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SUMMARY OF HEALTH AND ENVIRONMENTAL IMPACTS OF U.S. NUCLEAR TESTING IN THE MARSHALL ISLANDS

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The tests and the test location

The United States carried out 23 nuclear weapon tests at Bikini Atoll between 1946 and 1958 with a total explosive power estimated at 76.8 megatons and 44 tests between 1948 and 1958 at Enewetak Atoll with a total explosive power of 31.7 megatons. The total explosive power of 108.5 megatons was about 100 times the total yield of all surface, tower, and atmospheric tests conducted at the Nevada Test Site (calculated from SCOPE 1999, Chapter 3, Table 3.1). Another metric is that the Marshall Islands tests were equivalent to exploding one Hiroshima size bomb every day for about 20 years.

The first nuclear tests after World War II were conducted at Bikini Atoll in July 1946 during Operation Crossroads. The tests were proposed by the U.S. military to examine the impact of nuclear bombs in a naval environment, including on ships, since, as one general noted, "[w]e now have full information on the atomic bomb on land targets", evidently referring to the atomic destruction of Hiroshima and Nagasaki in August 1945 (as quoted in Jonathan Weisgall, *Operation Crossroads: The Atomic Tests at Bikini Atoll*. Annapolis, Maryland: Naval Institute Press, 1994, p. 15). Commodore Ben Wyatt recounted that he persuaded the people of Bikini to move on a Sunday after church services, because he "compared the Bikinians to the children of Israel whom the Lord saved from their enemy and led into the Promised Land." (as quoted in Weisgall 1994, op. cit., p. 107).

The matter was put more bluntly by Admiral William Blandy, who was the commander of an amphibious task force in the Pacific theater during World War II: "We wish to acquire … a few miserable islands of insignificant economic value, but won with the precious blood of America's finest sons, to use as future operating bases. All that can be raised on most of these islands is a few coconuts, a little taro, and a strong desire to be somewhere else" (as quoted in Weisgall 1994, op. cit., p. 311). The evacuation caused loss of ancestral homes, livelihood and tradition. The places of resettlement were not a "Promised Land"; in fact, the Bikinians preferred their own land and made that explicit when asked a few months after they had been moved (Weisgall 1994, op. cit. p. 308 and p. 310).

[1] The number of tests at Enewetak and the amounts of residual cesium-137 and strontium-90 were corrected upon re-reading the paper in January 2024

The Marshall Islands were remote from large population centers – a factor in their selection. But they were not remote for the Marshallese people; they were home. And they were selected despite the fact that the military's own evaluation stated that the location did not "in the main" meet the meteorological criteria for safety; one of the criteria was that there should be "no possibility of subjecting personnel to radiological hazards or surrounding land or water area to unintentional radioactive contamination" as quoted in IPPNW and IEER 1991, p. 72). The testing location was also contrary to the recommendation of Colonel Stafford Warren after the July 1945 test in New Mexico that similar tests should be done in a place that was "at least 150 miles" away from human habitation. (Warren 1945). Ailinginae, Rongerik, and Rongelap Atolls are all less than 100 miles from Bikini Atoll. Later tests were also done at Enewetak Atoll; Bikini Atoll is well under 150 miles from Enewetak.

Finally, it is important to note that the initial tests bore out the negative meteorological assessment. After the 1948 Operation Sandstone tests at Enewetak, James P. Cooney, who was a radiological safety officer, wrote that "Enewetak Atoll has proven to be a far from satisfactory site for atomic tests" (as quoted in IPPNW and IEER 1991, p. 72). Yet the United States persisted in testing in the Marshall Islands, including at Enewetak Atoll, with tragic results. In fact, about two-thirds of the tests were done at Enewetak Atoll.

Health Impacts

Fallout occurred all over the Marshall Islands as a result of the 67 nuclear weapon tests carried out there; this is evident from the fallout map from just the 1954 CASTLE test series (see maps below, from List 1955), based on measurements at the time and published by the U.S. Department of Commerce. Yet, most of the Marshall Islands is not yet operationally recognized as an affected area by the United States government.

In addition to Bikini and Enewetak, where the tests were carried out, the most severely impacted atolls were northern atolls to the east of these test sites, including Rongelap, Ailinginae, Rongerik, and Utrik atolls. Atolls to the southeast, like Ailuk Atoll, 300 miles from Bikini, also suffered high fallout, especially from the 15 megaton thermonuclear weapon test at Bikini called BRAVO, carried out on March 1, 1954 (Moss-Christian 2021, p. 2).

The BRAVO test showed an attitude that was worse than disregard of Warren's safety recommendation. The weather report in the days before the test indicated westerly winds, which meant that atolls to the east of Bikini were at risk. The outlook worsened a few hours before the test and indicated that Ailinginae, Rongerik, and Rongelap would be directly in the path of the fallout. The test was carried out anyway (Barbara Rose Johnston and Holly M. Barker. *Consequential Damages of Nuclear War: The Rongelap Report*, Walnut Creek, CA: Left Coast Press, 2008 and Ruff 2016, p. 21). The U.S. military chose not to evacuate those atolls immediately or even warn the people who lived there that they were at risk, unlike prior tests in the Marshall Islands (Ruff 2016, pdf. p. 21). In fact, atolls farther out, like Ailuk, were also impacted seriously but were never evacuated (Moss-Christian 2021, p. 2).

The catastrophe that followed the BRAVO test is well documented; it was summarized by Dr. Tilman Ruff in an article for the International Review of the Red Cross (Ruff 2016, pdf p. 21, italics added):

> 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. 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*.

There were short-term somatic effects, like vomiting, damage to the mucosal lining of the gastro-intestinal tract, and radiation burns (called "beta burns") on the skin. Such acute radiation sickness occurs only with high exposures. The average exposure to 86 people on Rongelap was officially estimated at 1.9 Sv (IPPNW and IEER 1991, p. 76), creating a cancer risk of one in five in this population from this single test. Of course many had exposures in excess of this amount.

A Japanese fishing boat, the Daigo Fukuryu Maru (Lucky Dragon No. 5), was in the vicinity at the time of the March 1 1954 BRAVO test; its crew also suffered high radiation exposures and acute radiation illnesses. One of the crew members died seven months later; others were hospitalized. It was not the only fishing boat contaminated in 1954; monitoring by Japan during that year found contaminated fish in the holds of 683 boats; 457 tons of tuna caught by Japanese boats had contamination above then-prevailing limits (IPPNW and IEER 1991, p. 78).

Doses from the Bravo test for the people who experienced high fallout were so high that the National Cancer Institute made the following, rather shocking statement in its 2004 assessment, after half a century of additional testing, fallout and the severe 1986 Chernobyl nuclear power plant accident (NCI 2004, p. 9):

> Doses at Rongelap and Ailinginae were very high and were in a range for which there is little experience in dose estimation or health risk assessment.

The same report concluded that the Marshall Islands population would suffer 500 excess cancers due to the radiation exposure from nuclear weapons testing. This is an enormous increase in cancer risk – nine percent, given the small population of the Marshall Islands (NCI 2004, p. 17); this is comparable to about six million excess cancers on the mid-1950s population of the United States.

People all over the Marshall Islands were exposed by the testing, far beyond the three islands that have been recognized (Rongelap, Ailinginae, and Utrik) for medical monitoring by the U.S. government. Even Enewetak is not so recognized (Moss-Christian 2021, pp. 1-2). The radiation doses estimated by the U.S. government tell a different story. For instance, the official average thyroid dose estimate to people in Kwajalein, considered a "low-exposure atoll", was as high as 270 mGy. Several atolls were designated "very low exposure atolls"; one such was Majuro, where the capital of the Marshall Islands is located; the people there (and other "very low exposure atolls") had an average thyroid exposure of 75 mGy (NCI 2004, Table 1, p. 8).

The National Cancer Institute, based on what it called "a carefully considered analysis", later revised its estimate down to 170 excess cancers (NCI 2010 and Simon et al. 2010); this would be equivalent to about 2 million excess cancers in the U.S. population. The revised dose estimates in the latter paper on which the lower estimate is based are far lower than independent estimates or even those of the Department of Energy itself.

For instance, Simon et al. estimate that the total thyroid doses to adults on Utrik and Rongelap from all tests was 760 mGy and 7,600 mGy respectively; children's exposures were estimated to be about three times higher (Simon et al. 2010). In contrast an 83-page-long 1985 Brookhaven National Laboratory

report, which was a careful analysis of thyroid doses alone from the BRAVO test alone based on radiological measurements, estimated the Utrik and Rongelap thyroid doses (average of male and female exposures) to be 1,650 mGy and 12,000 mGy respectively; six-year old children were estimated to have exposures about twice as high, while the doses to one-year-olds were estimated to be four times higher. These estimates would lead to cancer estimates closer to those in the 2004 NCI report, cited above.

Independent dose estimates are even higher than the above DOE estimates. For instance, a study prepared for Sanford Cohen & Associates, a company that undertakes radiation-related contracts with various U.S. government agencies, compared various dose estimates and cited thyroid doses to adults on Utrik as 27 Sv, about 17 times higher than the 1985 DOE estimate and 35 times higher than the estimate used by the National Cancer Institute in 2010. The dose estimates for children were similarly higher (Bernd Franke, *Review of Radiation Exposures of Utrik Atoll Residents*. Heidelberg, Germany: ifeu-Institut für Energie- und Umweltforschung, GmbH, prepared for Sanford Cohen & Associates, 2002, p. 39).

The DOE dose estimates are high; the independent estimates are extremely high. Such estimates would indicate a much higher health toll, including but not only in terms of excess cancer mortality. Indeed, the findings of a Special Rapporteur for the United Nations Human Rights Council who investigated the impacts of testing on the Marshall Islands included the following (UN Human Rights Council 2012):

> 30. The Special Rapporteur heard compelling testimony by women on their experience of returning from Rongelap Atoll, including on the alarmingly high rates of stillbirths, miscarriages, congenital birth defects and reproductive problems (such as changes in menstrual cycles and the subsequent inability to conceive, even in those who previously had no such difficulties). Some gave birth to babies that ultimately died from foetal disorders, and they still endured the shame and trauma they experienced as a result….
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> ….
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> 31. Several years after exposure, a high incidence of thyroid cancer was reported, as well as an unusually high prevalence of stunted growth among Marshallese children. The incidence of such cases was also supported by the number of claims before the Nuclear Claims Tribunal.

The use of the terms “low exposure” and “very low exposure” in the 2004 National Cancer Institute report should be put in context of exposures elsewhere, notably the United States. The National Cancer Institute has also done estimates of thyroid exposures in the United States due to atmospheric testing in Nevada (NCI 1997), which roughly overlapped in time with the testing in the Marshall Islands.[2] The highest exposures were in five counties, four in Idaho and one Montana (out of about 3,000 total counties in the United States). The average doses in these five counties were 120 mGy to 160 mGy; the average estimated exposure in the so-called “low exposure atolls” was approximately double that in the highest exposed U.S. counties. Given that these are averages over significant areas and populations, many individual doses would lower and many would be substantially higher, the latter bringing with it a

[2] Nevada Test Site atmospheric testing started and ended a few years later than Marshall Islands testing – 1951 to 1962 compared to 1946 to 1958 respectively.

correspondingly higher risk of cancer and other health problems. Children, especially female children, would be the most affected because their risk of cancer per unit of exposure is much higher than that of adults (Makhijani, Smith, and Thorne 2006; Table 6 and Figure 6, p. 38, summarize the risk factors). However, the United States government has never recognized any but three atolls as having been affected – Rongelap, Alinginae, and Utrik. No one else has been deemed exposed enough to merit health evaluations, much less care (Moss-Christian 2021, pp. 1-2). The opportunity to reduce the health impact by providing medical care or even to identify the health problems at the atolls deemed "low exposure" and "very low exposure" has been missed for all the decades since the tests.

The fact that those Marshallese who were given checkups and some care were seen as experimental subjects should be noted. A 1956 U.S. Atomic Energy Commission document explicitly referred to them in the following words (as quoted in IPPNW and IEER 1991, p. 82, italics added):

> While it is true that these people do not live, I would say, the way Westerners do, civilized people, it is nevertheless true that they are more like us than *the* mice.

The italicized word "the" refers to the experimental mice in laboratories on whom a large amount of radiation research was, and is, done. In fact, the exposed people were enrolled in a secret human experiment without informed consent, as the Chair of the Marshall Islands National Nuclear Commission stated in her 21 October 2021 testimony to a Congressional oversight subcommittee (Moss-Christian 2021, p. 2):

> Following their evacuation after the Bravo event, the people of Rongelap and Utrōk were unknowingly enrolled by the U.S. Government in a top-secret medical experimentation program known as "Project 4.1" to study the effects of radiation exposure on human beings. This study includes control populations whose bodies were similarly used by U.S. medical researchers to harvest bone marrow, teeth, organs, and blood to better understand the capabilities of U.S. weapons of mass destruction.

Nuclear testing in the Marshall Islands was a disaster from the very first test series in Bikini, Operation Crossroads, through the entire program until it ended in 1958. As the fallout maps, the impact was global, especially, but not only, in the Northern Hemisphere. It was also a disaster for the armed forces personnel who participated. The cumulative fallout from the 1954 test series as measured and estimated by the United States government is shown in the maps at the end of this article (from List 1955, pdf pages 20 and 21).

Consider also Test Baker, the second test, on 25 July 1946, during Operation Crossroads at Bikini. It was exploded just underwater; it sent a million tons of radioactive spray 6,000 feet into the air, which came raining down on everything in the vicinity. Prior to the test, the radiation safety team had warned that "extremely serious" radiological conditions would be created if the water column did not rise to more than 10,000 feet. It also warned that the radiological problem "may remain dangerous for an interminable time thereafter." The advice was ignored and the test was carried out (Operation Crossroads documents as quoted in Makhijani and Albright 1983, pdf, p. 3).

A number of captured Japanese "target ships" were stationed in Bikini lagoon as part of the test. The lagoon itself became intensely radioactive, since some of the neutrons released from the underwater test converted the normal, non-radioactive sodium in sea salt into sodium-24, which is a very high energy beta-emitting radionuclide. Contrary to radiological safety advice, U.S. Navy ships were moved

into the lagoon; the radioactive lagoon water was used, among other things, to wash down meat, to wash the decks, and in distillation equipment on board. Sailors scrubbed the decks to try to clean them, suspending radioactive material; there were hot spots scattered all over. As might be expected, naval officers did not know how to handle such situations, since this was their first encounter with atomic weapons and related radiation. The radiological safety team was led by Colonel Stafford Warren, who also led the team during the first-ever nuclear test in July 1945 in New Mexico. But their experience was largely ignored; indeed, one of the safety team members complained of "the blind 'hair-chested' approach to the matter [of radiological safety] with a disdain for the unseen hazard" among many naval officers. (See Makhijani and Albright 1983 generally for this paragraph; the quote is from pdf p. 4).

The existence of hot spots that could give many times the then-permitted daily dose limit to armed forces personnel of 1 mGy/day[3] was noted in the safety documents. Instruments to measure plutonium in the field were not available; rather, gamma radiation and beta radiation were measured. Operation Crossroads' chief of radiological safety, Stafford Warren noted that "[e]very contaminated place as evidenced by the gamma or beta radiation on any surface of any vessel *may be in fact the residence of many lethal doses* of this alpha emitter [plutonium]" (as quoted in Makhijani and Albright 1983, pdf p. 20, italics added).

Besides the direct health impacts of radiation, there have also been other health impacts. Nuclear explosions have damaged coral reefs, which encourages the growth of a single-celled organism that produces a toxin and contaminates fish. Known as ciguatera poisoning, it does not impact the fish, but does impact the people who consume them, as it has the Marshallese. A 1982 survey found that over half of the Marshallese reported such poisoning in the prior year (IPPNW and IEER 1991, pp. 86-88).

There have also been serious impacts from dislocation and the concomitant loss of traditional work and diet, the consumption of processed food supplied, the long and costly distances to medical care, and the enduring stresses of loss of homelands to which many have not been able to return (Moss-Christian 2021, pp 6-7).

Radiological contamination

Marshall Islands testing produced widespread radiological contamination. Nearly 80 percent of the explosive power of 138.6 megatons of all U.S. atmospheric tests is accounted for by the tests on the Marshall Islands. Assuming rough proportionality of fission products, there would remain about 90,000 terabecquerels of cesium-137 and 50,000 terabecquerels of strontium-90, decay corrected to 2020, in addition to long-lived fission products like technetium-99 and iodine-129 which would be essentially undecayed from their initial amounts; about 160 kilograms of plutonium-239 would also remain. (Calculated from data in IPPNW and IEER 1991, Chapters 2 and 3).

Bikini and Enewetak atolls, where the testing was done, would have been impacted the most in terms of residual radioactivity. In addition, the United States create a vast nuclear waste site on Runit Island in Enewetak Atoll in the 1970s in a crater created by one of the nuclear tests. The crater was not lined before tens of thousands of cubic meters of radioactive waste were dumped into it, including local U.S.-generated waste and waste sent to Runit from the Nevada Test Site. The waste pit was covered with a concrete dome (DOE 2020). The pit itself is unlined and is in communication with the ocean and its tides

[3] The regulation at the time was 0.1 roentgen per day, which is approximately 1 mGy/day.

and currents. As a result it leaks radioactivity into the Pacific Ocean and Enewetak Atoll's lagoon. While Runit itself is uninhabited, people did move back to other parts of the atoll in 1980.

In its 2020 report to Congress on the Runit dome, the Department of Energy noted that there was damage to the concrete dome, including cracks in it; it nonetheless opined that "the dome is not in any immediate danger of collapse or failure" (DOE 2020, p. 4). Independent researchers at the Center for Nuclear Studies, Columbia University, point to the reasons for far greater concern (Rapaport and Nikolic-Hughes 2022):

> The structural integrity of the Runit Dome, a concrete shell covering over 100,000 cubic yards of nuclear waste on an island of Enewetak Atoll, is at risk because of rising sea levels. Leakage from the dome—already occurring—is likely to increase and higher tides threaten to break the structure open in the coming decades.

The DOE report did note that leakage of radioactivity from the dome was entering the ocean and hence "the marine food chain"; but apart from some maintenance, monitoring and repair of the concrete, no remedial action is planned (DOE 2020). Of course, Enewetak lagoon and the inhabited islands are also contaminated; in fact the vast majority of the contamination is in these places (Moss-Christian 2021, p.2).

The Runit dome dramatically illustrates one of the major problems of remediation. If radioactive materials are gathered from exposed and dispersed locations, their disposal in a well-constructed site could temporarily lower risks, especially from radionuclides with relatively short half-lives. However, man-made structures are no match for the longevity of radionuclides like plutonium-239 (half-life more than 24,000 years), especially when subject to harsh conditions such as salty air and spray as well as the eroding impacts of tides and storms, exacerbated by global heating associated sea-level rise and increasing severity of storms and other extreme weather events. In the case of the Runit dome, the problem is much worse because the disposal site was an unlined crater created by a nuclear blast that would have severely damaged and fractured it, essentially guaranteeing leakage into the marine environment. In contrast, at about the same time that this unlined disposal site was created at Runit, the United States decided, in 1978, to spent vast sums of money to move tens of millions of tons of uranium mill tailings from unlined ponds where they were contaminating groundwater, to lined ponds. As of 1999, about 1.5 billion dollars had been spent to make such transfers to protect groundwater and the environment (Energy Information Administration 1999).

Conclusions

The Marshall Islands tests, like others, were accompanied by evaluations of the military use of nuclear weapons in wartime. Among the most stark was the evaluation done after the very first tests, Operation Crossroads in 1946, conducted at Bikini. Radiological contamination due to second test of the series, Test Baker on 25 July 1946, was so severe that the Joint Chiefs of Staff evaluation considered the contamination itself as a possible major element of the use of nuclear weapons in war: the aim would be to produce "fear" in the civilian population. It is worth quoting at length because it puts in stark contrast the treatment and lack thereof afforded the people of the Marshall Islands who actually experienced the fallout IPPNW and IEER 1992, p. 143, italics added):

> We can form no adequate mental picture of the multiple disaster which would befall a modern city, blasted by one or more bombs and enveloped by radioactive mists. 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 a fear of death and the uncertainty of the time of its arrival*.

The psychological element of the feat was also made clear in the same evaluation (IPPNW and IEER 1992, p. 144, italics added):

> 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*. We may deduce from a variety of established facts that the effective exploitation of the bomb's psychological implications will take precedence over the application of the destructive and lethal effects in deciding the issue of war.

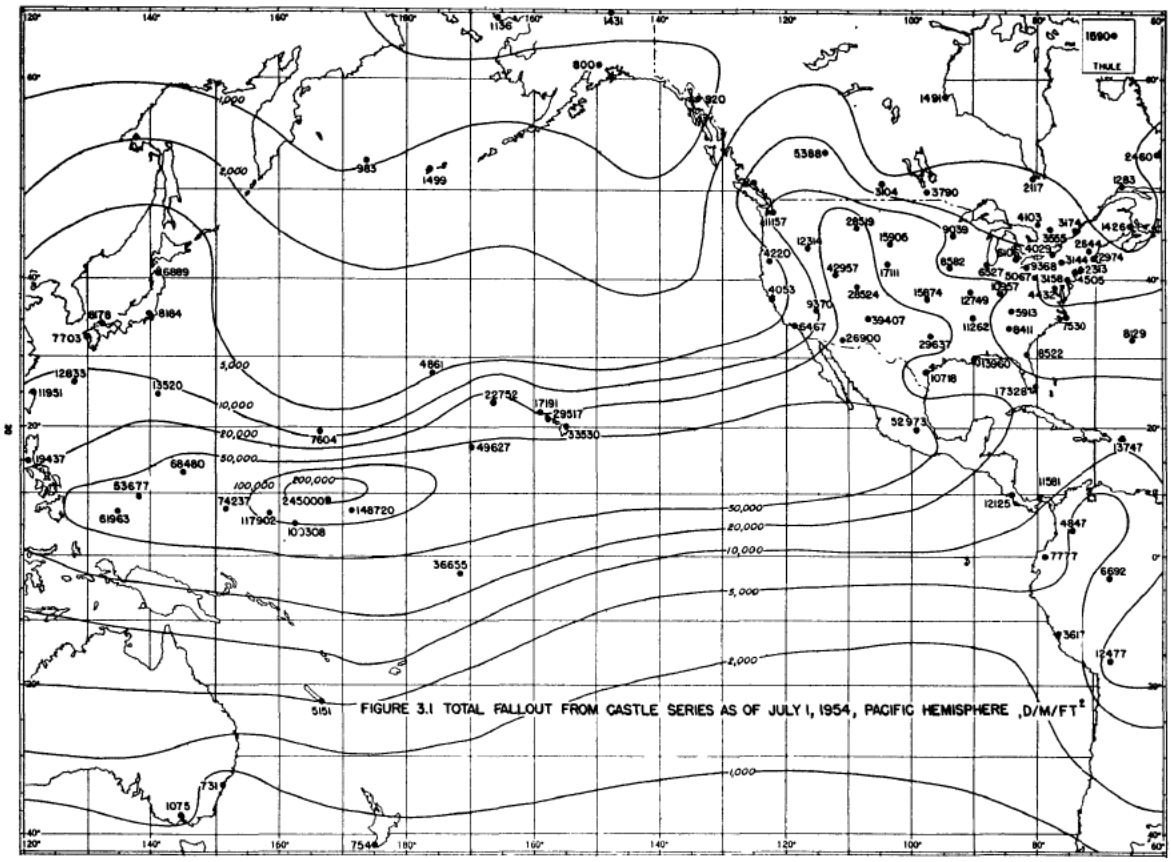
Despite some compensation as part of the Compact of Free Association, which ended the trusteeship of the United States and made the Marshall Islands an independent country, the Marshallese people continue to suffer; adequate compensation and health care have not been forthcoming, as indicated by the October 2021 testimony of the Chair of the Marshall Islands National Nuclear Commission, Rhea Moss-Christian, to a congressional oversight subcommittee (Moss-Christian 2021, p. 9):

> The Nuclear Claims Tribunal remains open to receive any claims of personal injury and property damage caused by the nuclear tests. Several claims remain pending, as well, dependent on Congress' replenishment of the Tribunal Fund. The last compensation award and initial payment were made in December 2008, leaving over $23 million in unpaid personal injury awards and over $2 billion in unpaid property damage awards, making it clear that by the end of 2008, the Tribunal would no longer be able to fulfil its mandate arising out of the Section 177 Agreement, "to render final determination upon all claims past, present, and future….which are based on, arise out of, or are in any way related to the Nuclear Testing Program." In this context, please recall that both the explosive force and the radiation doses suffered by the Marshall Islands were greater than the Nevada Test Site downwinders, but the awards for the Marshallese have been much lower.

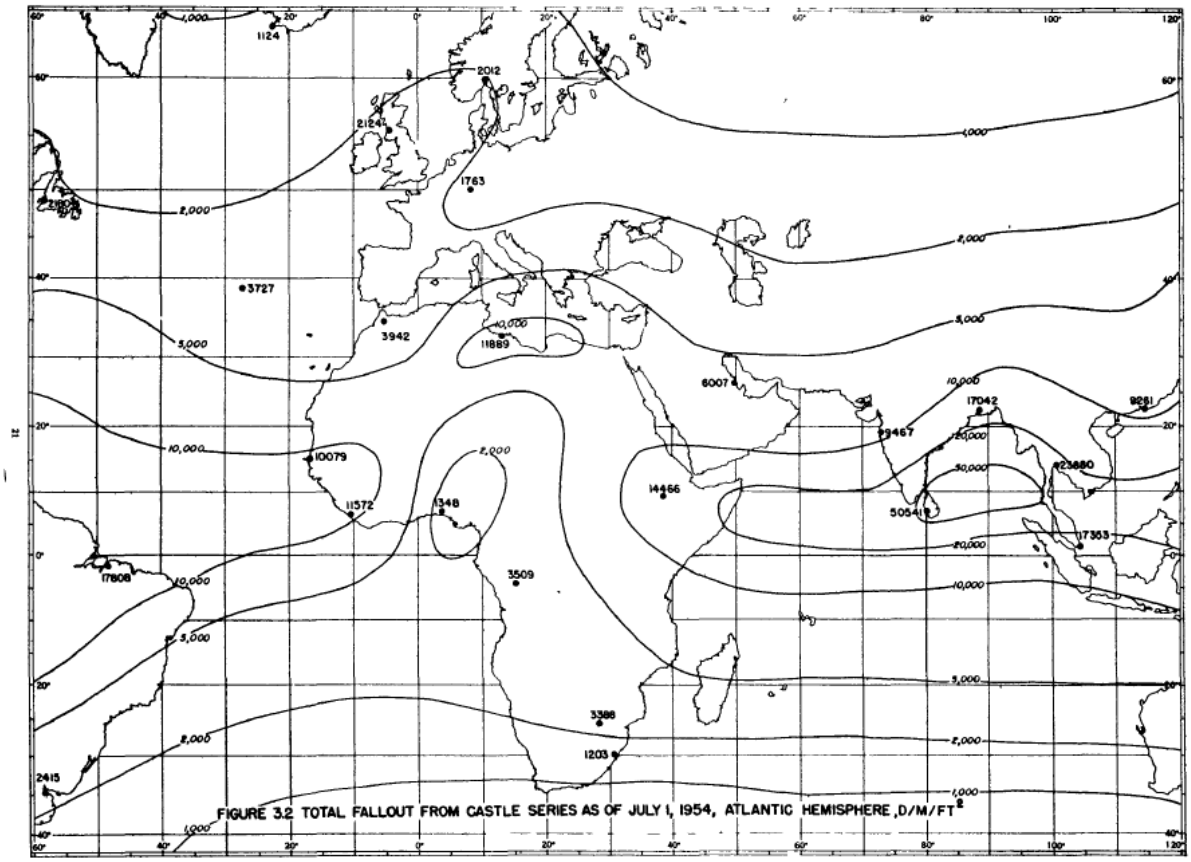
More than six decades after testing ended and more than three decades after the Soviet Union collapsed, the Marshall Islands are still left pleading for justice (Moss-Christian 2021, [pp. 9-10):

> There is still so much work to do and through this Subcommittee's efforts, there is a chance for progress, but this requires an acknowledgment of the full scope of damages and injuries by the US Government. To this day there has never been an apology from the US Government for the ongoing hardships Marshallese endure. The Nuclear Claims Tribunal is the mutually-agreed established forum for addressing the harms of the U.S. nuclear testing program. People who have been granted awards deserve to get them in full; others, who are in process or who may apply in the future, deserve a chance to be heard and have their claims fairly adjudicated. The Runit Dome and all that it represents about radiation still present in our environment requires closer attention and a

reassessment and revision of DOE's mandate. People require health care beyond our means to provide in the RMI; they deserve a U.S. standard of health care to treat illnesses linked to U.S. activities on our islands. And people need the tools and knowledge to be able to participate and contribute to research that seeks to enhance our understanding of how radiation is impacting our lives and livelihoods.



Source: List 1955, pdf p. 20



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