



The Health Effects of Radioactive Fallout on Marshall Islanders: Health Policy Issues of Nuclear Weapons Production

Thomas E. Hamilton, M.D., Ph.D.*

Between 1946 and 1958, the United States conducted 66 nuclear tests in the Marshall Islands. One such test, code-named BRAVO, contaminated individuals from at least two northern atolls. Decisions regarding this test, the details of which have not previously been published in the general medical literature, greatly affected the radiation dose received by the Marshallese people. Actions regarding resettlement of the Marshallese on their exposed atoll are examined as well as the epidemiologic health studies that have been conducted in this population since 1954. Analysis of these decisions and studies suggests that ensuring public health has not been a high priority of the Atomic Energy Commission or its successor agency, the Department of Energy. Furthermore, recent disclosures and a critical assessment by the Secretary of Energy indicate that similar problems characterize the Department of Energy policy of nuclear weapons facilities. An independent federal agency with a primary mandate to protect public health, worker safety, and the environment should be charged with all future monitoring and investigation of radiation-induced health effects in Marshall Islanders, as well as in populations surrounding nuclear weapons facilities in the United States. PSRQ; 1991;1:15-23

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* IEH is Assistant Clinical Professor of Medicine and Environmental Health at the University of Washington. Address correspondence and reprint requests to T. E. Hamilton, M.D., FHCRC, 1124 Columbia Street, MP 425, Seattle, WA 98104.

Between 1946 and 1958, the United States conducted a total of 66 nuclear tests at the Pacific Proving Ground in the Marshall Islands. This country, consisting of approximately 30 atolls (coral islands surrounding a central lagoon), is located

2,500 miles southwest of Hawaii (Fig 1). The testing of nuclear weapons on these islands, and particularly the 1954 BRAVO test, has had profound direct and indirect effects on the health of the Marshall Islands residents as well as on their environment and culture.

The responsibility for conducting these nuclear tests and for protecting the islanders from potential consequences of nuclear testing has rested with the Department of Energy (DOE) or one of its predecessor agencies, beginning with the Atomic Energy Commission (AEC). The Atomic Energy Acts of 1946 and 1954 specify the mandate of the AEC to protect and safeguard the public from hazardous activities stemming from nuclear testing and weapons productions [1].

In the last several years, the media and the public have given great attention to the health and environmental hazards from nuclear weapons production and testing facilities in the continental United States. These nuclear weapons production and testing sites include facilities in Washington, Idaho, California, Nevada, New Mexico, Colorado, Texas, Kentucky, Ohio, Tennessee, Missouri, Florida, and

South Carolina. The Marshall Islands continue to be a key weapons test site for activities relating to the Strategic Defense Initiative.

The recent critical evaluation of safety and environmental violations at U.S. nuclear weapons facilities by Secretary of Energy James Watkins is laudable and long overdue. However, information that is available to the public concerning the extent of the problem is still quite limited, in part because health studies of populations surrounding these sites have not been conducted.

On the other hand, information concerning the radiation exposure of Marshall Islanders from the 1954 BRAVO test is accessible in technical reports of the Departments of Energy and Defense. This information, useful for what it reveals about the U.S. testing program in the Pacific, also bears directly on health policy issues at other nuclear weapons facilities.

Although criticism by the Marshallese about the effects of nuclear testing on their health, their homeland, and their culture has been increasing for over 30 years [2], this history is largely unknown to the majority of Americans.

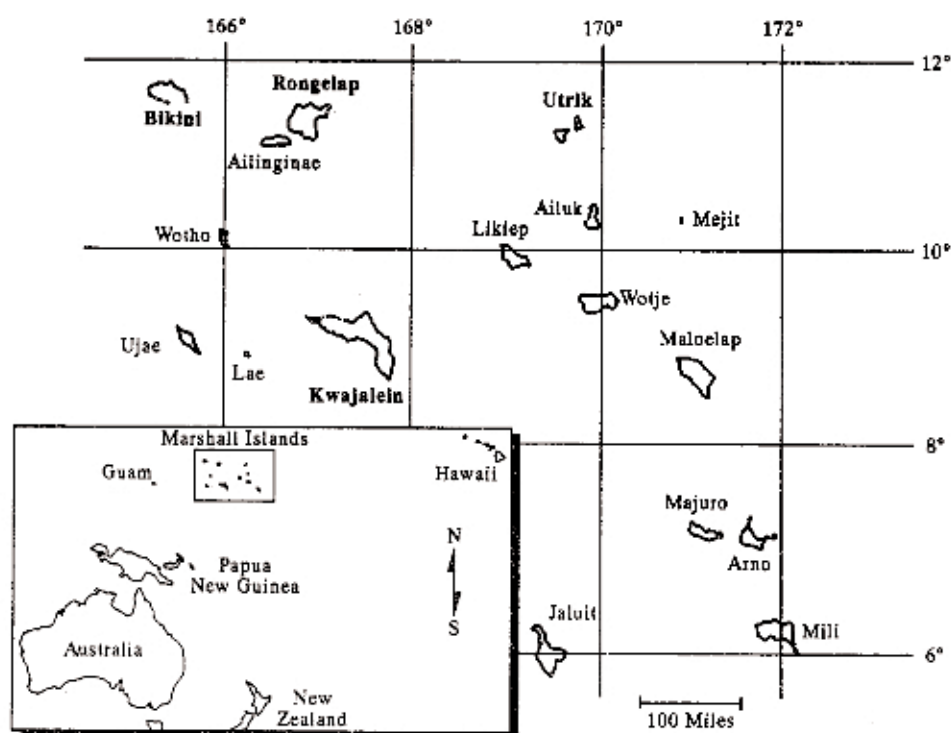


FIGURE 1. Marshall Islands. The BRAVO test site is on Bikini Atoll. Drawings outline atolls, with the solid lines representing the coral islands of each atoll surrounding its central lagoon.

The purpose of this article is to examine the events surrounding the radiation exposures to the Marshallese people in 1954, to present the known health consequences from this exposure, and to assess the epidemiologic health studies conducted to date. Although the nuclear weapons testing program has had a significant impact on the culture and society of the Marshallese, this report focuses on the impact that the radiation exposure has had on health. This report also considers whether the problems now recognized in protecting public health in the Marshall Islands are applicable to nuclear weapons facilities within the United States, and if so, what changes are required.

THE BRAVO TEST

The most powerful of the 66 nuclear tests conducted in the Marshall Islands by the United States was the 15 megaton thermonuclear BRAVO Test detonated on the surface of Bikini Atoll on March 1, 1954. Within 48 hours of exposure to radioactive fallout from this test, the majority of the small population (86 persons) from Rongelap Island, located at the southeastern tip of Rongelap Atoll (Fig 1), developed symptoms and signs of acute radiation sickness. Two days later they were evacuated to Kwajalein Atoll. Over the next several months individuals developed varying degrees of nausea, anorexia, vomiting, pruritis, beta burns of the skin, epilation, leukopenia, and thrombocytopenia [3]. Early health effects also included a transient increase in spontaneous abortions during the 5 years post-exposure in highly exposed Marshallese women [4]. A high level whole-body exposure (from external photon radiation) of approximately 190 cGy (rad) resulted from the 2-day post-BRAVO residence time on Rongelap, with lesser doses received by persons from Utrik farther east of Bikini [5,6].

The whole-body radiation dose of the Marshallese people, especially those living on Rongelap, was directly affected by at least three factors. First, the Rongelapese were not evacuated to prevent possible radiation contamination, as they had been in the 1946 Crossroads test series. Second, the wind direction was due east, toward Rongelap, prior to the detonation of BRAVO. Several weather briefings before detonation indicated that winds at 20,000 feet were headed for Rongelap. However, it was felt that the predicted speed of these winds was low enough to be of no concern [7]. Third, the Rongelap

and Utrik populations were allowed to remain on their home island for at least 2 days after the test, before they were evacuated. During this time, individuals were exposed to external whole-body radiation from the fallout cloud as it passed over the island, as well as fallout on the ground. In addition, children played in the "fallout snow" and many islanders consumed contaminated food and water.

No formal investigation of the decision to conduct the test with the wind blowing toward Rongelap, and of the failure to evacuate these inhabitants immediately, has ever been made public. Although many details may be unrecorded or classified as secret, a Defense Nuclear Agency report published in 1982 provides data that indicate that it was logistically possible to evacuate these 86 people from Rongelap Island and nearby Ailinginae Atoll [7]. This report documents the operations and radiologic safety activities of U.S. military personnel during the BRAVO test, including the nautical positions and radiation monitor logs of all naval vessels at the time of the BRAVO test. Figure 2 shows the position of some of the naval vessels relative to the location of Bikini and Rongelap, just prior to and during the BRAVO detonation. The U.S.S. Gypsy lay within a few miles and just outside the lagoon of Rongelap, 80 miles southeast from the Bikini test site, and adjacent to Ailinginae. In addition, at least six other naval vessels (the U.S.S. Curtiss, Sioux, Tawakoni, Estes, Belle Grove, and Bairoko) were in position between Rongelap and Bikini at the time of detonation.

If the people of Rongelap had been evacuated immediately or within hours after the BRAVO test, they could have been spared most of the whole-body doses from external radiation, and the organ doses from internal radiation exposure, that they eventually received. Why were the Marshallese people not evacuated on the morning of the BRAVO detonation when naval transportation was available? There is no public information that addresses this question. In fact, the above information concerning ship locations near Rongelap comes from a safety report of U.S. military personnel during BRAVO, which does not discuss safety issues of Marshall Islanders. Nor does the original map of naval ship positions include the inhabited atolls on it. In addition, none of the DOE or AEC health studies address this issue so that it is unclear whether any communication occurred between the AEC and

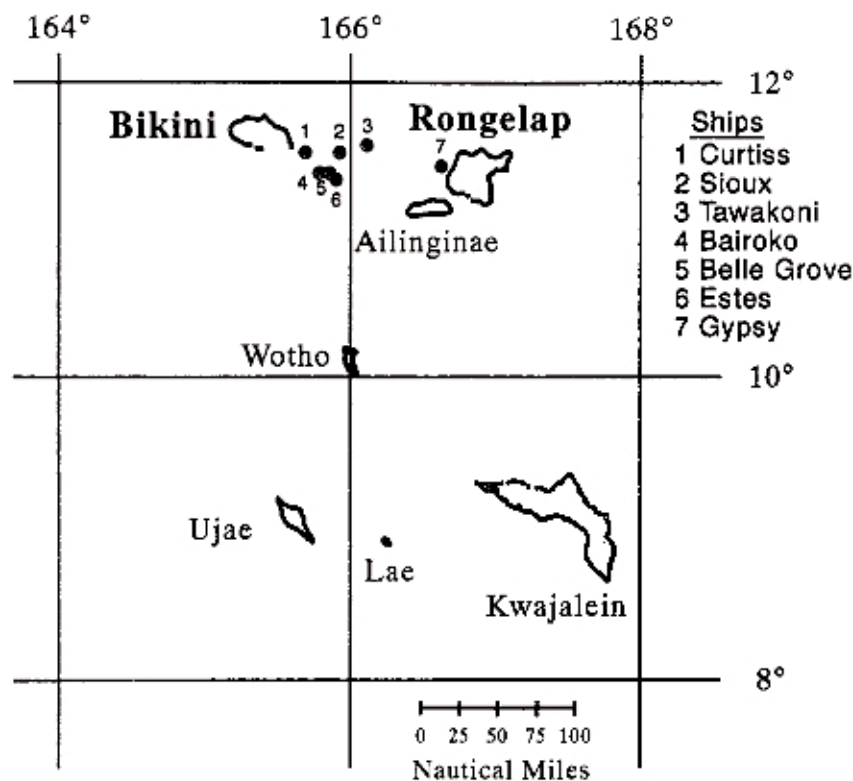


FIGURE 2. Locations of naval vessels (solid circles) at the time of BRAVO detonation in relation to Rongelap Atoll. Adapted from Defense Nuclear Agency report [7].

the U.S. Navy regarding possible early evacuation of the Rongelap people.

Although many reasons might be offered for the failure to act (such as risk of radiation exposure to the ships' military personnel, inadequate information about the extent of the fallout cloud, or poor communication), one conclusion is inescapable: the personal safety of the Rongelapese and other Marshallese people was not a high priority of the AEC in 1954.

The Resettlement of Rongelap

Three years after the Rongelap population was evacuated, the AEC decided that Rongelap Island, but not the entire atoll, was safe for habitation. Resettlement occurred in June, 1957 [3,4,8,9]. During the 5 years after their return to Rongelap, the Rongelapese people were monitored for body burdens of radioisotopes. The AEC found that the mean body burden of cesium-137 was 60 times higher in 1958 than in 1957 and that the mean body burden of zinc-65 was 8 times higher [8]. In addition, the cesium-137 body burden increased through 1961. In 1959 it was 300 times higher than that of the administering medical team, which was used for

comparison. The mean strontium-90 body burden was 6 times higher in 1962 than in 1958. During 1958 alone, the Rongelapese received an estimated bone marrow radiation dose of 559 mrad/year (68% from fission products, 32% from background radiation) [8].

These DOE reports state that these doses were generally felt to be within U.S. "maximum permissible levels" [8]. However, two important questions remain unaddressed. Why, over a period of 5 years, during which body burdens of radioisotopes were steadily increasing, was there no investigation of whether or not this population should continue living in this environment? Second, what was the wisdom of comparing current body burdens of radioisotopes in these people to "maximum permissible levels" established for the general (and presumably unexposed) population, when these people had already been acutely exposed to 190 rad (cGy) of whole-body radiation?

Thyroid Neoplasia in Marshall Islanders: Brookhaven Studies

Since 1957, Brookhaven National Laboratory (BNL) has been under contract by the DOE to per-

form medical examinations on Marshall Islanders exposed to nuclear fallout. The results of these studies have been published primarily in the BNL or DOE literature [3-6,8-19], although numerous articles on this subject appeared in the general scientific literature during the 1960s and 1970s [20-32].

The most prevalent long-term health effect in the Marshallese population has been the development of benign and malignant thyroid neoplasms [3,33]. Approximately 30% of adults on Rongelap (and over 60% of children exposed when younger than 10 years of age) developed thyroid nodules, a small proportion of which were thyroid carcinoma [3].

Long-term health effects other than thyroid neoplasia have included hypothyroidism [31], growth retardation in several individuals, and most probably two deaths, one each from acute myelogenous leukemia and gastric carcinoma, among the 86 Rongelapese persons who were highly exposed [3,28]. In addition, chromosomal aberrations in this group were increased relative to comparison groups 10 years after exposure to fallout radiation [3,20].

To evaluate thyroid neoplasia, Brookhaven researchers selected exposed and unexposed cohorts. Persons classified as exposed were present on Rongelap (and Ailinginae) and Utrik at the time of the detonation of BRAVO. Although dose estimates have been revised on several occasions [3,5,6], there is no question that persons residing on these two atolls, especially Rongelap, received significant radiation doses to the thyroid gland. The uncertainty around individual thyroid dose estimates is quite large, and there are large differences between the Rongelap and Utrik thyroid dose estimates; nevertheless, these people are correctly classified as exposed. These persons were prospectively followed and continue to be carefully examined on an annual basis by Brookhaven physicians.

The unexposed cohort was defined and examined in an entirely different manner. This cohort initially consisted of Rongelap and Utrik persons who were not present on their home atolls at the time of the BRAVO detonation. Because of attrition among the unexposed cohort, several hundred persons from other northern atolls were added to this control group in the 1970s, and their thyroid glands were examined. These persons were not prospectively followed, but the point prevalence of thyroid neoplasms among them was combined with the prevalence in the original unexposed cohort to describe

what was called the background rate of thyroid neoplasms in the Marshall Islands [3].

Although the assumption is repeatedly made in DOE and Brookhaven reports that these persons were unexposed to fallout radiation, no dosimetry information is available to support the contention that persons living on atolls other than Rongelap or Utrik were in fact unexposed. On the contrary, several reports from other agencies suggest that fallout radiation contaminated other northern atolls along with Rongelap and Utrik.

One fallout pattern, derived from an experimental model that used wind data and field radiation data at the time of BRAVO detonation, indicated a significant gamma radiation dose on Ailuk Atoll [34], located southeast of Rongelap (Fig. 1). In addition, Peterson [35] used meteorological data to perform a computer simulation of the BRAVO fallout cloud with results suggesting that the fallout path changed from an initial eastern direction to a south or southwestern direction toward Kwajalein. A third report also indicated that several inhabited atolls other than Rongelap and Utrik contained long-lived radionuclides, which were likely residual from intermediate-range fallout in the Marshall Islands [36].

There are, therefore, several important design limitations of the medical surveillance program conducted since 1957. Although the exposed cohort appears to have been qualitatively correctly classified, and carefully followed and examined on a prospective basis, the unexposed cohort was not prospectively followed and examined, and it is not clear exactly how this group was selected. No evidence is available in the literature that indicates that the unexposed cohort was truly *unexposed* to radioiodine. Data from independent sources, described below, suggest that some members of the unexposed cohort may have resided on atolls that were exposed to fallout at the time of detonation.

Thyroid Neoplasia in Marshall Islanders: Independent Studies

Only one major epidemiologic study of thyroid neoplasia has been conducted in the Marshall Islands under auspices independent of DOE, and this study occurred more than 30 years after the BRAVO test. This retrospective cohort study of solitary thyroid nodules in approximately 7,000 Marshallese people was conducted from 1982 through 1985 [33].

The fieldwork was funded by a litigation project on behalf of the Marshallese people. The data analysis and publication were done at the University of Washington.

The purpose of this study was to determine the prevalence of thyroid nodules by physical examination of persons who were living on the following atolls at the time of the 1954 BRAVO test: Rongelap and Utrik; seven northern atolls previously thought by Brookhaven to be unexposed to fallout radiation; and, as the best available, unexposed control group, three atolls in the southern Marshall Islands. The prevalence of thyroid nodules in Rongelap and Utrik individuals was found to be 39% and 9%, respectively, in close agreement with prior Brookhaven data. The prevalence of thyroid nodules (including persons with prior thyroidectomy for thyroid nodules) in the remaining 12 atolls (which past researchers had assumed were *unexposed* to fallout), ranged from 0.9% to 10.6%. A strong, statistically significant, negative correlation exists between the prevalence of thyroid nodules on these 12 atolls and the distance of each atoll from the Bikini test site. The prevalence decreases in a linear fashion as distance from Bikini increases. Furthermore, the prevalence of thyroid nodules in people from the most distant atolls is two to three times lower than that among people from northern atolls who were previously assumed to have been unexposed to fallout radiation. These results strongly suggest that the geographic extent of the BRAVO fallout, and the distribution of health effects to the thyroid, were greater than previously reported.

Although the study did not prove that the decreasing prevalence of thyroid nodules was associated with decreasing radioiodine doses to the thyroid (no radiation dosimetry is currently available on atolls south of Rongelap and Utrik), it strongly suggested that there is a correlation between the proximity of an atoll to the BRAVO test site and the risk that a person residing on that atoll at the time of the BRAVO test would develop a thyroid neoplasm.

In order to provide additional data to determine whether the previously classified unexposed atolls may have received fallout radiation, a second study was conducted to determine the concentrations of cesium-137 (half-life of 30 years) in soils from the same northern and southern atolls used in the above study [37]. Preliminary results indicate that identi-

cally low concentrations of cesium-137 existed on the two southern atolls (Majuro and Mili) and that concentrations of cesium-137 on northern atolls previously thought unexposed to fallout were 1.5 to 3 times higher than cesium-137 concentrations in soils from the southern atolls. These preliminary results do not yet provide a basis for estimating thyroid doses, but they are consistent with the results of the earlier epidemiologic thyroid study, and indicate that atolls in addition to Rongelap and Utrik probably received radiation contamination from test fallout.

IMPLICATIONS FOR U.S. NUCLEAR WEAPONS FACILITIES

The information presented above indicates that the promotion and evaluation of public health in the Marshall Islands was not a high priority of the AEC or DOE, certainly not relative to their primary objective of producing and testing nuclear weapons. An important question is whether issues of public health have been given similarly low priority at nuclear weapons facilities within the U.S. Although much additional data are needed to answer this question definitely, several disturbing reports have surfaced recently.

One report concerns the Hanford Nuclear Reservation in Washington State, a major site for plutonium production. In 1986, the DOE, in response to requests filed under the Freedom of Information Act, released 19,000 pages of previously classified documents relating to the Hanford Nuclear Reservation in Washington State. These documents revealed that massive amounts of radioactive iodine (in excess of 500,000 curies) had been released to the atmosphere from Hanford during the late 1940s and 1950s. Although some details of these operations remain classified as secret, the major reasons for these environmental releases were the lack of technology to filter the radioactive emissions and shortened cooling times of spent fuel to increase plutonium production for nuclear weapons.

As a result of these revelations, two studies have been initiated. The Hanford Environmental Dose Reconstruction Project, directed by an independent Technical Steering Panel, will estimate individual radiation doses that individuals may have received from Hanford off-site exposures. A recent preliminary Phase I report from July, 1990, has indicated

that individuals exposed as infants in several counties from the states of Washington and Oregon may have received significant radiation doses to the thyroid gland from iodine-131 [38].

The Hanford Thyroid Disease Study is a second study, administered by the Center for Disease Control and funded by Congress in 1988. This study will attempt to determine whether thyroid disease is increased among individuals who were potentially exposed to radioactive iodine from the Hanford site.

More recent insight into the extent to which the DOE has given priority to issues of public health has come from a critical evaluation of the nuclear weapons industry by Secretary Watkins. In 1989, he selected an investigative panel to evaluate the nation's health research activities at nuclear weapons facilities. This panel, the Secretarial Panel for the Evaluation of Epidemiologic Research (SPEERA), concluded that the health and safety mandate of the Atomic Energy Act of 1946 to conduct studies for "the protection of health during research and production activities" was an appropriate mandate for the DOE [39]. They further concluded that the DOE "had not developed goals to guide people in carrying out the mandate." The SPEERA report recommended that the long-term and large-scale epidemiologic research program be transferred out of DOE to the Department of Health and Human Services.

If the United States continues to produce and test nuclear weapons, it is imperative that the public be both protected from, and informed about, potential risks emanating from nuclear weapons production. Rigorous and scientifically credible research must be conducted on past and future health hazards stemming from these production activities. Yet given the past history within the DOE, none of this is likely to happen unless the public health mandate is transferred from DOE to another agency, one that has expertise in public health and epidemiologic research and that does *not* have the competing mandate of nuclear weapons production. The scope of this mandate should include not only the Marshall Islands, but *all* facilities in the U.S. nuclear weapons complex.

CONCLUSIONS

1. The initial exposure of the Marshallese people to radiation from the 1954 BRAVO test could prob-

ably have been prevented entirely or significantly reduced by a) evacuating the residents prior to the test as had been done for earlier tests, b) postponing the detonation when it was known that winds were in the direction of Rongelap, or c) evacuating the residents immediately after the detonation, by using naval vessels stationed near Rongelap, and thus reducing or eliminating their 2-day exposure time.

2. Although acute exposure in 1954 was by far the most significant contribution to radiation dose, additional exposure to the Rongelap people could have been prevented by either postponing their 1957 return or by evacuating them again during the subsequent 5 years, when it was known that their body burdens of radionuclides were steadily increasing.

3. Thyroid dosimetry studies of Marshall Islanders have been limited to only two atolls in the northern Marshall Islands. The primary reason for this limitation appears to be the assumption that no atolls other than Rongelap and Utrik were exposed to fallout radiation. This assumption was not tested by DOE or its predecessor agencies, and there is now good reason to believe it is false.

4. The available medical and epidemiologic studies of thyroid neoplasia performed by DOE on Marshall Islanders have significant limitations. Although a reasonable protocol has been followed for examining exposed persons, entirely different methodologies have been used for unexposed persons. No evidence has been provided to validate the classification of the unexposed cohort as an appropriate control group that did not have radiation exposure. There is a strong possibility that the exposed and unexposed cohorts were in fact both exposed, leading to an underestimation of the extent of thyroid health effects in the Marshallese people.

5. No formal investigation of the BRAVO exposure, resettlement issues, or quality of the medical and research programs conducted by the DOE on Marshall Islanders has ever been conducted by an independent federal agency whose primary focus is to promote public health and environmental safety.

6. Preliminary information, both from nuclear weapons sites within the United States and from the SPEERA report, suggests that insufficient priority has been given to addressing epidemiologic research and public health issues at these facilities as well.

The record to date suggests that this situation is not just a matter of a few poor judgments by officials

in government regarding the public health of the Marshallese. Instead, a series of decisions over almost four decades has endangered the health of the Marshallese and has limited rigorous investigations, both scientifically and politically, of the consequences of their exposure to fallout radiation.

The intent of this report is not to impugn the integrity of individual scientists and physicians who have been involved with AEC, DOE, or BNL programs during the last 40 years. Indeed, clinicians and researchers who are well respected in their fields of expertise have been selected to participate in these programs and collectively and individually have contributed great effort in examining the Marshallese people. This report instead seeks to address a system that has failed to protect the Marshallese, and possibly Americans in general, from consequences of nuclear weapons production and testing. This failure has occurred despite the mandate given the AEC to protect public health and safety.

Protection of public health and safety requires research and monitoring programs whose findings are given to peer and public review. A key factor in the DOE's failure to protect is the heavy veil of secrecy placed over activities at nuclear weapons production and testing sites since the beginning of the Manhattan Project in 1942. Such secrecy has prevented the public, independent scientists, and non-DOE federal agencies from knowing which studies have been done, and more importantly, what health and environmental studies should have been conducted concerning hazards that may have occurred.

Nothing can reverse the radiation exposures of the Marshall Islanders, but changes can be implemented now. Permanent responsibility for health protection and health research can and should be transferred out of the nuclear weapons industry. Credible epidemiological research programs should be developed at all nuclear weapons sites. The results of such studies should be made easily accessible to the public and to independent investigators. As physicians and health care professionals we have an obligation to demand these reforms.

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