Secretary General's Report on A/RES/78/240, 31 May 2024, at: https://bit.ly/3Xaen7F, 1.


I Got Cancer Living Downwind of Trinity!
THE BOMB HURT NEW MEXICANS

Chapter 21:

# Addressing the Impact of Nuclear Testing in the United States

Marian Casey-Maslen and Stuart Casey-Maslen

**Downwinders:** Tina Cordova photographed during a protest in front of the entrance of White Sands Missile Range where the Trinity test site is located, near White Sands, New Mexico, on 21 February 2024. Cordova is one of five generations in her family diagnosed with cancer since 1945, and she is the founder of the Tularosa Basin Downwinders Consortium, an organization that raises awareness about victims of the very first nuclear test, the so-called Trinity test in 1945. Photograph by Tularosa Basin Downwinders Consortium.

## Key Facts about Nuclear Testing in the United States

**Testing State:** United States

**Testing period:** 1945–92

**Number of tests:** 945 tests on continental US territory, including more than 100 atmospheric tests, 88 safety tests, and 28 tests conducted jointly with the United Kingdom.

**Testing locations:** Mainly the Nevada Test Site (NTS) north-west of Las Vegas, but also at various other locations in Nevada, as well as in Alaska, Colorado, Mississippi, and New Mexico.

**Widespread fallout:** The atmospheric tests caused widespread radioactive fallout across the United States and into Canada and Mexico, leading to environmental contamination and population exposures. New research shows that the harmful effects of the nuclear tests has previously been significantly underestimated.

**'Downwinders':** Cancer rates are higher in some towns situated downwind of testing sites, where many feel betrayed by the government. Some communities have clinics and cancer centres, but others lack such support.

**Indigenous Peoples affected:** More than 900 nuclear tests were conducted on Shoshone territory in violation of the Treaty of Ruby Valley signed in 1863, causing cancer, thyroid diseases, and congenital anomalies. Indigenous communities received substantial exposures and were disproportionately affected due to traditional lifestyles.

**Military exposure:** Around 250,000 US soldiers participated in nuclear tests. Many were exposed to harmful radiation and bound by secrecy oaths until 1996.

**Environmental devastation:** Soil, groundwater, and ecosystems near test sites were contaminated. Cleanup is ongoing.

**RECA:** The 1990 Radiation Exposure Compensation Act (RECA) has provided one-off compensation to some of the victims of the radiation generated by the tests, but excludes many affected groups, like people living downwind of the first Trinity test. RECA was allowed to expire in June 2024 but was resuscitated in June 2025.

> The radiation has caused Shoshone, Ute, Navajo, Hopi, Paiute, Havasupai, Hualapai and other downwind communities to suffer from cancer, thyroid diseases and birth defects. We are now the most bombed nation in the world.
>
> Chief Raymond Yowell, Western Shoshone (1994)[1]

## History of testing in the United States

The first test of the nuclear age occurred in the early morning of 16 July 1945 on what was then the Alamogordo Bombing Range, now the White Sands Missile Range, in New Mexico, near to the city of Socorro. The atmospheric test effectively confirmed that the implosion design weapon used in the atomic bomb to be dropped on Nagasaki less than a month later would produce a substantial nuclear detonation.[2] The United States (US) would go on to conduct a total of 1,054 nuclear tests[3] and 1,149 individual detonations.[4] Of the total reported tests, 945 were on continental US territory,[5] including 24 underground and 4 atmospheric tests conducted jointly with the United Kingdom.

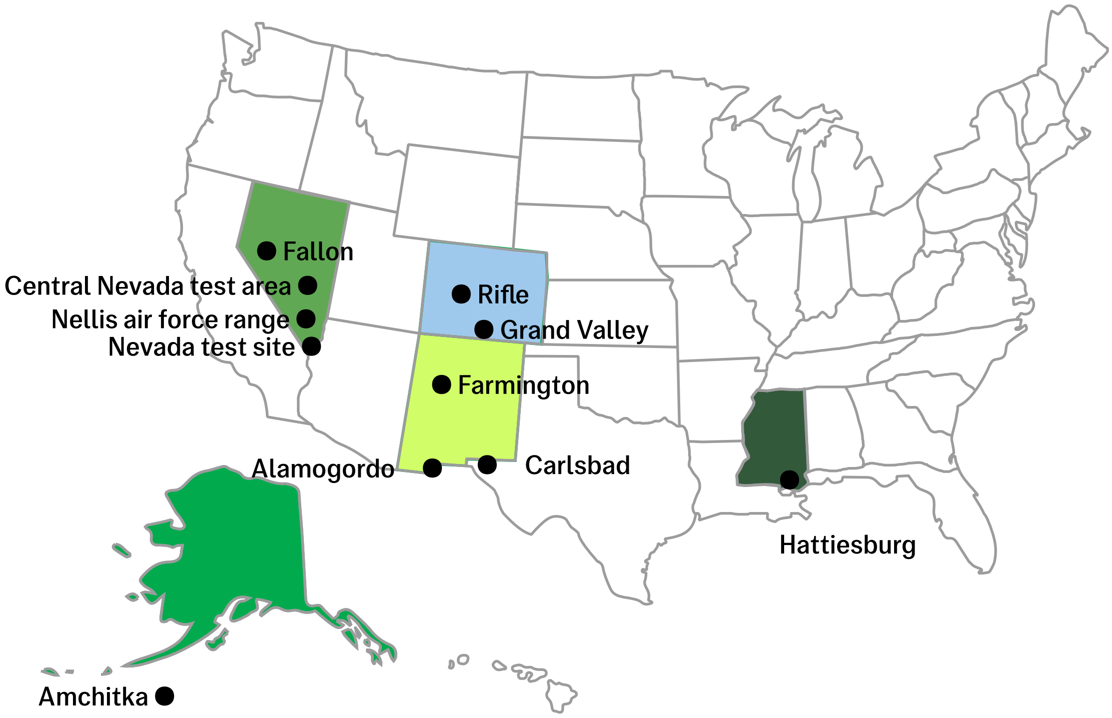
Between 1945 and 1992, 928 nuclear tests involving 1,021 detonations were conducted at what was then the Nevada Test Site (NTS), now the Nevada National Security Site (NNSS),[6] a 1,350 square-mile area about 65 miles north-west of Las Vegas.[7] Of these, 828 tests with 921 detonations were conducted underground. The last of 100 atmospheric tests there took place on 17 July 1962.[8] A total of 17 nuclear tests were conducted in the United States at locations outside the NTS: The Alamogordo Bombing Range where the Trinity test took place, as well as Amchitka Island, Alaska (3 tests); Carlsbad (1 test) and Farmington (1 test) in New Mexico; Central Nevada (1 test) and near Fallon, Nevada (1 test); the Nevada Test and Training Range on Nellis Air Force Base (5 tests); near Hattiesburg, Mississippi (2 tests); and near Meeker (1 test) and Parachute (1 test) in Colorado. (See Figure 1 overleaf).

Since June 1963, all nuclear tests conducted in the United States were underground,[9] and after 17 May 1973, all US nuclear tests were conducted at the NTS.[10] The last US nuclear test took place at the NTS on 23 September 1992.[11] That year, Congress passed legislation that prohibited the US government, on a unilateral though only

1 Cited by V. Kuletz 'Invisible Spaces, Violent Places: Cold War Nuclear and Militarized Landscapes', in N. Peluso and M. Watts (eds.), *Violent Environments*, Cornell University Press, Ithaca, 2001, 237–60, at p. 237.
2 *The Nuclear Matters Handbook 2020*, Rev'd Edn, Office of the Deputy Assistant Secretary of Defense for Nuclear Matters, at: https://bit.ly/48MDe5U, 183. Ascertaining the likely yield—in order to determine the optimum burst height to achieve maximum destruction—and ensuring the device would not 'fizzle' was the reason for the test, not just confirming that it would explode. Email from Stephen Schwartz, 20 April 2024.
3 The Nuclear Matters Handbook 2020, 184; US Department of Energy (DoE), 'United States Nuclear Tests July 1945 through September 1992', Doc. DOE/NV--209-REV 16, Nevada Operations Office, December 2015, at: https://bit.ly/45QN1Yd, p. xvi.
4 This is because 63 underground tests, almost all in Nevada, included the detonation of more than one device. Email from Stephen Schwartz, 20 April 2024; US DoE, 'United States Nuclear Tests July 1945 through September 1992', Doc. DOE/NV--209-REV 16, Nevada Operations Office, p. xvi.
5 In addition, the United States conducted nuclear tests at Johnston Atoll (an unincorporated territory of the United States), the Marshall Islands, and Kiribati, as well as over the Pacific Ocean and the southern Atlantic Ocean.
6 The Nevada Test Site name was changed to the NNSS in 2010.
7 US DoE, 'United States Nuclear Tests July 1945 through September 1992', Doc. DOE/NV--209-REV 16, p. xvi.
8 Utah Department of Environmental Quality, 'Impacts of Radiation from Aboveground Nuclear Tests on Southern Utah', at: https://bit.ly/3vTO1wF.
9 US DoE, 'United States Nuclear Tests July 1945 through September 1992', Doc. DOE/NV--209-REV 16, p. viii.
10 *The Nuclear Matters Handbook 2020*, Rev'd Edn, 186.
11 Atomic Heritage Foundation, 'Nevada Test Site', 2022, at: https://bit.ly/47FMybb.

temporary basis, from conducting even an underground nuclear test.[12] Since 1993, President Bill Clinton and every subsequent US president has decided to maintain the moratorium on nuclear testing (excluding periodic subcritical experiments which generate no self-sustaining nuclear chain reaction and thus produce no explosive yield).[13]

**Figure 1:** US nuclear test locations – Nevada Test Site and other locations[14]




The nomenclature for test yields has varied according to changing US policy over time. In some cases, no yield information was released; in a few cases, the terms 'very slight' and 'slight' were used without further clarification. Certain tests were recorded as 'about 2 kt [kilotons]', 'several Mt [megatons]', or 'less than 0.1 kt'.[15]

Table 1 opposite summarizes all reported 1,054 US nuclear tests globally by yield. Tests between 1945 and April 1976 included 33 detonations above 1 Mt, 23 detonations between 500 kt and 1 Mt, and 26 detonations between 150 and 500 kt. An additional 79 tests may have had yields exceeding 150 kt.[16] A test underneath the island of Amchitka in Alaska gave a yield of 5 Mt, the highest ever conducted by the United States on its continental territory.[17] A total of 870 tests had yields that were greater than zero but less than 150 kt. The Office of the US Deputy Assistant Secretary of Defense for Nuclear Matters notes that even a very low-yield, 1 kt detonation

> produces severe damage effects approximately one quarter of a mile from GZ [ground zero]. Within the severe damage zone, almost all buildings would collapse and 99 percent of persons become fatalities quickly. Moderate damage would extend approximately one-half mile and would include structural damage to buildings, many prompt fatalities, severe injuries, overturned cars and trucks, component damage to electronic devices, downed cellphone towers, and induced radiation at ground level that

12 Hatfield-Exon-Mitchell Amendment, P.L. 102-377, §507.
13 Congressional Research Service, 'U.S. Nuclear Weapons Tests', Last updated 4 December 2020, available at: https://bit.ly/3uaTpuQ.
14 Reproduced from an illustration in US DoE, 'United States Nuclear Tests July 1945 through September 1992', at: https://bit.ly/3HGXo5o.
15 US DoE, 'United States Nuclear Tests July 1945 through September 1992', September 2015, p. x.
16 Ibid., 186.
17 United Press International (UPI), 'Nuclear test sites studied by scientists', *The Bulletin* (Bend, Oregon), 8 November 1971, 1, available at: https://bit.ly/47XiUxv.

could remain hazardous for several days. Light damage would extend out approximately 1.5 miles and include some prompt fatalities, some persons with severe injuries, and the effects on infrastructure as stated for medium damage. Some fatalities or injuries may occur beyond the light damage zone.[18]

**Table 1:** **Reported yield of US nuclear tests**[19]

| Time Period | Zero or Near-Zero | > 0 to 150 kt | Possible > 150 kt | > 150 to 500 kt | > 500 kt to 1 MT | > 1 MT |
|---|---|---|---|---|---|---|
| 1945–1948 | 0 | 6 | 0 | 0 | 0 | 0 |
| 1951–1958 | 17 | 137 | 0 | 13 | 1 | 20 |
| 1961–11/04/62 * | 0 | 79 | 0 | 4 | 8 | 9 |
| 11/8/62–03/17/76 ** | 5 | 391 | 79 | 9 | 14 | 4 |
| 5/76–1992 | 1 | 257 | 0 | 0 | 0 | 0 |
| **Total** | **23** | **870** | **79** | **26** | **23** | **33** |
| **Grand Total: 1,054 Nuclear Tests** | | | | | | |

**Note:**

* Last US above-ground or surface detonation
** = Last US detonation above 150 kt

A total of 88 of the recorded detonations were 'safety experiment' tests, some with zero or near-zero explosive yields, and some with yields that could be measured in several kilotons. This included assessments of plutonium dispersion in case of an accident involving a nuclear weapon (meaning a serious 'Broken Arrow' incident).[20]

Included in the total number of US nuclear tests are also 27 so-called peaceful nuclear explosions (nuclear tests for non-military purposes, to explore the potential use of nuclear explosive devices for i.a. excavation for the building of canals or harbours). They were all conducted underground on continental US territory in the Plowshare programme from late 1961 to the middle of 1973.[21] The Plowshare programme was discontinued at the end of 1975 due to economic and environmental concerns.

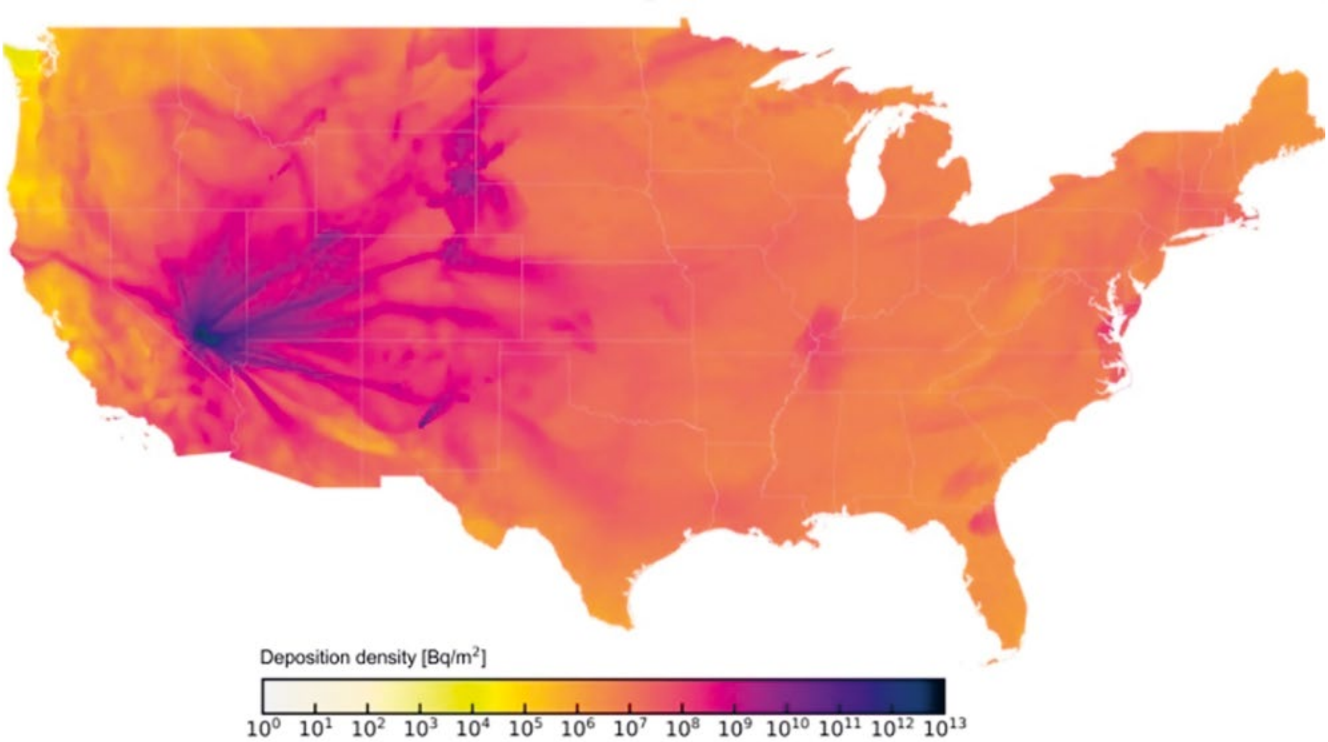
The underground 'Sedan' detonation at the NTS in June 1962 was conducted as an investigation of the potential of 'clean' nuclear devices for producing large craters cheaply (for canal or harbour construction, for example).[22] Sedan is considered one of the 'dirtiest' nuclear tests, releasing 880,000 curies of Iodine-131 and exposing roughly 13 million people in the United States to substantial radioactive contamination, including hot spots as far away as Iowa and Illinois. The test created a crater that was 1,280 feet wide and 320 feet deep.[23]

18 *The Nuclear Matters Handbook 2020*, Rev'd Edn, Office of the Deputy Assistant Secretary of Defense for Nuclear Matters, at: https://bit.ly/48MDe5U, 169.
19 Source: *The Nuclear Matters Handbook 2020*, Rev'd Edn, 188.
20 In addition to the 88 US safety experiments, Operation Roller Coaster in 1962 was a joint US-UK test programme to collect data on the safety of weapons due to accidental detonation. The warheads used in these and other similar tests were known to be one-point safe and one of the aims of the tests was to assess the hazard presented by the dispersal of plutonium if the explosives were accidentally detonated (as happened in the hydrogen bomb accidents at Palomares, Spain, in 1966, and Thule, Greenland, in 1968). US DoE, 'Plutonium Dispersal Tests at the Nevada Test Site', August 2013, at: https://bit.ly/3UvSf7I; US DoE, 'United States Nuclear Tests July 1945 through September 1992', 2015.
21 US DoE, 'United States Nuclear Tests July 1945 through September 1992', Doc. DOE/NV--209-REV 16, p. x.
22 'Operation Storax', nuclearweaponarchive.org, at: https://bit.ly/4bdl7b0.
23 R. L. Miller, *U.S. Atlas of Nuclear Fallout, 1951–1970*, Vol. 1, Two Sixty Press, 2002, 340.

## Assessments

A 2023 study using US government data, historical weather data, and advanced atmospheric modelling methodology estimated that the harmful effects of atmospheric nuclear tests conducted in the United States had previously been significantly underestimated.[24] According to Philippe and others, cumulative radioactive fallout from the first Trinity test in 1945 and 93 subsequent tests reached all 48 contiguous US states as well as Canada and Mexico. Their estimates indicate that at certain locations in New Mexico and other states, including federally recognized tribal lands, radionuclide deposition reached levels higher than in counties covered by the 1990 Radiation Exposure Compensation Act (RECA) for which compensation was awarded to certain affected individuals.[25] The findings of Philippe and others offer an opportunity to re-evaluate the public health and environmental implications from atmospheric nuclear testing. Figure 2 shows the cumulative radionuclide deposition density map following the first five days after each of the ninety-four atmospheric tests included in the study.

**Figure 2:** **Reconstruction of fallout over the United States from its atmospheric nuclear testing**[26]




The Figure shows estimated deposition density (Bq/m-2) of fission products from 94 atmospheric nuclear tests conducted in New Mexico and Nevada, across the contiguous United States. The highest deposition points indicate the ground zeros of the Trinity test in New Mexico and of the 93 atmospheric tests in Nevada. © Philippe *et al.*

As noted below, the US government long neglected to monitor the effects of its nuclear tests. In later decades, multiple reports and studies—by both government and independent agencies—have evaluated the risks posed by these tests, some of which are referenced in the following sections on human effects and environmental contamination. However, further assessments remain necessary.

24 S. Philippe, S. Alzner, G. P. Compo, M. Grimshaw, and M. Smith, 'Fallout from U.S. atmospheric nuclear tests in New Mexico and Nevada (1945–1962)', *arXiv*:2307.11040, at: https://bit.ly/3UFpBjw.

25 Ibid.

26 Ibid.

## Human effects

Month-by-month data from New Mexico for the years 1943 to 1948 revealed that the highest infant mortality rates occurred in the late summer of 1945 following the Trinity blast, with a significant peak in September of that year. Infant mortality for the months August, September, and October of 1945 after the explosion indicated that New Mexican infants had a 56 per cent higher risk of dying, with less than a 0.0001 per cent chance that this was due to natural fluctuation.[27] According to Sternglass:

> many studies have shown that the foetus is much more sensitive in the early stages of development than in the last stage close to delivery, by as much as a factor or 10 times. In addition, there is evidence from direct measurements of the concentration of iodine-131 in foetal thyroids during periods of heavy fallout from bomb testing by Beierwaltes *et al* and other investigators that the radiation dose to the foetal thyroid is as much as 100 times larger than to adults, like the mother inhaling the air or ingesting milk and food during the same period.[28]

Despite extensive flora and fauna (notwithstanding the harsh climate) and nearby population centres (and smaller communities closer by), the US Department of Energy has claimed that the NTS

> is where it is for good reason. Few areas of the continental United States are more ruggedly severe and as inhospitable to humans. The site and the immediate surrounding area have always been sparsely populated. Only once prior to 1950, and then very briefly, did more than a few hundred people call the site home. In most periods of habitation, far fewer have lived there. Although no locale can be said to be ideal or optimal for nuclear weapon testing, the Nevada Test Site was perhaps the best continental site available for avoiding collateral damage and radiation exposure to plants, animals, and, most importantly, human beings off site.[29]

This is not factually accurate. As Makhijani has written, the NTS was chosen largely on the basis of expediency not safety – because it was already owned by the US government and it was close to Los Alamos.[30] That was so, even though officials understood that testing there would regularly subject most of the country to significant doses of dangerous radioactive fallout.[31] Schwartz avers that 'the best continental site available to avoid collateral damage and radiation exposure' would have been the Pamlico Sound area of North Carolina, where the fallout would have largely drifted over the Atlantic Ocean.[32]

### The impact on Indigenous populations

Yet, all of the places used for nuclear testing in the United States were originally inhabited or used by Indigenous Peoples. In Kuletz's words, this new form of colonialism linked Indigenous People to the brave new world of the transuranic elements which invade not only traditional landscapes but also the bodies of their local inhabitants.[33]

27 K. M. Tucker and R. Alvarez, 'Trinity: The most significant hazard of the entire Manhattan Project', Bulletin of Atomic Scientists, 15 July 2019, citing Communication with Prof. David Richard, University of North Carolina School of Public Health, 27 November 2017.
28 Summary of Testimony by Dr Ernest J. Sternglass to the Nuclear Regulatory Commission, 20 March 1985, in: https://bit.ly/49oimSj.
29 T. R. Fehner and F. G. Gosling, *Battlefield of the Cold War*, Vol. I, 'Atmospheric Nuclear weapon testing 1951 – 1963', Part IV: Atmospheric Testing in the Balance, 1955–1956, US DoE, September 2006, 9 and 10.
30 P. Ortmeyer and A. Makhijani, 'Let Them Drink Milk', online article, Institute for Energy and Environmental Research (IEER), Takoma Park, MD, October 1997 (last updated 15 April 2009), at: https://bit.ly/4davKei.
31 See S. Schwartz, *Atomic Audit: The Costs and Consequences of U.S. Nuclear Weapons since 1940*, Brookings Institution Press, Washington, DC, 1998, 50–51.
32 Email from Stephen Schwartz, 20 April 2024.
33 V. Kuletz, 'Invisible spaces, violent places: Cold War nuclear and militarized landscapes', Chap. 10 in N. L. Peluso and M. Watts (eds.), *Violent Environments*, Cornell University Press, Ithaca, NY, 2001, 239–40.

Indeed, according to LaDuke, who is credited with coining the term radioactive/nuclear colonialism along with Ward Churchill,[34] 'much of the world's nuclear industry has been sited on or near Native lands' including 'reservation, treaty-guaranteed or sacred lands'. This 'operates at the expense of the health of Indigenous peoples, their cultural survival and their self-determination'.[35] But according to the Department of Energy, although the area around the NTS was home to widely scattered groups of hunter gatherers known today as Southern Paiute and Western Shoshone, by the early twentieth century, most of the free-roaming Native Americans had moved to surrounding towns or relocated to reservations.[36]

More than 900 nuclear tests were conducted on Shoshone territory in the US in breach of the Treaty of Ruby Valley signed in 1863.[37] In 1994, a Western Shoshone Chief said: 'The radiation has caused Shoshone, Ute, Navajo, Hopi, Paiute, Havasupai, Hualapai and other downwind communities to suffer from cancer, thyroid diseases and birth defects.'[38]

Ian Zabarte, the Principal Man of the Western Bands of the Shoshone Nation of Indians, told *Al Jazeera* in 2020 that while fallout from these tests covered a wide area

> it was Native American communities living downwind from the site who were most exposed – because we consumed contaminated wildlife, drank contaminated milk, lived off contaminated land. For Native American adults, the risk of exposure has been shown to be 15 times greater than for other Americans, for young people that increases to 30 times, and for babies in utero to two years of age it can be as much as 50 times greater. When the fallout came down, it killed the delicate flora and fauna, creating these huge vulnerabilities across thousands of square miles of Shoshone territory. The pine trees we use for food and heating were exposed, the plants we use for food and medicine were exposed, the animals we use for food were exposed. We were exposed. [39]

In 2000, a study by Frohmberg and others found that:

> Native Americans residing in a broad region downwind from the Nevada Test Site during the 1950s and 1960s received significant radiation exposures from nuclear weapon testing. Because of differences in diet, activities, and housing, their radiation exposures are only very imperfectly represented in the Department of Energy dose reconstructions. There are important missing pathways, including exposures to radioactive iodine from eating small game. The dose reconstruction model assumptions about cattle feeding practices across a year are unlikely to apply to the native communities as are other model assumptions about diet. Thus, exposures from drinking milk and eating vegetables have not yet been properly estimated for these communities.[40]

The authors drew five main conclusions from their study:

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34 W. Churchill and W. LaDuke, 'Native North America: The Political Economy or Radioactive Colonization', in M. A. Jaimes (ed.), *The State of Native America: Genocide, Colonization and Resistance*, South End Press, Boston, 1992.

35 D. Endres, 'The Rhetoric of Nuclear Colonialism: Rhetorical Exclusion of American Indian Arguments in the Yucca Mountain Nuclear Waste Siting Decision', *Communication and Critical/Cultural Studies*, Vol. 6, No. 1 (2009), 39–60.

36 T. R. Fehner and F. G. Gosling, *Battlefield of the Cold War*, Vol. I, 'Atmospheric Nuclear weapon testing 1951 – 1963', Part IV: Atmospheric Testing in the Balance, 1955–1956, US DoE, September 2006, 9 and 10.

37 The 1863 Treaty of Peace and Friendship (Treaty) signed at Ruby Valley, Nevada, between the United States and the Western Bands of the Shoshone Nation of Indians (commonly referred to as the Western Shoshone), demarcated the boundaries of the Western Shoshones' ancestral territory. I. Sansani, 'American Indian Land Rights in the Inter-American System: *Dann* v. *United States*', *Human Rights Brief*, Vol. 10, No. 2 (2003), 2–6, at: https://bit.ly/4aMf38C.

38 Chief Raymond Yowell, Western Shoshone, quoted in Kuletz, 'Invisible spaces, violent places: Cold War nuclear and militarized landscapes', 237.

39 'A message from the most bombed nation on earth', *Al Jazeera*, 29 August 2020, at: https://bit.ly/4bmieo9.

40 E. Frohmberg, R. Goble, V. Sanchez, and D. Quigley, 'The assessment of radiation exposures in Native American communities from nuclear weapon testing in Nevada', *Risk Analysis*, Vol. 20, No. 1 (February 2000), 101–12.

1. Native American community members living in their ancestral lands received substantial exposures from nuclear weapon testing at the NTS.
2. These exposures are not adequately described by the Department of Energy's dose reconstruction: (i) missing pathways include iodine exposures from the hunting of small game; (ii) the model assumptions about the feeding of cattle that provide dairy products do not generally apply; and (iii) assumptions about other food pathways may also not apply.
3. The information base collected by the Department of Energy is not adequate to address these important aspects of a dose reconstruction, and this failing stems from the lack of participation by Native community members in the collection, interpretation, and planning for the use of key information about lifestyles and concerns.
4. Approximate estimates of radiation doses to thyroids received from eating rabbit thyroids can be estimated on the basis of scattered data from the Department of Energy studies and information selectively gathered from affected communities. Calculations by the researchers showed that these exposures were severe.
5. A successful dose reconstruction, i.e., a dose reconstruction that is both useful and reasonably accurate, can be achieved only with active participation by members of the affected communities.[41]

### The impact on military personnel

About 250,000 members of the US armed forces participated in the atmospheric nuclear weapon testing programme.[42] During many of the tests, thousands of soldiers were stationed nearby, and some were ordered to march toward ground zero (or otherwise perform manoeuvres) shortly after the detonation. These experiences, which have been documented in detail by the Dutch filmmaker Morgan Knibbe in his documentary *The Atomic Soldiers*[43]

> left many veterans scarred; for the rest of their lives, they remembered the mushroom clouds so clearly it was as if they had never vanished. Many suffered long-term illnesses likely related to their exposure to the tests. Even worse, the veterans were barred from telling anyone, including family members, about their experiences. This 'secrecy oath' was only rescinded in 1996 and by then, many atomic veterans had already passed away, never able to tell their stories.[44]

There have been studies of cancer in members of the military who witnessed nuclear tests in the 1950s. Glyn Caldwell and collaborators at the Centers for Disease Control and Prevention published studies of leukaemia and polycythaemia vera (a disease characterized by excessive production of red blood cells) in a cohort of veterans who were at the NTS in August 1957. The studies found increases in the incidence of both diseases above expected rates. Research on other cohorts of atomic veterans has not found disease elevations but cannot rule those out due to the low statistical power of the studies.[45] Moreover, as Adams observes, only about 45 per cent of the soldiers involved in above-ground tests ever had recorded doses from film badges (dosimeters used for monitoring cumulative radiation doses). Furthermore, film badges would not account for internal doses from inhalation or ingestion.[46]

41 Ibid., 110.
42 A. Makhijani, H. Hu, and K. Yih (eds.), *Nuclear Wastelands: A Global Guide to Nuclear Weapons Production and its Health and Environmental Effects*, Special Commission of International Physicians for the Prevention of Nuclear War and the Institute for Energy and Environmental Research, MIT Press, Boston, 2000, 586.
43 'Atomic Veterans Were Silenced for 50 Years. Now, They're Talking', Video by Morgan Knibbe, 27 May 2019, at: https://bit.ly/3SBqtFv.
44 J. McKeon, 'Mushroom Clouds That Never Vanished: The Fight to Secure Compensation for Nuclear Test Victims', Atomic Pulse, 9 November 2023, at: https://bit.ly/3OK0BVZ.
45 Makhijani, Hu, and Yih (eds.), *Nuclear Wastelands: A Global Guide to Nuclear Weapons Production and its Health and Environmental Effects*, 280.
46 Email from Lilly Adams, Outreach Consultant, Union of Concerned Scientists, 11 September 2024.

As Schwartz reports, some pilots were also ordered to fly through mushroom clouds shortly after a test explosion to see whether they would be able to fight in a nuclear war scenario. 'The degree of internal radiation was measured by having pilots swallow a Vaseline-coated film badge sensitive to radiation attached to a string that hung out of their mouths. That military personnel were deliberately exposed to radiation in such exercises is clear from extensive records compiled by the Presidential Advisory Committee on Human Radiation Experiments'.[47]

A highly controversial 2022 study, however, seems to contradict these and many others. Participants at seven test series, previously studied with high-quality dosimetry and personnel records, and the first test at Trinity formed the cohort of 114,270 male military participants traced for vital status from 1945 through 2010. The study concluded that:

> No statistically significant radiation associations were observed among 114,270 nuclear weapons test participants followed for up to 65 years. The 95% confidence limits were narrow and excluded mortality risks per unit dose that are two to four times higher than those reported in other investigations. Significantly elevated SMRs [Standardized Mortality Ratios] were seen for mesothelioma and asbestosis, attributed to asbestos exposure aboard ships.[48]

### Transgenerational human effects

Several studies have pointed to the transgenerational effects of the US nuclear testing[49] as well as from uranium mining. Thus, the multi-agency Navajo Birth Cohort Study initiated in 2010 found that people living on the Navajo Nation, including babies, have extremely elevated levels of uranium contamination in their bodies.[50] The study found that about one quarter of Navajo women and some infants who were part of the study on uranium exposure had high levels of the radioactive metal in their systems, decades after mining ended on their reservation. Dr Loretta Christensen, Chief Medical Officer of the Navajo Nation for Indian Health Service, said 781 women were screened during an initial phase of the study that ended in 2018. Among them, 26 per cent had concentrations of uranium that exceeded levels found in the highest 5 per cent of the US population, and newborns with equally high concentrations continued to be exposed to uranium during their first year, she said.[51]

It has been observed that although the stories of atomic bomb survivors in Hiroshima and Nagasaki have been 'relatively heard and known', neither the narratives of downwinders in the United States nor the second generation of nuclear survivors have been widely recognized:

> The second generations of nuclear victims have been neglected by all compensation acts ever since they were born, both in the United States and Japan. Although their experiences are quite different from the first generations and atomic bomb survivors, they faced similar issues like high cancer rates and social and internal stigmatization. Additionally, the narratives of the second generation of nuclear victims are under-represented, since most of the literature about nuclear

47 S. I. Schwartz, *Atomic Audit: The Costs and Consequences of U.S. Nuclear Weapons since 1940*, 405, citing Advisory Committee on Human Radiation Experiments, Final Report (GPO), 1995.

48 J. D. Boice, S. S. Cohen, M. T. Mumma, H. Chen, A. P. Golden, H. L. Beck, and J. E. Till, 'Mortality among U.S. military participants at eight aboveground nuclear weapons test series', *International Journal of Radiation Biology*, Vol. 98, No. 4 (2022), 679–700.

49 See, e.g., S. L. Simon, A. Bouville, and C. E. Land, 'Fallout from Nuclear Weapons Tests and Cancer Risks', *American Scientist*, Vol. 94, No. 1 (January–February 2006), at: https://bit.ly/3unTUla; J. D. Boice Jr., 'The Likelihood of Adverse Pregnancy Outcomes and Genetic Disease (Transgenerational Effects) from Exposure to Radioactive Fallout from the 1945 Trinity Atomic Bomb Test', *Health Physics*, Vol. 119, No. 4 (October 2020), 494–503, at: https://bit.ly/3w45QcA.

50 Southwest Research and Information Center, 'Navajo Birth Cohort Study (NBCS)/Environmental Influences on Child Health Outcomes (ECHO+)', at: https://bit.ly/3SkAXYJ.

51 M. Hudetz, 'US official: Research finds uranium in Navajo women, babies', *Associated Press*, 8 October 2019, at: https://bit.ly/4boDHgg.

issues has focused on the first generation of victims. The inhumanity of nuclear weapons remains in the lives of subsequent generations in the forms of 'physical, socioeconomic, cultural, and social factors'. The 'domino effect of trauma' prevents the second-generation victims from living a life as other non-victims do.[52]

## Societal effects

Many of the above-ground tests at the NTS generated more explosive power than the atomic bombs detonated over Japan.[53] As new or higher rates of cancers began to appear in some 'downwind' towns, people often began to feel betrayed by their own government – which they thought was supposed to protect them from their ultimate enemy: the Soviets. Today in some downwind communities, entire health clinics and cancer centres have arisen—some funded by RECA—to help those in need. 'Other areas have not been as lucky and are left to deal with the scant medical resources that exist, or travel long distances for care. For those communities impacted by the Cold War era, health issues and resources are a significant concern and there is a need for further research and assistance.'[54]

The US government did set up an operation in Japan—the Atomic Bomb Casualty Commission—to monitor the long-term effects of radiation on survivors of the Hiroshima and Nagasaki bombings, but did not create a similar commission to study, or even acknowledge, Trinity test survivors. 'No one really wanted to pursue the radiation possibilities for fear of getting involved in litigation', Dr Stafford Warren, the Manhattan Project's chief medical officer, recalled later.[55] After the Trinity test in 1945, Dr Louis Hempelmann, Director of the Health Group at the Los Alamos site, said some people 'were probably over-exposed [to the test], but they couldn't prove it and we couldn't prove it. So we just assumed that we got away with it.' In addition, during the period of above-ground tests at the Nevada Test Site, the US government failed to monitor fallout beyond an extremely limited area or undertake health monitoring in downwind areas.[56]

When he was in high school, Preston Truman was diagnosed with lymphoma. Chemotherapy and other medical treatment over the next thirteen years cost about $100,000. As was true for all other downwind residents at the time, the government did not provide a penny for this care. But Truman was relatively lucky. In 1980, he was in remission from the usually fatal lymphoma. Of nine children who were his friends in the immediate area of Enterprise in Utah when he was a child, Truman was the only one who reached the age of twenty-eight. The rest died of leukaemia or cancer. The lethal potential of the nuclear tests was not immediately apparent to Truman and others. Especially in the first years of the tests there was confidence in the government. 'It was kind of almost a carnival atmosphere in the beginning with the radio telling us where the clouds were going, following the tests, and always assuring us there was no danger', he recalled. 'But that wasn't the way it continued.'[57]

None of those living near the Trinity site was warned or evacuated before or after the blast. The location had been selected in part for its supposed remoteness from human settlement, but census data from 1940

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52 Imari Yasuno '24, 'Representation of Intergenerational Trauma: Narratives of Second-Generation Nuclear Victims', Amherst College, Summer 2023, United States and Japan, citing M. Tatara, 'The Second Generation of Hibakusha', in Y. Danieli (ed.), *International Handbook of Multigenerational Legacies of Trauma*, Plenum Press, 1998, 141–46.

53 The 74 kt Hood test on 5 July 1957 was the highest-yield atmospheric test in Nevada. The 1.3 Mt Boxcar test on 26 April 1968 was the largest underground test.

54 'The Unknown Human Health Legacy of Nuclear weapon testing', *IEEE Pulse*, 13 May 2020, at: https://bit.ly/42rvN1N.

55 L. M. M. Blume 'Collateral damage: American civilian survivors of the 1945 Trinity test', *Bulletin of the Atomic Scientists*, 17 July 2023, citing J. L. Nolan, Jr., *Atomic Doctors: Conscience and Complicity at the Dawn of the Nuclear Age*, Belknap Press of Harvard University Press, Cambridge, MA, 2020.

56 Email from Lilly Adams, Union of Concerned Scientists, 11 September 2024.

57 H. Wasserman and N. Solomon with R. Alvarez and E. Walters, *Killing Our Own - The Disaster of America's Experience with Atomic Radiation*, Delta Book, 1982, Chap. 3, at: https://bit.ly/484sgrq.

show that nearly half a million people in New Mexico, Texas, and Mexico lived within 150 miles of ground zero. (Privately acknowledging the 'very serious hazard' posed by the blast, Warren advised that future tests should only be conducted where no one lived within a 150-mile radius.) Officials told people that a nearby ammunition dump had exploded. Many learned the truth about the blast only years later, and Trinity test survivors are not among the downwinders eligible for government compensation.[58] Udall suggests that the AEC's radiologists

> not only knew that infants and pregnant women were the individuals most at risk in the downwind zone, they were also acutely aware that the hazards would be reduced or avoided if the residents of exposed communities were either evacuated during the tests of big bombs or required to stay indoors when winds swept fallout clouds over their homes.[59]

## Victim assistance

Today, the Shoshone people are 'beginning to understand' what has happened to them. As Ian Zabarte told *Al Jazeera*:

> For more than 50 years, we have been suffering from this silent killer and the US government's culture of secrecy keeps it silent. But we need relief. In every other part of the world where there have been nuclear catastrophes or nuclear testing—such as Kazakhstan, Japan, even Chernobyl—there are health registries to monitor those who have been exposed, even if the numbers are kept artificially low in some places. We do not have that here in the US. We do not have that for Native American downwinders. We need that kind of testing. We need health registries. We need monitoring. We cannot wait any longer for the health disparities we are experiencing to be identified. We are having to fight the US to get it to understand our basic health needs. We have managed to obtain documents that were declassified in the 1990s. But there are almost two million pages. Trying to understand all of that is daunting. We do not have any funding and we do not have the support of the US to get that work done. So we are having to do this ourselves as we suffer through this continuing health crisis. And all the while, military activities are still being conducted on our land.[60]

As Taylor has observed, second- and third-generation downwinders continue their legal struggle to be recognized as an impacted community. To date, however, none of these individuals has received reparation, even though many of them suffer pre-existing diseases and conditions they believe are associated with their residency near the NTS.[61]

In December 2023, Congress stripped a provision from the final National Defense Authorization Act (NDAA) that would have ensured more victims of US nuclear weapon tests (most notably those in New Mexico exposed to the fallout from the first nuclear test in 1945) would have access to healthcare and compensation for longer to help cover medical debt and other expenses.[62] Despite the expansion and extension clearing the Senate on a bipartisan vote, it was cut from the House version of the bill after negotiations among senior congressional leaders.[63] Again in 2024, the Senate passed another bill to extend and expand RECA, with a 69 to 30 bipartisan

58 L. M. M. Blume, 'U.S. nuclear testing's devastating legacy lingers, 30 years after moratorium', *National Geographic*, 22 September 2022, at: https://bit.ly/46sqZuk.
59 S. L. Udall, *The Myths of August: A Personal Exploration of Our Tragic Cold War Affair with the Atom*, Rutgers University Press, 1998, 223 and 224.
60 'A message from the most bombed nation on earth', *Al Jazeera* 29 August 2020.
61 T. Taylor, 'Nevada Test Site Downwinders', Atomic Heritage Foundation, 31 July 2018, at: https://bit.ly/3Ox8ttA.
62 K. A. Sebastian, 'Congress Fails Victims of U.S. Nuclear Tests, Production', Union of Concerned Scientists, 7 December 2023, at: https://bit.ly/47YuZ5x.
63 K. Dunphey, '"How much money are our lives worth?": Utah downwinders call RECA expansion's failure a betrayal, *Colorado Newsline*, 12 January 2024, at: https://bit.ly/3SFle80.

vote, yet House Leadership refused to bring the bill for a vote, and ultimately let RECA expire in June 2024. Speaking for those affected in Utah, Steve Erickson said:

> Too many continue to suffer, and too many have died waiting for the help they need. 'Nothing will bring back what survivors have lost—their health and their loved ones—nor will it ease the burden of staggering medical bills and the emotional toll they and their families have suffered. But strengthening RECA [the Radiation Exposure Compensation Act] would at last help Utahns and others who have paid the price of America's nuclear weapons program achieve the recognition and justice they deserve.[64]

As noted below (see the section, 'Legal issues'), RECA was resuscitated in July 2025.

## Environmental contamination

As a result of the 928 nuclear tests at the NTS, groundwater, surface soils, and industrial facilities were contaminated. Indeed, Taylor affirms that the NTS contains some of the most radioactive land in the world. The contamination came largely from the underground testing, which irradiated dirt and rubble around the site as well as underground aquifers.'[65] The Department of Energy's Environmental Management Nevada Program is responsible for completing clean-up actions at these historic nuclear testing locations. In 1989, the Department's National Nuclear Security Administration Nevada Site Office began to address the environmental impacts of testing-related contamination at specific locations on the Nevada National Security Site (NNSS) and the Nevada Test and Training Range, which includes the Tonopah Test Range.

'A major part of this effort involved exploring surface contamination resulting from historic atmospheric tests.'[66] The process is said to have involved a 'systematic approach':

> Crew members first conducted historical reviews at each site – identifying tests performed and evaluating existing records. Next, field crews utilized radiological surveys, using aerial flyover data to estimate the extent of contamination and ground surveys for more precise observations. This was part of the onsite characterization process, which typically includes radiological surveys and a rigorous soil sampling campaign. The information was then used to formulate a clean-up, or remediation, strategy for each location. This remediation approach … weighs the risks and benefits of removing and disposing contaminated media as opposed to closing a site in place with use restrictions.[67]

## Environmental remediation

The Department of Energy's Office of Environmental Management announced on 27 October 2020 that it had completed remediation activities on and around the Tonopah Test Range. Clean-up of the site was completed in less than half the time initially estimated, according to the Department.[68] The Environmental Management Nevada Program remediation mission claims to be 'now complete for sites with soil contamination from

64 M. Dickson, 'Time is running out to give justice and medical aid to Utah's nuclear downwinders', *Salt Lake City Weekly*, 31 January 2024.
65 Taylor, 'Nevada Test Site Downwinders', Atomic Heritage Foundation, 31 July 2018.
66 Office of Environmental Management, 'Nevada National Security Sites (NNSS)', undated but as accessed 1 February 2024, at: https://bit.ly/4blybef.
67 US DoE, Environmental Management (EM) Nevada Program, 'Soil Sites – Safe, Secure, Successful', doc. DOE/NV--1047 REV4 (EMRP Log No. 2022-076), October 2022.
68 Radwaste Solutions, 'DOE completes cleanup at Nevada's Tonopah Test Range', *Nuclear Newswire*, 2 November 2020, at: https://bit.ly/3SIvbld.

atmospheric nuclear testing and similar activities'.[69] It is further claimed that: 'Today, less than 1% of surface soils at the NNSS are posted as radiologically contaminated.' That said, as the US Environmental Protection Agency (EPA) acknowledges,[70] no single data source tracks the full extent of contaminated land in the United States. Furthermore, clean-up efforts at the Nevada National Security Site are planned to be completed only by 2032, with waste storage needed beyond that time.[71]

The annual DOE clean-up programme budget for former defence-related sites exceeds US$7 billion.[72] The fiscal year 2024 DoE budget justification to Congress notes that the federal budget included $196 million for the Office of Legacy Management to protect human health and the environment by providing long-term management solutions at over 100 World War II and Cold War-era sites 'where the federal government operated, researched, produced, and tested nuclear weapons and/or conducted scientific and engineering research.'[73] This is only a drop in the ocean. For what was once

> an employment boom to state and local economies during the years of nuclear weapons research, testing and production is now an environmental burden, and states bear some of the responsibility for the long-term clean-up of that legacy. This effort is the largest environmental clean-up program in the world and presents the 12 states most directly involved with numerous technical, financial and policy challenges.[74]

Indeed, some 380 sites covered under the Energy Employees Occupational Illness Compensation Program Act (EEOICPA) are sites that were involved in some way in the production of nuclear weapons, and where workers are now eligible for compensation due to exposure to radiation or toxins.[75]

Nevertheless, the EPA declares on its website that: 'Very little radioactivity from weapons testing in the 1950s and 1960s can still be detected in the environment now.' Since the end of above-ground nuclear weapon testing,

> the day-to-day radiation in air readings from monitoring sites has fallen. For many years, analysis of air samples has shown risk levels far below regulatory limits. In fact, results are now generally below levels that instruments can detect. The EPA maintains a system of radiation monitors throughout the United States. These monitors were originally designed to detect radionuclides that were released after a nuclear weapon detonation. Now, the EPA uses this system, called RadNet, to look at background radiation levels at many locations across the United States. Background radiation is around us all the time, mostly from natural sources, like naturally occurring radon and uranium.[76]

But while little radiation can be detected from above-ground nuclear testing, testing has left an indelible mark on the world, with many scientists now considering plutonium from testing in lake sediments to mark the start of a new geological epoch – the 'Anthropocene'.[77] Moreover, as a Centers for Disease Control (CDC) study

69 US DoE, EM Nevada Program, 'Soil Sites – Safe, Secure, Successful'.
70 EPA, 'Radioactive Fallout From Nuclear weapon testing', at: https://bit.ly/3Uovy5m.
71 NNSS, 'EM Nevada Program announces 2022-32 Strategic Vision focused on safe, secure, and successful completion of cleanup mission', 18 March 2022, at: https://bit.ly/4gqscrd.
72 Email from Stephen Schwartz, 20 April 2024.
73 US DoE, *FY2024 Budget in Brief. FY 2024 Congressional Justification*, March 2023, at: https://bit.ly/3HJS55a, 4.
74 National Governors Association, 'Cleaning Up America's Nuclear Weapons Complex, 2023 Update for Governors', 2023, at: https://bit.ly/4bhPVat, 56.
75 US Department of Labor, 'About Energy program', Office of Workers' Compensation Programs, undated but accessed 14 September 2024, at: https://bit.ly/3ZoHdE3.
76 EPA, 'Radioactive Fallout From Nuclear weapon testing', Last updated 3 July 2023, at: https://bit.ly/3Uovy5m.
77 S. Pare, 'Nuclear bombs set off new geological epoch in the 1950s, scientists say', online article, Live Science, 14 July 2023, at: https://bit.ly/4ejWWs7.

from the early 2000s noted: 'Any person living in the contiguous United States since 1951 has been exposed to radioactive fallout, and all organs and tissues of the body have received some radiation exposure.'[78]

## The impact of climate change[79]

Climate profiles do not clarify how precipitation rates may change, but ephemeral stream flows at the NTS from infrequent intense rainfall and spring snowmelt could be impacted with seasonal shifts from snow to rain.[80] Groundwater flowing under the test area is predominantly recharged by precipitation in the highlands and discharged at springs and seeps in Oasis Valley, or by the Alkali Flat-Furnace Creek Ranch or Ash Meadows flow systems and their tributaries.[81] The concentration and discharge of contaminants via the groundwater system could be affected by climate change. Although the area is sparsely vegetated, landscape fires are expected to increase, which could lead to the transport of airborne contaminants. This could include the airborne release of radionuclides taken up and bioaccumulation in plants. The test area has been impacted by landscape fires in the past.[82] Nevada is also vulnerable to earthquakes, and climate change has been identified as potentially increasing seismic activity.

A summary of trends and potential climate-related impacts for areas in Nevada is given in Table 2.

**Table 2: Summary of key climate trends and impacts, Nevada[83, 84]**

<table>
<tr><th>Climate system/ hazard</th><th>Historic trends</th><th>Projected trends</th><th>Possible impact on risk components</th></tr>
<tr><td>Temperature</td><td>Increasing</td><td>Increase in average temperatures, as well as frequency and severity of heatwaves</td><td rowspan="6">Source: changes in physico-chemical behaviour affecting mechanisms by which contaminants may be released. Includes physical landform changes caused by soil desiccation, erosion, wildfires, and high winds<br><br>Pathway: potential changes in water infiltration, water tables, dilution, and flow rates. Changes to release of airborne contaminants<br><br>Receptor: changes in species assemblages and/or sensitivity to contaminants, water abstraction or dependency, and exposure routes for people, including by wildfires**</td></tr>
<tr><td>Precipitation</td><td>No change</td><td>Not clear, although some models indicate a slight increase in precipitation for central Nevada*</td></tr>
<tr><td>Drought</td><td>Increasing evaporative demand and worsening droughts</td><td>Increase in drought frequency and severity</td></tr>
<tr><td>Snow melt</td><td>Decrease in snowpack in 1955–2016</td><td>Shift from snow to rain, and earlier annual snow melt</td></tr>
<tr><td>Flooding</td><td>No historic trends</td><td>Increased frequency due to shift from snow to rain and storm events</td></tr>
<tr><td>Wildfires</td><td>Increase in wildfire size and severity</td><td>Increased risk of wildfires</td></tr>
<tr><td>Seismic activity</td><td></td><td>Uncertain</td><td></td></tr>
</table>

* Projections uncertain ** Includes soil-bound radionuclides or radionuclides taken up by plants

78 CDC, 'A Feasibility Study of the Health Consequences to the American Population from Nuclear Weapons Tests Conducted by the United States and Other Nations', Study Report, 2002, Executive Summary, at: https://bit.ly/3z6IZ1W.
79 This section was contributed by Linsey Cottrell.
80 J. M. Fenelon, D. S. Sweetkind, and R. J. Laczniak, 'Groundwater flow systems at the Nevada Test Site, Nevada: A synthesis of potentiometric contours, hydrostratigraphy, and geologic structures', US Geological Survey Professional Paper 1771, 2010, at: https://bit.ly/3TuxV4T.
81 Ibid.
82 Energy Research and Development Administration, 'Final Environmental Impact Statement, Nevada Test Site', September 1977, at: https://bit.ly/3TcQzxW.
83 University of Nevada, 'Climate Change Impacts in Nevada', 2021, at: https://bit.ly/43djAOk.
84 ThinkHazard! High-level hazard profile for Nye, at: https://bit.ly/3Pdx6fp; for Lincoln, at: https://bit.ly/49H4mUk; and for Clark, at: https://bit.ly/3VbHyYv.

## Legal issues[85]

### Individual compensation schemes

In 1990, the US Congress passed RECA – legislation under which veterans and civilians who had participated in nuclear weapon tests ('onsite participants'), some 'downwinders', and some uranium workers, and who were suffering from certain radiogenic cancers would automatically be allowed benefits on the presumption that their cancers were connected to their exposure. They do not have to prove this connection on an individual basis. RECA provides one-time benefit payments to successful claimants, and offers cancer screenings in covered areas through the Radiation Exposure Screening and Education Program. Administered by the Department of Justice, to date RECA has awarded almost US$2.7 billion in one-time benefits to more than 41,600 claimants since its inception in 1990, with downwinders accounting for 78 per cent of claims. However, nearly 14,000 additional claims have been denied.[86]

RECA establishes lump sum compensation awards for individuals who contracted specified diseases in defined populations. 'Onsite Participants' at atmospheric nuclear weapon tests may be eligible for one-time, lump sum compensation of up to $75,000. Individuals who lived downwind of the NTS ('Downwinders') in selected areas of the states of Utah, Nevada, and Arizona may be eligible for one-time, lump sum compensation of $50,000. A claimant must establish physical presence in the Downwinder area for at least two years during the period beginning on 21 January 1951, and ending on 31 October 1958, or for the entire period beginning on 30 June 1962, and ending on 31 July 1962. Uranium miners, millers, and ore transporters are eligible for $100,000, plus an additional $50,000 through the EEOICPA. An eligible claimant must also establish a subsequent diagnosis of a specified compensable disease.[87]

But the process for receiving compensation has been criticized as cumbersome, and according to commentators, 'some controversaries continue.'[88] For both RECA and EEOICPA there are concerns that some potential applicants (particularly those without facility in English) find the paperwork difficult to understand or may not be aware they are eligible. Others have found getting the necessary medical diagnoses difficult, given the inequities in the US healthcare system.[89] RECA has also been criticized for its omission of other areas where fallout was deposited, notably those downwind of the Trinity test in New Mexico,[90] as well as its exclusion of affected communities in the Pacific, such as in the Marshall Islands.[91]

In June 2022, the US President signed into law the RECA Extension Act, prolonging the RECA Trust Fund and the filing deadline for all claims for two additional years, 32 years after its date of enactment.[92]

85 See also D. Lochbaum, 'ContamiNATION: How the US Nuclear Weapons Program Harmed Thousands of Americans and Why Those Americans Had to Fight for Decades to Receive Compensation for that Undue Harm', Research Paper, United States, March 2024.

86 Congressional Research Service, 'The Radiation Exposure Compensation Act (RECA): Compensation Related to Exposure to Radiation from Atomic Weapons Testing and Uranium Mining', Updated 14 June 2022; and see also Department of Justice Civil Division, 'Radiation Exposure Compensation System: Claims to Date Summary of Claims Received by 04/19/2024 All Claims', at: https://bit.ly/3w0901h.

87 US Department of Justice, Office of Public Affairs, 'Justice Department Surpasses $2 Billion in Awards Under the Radiation Exposure Compensation Act', Press Release, 2 March 2015, at: https://bit.ly/3SIk1f5.

88 Makhijani, Hu, and Yih (eds.), *Nuclear Wastelands: A Global Guide to Nuclear Weapons Production and its Health and Environmental Effects*, 284.

89 K. M. Allen, 'Indigenous Nuclear Injuries and the Radiation Exposure Compensation Act (RECA): Reframing Compensation Toward Indigenous-Led Environmental Reparations', *Arizona Journal of Environmental Law and Policy*, Vol. 10, No. 2 (2020), 264–90.

90 M. E. Salinas, L. DiMundo, C. Bladt, K. Klimara, and I. Pereira, 'New Mexico "downwinders" fight for aid after Manhattan Project amid community's cancer concerns', *ABC News*, 2 November 2023, at: https://bit.ly/3ItlUqV.

91 G. Johnson, 'Marshall Islands reacts to US expansion of nuclear compensation', *Marianas Variety*, 21 August 2023, at: https://bit.ly/3Int1RO.

92 US Department of Justice (Civil Division), 'Radiation Exposure Compensation Act', Updated 29 January 2024, at: https://bit.ly/48RyHzf.

For decades, many communities that are also considered exposed have sought to expand RECA to cover their communities. This has included:

- downwinders of the first nuclear weapon test in New Mexico;
- downwinders of the Nevada Test Site in states estimated by government studies to have received high levels of fallout, such as Colorado, Idaho, and Montana;
- downwinders in Guam exposed to fallout from testing in the Pacific and radiation from ship decontamination efforts;
- veterans involved in nuclear clean-up missions from nuclear testing and accidents;
- uranium workers employed after 1971, and those employed as core drillers and remediation workers; and
- communities exposed due to improper radioactive waste dumping/storage.

In March 2024, the US Senate passed a bill to cover many of these additional communities, increase compensation amounts, and add additional compensable illnesses. As of September 2024, the bill was awaiting a vote in the House of Representatives. In July 2025, however, RECA was renewed and expanded to include New Mexico's Trinity test downwinders; post-1971 uranium mine workers; and other affected communities in Alaska, Kentucky, Missouri, Tennessee, and Utah.[93] Compensation for qualified downwinders and onsite participants is increased to $100,000 under the new law, which applies until 2028, up from the existing $50,000. The Congressional Budget Office has estimated that the programme could cost a total of $7.7 billion.[94] Detailed guidance on applications was due to be posted by the US Department of Justice's Civil Rights Division on its website.[95]

## Court judgments

### Allen v. United States

*Allen* was a landmark case with more than 1,100 plaintiffs (downwinders who had developed radiation-related illnesses) represented under 24 representative claims. In 1984, Judge Bruce Jenkins ruled in a Utah district court in favour of the people, holding the government liable for negligence. He found that the defendant had failed to adequately warn the plaintiffs or their predecessors of known or foreseeable long-range biological consequences to adults and to children from exposure to fallout radiation from open-air atomic testing and that such failure was negligent.[96] He also found that the government was negligent in monitoring off-site radiation exposure from testing, and ruled in favour of nine NTS downwinder bellwethers, 'holding the US government liable for illness and wrongful death from childhood leukaemia, breast cancer, and thyroid cancer'.[97]

But the government successfully appealed with the Court of Appeals for the Tenth Circuit overturning the original judgment in 1987.[98] The court determined that Congress must take up the issue, which ultimately led to the passage of RECA.

### Roberts et al. v. United States

The *Roberts* case concerned an action by the widows of two men who died from leukaemia four years after contamination by radioactive fallout produced by the venting of the Baneberry underground nuclear test on 18 December 1971. After a Nevada district court judgment in favour of the Government, which found that Harley

93 F. Guillen, 'More Americans can get compensated for nuclear poisoning. But there's a catch', *Missouri Independent*, 28 July 2025, at: https://bit.ly/46DejUj.
94 D. G. Kimball, 'Republican Spending Bill Revives Program for Radiation Victims', *Arms Control Today*, July/August 2025, at: https://bit.ly/4m5PqFK.
95 US Department of Justice Civil Rights Division, 'Radiation Exposure Compensation Act', accessed 1 August 2025, at: https://bit.ly/41qls6L.
96 Utah District Court, *Allen* v. *United States*, 588 F. Su247 (1984).
97 T. T. Pritikin, *Hanford Plaintiffs: Voices from the Fight for Atomic Justice*, University Press of Kansas, Lawrence, KS, 198.
98 US Court of Appeals for the Tenth Circuit, *Allen* v. *United States*, 816 F.2d 1417 (10th Cir.) 1987.

Roberts' maximum dose was 0.42 rem and William Nunamaker's was 0.08 rem and that the radiation exposure did not cause Mr Roberts' or Mr Nunamaker's leukaemia, the plaintiffs appealed.[99] In his 1989 opinion, Judge Thomas Tang was asked to consider whether the district court had erred in imposing a standard of proof of causation of 'a reasonable degree of medical certainty'. The appeal on the merits of the case was unsuccessful.

**Bulloch v. United States**

In 1955–56, five lawsuits were brought against the government by ranchers of Iron county, which lies on the western edge of Utah, alleging that atmospheric testing of nuclear devices in the spring of 1953 had damaged their herds. In the first case, expert witnesses for the government testified that radiation damage could not have been a cause or a contributing cause to the sheep deaths. But in 1979, congressional oversight hearings uncovered evidence of AEC deception from 1956 and Judge Christensen reopened the suit. He concluded that the new information demonstrated that fraud had been committed upon the court by government lawyers and federal employees acting 'intentionally false or deceptive'. He also noted improper attempts to pressure witnesses not to testify, a vital report that was intentionally withheld, and 'deliberate concealment of significant facts with references to the possible effects of radiation upon the plaintiffs' sheep'. He set aside his prior judgment and granted the sheepmen's motion for a new trial.[100]

But in its judgment, the Court of Appeals for the Tenth Circuit,[101] in what one commentator called a 'grotesque episode of American jurisprudence',[102] rejected Judge Christensen's findings, maintaining that the material from the congressional hearings was not admissible under the rules of federal procedure. The Court of Appeals held that 'nothing new' had been presented and it saw 'no reason' to overturn the first instance judgment of twenty-five years before. In 1986, the Supreme Court refused to hear an appeal of the circuit court decision. By that time, the older-generation ranchers were dead or dying. Only two of the original families were still sheep ranching; all had suffered financial losses. Hope of ever recovering damages ended with the Supreme Court rejection in 1986.[103]

**Winnemucca Indian Colony v. United States**

Invoking RECA, a group of residents living downwind of the NTS joined the Shoshones as parties in a lawsuit – *Winnemucca Indian Colony* v. *United States*. The Shoshones brought a claim under the Ruby Valley Treaty of 1863. The plaintiffs invoked the treaty to maintain that the US government did not have the right to test a huge non-nuclear explosive weapon at the site (equating to more than 500 tons of TNT) because of the risk of throwing up more fallout into the atmosphere. In 2007, nine months after the filing of the suit, the Defense Threat Reduction Agency (DTRA) announced the cancellation of Divine Strake. But the lawsuit's effectiveness in stopping weapons testing at the site may have been only temporary. In the announcement, the DTRA Director asserted that the department still planned to conduct similar experiments 'at a much smaller scale'.[104]

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99 Court of Appeals for the Ninth Circuit, *Dorothy Roberts et al.* v. *United States*, 887 F.2d 899 (1989).
100 Seegmiller, 'Nuclear Testing and the Downwinders'.
101 Court of Appeals for the Tenth Circuit, *Bulloch* v. *United States*, 763 F.2d 1115, Decided 22 May 1985.
102 S. L. Udall, *The Myths of August: A Personal Exploration of Our Tragic Cold War Affair with the Atom*, Rutgers University Press, New Brunswick, NJ, March 1998.
103 Seegmiller, 'Nuclear Testing and the Downwinders'.
104 B. McDonald, 'How a Nineteenth Century Indian Treaty Stopped a Twenty-First Century Megabomb', *Nevada Law Journal*, Vol. 9, No. 3 (2009), 749–74, at: https://bit.ly/4bk0v0G, at 751, citing District Court for Nevada, Second Amended Motion for Temporary Restraining Order and for Preliminary Injunction at 1–2, 13–14, *Winnemucca Indian Colony* v. *United States*, No. 2:06cv-00497-LDGPAL, 22 May 2006.

Chapter 22:

# Addressing the Impact of Nuclear Testing in China

Stuart Casey-Maslen

**First Chinese Test:** A historical photograph from China's first successful nuclear test, known as Project 596, which took place on 16 October 1964 at the Lop Nur test site in Xinjiang. The image captures a mushroom cloud shortly after detonation. Photograph © CPA Media Pte Ltd/Alamy Stock Photo/NTB.

## Key Facts about Nuclear Testing in the China

**Testing State:** China

**Testing period:** 1964–96

**Number of tests:** 45 (or possibly 47). Half of the detonations were atmospheric, including several hydrogen bombs.

**Testing location:** Lop Nur test site in the Xinjiang Uyghur Autonomous Region in the north-west of the country.

**Human impact:** Little is known for certain of the human impact of nuclear testing in China. There are no known Chinese government studies of the impact. The scientist Jun Takada estimated 194,000 deaths and 1.2 million people receiving doses capable of causing cancers and fetal damage.

**Indigenous Peoples affected:** Memories of the nuclear tests and fears of ongoing contamination remain a major grievance of the Uyghur people.

**No victim assistance:** There is no known Chinese government programme to assist civilians affected by the tests. Medical experts observed spikes in cancer, with Uyghurs often unable to afford or access healthcare.

**Environmental impact and secrecy:** While contamination is suspected to be severe, the Chinese government has not acknowledged the environmental damage nor initiated remediation efforts. There are no known government studies of the contamination from the tests.

**No compensation to civilians:** In 2008, some military personnel involved in the tests reportedly received undisclosed compensation payments, but compensation has never been paid to the civilian victims.

> For three days, it was as if the sky had rained down on the ground. No sun, no moon.
>
> Dr Enver Tohti (2009)[1]

## History of testing in China

Little is known about the impact of China's nuclear testing and indeed the exact number of tests is not known for certain. This brief chapter summarizes existing knowledge of the testing programme and best available estimates of its impact. Around half of China's nuclear tests, including several hydrogen bomb detonations between the 1960s and the beginning of the 1980s, were certainly atmospheric.

After the Korean War in the 1950s, China decided to develop a nuclear weapon, initially with the help of the Soviet Union. The design of China's first nuclear weapon began at the Institute of Physics and Atomic Energy in Beijing, with uranium enrichment taking place in Lanzhou, the capital city of Gansu province in the north-west of the country. When the relationship between Chairman Mao and Premier Khrushchev (who had always disliked each other) disintegrated in the aftermath of the Hungarian uprising of 1956, China continued the development of nuclear weapons on its own.[2]

The first Chinese nuclear test took place in October 1964 in the vicinity of Lop Nur in the Xinjiang Uyghur Autonomous Region of north-western China. The test, code-named Project 596, involved a fission device with a yield believed to be (depending on the source) between 20 and 25 kilotons (kt) of explosive energy.[3] After the test was completed, China announced it to the world in a statement, which described the detonation as 'a major achievement of the Chinese people in their struggle to increase their national defence capability and oppose the United States imperialist policy of nuclear blackmail and nuclear threats'.[4]

In total, China conducted at least 45 nuclear tests between 1964 and 1996, all at the Lop Nur test site.[5] The yields ranged from 1 kt to 4 megatons (Mt). The yields of a number of the tests are, however, only rough estimates.[6] In December 1966, China detonated its first hydrogen bomb, with the atmospheric test providing a relatively low yield of 122 kt. Development of the hydrogen bomb had initially taken place at a separate research facility at the Institute of Atomic Energy so as not to disturb the production of the first atomic bomb. A 'full-yield' hydrogen bomb (Device 639) was dropped from a bomber on 17 June 1967, with an equivalent explosive yield of 3.3 Mt.[7]

1 Z. Merali, 'Did China's Nuclear Tests Kill Thousands and Doom Future Generations?', *Scientific American*, July 2009, available at: https://bit.ly/3wzeMGR.
2 J. Wilson Lewis and X. Litai, *China Builds the Bomb*, Stanford University Press, Stanford, CA, 1988.
3 D. Kimball, 'Nuclear Testing and Comprehensive Test Ban Treaty (CTBT) Timeline', Fact Sheet, Arms Control Association, Last reviewed July 2024, at: https://bit.ly/47mLytf. The ACA gives an estimate of 20 kt. Atomic Archive reports 25 kt. Atomic Archive, 'Chinese Becomes A Nuclear Nation', undated but accessed 1 March 2024 at: https://bit.ly/48SMl45. Other experts suggest between 20 and 22 kt. See, Center for Nonproliferation Studies, 'China's Nuclear Tests: Dates, Yields, Types, Methods, and Comments', June 1998, 20 December 2013, at: https://bit.ly/3Tu2ecF, citing inter alia B. Gill, 'China's Military Modernization: Implications For Proliferation', Presentation, Center for Nonproliferation Studies, Monterey Institute of International Studies, 27 February 1996.
4 Cited in J. Carter, 'This Week in China's History: October 16, 1964', The China Project, 13 October 2021, at: https://bit.ly/4ghQT9n.
5 See e.g., Arms Control Association, 'The Nuclear Testing Tally', January 2024, at: https://bit.ly/4jE0BmP.
6 Atomic Archive, 'China's Nuclear Tests', undated but accessed 1 March 2024 at: https://bit.ly/43afDdk.
7 H. Zhang, 'The short march to China's hydrogen bomb', Online article, *Bulletin of the Atomic Scientists*, 11 April 2024, at: https://bit.ly/47pLMQi.

In total, twenty-three of China's forty-seven (or forty-five) tests were atmospheric.[8] On 27 October 1966, China launched a Dong Feng-2 (DF-2) medium-range ballistic missile from the Shuangchengzi Missile Test Site in Gansu province, which struck its target in the Lop Nur Test Site. The missile carried a 12 kt nuclear warhead, marking the only time that a country has tested a nuclear warhead on a ballistic missile over populated areas.[9] The last of the atmospheric tests was in June 1980. This was a 1 Mt detonation, which was also the last atmospheric test occurring anywhere in the world.[10] China's final nuclear test detonation took place on 29 July 1996, an event reported by the authorities in Beijing later that year.

According to one expert, China's nuclear modernization efforts during the past two decades have focused on maintaining and strengthening the safety, security, and reliability of nuclear weapons without nuclear testing; enhancing the mobility of delivery systems to improve survivability; and research on technology to improve penetration capabilities.[11] At the time of writing, China was in the process of significantly increasing its nuclear arsenal. As of March 2025, the Federation of American Scientists (FAS) estimated that China had produced a stockpile of some 600 nuclear warheads, all of which are available for delivery by land-based ballistic missiles, sea-based ballistic missiles, and bombers.[12]

## Assessments

Little is known for certain of the impact of nuclear testing in China, although 20 million people live in the Xinjiang Uyghur Autonomous Region, the majority of whom are Uyghur, Kazakh, Kyrgyz, and other Turkic communities. There are no known Chinese government studies of environmental or human impact.

## Human effects

Few reports have emerged of the human effects of the Chinese nuclear testing programme. Dr Ilham Tohti is one of the few who saw the impact of nuclear tests since his childhood. In an interview after leaving China, he described the radioactive clouds that appeared following the tests: 'For three days, it was as if the sky had rained down on the ground. No sun, no moon.' When the children asked their teachers, the answer they received was that it was from a storm on the planet Saturn.[13]

The Japanese scientist, Jun Takada, has estimated that about 194,000 people died as a result of China's tests.[14] Takada developed a computer model to estimate fallout patterns using Soviet records of detonation size and wind velocity as well as radiation levels measured in Kazakhstan from 1995 to 2002. Dr Takada was not allowed into China, so he extrapolated his model and used information on population density in Xinjiang to arrive at the estimate, which he describes as 'a conservative minimum'. Around 1.2 million people received doses high enough to induce leukaemia, solid cancers and foetal damage, he claims.[15] The reliability of this estimate has not been confirmed.

8 Atomic Archive, 'China's Nuclear Tests'.
9 J. Wilson Lewis and X. Litai, *China Builds the Bomb*, Stanford University Press, Stanford, CA, 1988, 202–03.
10 Center for Nonproliferation Studies, 'China's Nuclear Tests: Dates, Yields, Types, Methods, and Comments'.
11 X. Sun, 'The Development of Nuclear Weapons in China', Chap. 3 in B. Li and Z. Tong (eds.), *Understanding Chinese Nuclear Thinking*, Carnegie Endowment for International Peace, 2016, at: https://bit.ly/4e8eA2w, 92.
12 H. Kristensen, M. Korda, E. Johns, M. Knight-Boyle, and K. John, 'Status of World Nuclear Forces', Federation of American Scientists, 26 March 2025, at: https://bit.ly/43PmGc2.
13 Z. Merali, 'Did China's Nuclear Tests Kill Thousands and Doom Future Generations?', *Scientific American*, July 2009, available at: https://bit.ly/3wzeMGR.
14 J. Takada, *Chinese Nuclear Tests*, Iryokagakusha, Tokyo, 2009, cited in Merali, 'Did China's Nuclear Tests Kill Thousands and Doom Future Generations?'.
15 Ibid.

## Societal effects

China's nuclear test programme was sited in the Xinjiang Uyghur Autonomous Region, an area whose people have been subjected to the gravest repression of fundamental human rights in recent years. One researcher found the memories of the nuclear tests, as well as fears of ongoing contamination, remain a major grievance of the Uyghur people, many of whom feel the radioactive legacies form part of a broader attack on their religious and ethnic identity.[16]

## Victim assistance

No reports have surfaced of any government assistance programme to the victims of the nuclear testing, especially the atmospheric testing. One medical expert, Dr Anwar Tohti, however, reported encountering many cancer patients in the region. He found that between 1990 and 2000, cases of cancer in the region had doubled.[17] He has further observed, though, that it is very difficult for Uyghurs to access health facilities due to their lack of money: 'They cannot afford healthcare costs. The only thing they can do is wait to die.'[18]

## Environmental contamination

The extent of environmental contamination is not known but is suspected to be extensive. According to Dr Tohti's information, nuclear tests in the Lop Nor region were carefully monitored by Soviet nuclear physicists in Kazakhstan. This was due to the radioactive clouds that appeared after each test affecting Almaty.[19] It has also been noted that the Chinese government 'steadfastly refuses to acknowledge' the consequences of the Lop Nur atmospheric nuclear tests.[20]

## Environmental remediation

There is no evidence of any environmental remediation by the Chinese authorities.

## Legal issues

There have been no successful claims for compensation by Uyghurs as a result of the nuclear testing in China whether within or outside the country. In 2008, however, Xinhua, the Chinese State news service, reported that the government was paying undisclosed compensation to military personnel involved in the tests.[21]

16 N. Baranovitch, 'The Impact of Environmental Pollution on Ethnic Unrest in Xinjiang: A Uyghur Perspective', *Modern China*, Vol. 45, No. 5 (2019), 504–36.
17 U. Gelis, '"The People's Bomb": China's Nuclear weapon testing Program', Women's International League for Peace and Freedom, Norway, at: https://bit.ly/3BeWsol.
18 Merali, 'Did China's Nuclear Tests Kill Thousands and Doom Future Generations?'.
19 Gelis, '"The People's Bomb": China's Nuclear weapon testing Program'.
20 Merali, 'Did China's Nuclear Tests Kill Thousands and Doom Future Generations?'.
21 Ibid.

# Glossary of Key Terms and Abbreviations

| | |
|---|---|
| 2MSP | Second Meeting of States Parties to the TPNW |
| ACC | Anti-Cancer Centre (Algeria) |
| AEC | Atomic Energy Commission (United Kingdom or United States) |
| ANFA | Australian Nuclear Free Alliance |
| ANVA | Australian Nuclear Veterans Association |
| ARPANSA | Australian Radiation Protection and Nuclear Safety Agency |
| ARS | Acute radiation syndrome |
| ASN | Nuclear Safety Authority (France) |
| AVEN | Nuclear Test Veterans Association in France (Association des Vétérans des Essais Nucléaires) |
| AWRE | Atomic Weapons Research Establishment (United Kingdom) |
| BEIR | National Research Council Committee on the Biological Effects of Ionizing Radiations |
| Bq | becquerel (the frequency of atomic disintegration – 1 Bq is 1 radioactive decay per second) |
| CAF | UN Cancun Adaptation Framework |
| CCM | Convention on Cluster Munitions |
| CCS | Site Security Consultative Commission (Algeria) |
| CE | Current era |
| CEA | Commissariat à l´Énergie Atomique (France) |
| CEDAW | Committee on the Elimination of Discrimination Against Women |
| CEMO | Oasis Military Experiment Centre (Algeria) |
| CEP | Centre d'Expérimentation du Pacifique |
| CESCEN | Commission of Inquiry on the Consequences of Nuclear Tests (Mā'ohi Nui) |
| CIVEN | Comité d'Indemnisation des Victimes des Essais Nucléaires |
| COFA | Compact of Free Association |
| CRS | Cutaneous radiation syndrome |
| CSEM | Saharan Centre for Military Experiments (Algeria) |
| CSO | Civil society organization |
| CT (scan) | Computed tomography |
| DDREF | dose and dose rate effectiveness factor |
| DDT | dichlorodiphenyltrichloroethane |
| DNA | deoxyribonucleic acid |
| DoE | Department of Energy (United States) |
| DTRA | Defense Threat Reduction Agency (United States) |
| EEOICPA | Energy Employees Occupational Illness Compensation Program Act (US) |
| EEZ | Exclusive economic zone |
| Effective dose | Summation of the equivalent doses to tissues and organs exposed, adjusting for the varying radiosensitivity of different tissues |
| EPA | US Environmental Protection Agency |
| ERW | explosive remnants of war |
| Equivalent dose | Measurement of the biological effect of the energy absorbed for a particular organ or tissue |
| GCFT | genetic and cytogenetic family trio |
| GM | Geiger-Müller (counter) |
| Gy | Gray (1 Gy is 1 joule of energy deposited per kilogram of mass) |
| GOEN | Nuclear Experiments Operational Group (Algeria) |
| Half-life | time taken for half the amount of a radioactive element to disintegrate |
| HEU | highly enriched uranium |
| Hibakusha | Survivors of the bombings of Hiroshima and Nagasaki |
| HPGe | High Purity Germanium (detector) |
| IAEA | International Atomic Energy Agency |
| ICAN | International Campaign to Abolish Nuclear Weapons |
| ICRC | International Committee of the Red Cross |
| ICRP | International Commission on Radiological Protection |
| IEER | Institute for Energy and Environmental Research |
| INSERM | Institut National de la Santé et de la Recherche Médicale |
| IPPNW | International Physicians for the Prevention of Nuclear War |
| IQ | Intelligence Quotient |
| IRME | Institute of Radiation Medicine and Ecology (Kazakhstan) |
| IRSE | Institute of Radiation Safety and Ecology (Kazakhstan) |
| ISRN | Nuclear Radiation and Safety Institute (France) |
| kt | kiloton(s) (the energy of a nuclear explosion with explosive power equivalent to 1,000 tons of TNT) |

| | |
|---|---|
| LABRATS | Legacy of the Atomic Bomb, Recognition For Atomic Test Survivors International |
| LEU | low enriched uranium |
| LNT | linear no-threshold |
| mGy | milligray |
| µSv | microsievert |
| mSv | millisievert |
| Mt | megaton(s) (the energy of a nuclear explosion equivalent to the explosive power of one million tons of TNT) |
| Mā'ohi Nui | Indigenous People's name for French Polynesia |
| NAAV | National Association of Atomic Veterans (United States) |
| NaI | Sodium Iodide (detector) |
| NAP | national adaptation plan |
| NASDA | National Association of State Departments of Agriculture (Kiribati) |
| NCRA | National Climate Risk Assessment |
| ND-GAIN | Notre Dame Global Adaptation Initiative |
| NFIP | Nuclear Free and Independent Pacific |
| NGO | non-governmental organization |
| NNC | National Nuclear Centre (Kazakhstan) |
| NNSS | Nevada National Security Site |
| North Korea | Democratic People's Republic of Korea |
| NPA | Norwegian People's Aid |
| NPT | Treaty on the Non-Proliferation of Nuclear Weapons (1968) |
| NRC | Nuclear Regulatory Commission (United States) |
| NRL | New Zealand National Radiation Laboratory |
| NTS | Nevada Test Site |
| NZTS | Novaya Zemlya Test Site |
| OECD | Organization for Economic Co-operation and Development |
| OHCHR | Office of the UN High Commissioner for Human Rights |
| OPAL | Open Pool Australian Lightwater |
| PCBs | polychlorinated biphenyls |
| PET (scan) | Positron Emission Tomography |
| PSIDS | Pacific Small Island Developing State |
| RAAF | Royal Australian Air Force |
| RECA | Radiation Exposure Compensation Act (US) |
| RMI | Republic of the Marshall Islands |
| SIPRI | Stockholm International Peace Research Institute |
| STS | Semipalatinsk Test Site |
| Sv | Sievert (the unit of measurement of equivalent dose and effective dose) |
| TNT | Trinitrotoluene |
| TPNW | Treaty on the Prohibition of Nuclear Weapons |
| Tritium | Tritium is a radioactive form of hydrogen (hydrogen-3) |
| TTPI | Trust Territory of the Pacific Islands |
| UK | United Kingdom |
| UN | United Nations |
| UNDP | UN Development Programme |
| UNDRP | UN Declaration on the Rights of Indigenous Peoples (2007) |
| UNECE | UN Economic Commission for Europe |
| UNFPA | UN Population Fund |
| UNICEF | UN Children's Fund |
| UNIDIR | UN Institute for Disarmament Research |
| UNMAS | UN Mine Action Service |
| UNSCEAR | UN Scientific Committee on the Effects of Atomic Radiation |
| UNV | UN Volunteers |
| US | United States |
| VAPV | Veterans Advisory and Pensions Committee |
| WHO | World Health Organization |
| WMO | World Meteorological Organization |

## Contributing Author Bios

**Nabil Ahmed** is a Professor at the Trondheim Academy of Fine Art at the Norwegian University of Science and Technology, and Principal Investigator of the NFR project Climate Rights: Designing Evidence for Climate Justice. He is founder and co-director of INTERPRT, a research agency for environmental justice. For over a decade, INTERPRT has investigated environmental destruction and human rights violations through visual and spatial methods. Its Moruroa Files investigation on French nuclear testing with DISCLOSE and Princeton University won the 2022 Sigma Award for Data Journalism.

**Becky Alexis-Martin** is a lecturer at the University of Bradford. Dr Alexis-Martin joined academia after a successful career in emergency management. Her research is conducted at the point where peace, science, and technology; humanitarian aid; and justice and human rights coalesce. She has tackled challenges including modelling the behaviours of city-dwellers during nuclear events, understanding the lives of nuclear test veterans and their families, exploring the afterlives of nuclear bunkers, writing on the lived experiences of those scarred by nuclear accident and warfare, sharing the aesthetics of 1950s atomic America, and identifying the humanitarian and environmental needs of nuclear weapons test-affected communities worldwide. Her first monograph, *Disarming Doomsday: The Human Impacts of Nuclear Warfare*, was the recipient of the L.H.M. Ling Outstanding First Book Prize.

**Matthew Breay Bolton** is professor of political science and co-director of the International Disarmament Institute at Pace University, New York City. He is also affiliated with the environmental studies department. Dr Bolton was part of the International Campaign to Abolish Nuclear Weapons (ICAN) team awarded the 2017 Nobel Peace Prize. He has collaborated for more than 20 years with United Nations and NGO efforts to address the humanitarian impact of landmines, cluster munitions, military robotics, and the arms trade. His field research has highlighted the concerns of communities affected by nuclear weapons in the Marshall Islands, Kiribati, Mā'ohi Nui/French Polynesia, Fiji, and the Cook Islands, as well as New York City. In 2023, Bolton was appointed by NYC Council Speaker Adrienne Adams to the city's Nuclear Weapons Free Zone Advisory Committee. He has six books to his name, including *Political Minefields* and *Imagining Disarmament*. He has a doctorate and a master's degree from the London School of Economics and a master's degree from SUNY Environmental Science and Forestry in Syracuse. He has been awarded honorary doctorates by Middlebury College and Graceland University.

**Marian Casey-Maslen** is a researcher and practitioner with 40 years' experience in international development and humanitarian work. She holds an LL.M in International Law in Armed Conflict from the Geneva Academy of International Humanitarian Law and Human Rights and an MA in Development Studies from the Development Studies Centre in Dublin as well as a certificate in Tropical Community Medicine and Health from the Liverpool School of Tropical Medicine. In 2016–23, she led the CDAC Network in London as its Executive Director, developing common services for communication and community engagement in natural hazards, armed conflict, and public health crises to enable a culture of rights, accountability and transparency.

**Stuart Casey-Maslen** is Visiting Professor of International Law at the Law Faculty of the University of Johannesburg in South Africa. He holds a doctorate in international humanitarian law and master's degrees in international human rights law and forensic ballistics. He has written widely on nuclear weapon issues, including a legal commentary on the Treaty on the Prohibition of Nuclear Weapons, published by Oxford University Press in 2019, and an analysis of law, policy, and practice on nuclear weapons, published by Cambridge University Press in 2021. He was legal advisor to the Austrian delegation in the negotiation of the Treaty on the Prohibition of Nuclear Weapons.

**Bonnie Docherty** is a lecturer on law at Harvard Law School's International Human Rights Clinic and director of its Armed Conflict and Civilian Protection Initiative. She is also Senior Arms Advisor in Human Rights Watch's

Crisis, Conflict, and Arms Division. Docherty has done extensive work in the field of humanitarian disarmament as lawyer, field researcher, and scholar. She played a key role in the negotiation of the reaty on the Prohibition of Nuclear Weapons, providing legal advice to the International Campaign to Abolish Nuclear Weapons (ICAN), which received the 2017 Nobel Peace Prize. Since the treaty's adoption, she has been closely involved in the implementation of the victim assistance and environmental remediation obligations. Docherty has also worked on creating and strengthening law on autonomous weapons systems, cluster munitions, explosive weapons in populated areas, incendiary weapons, and the environment in armed conflict.

Jean-Marie Collin is the director of ICAN France. His areas of expertise cover arms control, non-proliferation, and the consequences of French nuclear test explosions. He has written several books on nuclear issues, notably one with the former French Minister of Defence, P. Quilès (*L'illusion nucléaire*, ELCM, 2018), as well as numerous studies (including 'The Waste From French Nuclear Tests in Algeria – Radioactivity Under the Sand' in 2020), and a series of policy papers on humanitarian initiatives with the Belgian think tank, GRIP (the Group for Research and Information on Peace and Security). He holds a master's degree in the politics and strategy of international public action and a bachelor's degree in political sciences from University of Jean-Moulin Lyon III.

Linsey Cottrell is Environmental Policy Officer at the Conflict and Environment Observatory (CEOBS). She is a chartered environmentalist through the Royal Society of Chemistry and worked in the environmental consultancy sector for 25 years before joining CEOBS in 2019. She holds an MSc in environmental pollution control, and a BSc in chemical sciences, both from the University of Leeds, as well as a post-graduate certificate in sustainability and environmental management. She is an experienced environmental practitioner, including in environmental risk assessment, contaminated land, environmental due diligence, and environmental impact assessment, and is registered in the United Kingdom as a Specialist in Land Condition (SiLC). From 2016 until 2022, she was also a trustee of the United Kingdom's Institution of Environmental Sciences.

Friederike Friess is a senior researcher at the Institute of Safety and Risk Sciences, BOKU University Vienna. She obtained her PhD in Physics from the Technische Universität Darmstadt in 2017 and was a member of the Interdisciplinary Research Group for Science, Technology and Security (IANUS). Friess is a board member of the International Nuclear Risk Assessment Group (INRAG) and the Research Association for Science, Disarmament and International Security (FONAS). Friess's current research focuses on the future of nuclear technology, both civil and military. This includes co-authoring the chapter *Global Stock and Production of Fissile Materials* in the Stockholm International Peace Research Institute (SIPRI) Yearbook, as well as various teaching and outreach activities on radiation protection.

Leila Hennaoui holds a PhD in Public International Law from the University of Algiers and has been a faculty member at Hassiba Ben Bouali University of Chlef, Algeria, since 2010. Her research focuses on nuclear non-proliferation, disarmament, and the global governance of nuclear weapons. Over the past decade, she has published extensively on these topics, contributing to academic discourse and fostering critical understanding of the intersection between international law and nuclear issues. Dr Hennaoui has also participated in international training programmes and conferences. Recently, she served as a visiting professor at Roma Tre University, where she delivered a seminar on 'Nuclear Proliferation and the Perspective of the Global South'.

Oemwa Johnson is pursuing a double major in biology and accounting, with a minor in Pacific Island Studies at Brigham Young University (BYU)-Hawaii. A particular area of concern that has captured her attention is nuclear weapons testing. Her family in Kiribati lived the experience of the nuclear testing on the atoll of Kiritimati. As an aspiring doctor, she is committed to working towards a world free from nuclear threats to ensure the well-being of current and future generations.

Karina Lester is a prominent Yankunytjatjara-Aṉangu woman and a respected advocate for Aboriginal land rights, language preservation, and anti-nuclear activism in Australia. The daughter of the late Yami Lester, a survivor of British nuclear testing at Emu Field, Karina has continued his legacy by raising awareness of the devastating impacts of nuclear weapons on Indigenous Traditional Lands. As a community leader, she plays a key role in maintaining and revitalizing Aboriginal languages and serves as a bridge between traditional knowledge and contemporary policy debates. Her work has made her a vital voice in environmental justice and Indigenous advocacy, both nationally and internationally.

Darvin Lisica is a full professor at the Faculty of Political Sciences of the University of Sarajevo in Bosnia and Herzegovina. He is also a Global Special Advisor for Mine Action in Norwegian People's Aid. He holds a PhD in security and defence from the University of Sarajevo. His research areas include the sociology of risk, risk perception, security risk management, and proliferation and disarmament policies.

Mary Olson is the founder and Chief Executive Officer of the Gender and Radiation Impact Project, working to promote public health by re-centring protective measures against radiation harm for the public on female children. Her work on radiation exposure consequences began in 1985 and her original analysis confirmed the disproportionate radiation harm inflicted on female bodies compared to male bodies. In 1991, she became Staff Biologist and Radioactive Waste Policy Analyst at the Nuclear Information and Resource Service. Olson served as a resource to nuclear-impacted communities, to Congress, the Clinton/Gore Administration, Duke Energy, and various bodies of the United Nations, including co-authoring a report published in November 2024 by the UN Institute for Disarmament Research (UNIDIR) entitled 'Gender and Ionizing Radiation: Towards a New Research Agenda Addressing Disproportionate Harm'. Ms Olson earned a Bachelor of Science (with distinction), from Reed College in 1981, with a double major of evolutionary biology and history of science.

Ivana Nikolić Hughes is President of the Nuclear Age Peace Foundation and a senior lecturer in the Discipline of Chemistry at Columbia University. She holds a BSc with Honors from Caltech, where she studied chemical engineering and completed her Senior Thesis with Professor. Frances Arnold, the first American woman to win a Nobel Prize in Chemistry. Dr Hughes obtained her PhD from Stanford University, where she was an American Heart Association Predoctoral Fellow. She has been a faculty member at Columbia University since 2008 and was awarded the Lenfest Distinguished Columbia Faculty Award for 2020. Her work on ascertaining the radiological conditions in the Marshall Islands has been covered widely. Dr Hughes currently serves as a member of the Scientific Advisory Group to the Treaty on the Prohibition of Nuclear Weapons.

Grethe Lauglo Østern is acting head of the Policy Section in Norwegian People's Aid (NPA) and the editor of the research project Nuclear Weapons Ban Monitor. Grethe has previously represented NPA on the International Steering Group of the International Campaign to Abolish Nuclear Weapons (ICAN), served as Co-Chair of the Cluster Munition Coalition (CMC), worked in the International Humanitarian Law Unit of the Norwegian Red Cross, and was a Field Assessment and Coordination Team delegate with the International Federation of Red Cross and Red Crescent Societies.

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**Ariana T. Kilma** is a descendant of survivors of the catastrophic Bravo Shot that was detonated in the Marshall Islands and is a strong advocate for nuclear justice. Born and raised in the Marshall Islands (RMI), she currently serves as the Chair of the RMI National Nuclear Commission (NNC). She holds a bachelor's degree in political science from the University of Hawai'i at Manoa. Ariana became involved in nuclear advocacy in 2018 when she conducted research with the Marshallese community living in Honolulu for the NNC. In 2019, Ariana became the NNC's Education & Public Awareness Coordinator and began co-teaching nuclear issues in the Pacific at the College of the Marshall Islands. She worked closely with the RMI's public schools system where she helped create a curriculum that would teach k-12 students the history of nuclear weapons testing in the Marshall Islands while leading multiple nuclear legacy campaigns and awareness efforts in the RMI. In 2022, she was appointed by the RMI President and members of the Cabinet as a Commissioner to the NNC and later re-appointed as Chair in 2023.

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