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The humanitarian impact and implications of nuclear test explosions in the Pacific region

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Abstract

The people of the Pacific region have suffered widespread and persisting radioactive contamination, displacement and transgenerational harm from nuclear test explosions. This paper reviews radiation health effects and the global impacts of nuclear testing, as context for the health and environmental consequences of nuclear test explosions in Australia, the Marshall Islands, the central Pacific and French Polynesia. The resulting humanitarian needs include recognition, accountability, monitoring, care, compensation and remediation. Treaty architecture to comprehensively prohibit nuclear weapons and provide for their elimination is considered the most promising way to durably end nuclear testing. Evidence of the

* This paper is humbly dedicated to the victims and survivors of nuclear explosions worldwide working for the eradication of nuclear weapons. The author thanks Nic Maclellan for his helpful suggestions.

humanitarian impacts of nuclear tests, and survivor testimony, can contribute towards fulfilling the humanitarian imperative to eradicate nuclear weapons.

Keywords: nuclear test explosions, nuclear tests, Pacific region, Pacific island countries, radioactive fallout.

Introduction

The peoples of the Pacific region have been caught up in the nuclear age from its beginnings as, generally without their prior knowledge or consent, their lands and seas have been used for and contaminated by the development, testing and deployment of nuclear weapons by distant powers – France, the United Kingdom and the United States. This has impacted their health, their homelands and their future. In 1945, the aircraft that dropped nuclear bombs on both Hiroshima and Nagasaki took off from Tinian in the Mariana Islands in the Pacific; and US nuclear tests in the Pacific began as early as 1946.[1]

Between 1945 and 2015, 2,055 nuclear explosions are known to have been undertaken globally.[2] Apart from the two bombs dropped on Hiroshima and Nagasaki, and 150 explosions which were ostensibly "peaceful",[3] the rest have been for the purpose of developing new nuclear weapons (making them more destructive, more compact and more deliverable), understanding their effects and developing plans for their use. Despite the conclusion of the Comprehensive Nuclear-Test-Ban Treaty (CTBT) in 1996, the Treaty has not yet entered into force.[4] However, the Democratic People's Republic of Korea has been the only State to conduct nuclear test explosions since 1998.[5]

1 Preparatory Commission for the Comprehensive Nuclear Test-Ban-Treaty Organization (CTBTO Preparatory Commission), *The United States' Nuclear Testing Programme*, available at: www.ctbto.org/nuclear-testing/the-effects-of-nuclear-testing/the-united-states-nuclear-testing-programme/ (all internet references were accessed in November 2015).

2 Stockholm International Peace Research Institute (SIPRI), *SIPRI Yearbook 2014*, Oxford University Press, Oxford, 2015, pp. 349–351.

3 The explosive device used for a peaceful nuclear explosion (PNE) is the same as for a weapons test, and the adverse effects on health and the environment are the same (see CTBTO Preparatory Commission, *Peaceful Nuclear Explosions*, available at: www.ctbto.org/nuclear-testing/history-of-nuclear-testing/peaceful-nuclear-explosions/). In addition, there is no objective way to verify that a nuclear explosion designated as "peaceful" does not have some military purpose. Because PNEs were widely regarded as a "back door" for nuclear weapons, they are prohibited under the CTBT. The best-known case of deceitful use of the designation of PNE is that of India's 1974 explosion. After conducting an explicit series of nuclear weapons test explosions in 1998, India admitted that its 1974 explosion had also been a nuclear weapon test. See Rebecca Johnson, *Unfinished Business: The Negotiation of the CTBT and the End of Nuclear Testing*, UN Institute for Disarmament Research (UNIDIR), Geneva, 2009, pp. 101, 322.

4 CTBTO Preparatory Commission, *The Treaty*, available at: www.ctbto.org/the-treaty/.

5 CTBTO Preparatory Commission, *Nuclear Testing 1945–Today*, available at: https://www.ctbto.org/nuclear-testing/history-of-nuclear-testing/nuclear-testing-1945-today/.

Nuclear test explosions have been conducted in the atmosphere, on the Earth's surface, underground, underwater and in space. All nuclear explosions have similar physical and biological effects. For practical purposes, it is useful to divide them into two categories: atmospheric tests (surface, space and underwater tests, usually and in this report termed "atmospheric" because they release radioactivity directly into air and water) and underground tests, where most radioactivity is retained underground, with long-term risks of groundwater contamination, although some underground tests have vented radioactivity directly into the atmosphere.[6]

Every phase of nuclear weapons production – development, deployment and use, beginning with mining of uranium – involves health and environmental hazards. This paper focuses on the nuclear test explosions conducted in Pacific islands and Australia; their global context; their health and environmental impact, especially but not limited to the health effects of ionizing radiation; the ongoing needs of military and civilian test workers and affected communities for recognition, care, monitoring and compensation; and the need for environmental monitoring, and clean-up and restoration of test sites where feasible. While the overwhelming hazard related to nuclear test explosions is the danger of war using the weapons that the test explosions have played an important role in developing and modernizing, the explosions themselves have left a legacy of ongoing environmental and health harm which requires continuing humanitarian attention even if it proves possible to eradicate nuclear weapons before they are again used in war.

There are only 90,000 of them out there. Who gives a damn?

– Former US Secretary of State Henry Kissinger, commenting on whether the United States should invoke its trustee power of eminent domain over the Trust Territory of the Pacific Islands to seize (rather than buy or lease) land for military purposes.*

The global context for Pacific nuclear test explosions

While nuclear-armed States occupying large continental land masses, including the United States, the Soviet Union, China and India (and some smaller nuclear-armed countries, such as Pakistan and North Korea), have conducted nuclear test explosions within their contiguous territory, it is notable that nuclear test programmes – which were claimed at the time to be without significant adverse health and environmental consequences – were often imposed on rural, minority, disenfranchised and colonized peoples. Though governments that have conducted

6 CTBTO Preparatory Commission, *Types of Nuclear Weapons Tests*, available at: www.ctbto.org/nuclear-testing/history-of-nuclear-testing/types-of-nuclear-weapons-tests/.

* Cited in Walter Hickel, *Who Owns America?*, Prentice-Hall, Englewood Cliffs, NJ, 1971, p. 208.

nuclear tests have been willing to accept harm to their own populations in the name of national security, they have been even more willing to do harm to others. For example, the total explosive yield of US nuclear test explosions in Pacific locations – Bikini and Enewetak Atolls in the Marshall Islands, Johnston Atoll in the central Pacific, and Kiritimati (Christmas Island, lent for the purpose by the British) – at 152.8 megatons (Mt), dwarfs the 1.05 Mt yield of atmospheric tests conducted in the continental US at the Nevada Test Site (land of the Western Shoshone people).[7]

Soviet nuclear tests were conducted in Kazakhstan and in the remote Arctic archipelago of Novaya Zemlya, home to the minority Nenetz people.[8] Chinese nuclear tests were conducted at Lop Nur, in the Xinjiang Uygur Autonomous Region, home to the Uygur minority.[9] The United Kingdom undertook its nuclear test explosions in Australia, most in the desert lands of the Maralinga Tjarutja people, and its larger thermonuclear test explosions in its then Pacific territory of the British Gilbert and Ellice Islands Colony.[10] France conducted its nuclear tests in its then colony Algeria, until forced by a rising independence struggle to relocate to the home of the Maohi people in its colony of French Polynesia.[11]

A secret operation not subject to laws … no one was to know what was going on.

– W. Henson Moore, US Deputy Secretary of Energy, speaking in June 1989 about nuclear weapons production.*

Attitudes of those conducting the test explosions often differentiated between "civilized" personnel and "primitive" indigenous people, as shown by a British report on the "Danger Area" for the 1957 Grapple nuclear tests on Christmas Island. It set a maximum radiation dose limit for "primitive" Pacific people exceeding that recommended internationally, and different from that for British personnel:

> The [radiation] dosage at this … level is about 15 times higher (for primitive peoples) than that which would be permitted by the International Commission on Radiological Protection [ICRP] …. [T]he levels recommended by the ICRP would necessarily be exceeded … [but] only a

7 Frederick Warner and René J. C. Kirchmann (eds), Scientific Committee on Problems of the Environment (SCOPE) of the International Council for Science, *SCOPE 59. Nuclear Test Explosions: Environmental and Human Impacts*, John Wiley & Sons, New York, 1999, pp. 19–22.

8 CTBTO Preparatory Commission, *The Soviet Union's Nuclear Testing Programme*, available at: www.ctbto.org/nuclear-testing/the-effects-of-nuclear-testing/the-soviet-unionsnuclear-testing-programme/.

9 CTBTO Preparatory Commission, *China's Nuclear Testing Programme,* available at: www.ctbto.org/nuclear-testing/the-effects-of-nuclear-testing/chinas-nuclear-testing-programme/.

10 CTBTO Preparatory Commission, *The United Kingdom's Nuclear Testing Programme*, available at: www.ctbto.org/nuclear-testing/the-effects-of-nuclear-testing/the-united-kingdomsnuclear-testing-programme/.

11 CTBTO Preparatory Commission, *France's Nuclear Testing Programme,* available at: https://www.ctbto.org/nuclear-testing/the-effects-of-nuclear-testing/frances-nuclear-testing-programme/.

* Cited in Arjun Makhijani, "A Readiness to Harm: The Health Effects of Nuclear Weapons Complexes", *Arms Control Today*, 1 July 2005, available at: www.armscontrol.org/print/1852.

very slight health hazard to people would arise, and that only to primitive people.[12]

Despite their relatively small numbers, Pacific island people have borne a disproportionate burden of the health and environmental costs of nuclear weapons development and testing. More than 315 atmospheric, underground and underwater nuclear tests were conducted in the region by Britain, France and the United States between 1946 and 1996 (see Table 1).

The use and testing of nuclear weapons have demonstrated their devastating immediate, mid- and long-term effects. Nuclear testing in several parts of the world has left a legacy of serious health and environmental consequences. Radioactive contamination from these tests disproportionately affects women and children. It contaminated food supplies and continues to be measurable in the atmosphere to this day.

– Chair's Summary, Vienna Conference on the Humanitarian Impacts of Nuclear Weapons, 8–9 December 2014.*

Nuclear weapons testing and development programmes have been massive industrial undertakings. In the United States alone, a quarter of a million military personnel participated in nuclear weapons tests, and more than half a million workers in the nuclear weapons development and production complex were exposed to radioactive and chemical hazards, often without proper information, training or protection.[13] These largely secret operations were not subject to usual laws, accountability or standards of protection for people and the environment.[14] At many test sites, local military and/or civilian personnel were engaged. As discussed further below, Australian personnel (in Australia) and Fijian and New Zealand personnel (at Malden and Christmas Island) performed more hazardous duties with less training, protection and radiation monitoring than their British counterparts.

There have been slow and incomplete developments towards accountability, care and compensation programmes for those harmed in the line of service building and testing nuclear weapons in some countries, such as the United States, Australia and Fiji. In the United States, as of March 2015, over $2

12 Air Vice-Marshal W. E. Oulton, "Danger Area", Top Secret Paper, No. GRA/TS.1008/1/Air, 19 November 1956; minutes of meeting on 27 November 1956 marked Top Secret – UK Eyes Only, XY/181/024, cited in Nic Maclellan, "Grappling with the Bomb: Opposition to Pacific Nuclear Testing in the 1950s", in Phillip Deery and Julie Kimber (eds), *Proceedings of the 14th Biennial Labour History Conference*, Australian Society for the Study of Labour History, Melbourne, 2015, p. 11.

13 Arjun Makhijani, "A Readiness to Harm: The Health Effects of Nuclear Weapons Complexes", *Arms Control Today*, 1 July 2005, available at: www.armscontrol.org/act/2005_07-08/Makhijani.

14 *Ibid.*

* Europe Integration and Foreign Affairs Federal Ministry, Republic of Austria, Report and Summary of Findings of the Conference, presented at the Vienna Conference on the Humanitarian Impacts of Nuclear Weapons, 9 Dec 2014, available at: www.bmeia.gv.at/fileadmin/user_upload/Zentrale/Aussenpolitik/Abruestung/HINW14/HINW14_Chair_s_Summary.pdf.

Table 1. *Nuclear explosions in the Pacific region, 1946–96*

Area	Location	Testing State	Atmospheric (including surface)	Underground or underwater	Estimated total yield of atmospheric tests (Mt)
Australia	Monte Bello Islands	UK	3		0.046
	Emu Field	UK	2		0.018
	Maralinga	UK	7		0.116
French Polynesia	Moruroa	France	42	137	6.388
	Fangataufa	France	4, including "Canopus" on 24 August 1968, at 2.6 Mt, France's largest ever explosion	10	3.742
Japan*	Hiroshima	US	1		0.015
	Nagasaki	US	1		0.021
Micronesia	Bikini	US	23, including "Castle Bravo" on 1 March 1954, at 15 Mt, the United States' largest ever explosion		76.8
	Enewetak	US	42		31.7

	Johnston (Kalama) Atoll	US	12		20.8
	Malden Island	UK	3		1.22
	Kiritimati (Christmas Island)	UK, US	9 (UK), 24 (US)		6.65 (UK), 23.25 (US)
Northern Pacific	Various (including near California)	US	2	2 underwater	0.102
USA	Amchitka, Alaska	US		3, including "Cannikin" on 6 November 1971, at 5 Mt, the United States' largest ever underground explosion	6.08

[*] The nuclear bombings of Hiroshima and Nagasaki are officially classified by the United States as nuclear tests and are included for comparison.
Discrepancies in reported numbers of nuclear tests explosions often relate to the fact that a number of "tests" involved more than one nuclear device. In all, there have been 2,055 nuclear tests involving 2,474 devices detonated.
Principal source: F. Warner and R. J. C. Kirschmann, above note 7, pp. 19–29.

billion has been awarded in compensation for specified illnesses recognized as related to radiation exposure from nuclear testing and uranium processing for nuclear weapons.[15] At the time of writing, however, no testing nation has extended such compensation beyond its own citizens.

Tests conducted in the Pacific region

British nuclear tests in Australia

Australia's willing hosting of British atmospheric nuclear test explosions resulted in extensive radioactive fallout and health harm to workers and downwind communities, followed by inadequate clean-up and continuing contamination.

Between 1952 and 1957, the United Kingdom undertook 12 nuclear test explosions in Australia – three at the Monte Bello Islands in Western Australia, two at Emu Field, and seven at Maralinga, South Australia, up to 98 kilotons (kt) in size.[16] In addition, about 600 "minor trials" were conducted at Emu and Maralinga. These involved predominantly chemical rather than nuclear explosions, and tested nuclear weapons components, dispersal of radioactive material, and the effects of impacts, fire and other accidents on nuclear weapons.[17] The Australian prime minister, Robert Menzies, immediately agreed to a British request to host nuclear test explosions, without consulting even cabinet colleagues,[18] announcing: "It [an atomic weapon test] will be conducted in conditions which will ensure that

It wasn't long after that a black smoke came through. A strange black smoke, it was shiny and oily. A few hours later we all got crook, every one of us. We were all vomiting; we had diarrhoea, skin rashes and sore eyes. I had really sore eyes. They were so sore I couldn't open them for two or three weeks. Some of the older people, they died. They were too weak to survive all the sickness. The closest clinic was 400 miles away.

– Yami Lester, Yankunytjatjara elder and nuclear test survivor, referring to the "Black Mist" radioactive fallout that blanketed Wallatinna Station, South Australia, after the nearby Totem 1 nuclear test on 15 October 1953.*

15 US Department of Justice, Office of Public Affairs, "Justice Department Surpasses $2 Billion in Awards under the Radiation Exposure Compensation Act", *Justice News*, 2 March 2015, available at: www.justice.gov/opa/pr/justice-department-surpasses-2-billion-awards-under-radiation-exposure-compensation-act.

16 Royal Commission into British Nuclear Tests in Australia, *The Report of the Royal Commission into British Nuclear Tests in Australia*, Australian Government Publishing Service, Canberra, 1985 (Royal Commission Report).

17 *Ibid.*, Vol. 2, para. 10.0.2, p. 395.

18 *Ibid.*, paras 2.1.34, 12.1.15, and Conclusion 1.

* Cited in International Campaign to Abolish Nuclear Weapons (ICAN) Australia, *Black Mist,* ICAN Australia, Melbourne, January 2014, p. 6.

there will be no danger whatever from radioactivity to the health of the people or animals in the Commonwealth."[19] His minister of supply, Howard Beale claimed: "England has the bomb and the knowhow; we have the open spaces, much technical skill and great willingness to help the Motherland."[20]

The major tests produced varying complex fallout patterns which contaminated the whole Australian continent, including cities. The Royal Commission found that the Australian Weapons Test Safety Committee failed in many of its tasks, and "at times it was deceitful and allowed unsafe firing to occur".[21] Official fallout measurements were incomplete and were concealed from the public and in many cases the government.[22] The more than 600 "minor trials" dispersed 24.4 kg of plutonium in an estimated 50,000 fragments in an 18 km major plume, with soil contamination up to 100 km; 101 kg of beryllium; and 8,083 kg of powdered uranium.[23]

Those at highest radiation exposure risk were local Aboriginal people and pastoralists, who were not systematically evacuated or even informed; and over 16,000 workers directly exposed to the tests.[24] Warning signs in English were usually incomprehensible to the Aborigines. Some were covered by local fallout (the "Black Mist" phenomenon).[25]

Mindful of the unacceptable harm that victims of nuclear weapons explosions and nuclear testing have experienced and recognising that the rights and needs of victims have not been adequately addressed …

– Austrian Pledge, Vienna Conference on the Humanitarian Impact of Nuclear Weapons, 8–9 December 2014.*

It was not until the 1985 Royal Commission that much of the truth about the nuclear tests emerged, particularly the "minor trials", which were not minor in their consequences and indeed were responsible for the bulk of persistent contamination. No Australian was present at any of these firings, and the Royal Commission described "persistent deception and paranoid secrecy", with "British authorities embarked on a course of determined concealment of information

19 Adrian Tame and F. P. J. Robotham, *Maralinga: British A-bomb Australian Legacy*, Fontana/Collins, Melbourne, 1982, p. 66.
20 Royal Commission Report, above note 16, p. 15, para. 2.1.25.
21 *Ibid.*, Conclusion 47.
22 *Ibid.*, Conclusions 2, 6, 9, 27–32, 47, 48 and others.
23 *Ibid.*, Vol. 2, pp. 398–401.
24 Richard Gun, Jacqueline Parsons, Philip Ryan, Philip Crouch and Janet Hiller, *Australian Participants in British Nuclear Tests in Australia*, Vol. 2: *Mortality and Cancer Incidence*, Department of Veterans Affairs, Canberra, 2006, p. xvii.
25 Royal Commission Report, above note 16, Conclusion 97, and Vol. 1, para. 6.4.92, p. 194 and accompanying account pp. 174–194. "Black Mist" refers to a dark cloud of radioactive fallout resulting from the "Totem 1" test on 15 October 1953 which enveloped and irradiated Aboriginal people living in the Wallatina community and neighbouring homesteads. The Royal Commission concluded that the phenomenon had been real, despite earlier denials by various British and Australian officials.
* Available at: www.bmeia.gv.at/fileadmin/user_upload/Zentrale/Aussenpolitik/Abruestung/HINW14/HINW14_Austrian_Pledge.pdf.

from the Australian Government".[26] The Royal Commission report was scathing about the appalling treatment of indigenous Australians during the tests. Aboriginal people were within and lived in prohibited zones during and for up to six years after tests, responsible officials demonstrated "ignorance, incompetence and cynicism" and failed to consider "their special vulnerability to radioactive fallout", and decades of denial of access to traditional lands "contributed to their emotional, social and material distress and deprivation".[27]

Permissible radiation dose limits for whole-body penetrating radiation for workers from 1950 were 5 millisievert (mSv) per week,[28] compared with current occupational limits averaging 20 mSv per year and 1mSv per year for the public. Yet measures to comply with even the low standards of the time were frequently deficient. Veterans describe lack of protective clothing and equipment, soldiers sent into ground zero the same day after an explosion, and unpressurized aircraft flying through fallout clouds.[29] The Royal Commission described "departures, some serious and some minor, from compliance with the prescribed radiation protection policy and standards".[30] Despite no more than 4% of veterans having radiation film-badge data available, external exposures of more than 400 mSv (following the first Monte Bello test) were documented.[31] A belated government-funded mortality and cancer study of test veterans was concluded in 2006. Despite a "healthy worker effect" (evident in reduced non-cancer mortality rates) and major methodological limitations of a retrospective study with incomplete data fifty years after the nuclear tests began, it found statistically significant 23% higher rates of cancer and 18% higher cancer mortality between 1982 (twenty-nine years after the first test) and 2001 in veterans exposed to nuclear tests compared with the general population.[32]

A hasty British clean-up in 1967 involving ploughing and disc-harrowing of plutonium-contaminated areas, and shallow burial of material from 180 hectares of heavily contaminated land (which was then declared "radiologically safe"), led to a 1968 agreement between the British and Australian governments releasing Britain from liability for any future claims related to its nuclear tests.[33] However, a 1984

26 *Ibid*., para. 10.2.64, p. 414.

27 *Ibid*., pp. 319, 323, Conclusions 90, 91, 117, 124–125, 140, 186. For a useful, more concise account, see Peter N. Grabosky, "A Toxic Legacy: British Nuclear Weapons Testing in Australia", in Peter N. Grabosky, *Wayward Governance: Illegality and Its Control in the Public Sector*, Australian Institute of Criminology, Canberra, 1989.

28 Royal Commission Report, above note 16, Vol. 1, pp. 39–85, especially Table 4.5.1, p. 78.

29 The Royal Commission Report provides extensive documentation of eyewitness accounts from test participants. A number of books also provide detailed eyewitness accounts. Two excellent examples are Frank Walker, *Maralinga*, Hachette Australia, Sydney, 2014; Roger Cross and Avon Hudson, *Beyond Belief. The British Bomb Tests: Australia's Veterans Speak Out*, Wakefield Press, Kent Town, 2005.

30 Royal Commission Report, above note 16, "Conclusions and Recommendations", Conclusion 52, p. 12.

31 *Ibid*., Recommendation 52 and pp. 125–126.

32 R. Gun, J. Parsons, P. Ryan, P. Crouch and J. Hiller, above note 24, pp. v–vi, and further detail in report body. The study is summarized in Richard Gun, Jaqueline Parsons, Philip Crouch, Philip Ryan, and Janet Hiller, "Mortality and Cancer Incidence of Australian Participants in the British Nuclear Tests in Australia", *Occupational and Environmental Medicine*, Vol. 62, No. 12, 2008.

33 Royal Commission Report, above note 16, pp. 539–540.

study by the Australian Radiation Laboratory demonstrated far more extensive and severe contamination than had previously been revealed, proving invalid the information and hazard assessment on which the 1968 agreement had been based.[34] The Commission recommended that "[a]ction should be commenced immediately to effect the clean-up of Maralinga and Emu … so that they are fit for unrestricted habitation by the traditional Aboriginal owners as soon as practicable", and that "[a]ll costs of any future clean-ups at Maralinga, Emu and Monte Bello Islands should be borne by the United Kingdom Government".[35]

Maralinga was declared safe in 2000 after a second limited A$108 million clean-up funded by both governments, despite expert concerns and failure to implement the planned process of immobilizing plutonium fragments through *in situ* vitrification.[36] A region of 450 km^2 remains unsuitable for permanent occupation with boundary markers that will last fifty years, while half the plutonium will still be there in 24,400 years.[37] Less than 2% of areas contaminated at the Taranaki "minor trials" site meet the clean-up clearance criteria, and 84% of the plutonium contamination remains on the surface,[38] yet no further clean-up is planned. In 2011, a report obtained under Freedom of Information laws documented that only a decade on, the massive Taranaki burial trench and other burial pits have been subject to subsidence and erosion, requiring further remediation.[39]

Unresolved issues many decades later include indigenous dispossession, remaining contamination, inadequate clean-up of test sites, and necessary compensation for Aboriginal people, ex-servicemen and civilians for their hazardous exposure, illness and loss.[40] In 2006, fifty-four years after the tests began, 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".[41] However, there is still no fully non-adversarial and readily available compensation for all test participants. Claimants have faced difficulties getting evidence – Maralinga hospital records are not available, and dosage records are grossly incomplete and, for reasons not

34 *Ibid.*, pp. 539–540, 549–552.
35 *Ibid.*, Recommendations 3 and 6 respectively.
36 Alan Parkinson, "Maralinga: The Clean-Up of a Nuclear Test Site", *Medicine & Global Survival*, Vol. 7, No. 2, 2002; and Alan Parkinson, "The Maralinga Rehabilitation Project: Final Report", *Medicine, Conflict and Survival*, Vol. 20, No. 1, 2004.
37 A. Parkinson, "Maralinga: The Clean-Up of a Nuclear Test Site", above note 36, p. 80.
38 Alan Parkinson, *Maralinga: Australia's Nuclear Waste Cover-up*, ABC Books, Sydney, 2007, pp. 184, 203.
39 Philip Dorling, "Ten Years after the All-Clear, Maralinga is Still Toxic", *Sydney Morning Herald*, 12 November 2011.
40 Tilman A. Ruff, *Australian Participants in British Nuclear Tests in Australia*, Submission to the Senate Standing Committee on Foreign Affairs, Defence and Trade, 27 October 2006, available at: www.aph.gov.au/Parliamentary_Business/Committees/Senate/Foreign_Affairs_Defence_and_Trade/Completed%20inquiries/2004-07/nuclear_tests_bills_06/submissions/sublist.
41 Department of Veterans' Affairs, Australian Government, *British Nuclear Tests*, November 2014, available at: www.dva.gov.au/benefits-and-payments/british-nuclear-tests.

explained, have been removed from the National Archives.[42] For survivors, time is running out. In 2013, it was estimated that only 2,000 of the over 16,000 Australian test participants were still alive.[43]

While investigation of radioactive contamination from nuclear tests is important, the conduct of much research and monitoring of fallout from nuclear tests has been seriously deficient in ethical conduct, respect for human rights, transparency and accountability. An Australian example is an extensive programme of sampling of human bones for strontium-90. 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 the fact that many remains were kept without their knowledge or consent for decades.[44] There are disturbing reports of families being denied access to their dead 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.[45] This study was one of approximately 4,000 human radiation experiments conducted under the auspices of the US Atomic Energy Commission over the period 1944–74. Some involved significant health risk to subjects; in some experiments, patients were subjected to sufficiently high doses to develop acute radiation sickness, which was sometimes fatal.[46]

British nuclear tests in the central Pacific

With mounting public concern over radioactive fallout, the Australian government in 1956 rejected hydrogen bomb trials for "safety reasons". As a consequence, Britain had to take its hydrogen bomb development to its then colonized area of the central Pacific. Undertaken in considerable haste because of an impending agreement to suspend atmospheric nuclear testing, the UK detonated its first three hydrogen bombs at Malden Island in 1957. Despite being airbursts, these massive explosions contaminated Malden, and subsequent tests were moved to Christmas Island (known locally as Kiritimati Island, now part of the Republic of Kiribati), the largest coral island in the world. In both places, hundreds of British soldiers and sailors, 551 crew on two New Zealand frigates, and nearly 300 Fijian soldiers and sailors worked in close proximity, as well as local Gilbertese

42 F. Walker, above note 29, p. 246.
43 *Ibid.*, p. 274.
44 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.
45 F. Walker , above note 29, pp. 218–230.
46 Advisory Committee on Human Radiation Experiments, *Final Report*, US Government Printing Office, Washington, DC, October 1995, p. 779.

plantation workers and their families. The latter were evacuated to Fanning Island or kept on ships during the tests.[47]

British military documents reveal that one of the purposes of the tests was to study the effects of nuclear explosions on people – for example, "The Army must discover the detailed effects of various types of explosion on equipment, stores and men, with and without various types of protection."[48] As in Australia, radiation exposures for service personnel in the Christmas and Malden Island tests were not systematically monitored, and personal protection was minimal. Personnel were assembled in the open at varying distances "backs to the blast" during each nuclear explosion.[49] "Clean-up" operations included disposing of thousands of seabirds maimed, blinded or killed by the nuclear explosions, as well as dumping drums of nuclear waste into the ocean. The massive 2.8 Mt Grapple Y explosion, on 28 April 1958, detonated lower than anticipated and sucked up large quantities of water and debris, accentuating the radioactive fallout, which was also exacerbated by a wind change that blew the main fallout cloud over Christmas Island. Personnel report being soaked by radioactive rainout after various blasts, with reports of hair loss and skin burns soon afterwards suggestive of acute radiation effects (and therefore high doses).[50]

"Sniffer" aircraft that flew through mushroom clouds minutes after the explosions to collect samples were associated with high exposures to the crews, with a mean of over 50 mSv per person per test.[51] Well-conducted studies among the New Zealand test veterans (who on average participated in three times as many nuclear tests as their British counterparts) demonstrated an excess of haematological cancers including leukaemia.[52] Sophisticated genetic studies in a group of veterans, compared with ex-servicemen controls extremely well matched except for their absence of nuclear test service, showed highly statistically significant (three-fold) higher rates of chromosomal abnormalities, such as translocations, dicentric chromosomes and complex chromosomal rearrangements, among the test veterans.[53] It is salutory that such evidence of long-term genetic damage was evident

47 Losena Tubanavua-Salabula, Josua M. Namoce and Nic Maclellan (eds), *Kirisimasi: Fijian Troops at Britain's Christmas Island Nuclear Tests*, Pacific Concerns Resource Centre, Suva, 1999, p. 15.
48 *Ibid*., p. 16.
49 Anthony Robbins, Arjun Makhijani and Katherine Yih, *Radioactive Heaven and Earth: The Health and Environmental Effects of Nuclear Weapons Testing In, On and Above the Earth*, Report of the IPPNW International Commission to Investigate the Health and Environmental Effects of Nuclear Weapons Production and Institute for Energy and Environmental Research, The Apex Press, New York, and Zed Books, London, 1991, pp. 126–128; Denys Blakeway and Sue Lloyd-Roberts, *Fields of Thunder: Testing Britain's Bomb*, Unwin Paperbacks, London, 1985, pp. 153–175.
50 L. Tubanavua-Salabula, J. M. Namoce and N. Maclellan (eds), above note 47, pp. 17–18, 60–61. Eyewitness accounts by British troops are documented in Denys Blakeway and Sue Lloyd-Roberts, *Fields of Thunder: Testing Britain's Bomb*, Unwin Paperbacks, London, 1985, pp. 156–157, 170–172.
51 A. Robbins, A. Makhijani and K. Yih, above note 49, p. 128.
52 Neil Pearce, Ian Prior, David Methven, Christine Culling, Stephen Marshall, Jackie Auld, Gail de Boer and Peter Bethwaite, "Follow-Up of New Zealand Participants in British Atmospheric Nuclear Weapons Tests in the Pacific", *British Medical Journal*, Vol. 300, May 1990.
53 May Abdel Wahab, Elizabeth M. Nickless, Radhia Najar-M'Kacher, Claude Parmentier, John V. Podd and R. E. Al Rowland, "Elevated Chromosome Translocation Frequencies in New Zealand Nuclear Test Veterans", *Cytogenetic and Genome Research*, Vol. 121, June 2008.

fifty years after the veterans' exposure to nuclear tests. The New Zealand government in 1998 provided full war pensions for disabilities relating to their service for Christmas Island nuclear test veterans.[54]

Fiji's Prime Minister Bainimarama announced on 30 January 2015 that the Fiji government would grant compensation to the surviving Fijian military personnel who witnessed the UK Grapple nuclear tests in 1957–58 (it was Bainimarama's father who led the first Fijian naval contingent sent to Christmas Island):

> To this day, Britain has refused to pay compensation to anyone despite successive surveys that have shown veterans suffering from a range of terrible ailments – leukemia, other blood disorders, skin complaints and other conditions. And worse, these effects appear to have passed to some of their children, who were born with congenital deformities and a range of diseases. …
>
> You may ask: why is Fiji taking responsibility for something that is the fault of Britain? My answer is this: Too much time has passed. The ranks of these survivors are rapidly thinning. Too many men – our fellow Fijians – have gone to their graves without justice. Those who remain deserve justice and Fiji as a nation is determined for them to finally get it. … There is a saying that justice delayed is justice denied. …
>
> You are living testament to our determination to never again allow our pristine Pacific environment to be violated by outside powers in such a destructive and terrible manner.
>
> … [N]ot only the British but other colonial powers such as the United States and France, used the Pacific to test weapons of mass destruction that some of them would never have tested in their own backyards. … As one, the Pacific nations stand and say: Never again. …
>
> It is a form of madness that we in the Pacific – the ocean that takes its name from the word "peace" – find incomprehensible. … [W]e will always be on the side of those nations pressing for the dismantling of the world's nuclear arsenals. And to finally draw a line under the era that these men here today witnessed for themselves.[55]

While is it regrettable that such recognition and compensation has come so long – almost sixty years – after the tests and not from the United Kingdom, which conducted the nuclear test explosions, the prime minister's emphasis on justice and the need for humane support for those put in harm's way is admirable. Notable too is his linkage of Pacific peoples' experience of the impacts of nuclear testing with informing and motivating rejection of nuclear weapons and action to eliminate them.

54 L. Tubanavua-Salabula, J. M. Namoce and N. Maclellan (eds), above note 47, pp. 68–69.

55 Voreqe Bainimarama, "Hon PM Bainimarama Speech at the First Pay-out to Veterans of Operation Grapple, Christmas Island", Fijian Government, 30 January 2015, available at: www.fiji.gov.fj/Media-Center/Speeches/HON-PM-BAINIMARAMA-SPEECH-AT-THE-FIRST-PAY-OUT-TO-.aspx .

French nuclear tests in Polynesia

After four atmospheric tests at Reganne, Algeria, in 1960–61, France continued its nuclear testing programme there even after independence in 1962, with thirteen underground tests at Eker between 1961 and 1966 while its Pacific Testing Centre was being built. France then detonated forty-six atmospheric and 147 underground nuclear explosions in Polynesia. The first was detonated on 2 July 1966. Because of the presence, insistence and impatience of President de Gaulle, despite unfavourable winds to the west, an explosion on 11 September 1966 carried fallout directly towards populated areas.[56] In Apia, Samoa, 3,700 km downwind, as a result of rainout, total beta radioactivity increased from the usual level of around 200 megabecquerel (MBq) per km^2 to 370,000 MBq per km^2 after this test.[57]

France refused US urging to sign the Partial Test Ban Treaty of 1963, which banned nuclear test explosions anywhere but underground; it continued atmospheric tests until 1974.[58] After a moratorium on nuclear tests from 1992 to 1995, France conducted a final six underground nuclear tests in 1995–96 in order to be able to continue developing new nuclear weapons without explosive testing, prior to signing the CTBT when it opened for signature on 24 September 1996.[59]

France's nuclear test programme has been associated with an extreme level of secrecy about all its aspects and initially categorical denial of any health or environmental impacts. Intelligence agencies undertook sabotage of protest boats and infiltrated organizations opposed to nuclear tests. The French State went to the violent lengths of destroying with two mines the Greenpeace flagship *Rainbow Warrior*, on 7 July 1985, while it was moored in Auckland Harbour *en route* to Moruroa; the operation, which killed photographer Fernando Pereira, was reportedly sanctioned by President Mitterrand.[60] Two captured perpetrators returned to France after cursory detention, receiving military promotions, and one a military medal.[61] Despite greater transparency since the end of the testing programme, much secrecy, for example about the extent of radioactive contamination, continues to this day.

Most of the early atmospheric tests were performed on the surface or on barges in the lagoon, resulting in high levels of radioactive fallout. Fallout repeatedly contaminated the neighbouring islands of Tureia and Mangareva, where the population totalling 1,100 were repeatedly evacuated to shelters.[62]

56 Bengt Danielsson, "Poisoned Pacific: The Legacy of French Nuclear Testing", *Bulletin of the Atomic Scientists*, Vol. 46, No. 2, 1990.
57 A. Robbins, A. Makhijani and K. Yih, above note 49, p. 143.
58 Only China conducted atmospheric tests later, until 1980. SIPRI, above note 2, pp. 349–351.
59 Nic Maclellan and Jean Chesneaux, *After Moruroa: France in the South Pacific*, Ocean Press, Melbourne, 1998, p. 102.
60 Marlise Simons, "Report Says Mitterand Approved Sinking of Greenpeace Ship", *International New York Times*, 10 July 2005, available at: www.nytimes.com/2005/07/10/world/europe/report-says-mitterrand-approved-sinking-of-greenpeace-ship.html.
61 N. Maclellan and J. Chesneaux, above note 59, p. 215.
62 A detailed review of the French Pacific nuclear tests including eyewitness accounts can be found in Commission d'Enquete sur les Consequences de Essais Nucleaire (CESCEN), *Les polynesiens et les essais nucleaires*, Deliberation No. 2005-072, Assemblee de la Polynesie Francaise. A useful report

Although tests were generally conducted when fallout would be carried eastwards towards South America, before circling the earth in lower and middle latitudes, sometimes fallout was carried westwards towards populated areas, neighbouring Pacific island countries, New Zealand and Australia. For example, following a test on 19 July 1974, average total beta activity in air increased from less than 0.3 to 1,460 mBq per m^3 in the Tahitian capital, Papeete.[63]

Extensive physical damage to the testing atolls occurred, with ongoing risks of collapse and leakage. Early tests were conducted under the atoll rim, until extensive fracturing and fissures in the coral and underlying basalt, subsidence and subterranean landslides necessitated use of the central lagoon. A 150 kt explosion beneath the reef at Moruroa was detonated on 25 July 1979, despite the device becoming stuck 800 metres down a 1,000-metre shaft. This caused a submarine landslide dislocating an estimated 1.1 million m^3 of coral and rock, resulting in a 3-metre wave which swept over the southern part of Moruroa and through the Tuamotu Archipelago.[64] Reports from 2011 and 2013 by the French Delegate for Nuclear Safety and Radiation Protection for Defense Activities (Délégué à la Sûreté Nucléaire et à la Radioprotection pour les Activités Intéressant la Défense, DSND)[65] and Atomic Energy Commission (Commissariat à l'Énergie Atomique et aux Énergies Alternatives, CEA)[66] respectively acknowledge previous collapses of the outer wall of the atoll – carbonates, mostly limestone and dolomite atop a basalt base. The reports note that even though the tests have ended, this type of event could happen again, particularly in three areas on the northeast flank of Moruroa, where six of twenty-eight underground tests released radioactivity into the ocean through fissures in the basalt. The CEA envisaged a possible scenario of a landslide of some 670 million m^3 of rock, creating a 15- to 20-metre tsunami wave, swamping the east of the atoll and threatening neighbouring inhabited islands.[67]

Extensive radioactive, chemical and other waste on land, in lagoons and in the ocean remains both at the former testing sites and at a network of facilities and infrastructure supporting the massive nuclear weapons enterprise, including the military harbours in Papeete and Mangareva, and the huge staging base for the nuclear test programme at Hao Atoll, which became the largest military base in the South Pacific.[68] In 2006, the DSND revealed that large amounts of radioactive

compiling eyewitness accounts in English is Pieter de Vries and Han 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, Lyon, 1997.

63 A. Robbins, A. Makhijani and K. Yih, above note 49, p. 143; Angelique Chrisafis, "French Nuclear Tests 'Showered Vast Area of Polynesia with Radioactivity'", *The Guardian*, 4 July 2013, available at: www.theguardian.com/world/2013/jul/03/french-nuclear-tests-polynesia-declassified.

64 A. Robbins, A. Makhijani and K. Yih, above note 49, p. 145.

65 DSND, *Surveillance geomecanique de Mururoa*, 25 January 2011, pp. 1–6.

66 Departement de Suivi des Centres D'Experimentations Nucleaires, Ministere de la Defense et des Anciens Combattants, *Surveillance des atolls de Mururoa et de Fangataufa*, Vol. 2: *Bilan de l'evolution geomecanique des atolls de Mururoa et Rangiroa*, DO 312 CEA/DIF/DASE/LDG, 13 September 2013, pp. 5–53.

67 *Ibid.*, p. 19.

68 CESCEN, above note 62, p. 55.

material were simply dumped in the ocean – 2,656 tons in two sites at Moruroa, and 532 tons at Hao.[69] All the waste on atolls and in lagoons will become more difficult to monitor, recover or otherwise remediate, and will increasingly be released into the marine environment as a result of inevitably accelerating sea-level rise related to global warming; whilst declining physical integrity and storms and hurricanes of increasing intensity will mean that more waste is physically disrupted and dispersed.

Despite extremely limited access and sampling opportunities, previous independent investigations have documented the presence of short-lived isotopes including iodine-131, tritium and caesium-134 in coral interstices and in lagoon sediment and plankton, indicating rapid leakage of fission products over a time frame as short as days, not centuries or millennia as previously claimed by French authorities. In addition, more than 20 kg of plutonium (an extremely potent carcinogen if inhaled) is estimated to be scattered across the Moruroa and Fangataufa lagoons.[70]

In 2006, the French Army published estimates of radiation exposures for six locations for the six tests that it states led to the highest fallout, though release of all available radiological data related to the Polynesian tests has still not occurred.[71] The highest estimated effective doses after a single test were up to 10 mSv for infants in the Gambier Islands, and an average of 5.2 mSv for infants in Tahiti, 1,200 km away. Thyroid doses for infants of up to 80 mSv in the Gambiers and up to 49 mSv in Tahiti were estimated, again following single tests, from a total of forty-five atmospheric nuclear test explosions. By way of perspective, these doses are within the range of anticipated thyroid radiation exposure for children under 18 years, along with pregnant and lactating women, warranting administration of stable iodine to protect against uptake of radioactive iodine (this threshold varies between 10 milligray (mGy)[72] and 50 mGy[73]). Independent researchers conclude that the limited data available likely miss areas of high exposure and probably underestimate the doses received.[74]

During the decades of the testing programme, protection, health monitoring and care of those at greatest risk were grossly neglected. Health data were inadequate – an incomplete cancer registry was only established twenty years after the tests began, and still failed to register congenital malformations. In 2008–09 the French government introduced the Morin Law, which established a

69 DSND, *Les essais nucleaires Francais dans le Pacifique: Mission du delegue a la Surete Nucleaire et a la Radioprotection pour les activites et Installations Interessant la Defense (DSND)*, May 2006.
70 A. Robbins, A. Makhijani and K. Yih, above note 49, pp. 143–149.
71 DSND, above note 69, pp. 8–12.
72 World Health Organization (WHO), *Guidelines for Iodine Prophylaxis Following Nuclear Accidents: Update 1999*, Geneva, 1999, p. 4.
73 Center for Drug Evaluation and Research (CDER), Food and Drug Administration, *Guidance: Potassium Iodide as a Thyroid Blocking Agent in Radiation Emergencies*, US Department of Health and Human Services, Rockville, MD, December 2001, p. 6.
74 Florent de Vathaire, Vladimir Drozdovitch, Pauline Brindel, Frederique Rachedi, Jean-Louis Boissin, Joseph Sebbag, Larrys Shan, Frederique Bost-Bezeaud, Patrick Petitdidier, John Paoaafaite, Joseph Teuri, Jacques Iltis, Andre Bouville, Elisabeth Cardis, Catherine Hill and Francoise Doyon, "Thyroid Cancer Following Nuclear Tests in French Polynesia", *British Journal of Cancer*, Vol. 103, No. 7, 2010, p. 1118.

mechanism for compensation for health impacts associated with service or employment at the nuclear tests sites. However, this law has been widely criticized as too restrictive in the access it provides to compensation for former test workers.[75] No medical follow-up was undertaken of the up to 13,000 Polynesians who worked in the test programme,[76] but evidence not only of health risk but also of health harm is clearly emerging. Recent data demonstrate that the incidence of acute myeloid leukaemia in French Polynesia is the highest in the world.[77] A clear gradient of thyroid cancer incidence associated with the level of radiation to the thyroid from the atmospheric nuclear tests has been demonstrated.[78] The International Agency for Research on Cancer's most recent report on global cancer rates that includes data for French Polynesia (covering the period 1998–2002) reveals that women in French Polynesia have the highest rates of thyroid cancer and myeloid leukaemia in the world[79] – both these cancers are among those most strongly associated with radiation exposure.

An important environmental and health impact of the nuclear test programme in French Polynesia and also in the Marshall Islands is outbreaks of ciguatera fish poisoning.[80] Ciguatera is the most common type of toxin poisoning by marine foods worldwide, and is found across many tropical regions. It is a disease of the food chain, with microscopic dinoflagellate plankton producing toxins which concentrate up the food chain, producing sometimes severe and protracted illness. Fish most likely to be toxic are larger carnivorous reef fish accessible to local people and prized for eating. The toxins cannot be identified by any simple means and survive cooking. Ciguatera plankton preferentially proliferate on dead or damaged coral surfaces. Outbreaks of ciguatera have been associated with many types of damage to coral reefs, including blasting, waste dumping, construction activities and nuclear test explosions. There is clear evidence of high levels of ciguatera in French Polynesia during the testing programme, extremely high levels of toxicity at Moruroa and in the military harbour at Mangareva, and extensive outbreaks associated with coral reef damage from construction, shipping and waste dumping associated with the nuclear test programme. For example, during construction of the staging base at Hao Atoll, a large outbreak affected almost half the population in

75 Campbell Cooney, "French Polynesia Rejects Nuclear Compensation", *Radio Australia*, 15 February 2012, available at: www.radioaustralia.net.au/international/radio/onairhighlights/french-polynesia-rejects-nuclear-compensation.

76 CESCEN, above note 62, p. 135.

77 Bernard Rio, Laurence Heuberger, Gilles Soubiran, Robert Zittoun and Jean-Pierre Marie, "Incidence Rates of Leukemia in French Polynesia", *International Journal of Cancer*, Vol. 131, 2012.

78 Constance Xhaard, Yan Ren, Enora Clero, Stephane Maillard, Pauline Brindel, Frederique Rachedi, Jean-Louis Boissin, Joseph Sebbag, Larrys Shan, Frederique Bost-Bezeaud, Patrick Petitdidier, Vladimir Drozdovitch, Francoise Doyon, Carole Rubino and Florent de Vathaire, "Differentiated Thyroid Carcinoma Risk Factors in French Polynesia", *Asian Pacific Journal of Cancer Prevention*, Vol. 15, No. 6, 2014; F. de Vathaire *et al.*, above note 74, pp. 1117–1119.

79 Christine Bouchardy, Simone Benhamou, Florent de Vathaire, Robin Schaffar and Elisabetta Rapiti, "Incidence Rates of Thyroid Cancer and Myeloid Leukaemia in French Polynesia", *International Journal of Cancer*, Vol. 128, 2011.

80 Tilman A. Ruff, "Ciguatera in the Pacific: A Link with Military Activities", *The Lancet*, Vol. 1, 1989.

1968.[81] Ciguatera has important nutritional, social and economic implications, interfering with local inshore, largely subsistence, traditional fishing and increasing dependence on imported foods, with their exacerbation of risk factors for chronic disease.[82]

US nuclear tests in the Marshall Islands

Following World War II, the Marshall Islands became part of the strategic Trust Territory of the Pacific Islands. In 1946, after the detonation of two atomic bombs in the Bikini lagoon, the United States was given authority by the United Nations (UN) to administer the islands as a Strategic Trusteeship. Such trusteeships were intended to "promote the political, economic, social and educational advancement of the inhabitants of the trust territories and their progressive development towards self-government or independence",[83] and "to encourage respect for human rights and fundamental freedoms".[84] The United States was obligated as the administering authority "to protect the land, resources, and health of Micronesia's inhabitants".[85] It is to the shame of all nations that two UN resolutions explicitly authorizing testing of nuclear weapons in the Marshalls were adopted in 1954[86] and 1956,[87] against the wishes of the Marshallese people.[88] These are the only instances in which the UN explicitly authorized nuclear weapons testing.

My island is contaminated. I have three tumours in me, and I'm frightened. I don't know whether I should have children or not, because I don't know if I will have a child that is like a jellyfish baby. All I know is that I must travel the world and share our story of the bombs, so that we can stop them – before they get to you.

– Darlene Keju, Marshallese activist and educator (1951–1996).*

When the US military governor of the Marshall Islands approached the Bikini Atoll community in February 1946, requesting that they leave their island,

81 *Ibid.*, pp. 202–203; Raymond Bagnis, "Naissance et development d'une flambee de ciguatera dans un atoll des Tuamotu", *Revue des Corps de Sante*, Vol. 10, No. 6, 1969.
82 Tilman Ruff, "Bomb Tests Attack the Food Chain", *Bulletin of the Atomic Scientists*, Vol. 46, No. 2, 1990.
83 UN Charter, 14 August 1941 (entered into force 24 October 1945), Art. 76(b).
84 *Ibid.*, Art. 76(c).
85 Human Rights Council, Report of the Special Rapporteur on the Implications for Human Rights of the Environmentally Sound Management and Disposal of Hazardous Substances and Wastes, Calin Georgescu, Addendum, Mission to the Marshall islands (27–30 March 2012) and the United States of America (24–27 April 2012), UN Doc. A/HRC/21/48/Add.1, 3 September 2012, p. 4, para. 10.
86 UN Trusteeship Res. 1082, 15 July 1954.
87 UN Trusteeship Res. 1493, 29 March 1956.
88 Human Rights Council, above note 85, p. 5.
* Cited in Nic Maclellan, "The Long Shadow of Bravo", *Inside Story*, 24 February 2014, p. 20, available at: http://insidestory.org.au/the-long-shadow-of-bravo.

it was so that the nuclear testing programme could redirect atomic energy "for the good of mankind and to end all wars".[89] Instead, what the Marshallese got was an influx of 42,000 US soldiers, causing displacement and dispossession; a massive programme of sixty-seven atmospheric nuclear explosions; vaporization of whole islands; and radioactive fallout repeatedly contaminating all their lands and seas. They also became uninformed and unconsenting subjects in harmful and unethical surveillance and research. The total explosive yield of the bombs detonated in the Marshalls was ninety-three times that of all US atmospheric tests conducted in Nevada;[90] the equivalent of 1.6 Hiroshima bombs each day over the twelve years of the tests (1946–58). What the Marshallese were left with as a result was a humanitarian disaster of fallout, displacement and human rights violations.[91]

The second US "Baker" test at Bikini in 1946 was an underwater explosion that threw up millions of tons of contaminated water and created vast radioactive mists. The US Joint Chiefs of Staff 1947 evaluation of the atomic bomb as a military weapon provides a chilling assessment of the extensive and indiscriminate nature of the radioactive fallout:

> Of the survivors in the contaminated areas, some would be doomed by radiation sickness in hours, some in days, some in years. But, these areas, irregular in size and shape, as wind and topography might form them, would have no visible boundaries. No survivor could be certain he was not among the doomed, and so added to every terror of the moment, thousands would be stricken with the fear of death and the uncertainty of the time of its arrival.[92]

Frequent claims of safety and lack of adverse health effects of nuclear tests common to all testing nations were starkly contradicted by military plans to use fallout as a weapon of terror, as the Joint Chiefs of Staff concluded in the same assessment:

> In the face of … the bomb's demonstrated power to deliver death to tens of thousands, of primary military concern will be the bomb's potentiality to break the will of nations and of peoples by the stimulation of man's primordial fears, those of the unknown, the invisible, the mysterious. … [E]ffective exploitation of the bomb's psychological implications will take precedence over the application of the destructive and lethal effects …[93]

The "Castle Bravo" test of 1 March 1954 at Bikini, 1,000 times as powerful as the Hiroshima bomb, was the largest US nuclear test ever conducted.[94] Although the

89 Ruth Levy Guyer, "Radioactivity and Rights: Clashes at Bikini Atoll", *American Journal of Public Health*, Vol. 91, No. 9, 2001.
90 F. Warner and R. J. C. Kirchmann (eds), above note 7, pp. 19–22.
91 Human Rights Council, above note 85, p. 6.
92 US Joint Chiefs of Staff Evaluation Board, *The Evaluation of the Atomic Bomb as a Military Weapon, Final Report*, 30 June 1947, Part IV, Section 7, para. 4, cited in Jonathan M. Weisgall, *Operation Crossroads: The Atomic Tests at Bikini Atoll*, Naval Institute Press, 1994, pp. 291–292. See also Matthew L. Wald, "Early Nuclear Plan Weighed Radioactive Sprays", *New York Times*, 19 November 1992, available at: www.nytimes.com/1992/11/19/us/early-nuclear-plan-weighed-radioactive-sprays.html.
93 US Joint Chiefs of Staff Evaluation Board, above note 92, Part IV, Section 8, para. 6
94 F. Warner and R. J. C. Kirchmann (eds), above note 7, pp. 19–22.

military had learned many hours before the blast that winds were blowing towards inhabited islands, they chose not to evacuate those in the likely path, nor to delay the explosion. Unlike for other nuclear tests over the previous eight years, there was no warning given to the people on Rongelap and other downwind islands, nor were they moved. Two islands and part of a third were vaporized in the explosion, and fallout rained down on the food crops, water catchments, houses, land and bodies of children, women and men going about their daily activities. Children played with the unknown "snow" and rubbed it in their hair and on their skin.[95] The residents of Rongelap, Ailinginae and Utrik Atolls were finally evacuated two and a half days later, after having received near-lethal doses of radiation, the highest following a single test in the history of nuclear test explosions worldwide.[96]

The 1955 US government assessment of "Bravo" fallout that all twenty-two populated atolls of the Marshalls received hazardous fallout was kept classified. As comprehensively documented in the *Rongelap Report*,[97] medical follow-up and interventions undertaken by US government agencies (principally the Brookhaven National Laboratory, Atomic Energy Commission and then Department of Energy) were aimed not primarily at serving patient care, but at monitoring and documenting long-term movement of radioisotopes in the environment, foodstuffs, and humans, and the health effects for people deliberately returned to a contaminated environment that was known to be hazardous. Research documenting the late effects of radiation, the secret Project 4.1, involved 539 children, women and men who did not give informed consent. Some received radioisotope injections including chromium-51, radioactive iodine, iron, zinc, carbon-14 and tritiated water, and underwent experimental surgery and procedures that were not carried out for their benefit. Many regularly underwent treatment that was dehumanizing, painful and traumatic.[98]

Thyroid doses in Rongelap were estimated at several tens of gray (Gy) for an adult and more than 100 Gy for a 1-year-old infant[99] – more than 2,000 times higher than the accidental thyroid exposure of 50 mGy for a child, which warrants urgent protective administration of stable iodine.[100] The majority of those highly exposed as children have developed one or more thyroid diseases, including cancer.

In 1954, the Marshallese lodged a petition with the UN Trusteeship Council just weeks after the Bravo test, requesting that "all experiments with lethal weapons in this area be immediately ceased."[101] The petition stated:

95 Barbara Rose Johnston and Holly M. Barker, *Consequential Damages of Nuclear War: The Rongelap Report*, Left Coast Press, Walnut Creek, CA, 2008, pp. 95–100.
96 Steven L. Simon, André Bouville and Charles E. Land, "Fallout from Nuclear Weapons Tests and Cancer Risks", *American Scientist*, Vol. 94, January–February 2006.
97 B. R. Johnston and H. M. Barker, above note 95, Part 3, pp. 109–161.
98 *Ibid*., pp. 103–107, 109–117; Human Rights Council, above note 85, pp. 12–13.
99 S. L. Simon, A. Bouville and C. E. Land, above note 96, p. 52.
100 CDER, above note 73, p. 6.
101 Petition from the Marshallese People Concerning the Pacific Islands, "Complaint Regarding Explosions of Lethal Weapons within Our Home Islands to United Nations Trusteeship Council, 20 April 1954", UN Trusteeship Council Doc. T/PET.10/28, 6 May 1954.

> The Marshallese people are not only fearful of the danger to their persons from these deadly weapons in case of another miscalculation [referring to the detonation of the "Bravo" test explosion, when the winds carried fallout towards inhabited islands], but they are also concerned for the increasing number of people removed from their land. … [L]and means a great deal to the Marshallese. It means more than just a place where you can plant your food crops and build your houses or a place where you can bury your dead. It is the very life of the people. Take away their land and their spirits go also.[102]

The people of Bikini were later moved to Rongerik, where they endured periods of near-starvation, then Kwajalein, then Kili, where there was no lagoon or fishing grounds to support their traditional way of life. They were later moved back to Bikini and then, owing to higher than permissible radiation, to the Kili and Ejit islands of Majuro Atoll.[103] The people of Rongelap were returned to their atoll in 1957, but voluntarily evacuated in 1985 because of evidence of continuing excessive radiation levels unacceptable in other US jurisdictions. Soil on Rongelap contains about 430 times the amount of plutonium-239 and other transuranics than the northern hemisphere average. In the words of Rongelap Councilwoman Rokko Langinbelik: "We left Rongelap because we didn't want our children to be poisoned like we are. Even if we were sad, we left. We left because we care about our children."[104] Important evidence of continuing residual radioactivity at contaminated atolls, and the concentration of key radioisotopes in major food sources such as iron-55 in reef fish and cesium-137 in coconut crabs, trees and fruit, was not made available to the affected Marshallese for decades.[105]

For almost sixty years, we have been displaced from our homeland, like a coconut floating in the sea.

– Lemyo Abon, nuclear test survivor, Rongelap Atoll, Marshall Islands.*

In 1986 the governments of the Marshall Islands and the United States adopted a Compact of Free Association, a program of US aid in return for continued US military exploitation. As part of the negotiations, the two governments agreed to establish a Nuclear Claims Tribunal to settle claims for personal injury and property damage resulting from the nuclear tests. In exchange for dropping $5 billion worth of civil claims before US courts, a $150 million trust fund was established to fund payouts for health impacts and property damage assessed by the tribunal judges. The Marshall Islands had to give up all claims "past, present and future … [that are] based on, arise out of or are in any way related to the Nuclear Testing Program, and which are against the

102 *Ibid.*
103 Human Rights Council, above note 85, pp. 4–5.
104 B. R. Johnston and H. M. Barker, above note 95, p.160.
105 *Ibid.*, pp. 116–125.
* Cited in N. Maclellan, below note 106, p. 1.

United States".[106] However the Marshallese right to return to the US Congress to expand the pool of funds was agreed, should "circumstances change" or new information come to light.

For property damage, only $4 million of awards totalling $2.3 billion have been paid. While the situation is somewhat better for health impact compensation, $23 million out of 2,000 awards totalling $96 million is still owing, and awards for clean-up of residual contamination amount to $531 million in excess of those allocated by the US government. No payments have been made since 2008; currently the Nuclear Claims Fund contains less than $50,000, and new claims have been suspended. Since 2001, the Marshall Islands have requested that the US Congress fully fund the Nuclear Claims Tribunal, arguing that circumstances had changed substantially as a result of declassification of information in 1996 and new data revealing a far greater extent of contamination and health harm than previously acknowledged. Of course, health impacts will continue to appear both for those exposed to the bombs and those living in contaminated environments. The US National Cancer Institute estimated in 2004 that about half the extra cancers that would occur as a result of fallout in the Marshalls were still to come.[107] Noting that the Nuclear Claims Tribunal was grossly underfunded, the US President's Cancer Panel has called for the US government to honour and make payments according to the judgment of the tribunal.[108]

Even in this case, where persistent pursuit of justice by the Marshallese and their supporters has led to welcome and overdue recognition and some compensation has been allocated, it is still too little and too late. The United States, like every other testing nation, is seeking to avoid its responsibility for the catastrophic, long-persisting fallout of its nuclear explosions, and the need to make amends.

The effects of radiation have been exacerbated by near-irreversible environmental contamination, leading to the loss of livelihoods and lands. Moreover, many people continue to experience indefinite displacement.

– UN Special Rapporteur Calin Georgescu on the legacy of nuclear testing in the Marshall Islands.*

Some northern atolls have been declared off-limits for the next 24,000 years, and some severely affected islands and hotspots are too severely contaminated ever to be effectively cleaned up.[109] Nor has the risk of further contamination ended with the nuclear tests. The UN Special Rapporteur expressed particular concern about the radioactive dump site on Runit Island, in view of evidence of lack of structural integrity. The Special Rapporteur noted that his

106 Nic Maclellan, "The Long Shadow of Bravo", *Inside Story*, 24 February 2014, available at: http://insidestory.org.au/the-long-shadow-of-bravo; Human Rights Council, above note 85, pp. 10–15.
107 Human Rights Council, above note 85, p. 7.
108 *Ibid.*, p. 12.
109 A. Robbins, A. Makhijani and K. Yih, above note 49, pp. 83, 85.
* Human Rights Council, above note 85, p. 6.

2012 visit was the first by a UN official in sixty-five years.[110] The United States has generally ignored his landmark recommendations. Especially given the historical role of the UN in designating the Marshall Islands as a strategic trust territory, there are at least moral and humanitarian obligations for the international community, through the UN, to assist in the care, compensation and clean-up owed to the environment, health and well-being of the Marshallese people.

Foreign exploitation of the Marshall Islands for nuclear military purposes continues in the use of Kwajalein (with the world's largest lagoon) and Aur Atolls as part of the Ronald Reagan Ballistic Missile Defense Test Site.[111] Used for missile, missile defence and space research, Kwajalein serves as a launch site for missiles, and its lagoon serves as a splashdown site for long-range ballistic missiles intended for delivery of nuclear weapons, launched from Vandenberg Air Force Base in California. The US military occupies eleven of Kwajalein's islands, while 10,000 Marshallese, many living in poverty, are crowded into 32 hectares on Ebeye Island, one of the most crowded places in the Pacific.[112]

The bitter experience and lingering legacy of nuclear explosions, the conviction born of the deep shared understanding, in the words of Marshallese foreign minister Tony de Brum, that "these weapons are the enemy of all humankind",[113] has inspired courageous legal action. In 2014 the Republic of the Marshall Islands (RMI) brought lawsuits against all nine nuclear-armed States before the International Court of Justice (ICJ), and additionally against the United States in the US Federal District Court in San Francisco, alleging that all are in breach of their Non-Proliferation Treaty and/or customary international law obligations to achieve nuclear disarmament.[114] In February 2015 a US federal judge dismissed the US case, ruling that the case was speculative and that the Marshall Islands lacked standing to bring the suit. The RMI appealed this decision and at time of writing this appeal is still before the US court. The cases brought by the RMI in the ICJ seek a declaration by the Court that each of the nuclear-armed States, by failing to pursue and bring to a conclusion negotiations leading to nuclear disarmament, while maintaining, building up and/or modernizing their nuclear arsenals, is in breach of their international obligations,

110 Presentation by Special Rapporteur Calin Georgescu with Women's International League for Peace and Freedom and International Campaign to Abolish Nuclear Weapons, UN Human Rights Council Side Event, Geneva, 14 September 2012.

111 Ronald Reagan Ballistic Missile Defense Test Site official website, available at: www.smdc.army.mil/RTS.html.

112 Dan Zak, "On the Island of Ebeye, a Nuclear Past and a Ballistic Present", *Pulitzer Center on Crisis Reporting*, 18 December 2015, available at: http://pulitzercenter.org/reporting/island-ebeye-nuclear-past-and-ballistic-present.

113 Tony de Brum, speech delivered to the Marshall Islands Parliament, 23 February 2015, available at: www.wagingpeace.org/speech-delivered-to-the-marshall-islands-parliament/.

114 ICJ, *Obligations concerning Negotiations relating to Cessation of the Nuclear Arms Race and to Nuclear Disarmament (Marshall Islands v. the United States, Russia, the United Kingdom, France, China, India, Israel, Pakistan and North Korea)*, applications submitted 24 April 2014; United States Court of Appeals, *Republic of the Marshall Islands v. United States*, Case No. 14-01885 (NDCA), dismissed, USCA No. 15-15636, 9th Circuit (appeal filed 31 July 2015). More information on the cases and related documents available at: www.nuclearzero.org.

and seeks orders for them to comply within one year. Among the nuclear-armed States, only India, Pakistan and the United Kingdom accept compulsory jurisdiction of the ICJ. They have raised objections to the cases proceeding. Only India and the United Kingdom have chosen to appear at the initial Court hearings that will take place in March 2016 to determine on jurisdiction and admissibility and whether the cases should proceed to consideration on their merits.[115]

Lessons and implications of Pacific nuclear test explosions

A number of common features and lessons emerge from this review of the humanitarian impacts – some short-term, some long-term – of nuclear test explosions in the Pacific region. An intrinsic structural conflict of interest was inevitable and manifest in every testing programme, where the military organizations prosecuting the tests were also in charge of monitoring and protection of the environment and downwind populations. The overall priority was nuclear weapons development, whatever the cost. Putting agencies whose mission is nuclear weapons development in charge of caring for those harmed by their core business is truly like putting the fox in charge of the henhouse.

In the headlong rush to develop, test and deploy the world's most destructive weapons, safety, environmental and health considerations were often irresponsibly sidelined, even by the available knowledge and standards of the time. In general in relation to radiation health effects, the more we learn, the greater the health harm that is associated with a given dose of radiation. From 1950 to 1991, the maximum recommended whole-body radiation annual dose limits for radiation industry workers declined from approximately 250 to 20 mSv.[116] States developing nuclear weapons in the name of national security harmed the health and security of the very citizens they claimed to be seeking to protect. Often the willingness to do harm was most evident in relation to minority, indigenous or colonized people. Disturbing elements of radioactive discrimination are in evidence, and may not lie solely in the past. For example, concerns have been raised that a Royal Commission into the nuclear industry established by the South Australian government in 2015 may have an objective of promoting the use of "sacrifice zones" – sites for further nuclear activities, including storage of radioactive waste – on indigenous lands contaminated by fallout from British nuclear tests.[117]

115 For updated information on developments and court documents, see Nuclear Zero, "Nuclear Zero Lawsuits", available at: www.nuclearzero.org.

116 See Royal Commission Report, above note 16, p. 78, for a summary of the evolution of radiation protection standards during the period of atmospheric nuclear test explosions; and Anthony D. Wrixon, "New ICRP Recommendations", *Journal of Radiological Protection*, Vol. 28, 2008, regarding the most recent recommendations of the ICRP.

117 These concerns are documented in detail in a number of submissions by Aboriginal organizations to the Nuclear Fuel Cycle Royal Commission, particularly Native Title Representative 10-9-2015, Yankunytjatjara Native Title Aboriginal Corporation 10-8-2015, and Maralinga Tjarutja, Yalata

Health aspects

Measurement of radiation was generally limited to external gamma radiation. The assumption that beta radiation was proportional to gamma radiation was found to be unwarranted in the early 1950s, yet beta radiation, induced radioactivity and internal exposures especially from alpha emitters such as plutonium isotopes were typically not measured adequately if at all.[118] Many test personnel had little or no effective monitoring of their radiation exposure. In a number of settings, radiation doses received by test personnel and downwind communities have been significantly underestimated. Nevertheless, in virtually every setting where epidemiological studies of adequate methodology and power were undertaken, sometimes decades after the relevant events, evidence of health harm to test personnel and downwind communities is unequivocal. However, the sound epidemiological principle that absence of evidence of effects does not constitute evidence of absence of effect applies all too often to the many settings where inadequate data have been gathered. In some settings, despite overwhelming evidence, implausible conclusions have been drawn. For example, the authors of the large study of Australian nuclear test participants concluded that the significant increases in cancer incidence and mortality they observed "do not appear to have been caused by exposure to radiation".[119] Underestimation of radiation exposures and/or radiation effects is a scientifically far more plausible reason for the lack of observed link between cancers and radiation doses estimated, which in any case does not invalidate in any way the observed cancer excess.

The dereliction of responsibility to monitor the effects of profoundly hazardous activities, analyse and disseminate data, and respond appropriately in relation to nuclear testing finds a direct corollary in the wilful neglect by many governments and international institutions of the humanitarian impacts of nuclear war. It is extraordinary that it was not until sixty-eight years after the nuclear bombings of Hiroshima and Nagasaki that the first of three intergovernmental conferences dedicated to the humanitarian effects of nuclear weapons was held, in Oslo in 2013.[120] Appropriately, each of the three conferences included testimony of nuclear test survivors; the voices of nuclear test survivors were most prominent at the third such conference, held in Vienna in December 2014.[121]

The health effects of nuclear weapons development and testing are not only connected to radiation. They include a wide range of other physical and chemical hazards related to the vast industrial infrastructure underpinning the nuclear

Community Inc 14-08-2015. All are available at: http://nuclearrc.sa.gov.au/submissions/?search=Submissions.

118 A. Robbins, A. Makhijani and K. Yih, above note 49, pp. 10–15.

119 R. Gun, J. Parsons, P. Ryan, P. Crouch, and J. Hiller, above note 24, p. vi.

120 Documents and presentations from the Oslo Conference are available at: www.regjeringen.no/en/topics/foreign-affairs/humanitarian-efforts/humimpact_2013/id708603/.

121 Documents and presentations from the Vienna Conference are available at: www.bmeia.gv.at/en/european-foreign-policy/disarmament/weapons-of-mass-destruction/nuclear-weapons-and-nuclear-terrorism/vienna-conference-on-the-humanitarian-impact-of-nuclear-weapons/.

enterprise around the globe. The social impacts of disempowerment; victimization; abuse of basic human rights; disruption of traditional communities, ways of life and means of sustenance; displacement; justified concern about unpredictable long-term health impacts extending to future generations; and concern about transmitting genetic mutations to one's children can all have profound and long-term direct and indirect physical and mental health consequences. Especially among the indigenous and traditional communities disproportionately impacted, these effects are not only individual and family, but extend to kin, communities and peoples. The association of outbreaks of ciguatera fish poisoning with nuclear test and other military and war-related damage to Micronesian and Polynesian coral reefs is another example of a health consequence unrelated to radioactivity.

Radiation health effects

The health impacts of ionizing radiation are central to the health consequences of nuclear explosions. Ionizing radiation is so named because its various types share the quality of being of sufficient energy to alter the structure of atoms (see Table 2[122]). It poses risks of acute illness (in high doses) and at any dose, long-term genetic mutations and increased risk of most cancers and a variety of chronic diseases, including cardiovascular and respiratory disease. Ionizing radiation has a high propensity to damage large, complex molecules like DNA, which are crucial to life, because its energy is delivered in large packets. A dose of radiation acutely lethal to a human being can contain no more energy than the heat in a sip of hot coffee.[123] The more we learn about the health effects of ionizing radiation, the greater the effects evident for a given radiation dose. Arguably the most authoritative and rigorous periodic assessments of radiation health risks are the Biological Effects of Ionizing Radiation (BEIR) reports produced by the US National Academy of Sciences. However, substantial new evidence has accumulated since the most recent report, BEIR VII, produced in 2006.[124] BEIR VII estimates that the overall increase in risk of solid cancer incidence across a population is about one in 10,000 (and about half that for

122 And see, for example, Centers for Disease Control and Prevention, "Ionising Radiation", available at: www.cdc.gov/nceh/radiation/ionizing_radiation.html; A. D. Wrixon, above note 116, pp. 161–168.

123 The average global background level of radiation we are all exposed to from inhalation of radon gas produced by the decay of uranium in the Earth's crust, cosmic sources, soil and rocks, and ingestion, is about 3 mSv per year. Acute exposures over 100 mSv produce effects on chromosomes measurable in laboratory testing. Acute symptoms are increasingly likely at acute doses above a few hundred mSv; without intensive medical care, doses around 4 Sv (4000 mSv) will be fatal for many of those exposed. All levels of radiation exposure are associated with increased risks of long-term genetic damage and increases in cancer, proportional to the dose. There is no dose of radiation below which there is no incremental health risk. A chest X-ray typically involves a dose of 0.02 mSv; a CT scan typically involves doses of 3–12 mSv or more. For non-medical exposures, 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; for nuclear industry workers the recommend maximum occupational dose limit is an average of 20 mSv per year.

124 US National Academy of Sciences, 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*, Washington, DC, 2006.

Table 2. *Common types of ionizing radiation*

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), not by clothing
Subatomic particles	Alpha (helium nucleus) and other heavy fission fragments like 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 a given 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.

cancer deaths) for each 1 mSv of additional radiation exposure. The increased risk for leukaemia is about 10% of this.[125]

The long-term follow-up studies of Hiroshima and Nagasaki *hibakusha* (nuclear bomb survivors) that have provided the bulk of historic data on which radiation health risks have been estimated – and based on which the recommended dose limits for nuclear industry workers and the public have been set – have been shown to have a range of methodological flaws which lead to underestimation of radiation risk.[126] Powerful new epidemiological studies have provided estimates both more accurate and demonstrating greater risk than previously estimated. For example, a greater than doubling of leukaemia risk has been identified for children living within 5 km of a normally operating nuclear power plant.[127] A large study of cancer risk after computerized tomography (CT) scans in young people, involving more than ten times the number of people exposed and four times the total radiation dose than the Japanese survivor data for low doses of radiation (less than 100 mSv), has demonstrated a 24% increase in cancer in the decade following one CT scan delivering an average effective dose of only 4.5 mSv, and 16% greater for each additional scan.[128] Cancers occurred as early as two years after exposure. While new cancers will continue to occur through the life of exposed individuals, the risk for leukaemia related to CT radiation was similar to that among *hibakusha* over several decades, and the risk of solid cancer over the first decade alone in the more powerful CT study was 3.5 to nine times higher than in the *hibakusha* studies to date. New studies of large numbers of nuclear industry workers demonstrate greater than previously estimated risks for leukaemia[129] and cancer.[130]

These large and powerful studies show a risk even at very low dose rates (a mean of 1.1 mGy per year) and doses well within recommended occupational limits. They do not support a reduction of risk for the same total dose if the dose

125 *Ibid.*, Executive Summary.

126 For example, see David Richardson, Steve Wing and Stephen R. Cole, "Missing Doses in the Lifespan Study of Japanese Atomic Bomb Survivors", *American Journal of Epidemiology*, Vol. 177, No. 6, 2013; John Mathews, Anna Forsythe, Zoe Brady, Martin Butler, Stacy Goergen, Graham Byrnes, Graham Giles, Anthony Wallace, Philip Anderson, Tenniel Guiver, Paul McGale, Timothy Cain, James Dowty, Adrian Bickerstaffe and Sarah 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, May 2013.

127 Peter Kaatsch, Claudia Spix, Renate Schulze-Rath, Sven Schmiedel and Maria Blettner, "Leukaemia in Young Children Living in the Vicinity of German Nuclear Power Plants", *International Journal of Cancer*, Vol. 1220, 2008.

128 J. Mathews *et al.*, above note 126.

129 Klervi Leuraud, David Richardson, Elisabeth Cardis, Robert Daniels, Michael Gillies, Jacqueline O'Hagan, Ghassan Hamra, Richard Haylock, Dominique Laurier, Monika Moissonnier, Mary Schubauer-Berrigan, Isabelle Thierry-Chef and Ausrele Kesminiene, "Ionising Radiation and Risk of Death from Leukemia and Lymphoma in Radiation-Monitored Workers (INWORKS): An International Cohort Study", *Lancet Haematology*, Vol. 1, 2015.

130 David Richardson, Elisabeth Cardis, Robert Daniels, Michael Gillies, Jacqueline O'Hagan, Ghassan Hamra, Richard Haylock, Dominique Laurier, Klervi Leuraud, Monika Moissonnier, Mary Schubauer-Berrigan, Isabelle Thierry-Chef and Ausrele 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.

is delivered over a longer time (low radiation dose rates compared with high dose rates), as assumed by BEIR VII and a number of radiation protection bodies such as the ICRP.[131]

Vulnerability to radiation risks differs substantially between different people. Females and especially children are most susceptible to the effects of ionizing radiation. In the BEIR VII assessment, following uniform whole-body exposure to the same level of radiation, women are 52% more likely to develop cancer than men and 38% 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% more likely to develop cancer than boys.[132]

Children are substantially more sensitive to radiation damage than adults – exposures in infancy (below 1 year of age) for boys 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.[133]

The combined effects of exposure during early childhood and greater female susceptibility are dramatic. For intake of fluid containing the radioactive isotope strontium-90, infant girls exposed to the same level of contamination are assessed to have a 20.6-fold higher risk of breast cancer than women aged 30 years. For the same level of contamination of ingested fluid with iodine-131, the risk for infant girls compared with 30-year-old women is 32.8 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.[134]

These differential vulnerabilities are obscured by averaging of risks across populations. The greater vulnerability of children to radiation extends to many other environmental hazards, such as toxic chemicals, also an issue at a number of nuclear test sites. The World Health Organization (WHO) has estimated that despite children under 5 years accounting for about 10% of the world's population, children bear over 40% of the global burden of disease attributed to environmental risk factors.[135] Protection of the most vulnerable – including against the adverse effects of radiation – is a fundamental humanitarian and governance imperative.

For indigenous people such as Marshall Islanders, Maohi islanders in French Polynesia and indigenous Australians, it has been shown that traditional lifestyles, in close physical contact with a natural environment contaminated by nuclear testing, sustained by gathering and hunting of traditional local foods and living in housing made of local materials, are associated with increased radiation

131 A. D. Wrixon, above note 116, pp. 161–168.

132 Arjun Makhijani, Brice Smith and Michael 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.

133 National Academy of Sciences, above note 124, pp. 470–499.

134 A. Makhijani, B. Smith and M. C. Thorne, above note 132, p. 40.

135 WHO, *Healthy Environments for Children: Initiating an Alliance for Action*, WHO/SDE/PHE/02.06, Geneva, 2002, p. 3, available at: http://whqlibdoc.who.int/hq/2002/WHO_SDE_PHE_02.06.pdf.

exposures. For example, for a 10-year-old indigenous Australian child living a traditional lifestyle near a test site, living on the ground with high dust exposure and eating local kangaroo, estimated effective annual doses range up to 470 mSv,[136] compared with less than 1 mGy whole-body external radiation doses estimated for local population centres that were monitored during some of the tests.[137] This heightened vulnerability to radiation exposure as a result of traditional indigenous lifestyles and food sources adds further layers of jeopardy, dispossession and pressures on cultural well-being to the discrimination of indigenous people being disproportionately put in the frontline of harm's way by nuclear testing.

It will be very interesting to go back and get good environmental data, how many per square mile, what isotopes are involved and a sample of food changes in many humans through their urines, so as to get a measure of the human uptake 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 these people are more like us than mice.

– Dr Merrill Eisenbud, US Atomic Energy Commission, regarding the people of the northern Marshall Islands.*

The radioisotopes produced by nuclear explosions which are most important in relation to human health are summarized in Table 3. The long persistence of a number of important radioisotopes, the impossibility of recovering or containing much of those already dispersed by nuclear tests, and the potential for future leakage and dispersal from test sites, including underground ones, means that their adverse health effects will continue for future generations across hundreds of thousands of years.

Global health impacts

Even though the largest population radiation doses associated with above-ground nuclear test explosions are borne by people living within hundreds of kilometres downwind, the largest collective radiation dose is borne not by members of downwind communities exposed to the highest individual doses, but globally by

136 United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), *Sources and Effects of Ionizing Radiation: UNSCEAR 2008 Report to the General Assembly with Scientific Annexes*, Vol. 1, UN, New York, 2010, pp. 352–353.

137 Steven Simon and Andre Bouville, "Radiation Doses to Local Populations Near Nuclear Weapons Test Sites Worldwide", *Health Physics*, Vol. 85, No. 5, 2002.

* US Atomic Energy Commission. Transcript of the 54th Meeting of the Advisory Committee on Biology and Medicine, 13–14 January 1956, pp. 232–233.

Table 3. *Radioactive isotopes from nuclear test explosions most significant in human health impact*

Radioisotope	Main type(s) of radioactivity emitted	Half-life (days: d; years: y)	Health significance and predominant means of exposure
Iodine-131	Beta, gamma	8 d	Ingestion, concentrated up food chain (especially milk); concentrated in thyroid gland; causes thyroid disease including cancer – children most vulnerable
Cesium-137	Beta, gamma	30 y	External and ingestion, body handles like potassium, the main positively charged ion inside cells; bio-concentrated; associated with many cancers; dominant cause of radiation exposure to world's people from atmospheric nuclear test explosions to date
Strontium-90	Beta	28 y	Ingestion, handled by the body like calcium, concentrates in bones and teeth; bioconcentrated; retained; causes leukaemia, bone cancer
Plutonium-239	Alpha	24,400 y	Inhalation, retained; internal hazard; causes lung cancer, especially when inhaled
Carbon-14	Beta	5,730 y	Ingestion, an activation product created by atmospheric nuclear tests from transmutation of atmospheric nitrogen by neutron bombardment; responsible for 85% of radiation dose to world population from atmospheric nuclear weapons explosions over thousands of years to come
Zirconium-95	Beta	64 d	External
Ruthenium-106	Beta	11.8 d	External
Tritium (hydrogen-3)	Beta	12.3 y	Ingestion

Source: based on A. Robbins, A. Makhijani and K. Yih, above note 49, pp. 3–9; UNSCEAR, *Sources and Effects of Ionizing Radiation: UNSCEAR 1993 Report to the General Assembly with Scientific Annexes*, Annex B, UN, New York, 1993, pp. 128–129.

the whole human population – much smaller exposures but to vast numbers of people. 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-sievert (Sv) to the year 2000 and 30.44 million person-Sv in total) and applied the then current radiation risk estimates of the BEIR V report of the US National Academy of Sciences to estimate global cancer deaths attributable to atmospheric nuclear weapons test fallout.[138] 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% confidence limits of 320,000 to 650,000. Together, caesium-137, zirconium-95, carbon-14 and strontium-90 delivered 76% of this total dose. However in the longer term, carbon-14, an activation product from above-ground nuclear tests that emits beta radiation and has a half-life of 5,730 years, delivers 85% of the total dose to the world's population over thousands of years to come.[139]

> ***When the nation exposes servicemen and women to hazardous substances, there is an obligation to keep appropriate records of both the exposures and the long-term medical outcome.***
>
> **– Advisory Committee on Human Radiation Experiments, 1995.***

The total excess cancer deaths over time were estimated to eventually reach 2.4 million.[140] The more recent UNSCEAR 1993[141] and SCOPE 59 (2000)[142] reports previously cited 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 estimates 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.[143] 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 described in the previous section, it is likely that these estimates substantially underestimate the true long-term toll of nuclear test explosions. The

138 A. Robbins, A. Makhijani and K. Yih, above note 49, pp. 34–40.
139 *Ibid.*, pp. 22–47.
140 *Ibid.*, pp. 163–164.
141 UNSCEAR, *Sources and Effects of Ionizing Radiation: UNSCEAR 1993 Report to the General Assembly with Scientific Annexes*, Annex B, UN, New York, 1993, p. 20, available at: www.unscear.org/docs/reports/1993/1993a_pages%201-30.pdf.
142 F. Warner and R. J. C. Kirchmann, above note 7, pp. 220–221.
143 *Ibid.*
* Advisory Committee on Human Radiation Experiments, Final Report, *Atomic Veterans: Human Experimentation in Connection with Atomic Bomb Tests*, US Government Printing Office, Washington, DC, October 1995, p. 486.

true number of excess cancer deaths will likely 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 overall around half of cancers (other than non-melanoma skin cancers) are fatal, for all these estimates a comparable additional number of non-fatal cancer cases can be expected.

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 any specific biological signature. The 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, the inability to identify individual victims of these excess cases of cancer which will be induced by test fallout and will cause distress and health harm, whether or not they ultimately prove fatal, is nevertheless real, warranting accountability of responsible institutions and individuals as well as feasible preventive and remedial public health action.

Environmental aspects

In addition to the intense, widespread and persistent hazards intrinsic to nuclear explosions, in every test programme there is evidence of accidents, unplanned events, wind shifts, unforeseen dangers and reckless decisions which aggravated the dangers, such as the 11 September 1966 nuclear test in Polynesia at the French president's convenience, despite the winds carrying the fallout directly towards the nearest population centres.

Comprehensive evidence of the nature and extent of environmental contamination and health effects of nuclear weapons testing was often not collected, incomplete, neglected or systematically covered up. This was compounded by high levels of secrecy which still surround many nuclear testing programmes in the Pacific region and beyond, particularly for France, China, India, North Korea and Pakistan. The geographic distribution of fallout was often inadequately monitored, with failure to identify heavily irradiated areas ("hotspots") where radioactivity could be hundreds to many thousands of times higher than average levels.[144]

In every place where they have been conducted, whether above or below ground or in the marine environment, nuclear test programmes have left a legacy of radioactive and other waste which will persist for extremely long periods of time. Underground nuclear tests, apart from unplanned direct venting of radioactivity, can also leak radioactive material from late-time seeps of gases through pores in overlying rock, as well as through intentional controlled tunnel purgings and operational releases.[145] All underground tests resulted in release of

144 A. Robbins, A. Makhijani and K. Yih, above note 49, pp. 15–17, 60–63.
145 *Ibid.*, pp. 20–21.

(radioactive) tritium into the atmosphere.[146] In essence, each underground nuclear test site is an unstudied, unlicensed repository of large quantities of highly radioactive waste injected into the underground environment, which through the same process undergoes extensive disruption and fracturing, compromising the ability of the environment to contain the radioactivity. Over seventy years into the nuclear age, no country has yet established a functioning licensed repository for high-level radioactive waste. Yet uncontrolled high-level radioactive waste repositories exist at every site of underground nuclear testing.

A source of potential confusion regarding the environmental effects of nuclear explosions relates to the compelling recent evidence of substantial and long-lasting global climate disruption – cooling, darkening and drying – that would disrupt agriculture and food supplies globally, by the smoke from burning cities ignited by the use of even less than one half of 1% of the global nuclear arsenal.[147] Even though much greater numbers and yield of nuclear weapons have been used in atmospheric nuclear tests than in such a scenario, nuclear test explosions have not disrupted climate globally because they have not been targeted at cities and have not produced simultaneous widespread urban and industrial fires.

All nuclear test sites require long-term monitoring and warrant feasible clean-up. Durable test site clean-up and remediation efforts have been feeble and few. Climate disruption will add stresses and risks to nuclear test sites. More frequent and intense extreme events, including wildfires, storms, floods, landslides, hurricanes/typhoons and extreme winds, are to be expected worldwide. Inevitably, progressing sea-level rise will inundate many former test sites and waste repositories, particularly in atolls such as in the Marshall Islands and French Polynesia, compounded at Moruroa by ongoing subsidence. This will make monitoring, preventing disintegration and environmental releases of waste material, and any remediation efforts much more difficult. In addition, glacial and ice-sheet melting might increase the frequency of earthquakes and associated tsunamis.[148] This may further exacerbate dispersal of radioactive and other toxic waste from former test sites. Particularly in the atoll locations in the Pacific, all these factors add considerable urgency to the need to control and remediate former test sites.

146 Carol Tadros, Catherine Hughes, Jagoda Crawford, Suzanne Hollins and Robert Chisari, "Tritium in Australian Precipitation: A 50 Year Record", *Journal of Hydrology*, Vol. 513, 2014, p. 268.

147 Michael J. Mills, Owen B. Toon, Julia Lee-Taylor and Alan Robock, "Multidecadal Global Cooling and Unprecedented Ozone Loss Following a Regional Nuclear Conflict", *Earth's Future*, Vol. 2, 2014; Ira Helfand, *Nuclear Famine: Two Billion People at Risk?*, IPPNW and Physicians for Social Responsibility, November 2013,

148 Fred Pearce, "Could a Changing Climate Set Off Volcanoes and Earthquakes?", *Yale Environment 360*, 7 May 2012, available at: http://e360.yale.edu/feature/could_a_changing_climate_set_off_volcanoes_and_quakes/2525/.

Addressing the needs of nuclear test survivors

For test personnel both military and civilian, and downwind communities, adequate recognition of the risk and harm they have been exposed to and the consequences they continue to suffer has frequently been missing, inadequate or inexcusably delayed. Justice delayed is justice denied. For example, in Australia more than half of test veterans had died by the time a cancer study demonstrating their heightened risk was completed in 2006 and more equitable and accessible arrangements for cancer care for test veterans were instituted. Even if delayed, all affected citizens deserve recognition, an official apology, ongoing care for their health needs and fair compensation for having being placed in harm's way.[149]

Fundamentally, the States that undertook nuclear test programmes are responsible for addressing the problems and the legacy that they created. While some have introduced programmes for their own citizens, few have extended care or compensation to the citizens of other countries, including those where nuclear tests were imposed. Where they have, such as the United States in relation to the Marshall Islands, it has been insufficient. Further, no such programmes address the situation and needs of subsequent generations whose lands have been polluted, social and cultural heritage disrupted and genetic legacy harmed, and many of whom continue to live in contaminated environments. Even perhaps the best compensation programme for test survivors, under the Radiation Exposure Compensation Act in the United States, will expire in 2022, and claims received after that date will be barred.[150]

Conclusion

The entry into force of the CTBT,[151] which would permanently prohibit all nuclear explosions in all environments, has been languishing since the Treaty was finally concluded in 1996, lacking ratification by all the required forty-four States possessing nuclear power and/or research reactors. While no State apart from North Korea has undertaken nuclear test explosions since 1998 and some nuclear test sites have been closed (e.g. those of France, and in Kazakhstan), only three of the current nine nuclear-armed States have ratified the Treaty.[152] A definitive end to nuclear explosions would of course be a substantial global health and environmental good. However, while in decades past a test ban would have been an important measure against new States acquiring nuclear weapons (horizontal proliferation) and the development of new nuclear weapons by States that already possess them (vertical proliferation), its effectiveness as a non-proliferation

149 Royal Commission Report, above note 16, "Conclusions and Recommendations", Recommendation 1, p. 31.
150 US Department of Justice, above note 15, p. 2.
151 Comprehensive Nuclear-Test-Ban Treaty, UN GA Res. 48/70, 10 September 1996 (not in force).
152 CTBTO Preparatory Commission, *Status of Signature and Ratification*, available at: www.ctbto.org/the-treaty/status-of-signature-and-ratification/.

measure and constraint on the development and proliferation of increasingly sophisticated nuclear weapons would now be substantially limited.[153]

While new weapons designs, particularly for advanced, miniaturized weapons, have historically generally been explosively tested, the physics and design of many types of nuclear weapons are readily available in the public domain, and Chinese nuclear weapon designs have been available through the nuclear black market established by the builder of Pakistan's nuclear bomb, Abdul Qadeer Khan.[154] The established nuclear-armed States have been able to continue to develop sophisticated new nuclear weapons in the past two decades without explosive testing because by the mid-1990s they had perfected a variety of advanced computer simulation techniques and laboratory testing, particularly sub-critical and hydrodynamic testing, to a point where new weapons could be developed and deployed without explosive testing. For example, France's last flurry of nuclear explosions at Moruroa in 1995 and 1996, before its Pacific test sites were closed, were for the purpose of perfecting non-explosive testing.[155] Israel has developed a sophisticated nuclear arsenal while having conducted at most a single explosive test.[156] Simple nuclear bomb designs, such as gun-barrel-type fission bombs using highly enriched uranium, like the Hiroshima bomb, are so simple and reliable that they did not in 1945 and do not now require any prior testing. As described in a companion paper in this issue of the *Review*,[157] all the nuclear-armed States are proceeding apace with extensive nuclear modernization programmes, essentially unimpeded by not conducting nuclear test explosions. North Korea is the only nuclear-armed State still undertaking explosive testing in order to develop its nuclear arsenal.

Thus while the CTBT had long been considered by many to be high priority and a litmus test of States' commitment to nuclear disarmament, its entry into force appears a distant prospect. While a durable end to nuclear test explosions is clearly a necessary part of the treaty regime that will be needed to achieve and sustain a world freed from nuclear weapons, it is not a large or decisive part. The UN Open-Ended Working Group that will report back to the 2016 General Assembly, charged with "substantively address[ing] concrete effective legal measures, legal provisions and norms that would need to be concluded to attain and maintain a world without nuclear weapons",[158] could most usefully consider a ban on nuclear testing in the context of a comprehensive legal instrument or package of measures to prohibit nuclear weapons and provide for their elimination – the greatest humanitarian imperative and precondition for global health, security and sustainability. Such an instrument should prohibit nuclear weapons development, production, testing,

153 R. Johnson, above note 3, pp. 179–180, 193–519, 222, 231.
154 Joseph Cirincione, Jon B. Wolfsthal and Miriam Rajkumar, *Deadly Arsenals: Nuclear, Biological and Chemical Threats*, 2nd ed., Carnegie Endowment for International Peace, Washington, DC, 2005, p. 247.
155 Philip Shenon, "France, Despite Wide Protests, Explodes a Nuclear Device", *International New York Times,* 6 September 1995.
156 Leonard Weiss, "Flash from the Past: Why an Apparent Israeli Nuclear Test in 1979 Matters Today", *Bulletin of the Atomic Scientists*, 9 September 2015.
157 See the article by Hans M. Kristensen and Matthew McKinzie, in this issue of the *Review*.
158 UNGA Res. A/RES/70/33, 11 December 2015, available at: www.unog.ch/oewg-ndn.

stockpiling, transfer, deployment, threat of use and use, as well as assistance for these activities.

Humanitarian priorities in regard to nuclear test explosions include the need to prevent further nuclear tests; to minimize further radioactive leakage through long-term monitoring of contaminated sites, emplacement of feasible barriers to leakage of contaminants into the biosphere, and clean-up of contaminated debris; and to provide recognition, care and compensation for affected workers and communities. However it is essential to recognize the unique nature, scale and persistence of nuclear impacts; the impossibility of comprehensive clean-up of radioactive materials dispersed into the atmosphere as fallout, or blasted into the sea or underground; and the impossibility of reversing the genetic and other health damage caused by exposure to radioactivity.

It is important in this context to emphasize that no effective humanitarian response is possible for even a single nuclear weapon detonated in a population centre, let alone nuclear war, as has been the unequivocal conclusion of the World Health Organization[159] and the International Red Cross and Red Crescent Movement for many years,[160] and is re-emphasized in this issue of the *Review*.[161]

The two most recent treaties banning a class of intrinsically indiscriminate, inhumane weapons, the 2008 Convention on Cluster Munitions[162] and the preceding Anti-Personnel Mine Ban Convention,[163] contain groundbreaking provisions for victim assistance. The CTBT includes no such provisions. There is currently no international legal instrument that provides for victims and survivors of nuclear explosions to seek assistance towards the realization of their rights,[164] nor any specific international obligations for efforts to decontaminate or otherwise remediate areas affected by nuclear explosions. Both these aspects could usefully be addressed in the development of new legal measures towards the prohibition and elimination of nuclear weapons. At the second World Nuclear Victims Forum held in Hiroshima in November 2015, Draft Elements of a Charter of World Nuclear Victims' Rights were developed which might provide a valuable reference for promoting and protecting the rights and health of the survivors of nuclear explosions.[165]

159 WHO, *Effects of Nuclear War on Health and Health Services*, 2nd ed., Geneva, 1987, p. 5.

160 Speech given by Peter Maurer, President of the International Committee of the Red Cross, Vienna Conference on the Humanitarian Consequences of Nuclear Weapons, 8 December 2014, available at: www.bmeia.gv.at/index.php?eID=tx_nawsecuredl&u=0&g=0&t=1455190832&hash=f1f7811a97b8c01733e346530ac7fcc44b61db32&file=fileadmin/user_upload/Zentrale/Aussenpolitik/Abruestung/HINW14/HINW14_Peter_Maurer_speech.pdf.

161 See Gregor Malich, Robin Coupland, Steve Donnelly and Johnny Nehme, "Chemical, Biological, Radiological or Nuclear (CBRN) Events: The Humanitarian Response Framework of the International Committee of the Red Cross", in this issue of the *Review*.

162 Convention on Cluster Munitions, 2688 UNTS 39, 3 December 2008 (entered into force 1 August 2010).

163 Convention on the Prohibition of the Use, Stockpiling, Production and Transfer of Anti-Personnel Mines and on their Destruction, 18 September 1997 (entered into force 1 March 1999), available at: www.icrc.org/ihl/INTRO/580.

164 Article 36, *"Victim Assistance" in a Treaty Banning Nuclear Weapons*, January 2015, available at: www.article36.org/wp-content/uploads/2015/01/victims-nuclear-weapons.pdf.

165 Draft Elements of a Charter of World Nuclear Victims' Rights, World Nuclear Victims Forum, Hiroshima, 21–23 November 2015, available at: www.fwrs.info/topics/2015/341.

Every human being alive carries in his or her body radioisotopes from nuclear test explosions, the largest collective source of radiation exposure by human hands. The victims and survivors of nuclear weapons production and testing around the world number in the millions. Nuclear test explosions have not only directly caused profound and persistent health and environmental harm which will extend across many generations, but have also been integral to building the destructive capacity of the enormous nuclear arsenals that now constitute an unprecedented, urgent, existential danger to all humanity. The humanitarian impacts of nuclear tests are severe enough, but they provide only a small glimpse of the largely irreparable devastation that would be wrought on the biosphere and all species by nuclear war. The evidence of these impacts, presented here for the Pacific region, and the lived human experience and compelling testimony provided by test survivors can play an important role in informing and motivating humanitarian-based efforts to stigmatize, prohibit and eliminate nuclear weapons. The suffering caused by nuclear explosions worldwide demands justice for the survivors, and that nuclear weapons claim no more victims.