Time Evolution of Radiological Conditions in the Marshall Islands: Experiences and Lessons Learned in Relation to Fukushima

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"Public sentiment is everything. With public sentiment nothing can fail; without it nothing can succeed." — Abraham Lincoln

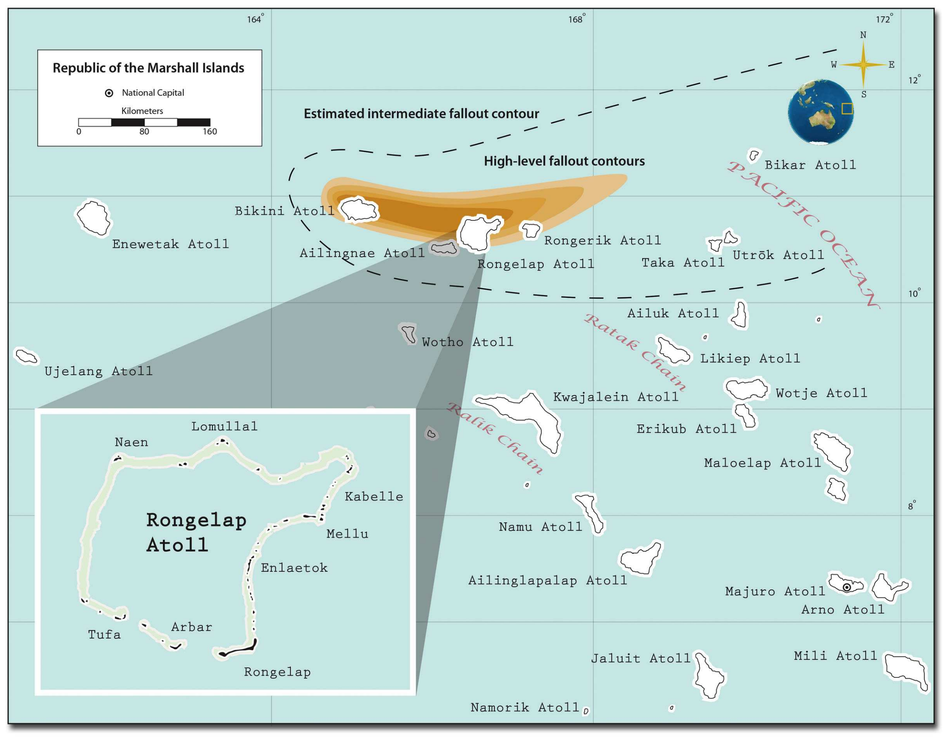
INTRODUCTION

The impacts of the U.S. atmospheric nuclear weapons testing program at Bikini and Enewetak Atolls in the northern Marshall Islands extend well beyond the hard facts of radiation exposure. The CASTLE Bravo test and the unfortunate circumstances surrounding the emergency evacuation of civilian populations located on Ailinginae, Rongelap and Utrōk Atolls have led to a great deal of despair, grave misgivings and decades of passionate debate within the Marshallese community. The legacy of distrust extends over to a board range of legal, social and humanitarian issues associated with the right to seek additional compensation, and covering such elements as long-term health effects of radiation exposure, loss of land, housing and community restructuring, forced change and claims of possible human rights violations.

Under the U.S. Department of Energy Marshall Islands Program, we continue to provide health care and cancer screening, and conduct environmental monitoring at affected atolls. Long-term individual radiological surveillance monitoring and educational programs have been developed. Measures have also been taken to improve food safety and security.

BACKGROUND

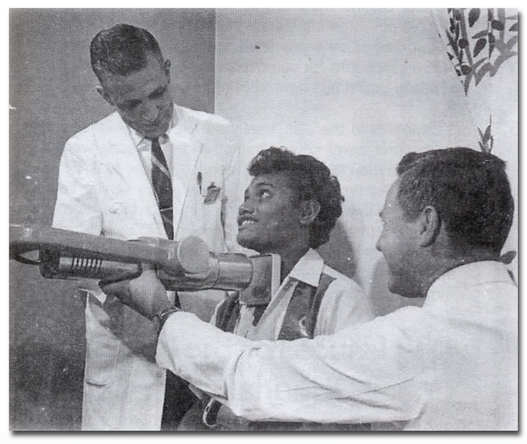
A total of 67 nuclear tests were conducted by the United States at the Pacific Proving Grounds (PPG) located at Bikini and Enewetak Atolls in the northern Marshall Islands (DOE, 2000). The CASTLE Bravo test detonated at Bikini Atoll at 0615 h on 1 March of 1954 was the highest-yield (15 MT) atmospheric nuclear even conducted by the United States, and the only U.S. nuclear weapons test known to cause prompt harm to civilian populations. A total of 82 people from Rongelap Atoll, including a fishing party residing on Sifo Island at Ailingnea Atoll, and 167 residents living on Utrōk Atoll had to be evacuated to Kwajalein Atoll to avert further exposure and receive medical care. Small groups of American Servicemen including weathermen stationed on Rongerik Atoll, and fishermen aboard the Japanese tuna fishing vessel, the *Lucky Dragon*, also experienced moderate to high level radiation exposures.



Map showing the fallout pattern form CASTLE Bravo test.

TIME EVOLUTION OF HEALTH EFFECTS

The highest radiation doses resulting from CASTLE Bravo were experienced on Rongelap Atoll. Bravo evacuees from Rongelap received about 1.9 Gy of radiation to the whole body and between 13 and 52 Gy to the thyroid gland. The immediate effects of the fallout included skin lesions, abdominal discomfort with loss of appetite and transient lowering of the white blood cell count. Children were at greater risk. Almost half of those exposed were below the age of 18 years. Acute intakes were largely a result of ingestion of radioactive particles containing short-lived beta-gamma emitters including iodine-131. Inhalation played only a very minor role. A comprehensive annual medical exam and cancer screening program were established for Bravo evacuees and a matched age and gender comparison group.

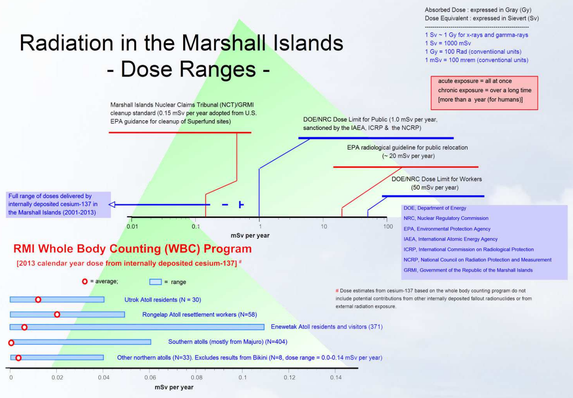


Early medical examination of Bravo patients.

Thyroid nodules were detected as early as 8 years after CASTLE Bravo. A total of 72 patients with nodules were operated. There were 48 benign nodules, 9 occult and 15 overt papillary thyroid carcinomas (10 female and 5 male). A total of 17 patients were in utero at the time of the fallout. None of these patients developed thyroid cancers. There have been no deaths directly related to thyroid cancer. One child with persistently low white blood cell count developed and died from acute myelogenous leukemia. There were also at least 2 reported cases of severe growth retardation, a known manifestation of low function of the thyroid gland. Other causes of death include breast, prostate, and lung cancers. The most prevalent disease amongst the surviving cohort (>50% of patients) is Type 2 diabetes mellitus. However, Type 2 diabetes is also a very prevalent disease within the general Marshallese population.

In contrast, long-term chronic intakes primarily arise from dietary intakes of cesium-137 through consumption of locally grown fruits. Internal contamination of fruits with cesium-137, e.g., coconuts, is much higher per unit soil concentration than in continental regions because of a deficiency of potassium and the low Si-based clay mineral content of coral soils. There have been no observable health effects from low-level, chronic environmental exposure to cesium-137.

THE MARSHALL ISLANDS WHOLE BODY COUNTING PROGRAM

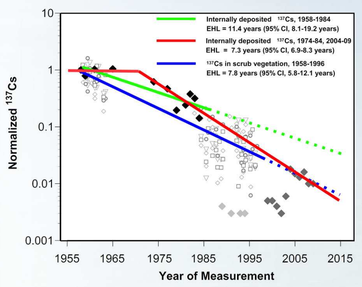


Permanent whole-body counting facilities have been established at Enewetak, Majuro and Rongelap Atolls. All the whole-body counting facilities in the Marshall Islands are operated and maintained by Marshallese technicians. Whole-body counting provides a direct measure of internally deposited cesium-137 inside peoples' bodies, and is a very reliable method for assessing the internal dose contribution from ingestion of cesium-137. The value of whole body count radiation protection monitoring resides in the fact that these data provide a direct measure of radionuclide deposition in the human body. Information about potential *high-end* health risks and seasonal fluctuations in the body burden of cesium-137 can be assessed from repeated measurement data rather than relying on a range of assumptions from different dietary scenarios. Whole body counting is viewed as a medical test, and appears to be a more acceptable form of assuring the general public about their radiation safety and health.

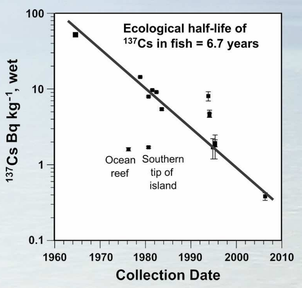
The individual measurement and dosimetric data for the Marshall Islands whole body counting and urinalysis bioassay programs are available on the Marshall Islands Program website, *https://marshallislands.llnl.gov/*. The atoll population average doses observed from internally deposited cesium-137 typically range from <1 to about 0.04 mSv per year.

The Enewetak Radiological Laboratory with Whole Body Counting System.

TIME EVOLUTION OF CESIUM-137



Environmental monitoring data for ^{137}Cs in scrub vegetation (1958-1996) on Kabelle Island, Rongelap Atoll (after Robison et al., 2003)
- Scavola Leaves
- Pisonia Leaves
- Guettarda Leaves
- Messerschidia Leaves



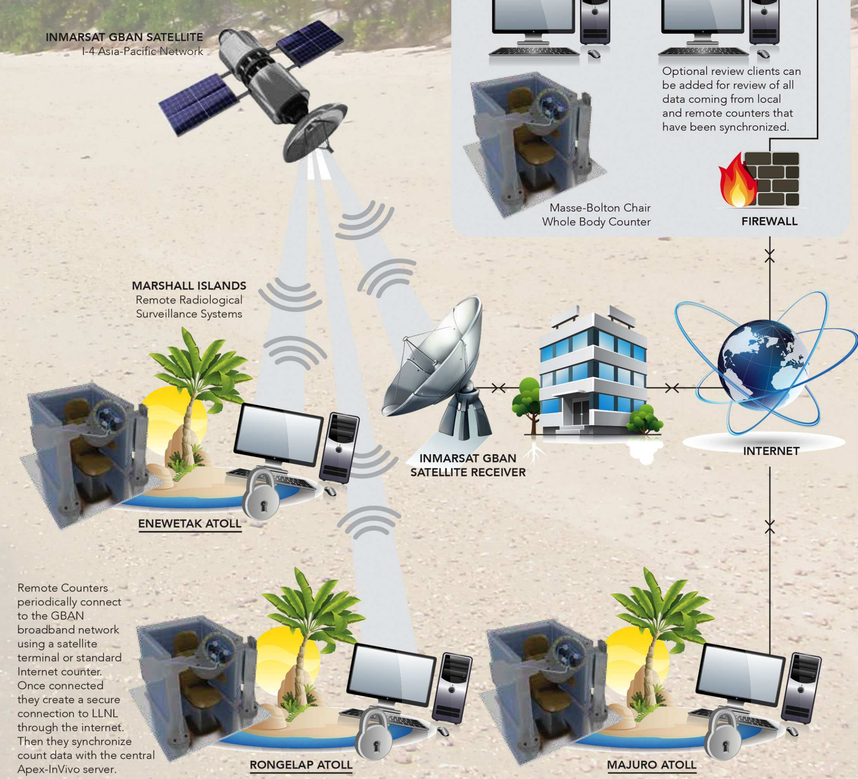
^{137}Cs in Surgeonfish muscle in the lagoon off the northern end of Runit Island, Enewetak Atoll

Individual monitoring data for internally deposited ^{137}Cs based on whole body counting
- Rongelap residents (1958-84, adult males, BNL)
- Kwajalein Atoll (Majetto Island resident) (1989-96, adult males, BNL)
- Rongelap resettlement workers(1999-2009, adult males, LLNL)

Cesium-137 accounts for up to 95% of the total nuclear test related radiation dose at nuclear affected atolls in the northern Marshall Islands. Depending on the atoll, about 85-90% is via consumption of locally grown foods containing cesium-137. About 10-15% is due to external gamma exposure from residual levels of cesium-137 in the soil. The mean-effective half-life of cesium-137 in vegetation is around 8.5 years (Robison and Hamilton, 2010). We have observed similar trends in the loss rate of cesium-137 between internally deposited cesium-137 in local population groups based on whole body counting and repetitive environmental measurements of cesium-137 in local vegetation.

CONCLUSION

The individual and environmental radiological surveillance programs developed under the DOE Marshall Islands Program are helping meet the informational needs of the United States DOE and the Republic of the Marshall Islands. Our mission is to provide high quality measurement data and reliable dose assessments, and to build a strong technical and scientific foundation to help sustain resettlement of nuclear affected atolls. The future success of the program hinges on building public trust, improving communications, and providing open public access to data and information.



Operational schematic of the Marshall Islands Whole Body Counting Program.

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2. Robison, W.L., and T.F. Hamilton (2010). Radiation doses for Marshall Islands atolls affected by U.S. nuclear testing: All exposure pathways, remedial measures, and environmental loss of ^{137}Cs, *J. Health Phys.*, **98** (1), 1-11.

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LLNL-POST-666551 / IAEA-CN-235-89
IEM on Strengthening Research and Development Effectiveness in the Light of the Accident at the Fukushima Daiichi Nuclear Power Plant, IAEA Headquarters, Vienna, Austria, 16-20 February 2015.
This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory in part under Contract DE-AC52-07NA27344. LLNL-POST-666551.