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MARSHALL ISLANDS DOSE ASSESSMENT AND RADIOLOGICAL PROGRAM

BIKINI · ENEWETAK · RONGELAP · UTRŌK

Individual Radiation Protection Monitoring in the Marshall Islands: Rongelap Atoll (2005–2006)

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March 2007

As a hard copy supplement to the Marshall Islands Program web site (http://eed.llnl.gov/mi/), this document provides an overview of the individual radiological surveillance monitoring program on Rongelap Island (Rongelap Atoll) along with a full disclosure of all verified measurement data (2005–2006).

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Rongelap Whole Body Counting Facility
Rongelap Atoll
Republic of the Marshall Islands

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INTRODUCTION

The United States Department of Energy has recently implemented a series of strategic initiatives to address long-term radiological surveillance needs at former U.S. nuclear test sites in the Marshall Islands. The plan is to engage local atoll communities in developing shared responsibilities for implementing radiation surveillance monitoring programs for resettled and resettling populations in the northern Marshall Islands. Using the pooled resources of the United States Department of Energy and local atoll governments, individual radiological surveillance programs have been developed in whole body counting and plutonium urinalysis. These programs are used to accurately track and assess doses delivered to Marshall Islanders from exposure to residual fallout contamination in the local environment. The key fallout radionuclides of radiological concern include fission products such as cesium-137 and strontium-90, and long-lived alpha emitting radionuclides such as plutonium-239, plutonium-240 and americium-241.

Permanent whole body counting facilities have been established at three separate locations in the Marshall Islands including Rongelap Atoll (Figure 1). These facilities are operated and maintained by Marshallese technicians with scientists from the Lawrence Livermore National Laboratory providing on-going technical support services. The concentration of cesium-137 in soils from the northern Marshall Islands is significantly elevated over that expected from global fallout deposition and may enter the body of local residents through ingestion of locally grown foods. Whole body counting provides a direct measure of internally deposited cesium-137 and is a very reliable method for assessing the internal dose contribution from ingestion of cesium-137.

We have also developed a state-of-the-art measurement technology in support of the Marshall Islands plutonium urinalysis (bioassay) program. Bioassay samples are collected by locally trained technicians under controlled conditions and returned to the United States for analysis of plutonium isotopes by Accelerator Mass Spectrometry (AMS). High-quality bioassay measurements based on AMS are providing more reliable and accurate baseline measurements, and could potentially be used to track and assess intakes of plutonium associated with resettlement.

Site specific environmental surveys are also conducted to determine the fate and transport of fallout radionuclides in the environment or simply to verify the effects of cleanup programs. The general aim of the environmental studies program is to develop fundamental scientific data on the behavior of key radionuclides in the environment.

Figure 1. The Rongelap Atoll Massic-Bolton whole body counter based on a design showing a plastic calibration phantom sitting in the chair.

These data and information will ultimately be used to develop more reliable predictive dose assessments for resettlement taking into account future change in radiological conditions. This information is essential in helping determine the most appropriate measures for cleanup and in assessing the impacts of changes in life-style, diet and land-use on radionuclide uptake and dose. Together, the individual and environmental radiological surveillance programs in the Marshall Islands are helping meet the informational needs of the United States Department of Energy 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 affected atolls. Perhaps most importantly, the recently established individual radiological surveillance programs provide atoll population groups with an unprecedented level of radiation protection monitoring where, for the first time, local resources are being made available to actively monitor resettled and resettling populations on a more permanent basis.

As a hard copy supplement to Marshall Islands Program web site (http://eed.llnl.gov/mi/), this document provides an overview of the individual radiation protection monitoring program established on Rongelap Atoll along with a full disclosure of all verified measurement data (2005–2006). Readers are advised that an additional feature of the associated web site is a provision where users are able to calculate and track doses delivered to volunteers (de-identified information only) participating in the Marshall Islands Radiological Surveillance Monitoring Program.

BRIEF HISTORY OF NUCLEAR TESTING IN THE MARSHALL ISLANDS

Immediately after WWII, the United States created a Joint Task Force to develop a nuclear weapons testing program. Planners examined a number of possible locations in the Atlantic Ocean, the Caribbean, and the Central Pacific but decided that coral atolls in the northern Marshall Islands offered the best advantages of stable weather conditions, fewest inhabitants to relocate and isolation with hundreds of miles of open-ocean to the west where trade winds were likely to disperse radioactive fallout. During the period between 1945 and 1958, a total of 67 nuclear tests were conducted on Bikini and Enewetak Atolls and adjacent regions within the Republic of the Marshall Islands. The most significant contaminating event was the Castle Bravo test conducted on March 1, 1954 (Figure 2). Bravo was an experimental thermonuclear device with an estimated explosive yield of 15 MT (USDOE, 2000), and led to widespread fallout contamination over inhabited islands on Rongelap and Utrōk Atolls, as well as other atolls to the east of Bikini. Today, the United States Department of Energy through the Office of International Health Studies continues to provide environmental monitoring, healthcare and medical services on the affected atolls.

Key directives of the Marshall Islands Dose Assessment and Radioecology Program conducted at the Lawrence Livermore National Laboratory are (1) to provide technical support services and oversight in establishing radiological surveillance monitoring programs for resettled and resettling populations in the northern Marshall Islands; (2) to develop comprehensive assessments of current (and assess potential changing) radiological conditions on the islands; and (3) provide recommendations for remediation of contaminated sites and verify the effects of any actions taken.

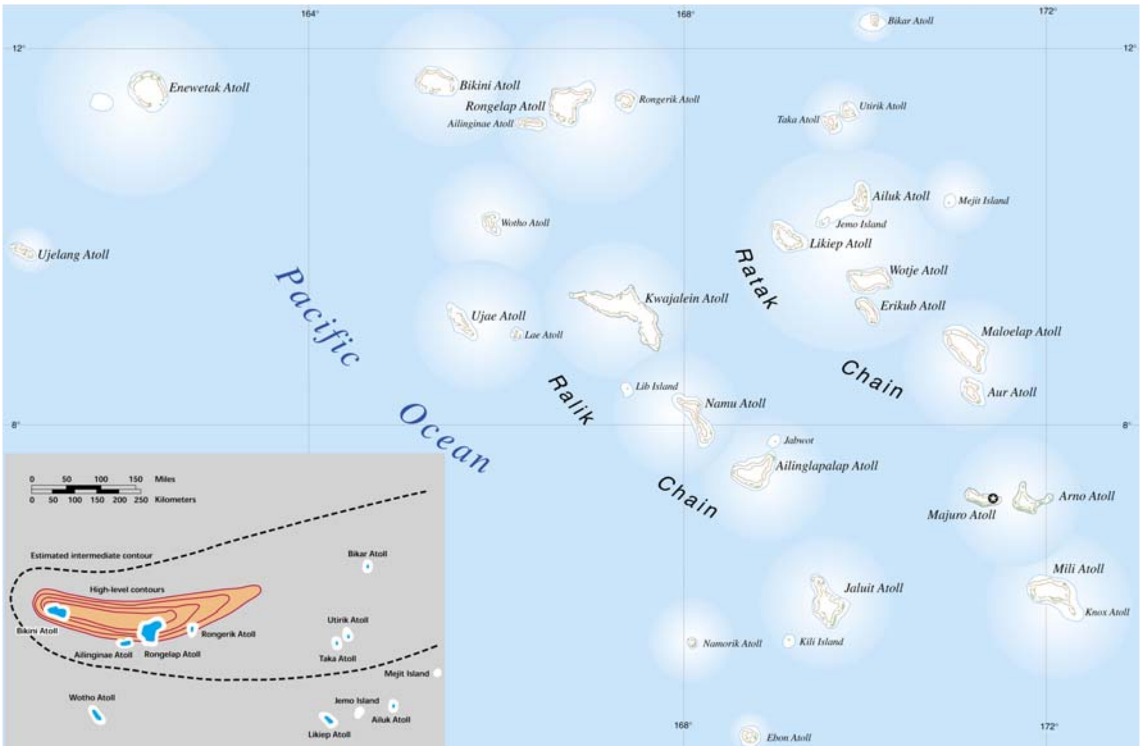
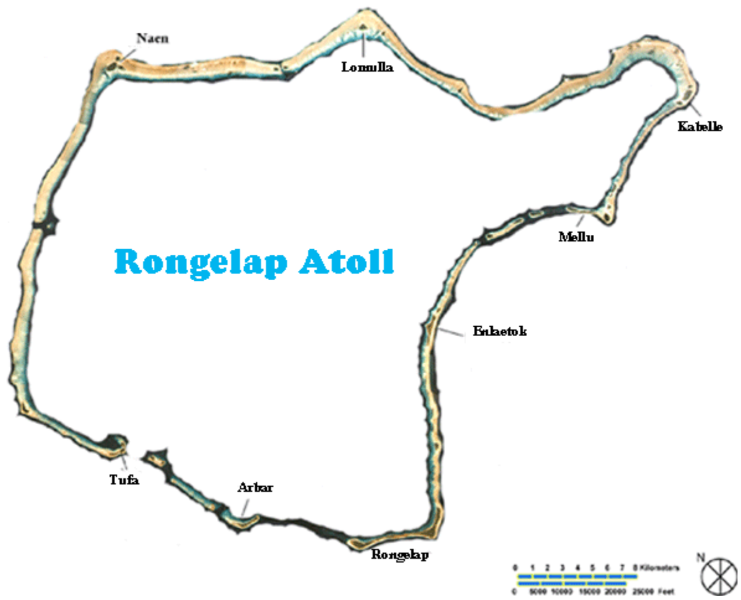


Figure 2. Map of the Republic of Marshall Islands showing the fallout pattern from the Bravo nuclear test conducted on March 1 of 1954.

RONGELAP ATOLL

People & Events | Resettlement of Rongelap Atoll



People and Events on Rongelap Atoll

On March 1, 1954 the United States conducted a nuclear test on Bikini Atoll in the northern Marshall Islands code named Bravo that led to widespread fallout contamination over inhabited islands of Rongelap, Ailinginae and Utrōk Atolls. Prior to Bravo, little consideration was given to the potential health and ecological impacts of fallout contamination beyond the immediate vicinity of the test sites. A total of 64 people living on Rongelap Atoll (including people residing on Ailinginae Atoll at the time of the blast) received significant exposure to 'fresh' radioactive fallout and had to be evacuated to Kwajalein Atoll for medical treatment. The Rongelap community spent the next 3 years living on Ejit Island (Majuro Atoll) before returning home to Rongelap in June of 1957. However, growing concerns about possible long-term health effects associated with exposure to residual fallout contamination on the island prompted residents to relocate again to a new temporary home on Mejatto Island on Kwajalein Atoll in 1985. The people of Rongelap are still resident on Mejatto today although parts of the community have split off to live on Ebeye Island (Kwajalein Atoll) and Majuro Atoll.

The Rongelap community has always expressed a strong desire to return to their ancestral homeland. Through the Rongelap Resettlement Act, the United States Congress approved and continued a 1996 resettlement agreement between the United

States and the Rongelap Atoll Local Government, and extended distribution authority for ten years to advance resettlement. As a part of the 1996 resettlement agreement, a Phase I resettlement program was initiated in 1998. The United States Department of Energy, the Rongelap Atoll Local Government and the Republic of the Marshall Islands have since signed a Memorandum of Understanding (MOU, 1999) outlining shared provisions in support of resettlement. Under this agreement, scientists from the Lawrence Livermore National Laboratory were tasked with developing individual radiation protection monitoring programs for resettlement workers and to verify the effects of the remedial actions.

Resettlement of Rongelap Atoll

Phase I resettlement of Rongelap Island is nearing completion. Rongelap Island now boasts a host of modern-day facilities including electrical power, freshwater reverse osmosis plant and holding tanks, a modern field station, a paved runway and airport terminal building, a whole-body counting facility with an adjoining health physics laboratory, and a large concrete pier and loading dock.

The remedial actions adopted under the Rongelap Resettlement Program are based on recommendations provided by scientists from the Lawrence Livermore National Laboratory. The remediation technique being employed is referred to as the *combined option* and involves replacing contaminated surface soil in the community-village area, where people spend most of their time, with a layer of clean crushed coral fill and adding potassium chloride fertilizer to the surrounding agricultural fields. Limited soil removal and addition of coral fill reduces external exposure to gamma/beta radiation as well as inhalation exposure to radioactive contamination in the air that people breathe (Figure 3 & 4). The addition of potassium fertilizer to the agricultural areas competitively blocks cesium-137 uptake into plants, especially into the fruits of the major subsistence crops such as coconut. It is expected that addition of potassium fertilizer on Rongelap Island will reduce the ingestion dose from cesium-137 to about 30% of the pretreatment level and, at the same time, help support plant growth and increase the productivity of plants (see related information under Bikini Atoll).

After living in exile for nearly 2 decades, the prospect that the people of Rongelap Atoll will soon return to their ancestral homeland is an important milestone in the history of the Marshall Islands Program. Moreover, the Rongelap resettlement program is among the first in which a local government has engaged the United States Department of Energy in developing shared provisions to monitor the resettling population.

Figure 3. Satellite image of Rongelap Island showing (insert) the location of the community center where surface soil was removed and replaced with clean crushed coral fill (approximately 11.4 ha or 36.1 acres).

Figure 4. View of the village area on Rongelap Island after the addition of crushed coral fill. The refurnished church in the background is the only original building remaining on the island from 1985.

INFORMATION NOTE

Contaminated soil around the proposed community center on Rongelap Island has been replaced with a layer of clean crushed coral to reduce external exposure to cesium-137 and other sources of penetrating radiation present in the underlying soil. The initial phase of this work was completed in March 2001. A detailed in-situ gamma monitoring survey of the entire community area was conducted in May 2001. Additional in-situ gamma surveys were carried out in 2006 to assess external gamma exposure rates inside and around newly constructed homes. The results of these studies clearly show that the combination of limited soil removal and addition of crushed coral fill is very effective in reducing external gamma exposure rates. The clean surface layer of coral also has the added benefit of reducing potential exposures from inhalation and ingestion of plutonium and other long-lived radionuclides present in the soils (Hamilton et al., 2001).

WHOLE BODY COUNTING

What is Whole Body Counting? | What Will Whole Body Counting Show? | Estimating Doses from Cesium-137 Based on Whole Body Counting | Performance Evaluation of the Whole Body Counting Program | Doses Delivered to Resettlement Workers from Internally Deposited Cesium-137 | Summary

What is Whole Body Counting?

The whole body counting systems installed in the Marshall Islands contain large volume sodium iodide radiation detectors that measure gamma-rays coming from radionuclides deposited in the body. The detector systems are modeled after the 'Masse-Bolton Chair' design (refer to Figure 1) and can be used to detect high-energy, gamma-emitting fallout radionuclides such as cesium-137 and cobalt-60 in most of the body and all of the internal organs. Using established procedures the whole body counting measurement data are converted into an annual effective dose using specially designed computer software (Canberra, 1998a; 1998b) and a dose report issued immediately to program volunteers.

There are currently three operational whole body counting facilities in the Republic of the Marshall Islands. These facilities are located on Enewetak, Rongelap and Majuro Atolls. The whole body counting systems are calibrated using a mixed-gamma point source method. The point source calibration procedure was developed by cross-reference to a Bottle Man-akin Absorption (BOMAB) phantom (or human surrogate) calibration source containing a standard mix of gamma-emitting radionuclides traceable to the U.S. National Institute of Standards and Technology (NIST).

Wherever possible, the whole body counting program in the Marshall Islands is conducted using the same quality control requirements as established under the U.S. Department of Energy Laboratory Accreditation Program (DOELAP) for internal dosimetry. A systems background and other quality control check counts are performed daily to ensure that the measurement system conforms to all applicable quality requirements. Also, the whole body counting facilities participate in performance testing under the umbrella of the Oak Ridge National Laboratory Intercomparison Studies Program (ISP). These '5-bottle' performance test samples are distributed around each of the facilities including a *mirror* whole body counting system located at Livermore under the Marshall Islands Program.

The performance of each facility is then evaluated by comparing results with those obtained by the Hazards Control Department at the Lawrence Livermore National Laboratory–a DOELAP accredited facility–and with the reference values supplied by the Oak Ridge National Laboratory. Based on our external quality assurance program, the Marshall Island Program whole body counting facilities consistently conform to the ANSI 13.30 criteria for accuracy and measurement precision (Kehl *et al.*, 2007).

Local Marshallese technicians are responsible for all daily operations within the facilities including scheduling of personal counts, performing systems performance checks, data reduction, and initial reporting of dosimetric data to program volunteers (Figure 5). The technicians receive an initial six weeks of intensive training at the Lawrence Livermore National Laboratory and are employed to run the facilities for up to 40 hours per week. Scientists from the Lawrence Livermore National Laboratory provide on-going technical support services, advanced training in whole body counting and basic health physics, and perform a more detailed data quality assurance appraisal before any data are released in reports or posted on the Marshall Islands Program web site.

Figure 5. Former whole body counting technician, Mr. Ericson Arelong, working in the Rongelap Whole Body Counting Facility.

What Will Whole Body Counting Show?

The main pathway for exposure to residual fallout contamination in the northern Marshall Islands is through ingestion of cesium-137 contained in locally grown foods such as coconut, *Pandanus* fruit and breadfruit (Robison *et al.*, 1997a). The strategic objective of the Marshall Islands Whole Body Counting Program is to offer island residents an unprecedented level of radiation protection monitoring until such time that it is clearly demonstrated that radiation surveillance measures can be relaxed. The value of this type of radiation protection monitoring program lies in the fact that whole body count data provides a direct measure of radionuclide uptake into local populations. Information about potential *high-end* health risks and seasonal fluctuations in the body burden of cesium-137 within various Marshallese atoll population groups can be assessed from repeated measurement data rather than relying on a range of assumptions from different dietary scenarios.

In combination with environmental monitoring data, residents who receive a whole body count showing the presence of cesium-137 can now make an informed decision about their eating habits or life-style based on what is considered a ‘safe’ or acceptable health risk. The Republic of the Marshall Islands Nuclear Claims Tribunal has adopted a standard for cleanup of radioactively contaminated sites of 0.15 millisievert (mSv) per year (or 15 mrem per year) [EDE, Effective Dose Equivalent] using a lifetime cancer risk criterion recommended by the U.S. Environmental Protection Agency (EPA). As displaced communities return to their ancestral homelands, the Marshall Islands Whole Body Counting Program will allow the U.S. Department of Energy to monitor the return of the people, and help assure resettled and resettling populations that radiation related health risks remain at or below these established standards.

Estimating Doses from Cesium-137 Based on Whole Body Counting

People living in the Marshall Islands may be exposed to cesium-137 contained in their diets from eating locally grown food crop products such as coconut. Whole body counting provides a direct measure of the amount of cesium-137 inside the body of people. The biokinetic behavior of cesium-137 inside the human body is well known and allows information from the whole body counter to be converted to a radiation dose. The radiation dose is what is used to quantify the potential health risks associated with radiation exposure. The dosimetric data graphics displayed on the Marshall Islands web site are based on the calendar year committed effective dose equivalent (CEDE) from intakes of cesium-137 in the year of measurement projected over 50 years (Daniels *et al.*, 2007). Dose equivalent is given in units of rem, the conventional units used by federal and state agencies in the United States. The SI unit of dose equivalent is the joule per kilogram or sievert (Sv). Doses from exposure to environmental radioactivity (natural or manmade) are normally expressed as 1/1000th of the base unit, i.e., in millirem (mrem) or millisievert (mSv). 1 mSv is equal to 100 mrem.

Information Note: The methodologies for computing doses from the whole body counting and plutonium urinalysis programs have recently been outlined in a Technical Basis Document (refer to *Daniels et al.*, 2007). This new methodology uses a 50 y dose commitment and complies more fully with ICRP methodology. The algorisms developed to allow users to compute doses directly from measurement data posted on the web site are also consistent with this new methodology.

Performance Evaluation of the Whole Body Counting Program

Whole Body counting facilities in the Marshall Islands as well as a *mirror* facility maintained at the Lawrence Livermore National Laboratory participate in bi-annual performance evaluation exercises conducted under the umbrella of the Oak Ridge National Laboratory Intercomparison Studies Program (ISP). The ISP was specifically designed to support whole body counting facilities to comply with requirements of the United States (U.S.) Department of Energy Laboratory Accreditation Program (DOELAP). In this way, the Marshall Islands Radiological Surveillance Program has established quality assurance measures that are consistent with standard requirements used to monitor DOE workers in the United States.

The performance evaluation samples for whole body count measurements are prepared in a mock-up geometry that simulates a human body torso, and usually contains a mix of barium-133 (^{133}Ba), cobalt-60 (^{60}Co), cesium-137 (^{137}Cs) and yttrium-88 (^{88}Y) isotopes at nominal concentrations of $\leq$ 500 nCi (or 18.5 kBq) per sample. The ISP at Oak Ridge use stock isotope solutions indirectly traceable to the National Institute of Standards and Technology (NIST). Details concerning the NIST stock solutions and ISP spikes used in the preparation of the whole body count performance evaluation samples can be found elsewhere (ISP Report, 2005). For practical purposes we have limited performance evaluation testing of the Marshall Island whole body counting facilities to detection and measurement of cesium-137.

For testing purposes, the relative bias (%, Br_i) for a whole body count measurement (i) shows how close the measured activity is to the reference (known) value of the test sample. The relative bias (%, Br) for any whole body count facility can then be calculated as the average of the individual relative biases Br_i as defined by;

$$B_r = \sum_{i=1}^{n} \frac{B_{ri}}{N}$$

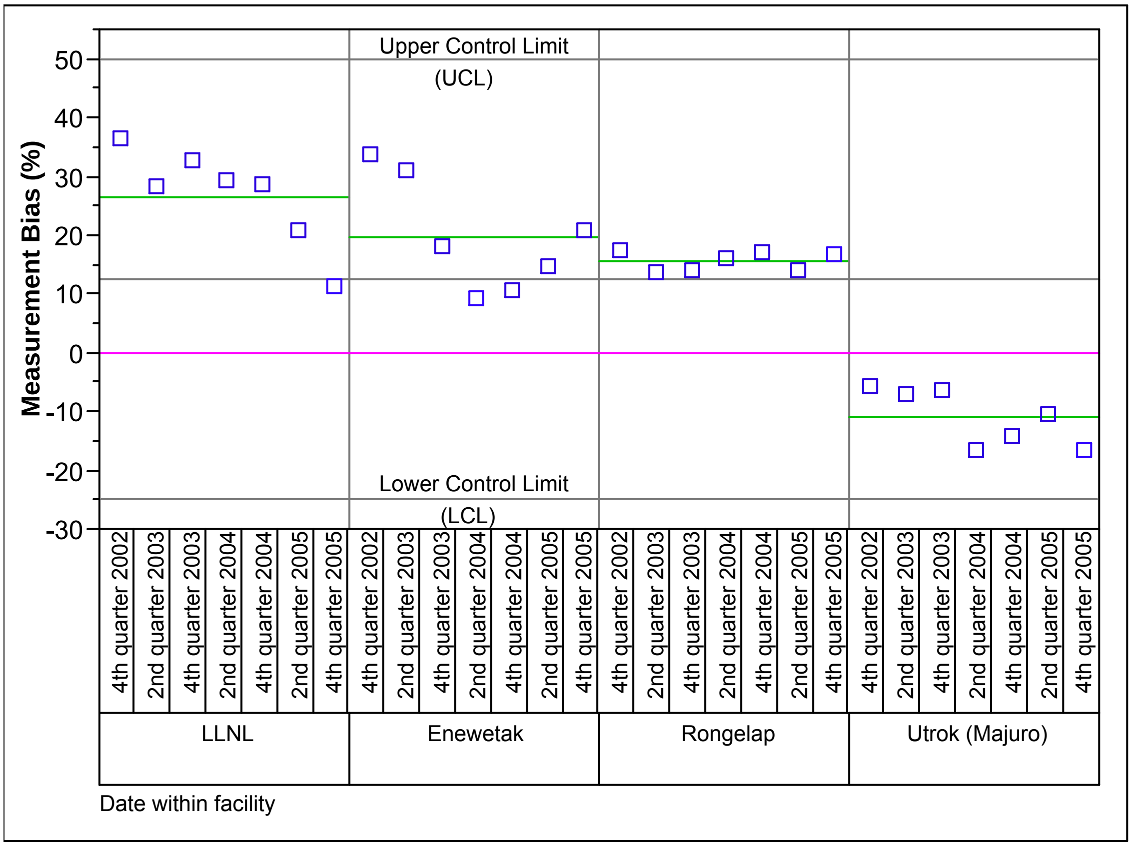
where N is the number of measurements performed within each facility.

The mean relative bias statistic for the LLNL, Rongelap, Enewetak and Utrōk (Majuro) facilities based on performance evaluation exercises conducted between 2002 and 2005 was 25%, 15.4%, 19.6% and -5.4%, respectively. This compares with ANSI 13.30 acceptance criteria used in the United States for radiobioassay service laboratory quality control, performance testing, and accreditation of -25% to +50%. The results for each performance evaluation exercise conducted between 2002 and 2005 are shown graphically in Figure 6 with the upper (UCL) and lower (LCL) control limits.

The relative precision (%, S_B) of the measurements performed across each whole body count facility is the relative dispersion of the values of Br_i from their mean Br, and is defined as;

$$S_B = \sqrt{\frac{\sum_{i=1}^{N} (Bri - Br)^2}{(N-1)}}$$

The acceptance criteria for the relative measurement precision statistic (S_B) based on the ANSI 13.30 standard criteria for radiobioassay service laboratory quality control, performance testing, and accreditation is less than or equal to 40%. The mean relative precision statistic for the LLNL, Rongelap, Enewetak and Utrōk (Majuro) facilities based on performance evaluation exercises conducted between 2002 and 2005 was 8.9%, 1.6%, 9.5% and 16.7%, respectively.



[Statistical reference lines include the null value (----); UCL (Upper Control Limit) = 50% (– - –); LCL (Lower Control Limit) = -25% (– - –); individual facility mean (——); and the overall or combined facility mean (-----)]

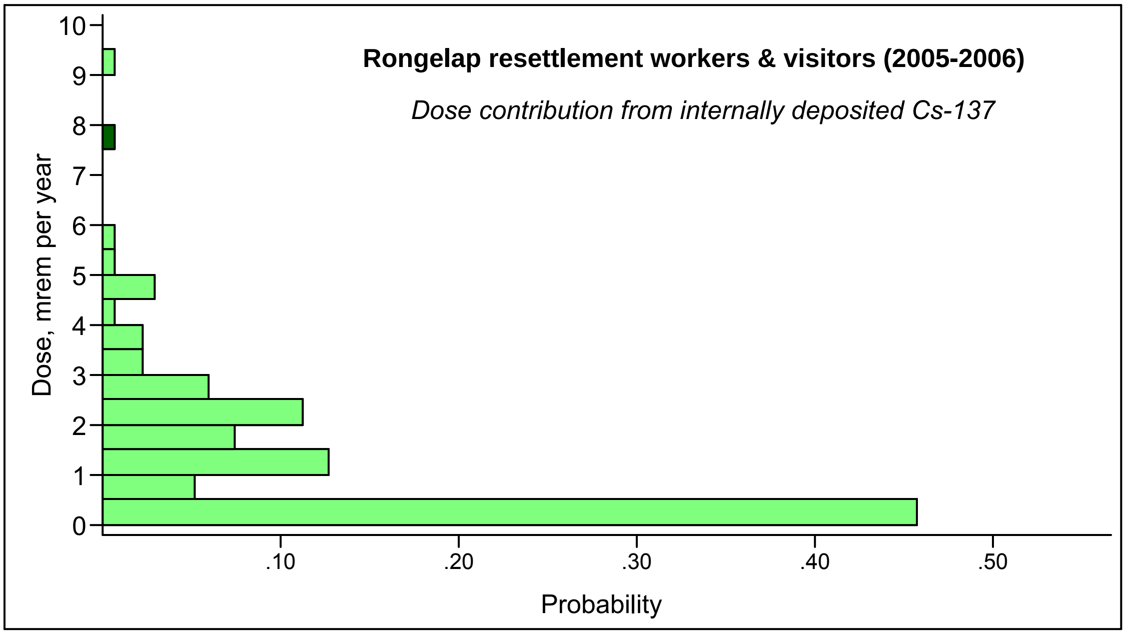
Figure 6. Multivar gage plot showing performance of whole body counting facilities for bi-annual performance evaluation exercises (2002–2005).

The combined mean relative bias and relative precision statistic across all the Marshall Islands whole body counting facilities was 12.6% and 20.5%, respectively. Consequently, whole body count facilities in the Marshall Islands have consistently passed ANSI 13.30 performance criteria for relative measurement bias and precision.

Doses Delivered to Resettlement Workers from Internally Deposited Cesium-137

The individual dosimetric data from the whole body counting program on Rongelap Island are available on the Marshall Islands web site.

A dose distribution plot of the committed effective dose equivalent delivered to program volunteers on Rongelap Island from internally deposited cesium-137, annualized to the year of measurement, is shown in Figure 7.



Moments: Median = 0.9; Mean = 1.3; Std. Dev. = 1.6; Std. Err. Mean = 0.14; Upper Confidence Interval Mean = 1.59; Lower Confidence Interval Mean = 1.0; N (number of volunteers) = 133

Figure 7. Dose distribution plot of the committed effective dose equivalent delivered to Rongelap resettlement workers (2005–2006) from internally deposited cesium-137, annualized to the year of measurement.

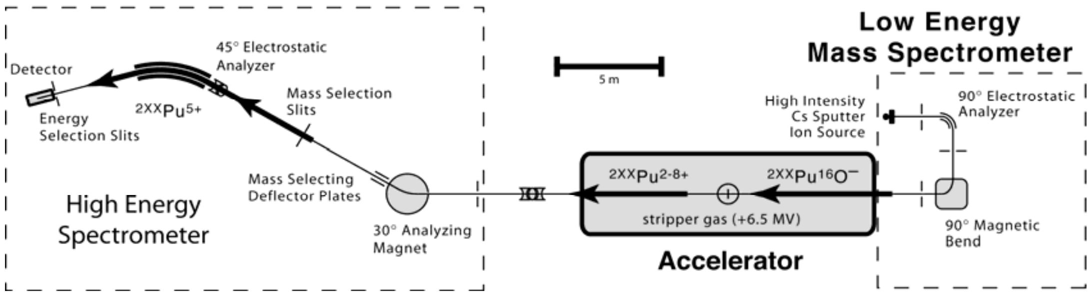
The majority of resettlement workers and visitors to Rongelap Island received internal doses from intakes of cesium-137 of less than 1 mrem (0.01 mSv) per year. The population average committed effective dose equivalent averaged over the past two years was 1.3±1.6 mrem (N=133). This compares with average population doses of 0.6±0.7 mrem reported for 1999 (N = 41), 0.5±0.6 mrem in 2000 (N = 66), 0.3±0.5 mrem in 2001 (N= 102), 0.3±0.5 mrem in 2002 (N=104), 0.3±0.7 mrem in 2003 (N=26) and 1.9±1.8 mrem in 2004 (N=36). The corresponding maximal individual committed effective dose equivalent observed for each measurement year since the introduction of this radiological surveillance monitoring program were 3.4 mrem (2000), 3.4 mrem (2001), 2.4 mrem (2002), 2.3 mrem (2003), 8.1 mrem (2004), 7.6 mrem (2005) and 9.0 mrem (2006). It should be noted that the body burden of cesium-137 in about 1 of every 4 volunteer program participants on Rongelap Island falls below the critical level of the measurements (Lc ~ 0.05 kBq) and, for the purposes of calculating summary statistics, was assigned a dose equal to zero.

Summary

All volunteers participating in the whole body counting program on Rongelap Atoll during 2005–2006 received annualized doses from cesium-137 ingestion of less than 10 mrem. The committed effective dose equivalent for internally deposited cesium-137 in resettlement workers and other visitors to Rongelap can be compared with the natural background Effective Dose Equivalent (EDE) of 140 mrem per year in the Marshall Islands and about 300 mrem per year in the United States. The observed internal doses from cesium-137 for all program volunteers on Rongelap was also significantly lower than the annual dose criteria of 100 mrem per year, excluding medical irradiation, imposed in 10CRF Part 20 (NRC, 2004) for protection of the public. The resettlement workers on Rongelap receive periodic shipments of imported foods but are know to consume some local produce. The results of the whole body counting program on Rongelap clearly demonstrate that resettlement workers are not being exposed to significantly elevated levels of cesium-137 in their diets. However, permanent residents living on Rongelap Atoll are more likely to adopt a traditional lifestyle and consume larger quantities of locally grown foods. Furthermore, as population dynamics on the atoll change there may be more pressure on the community to make wide use of atoll resources including the use of other pantry islands where levels of fallout contamination are higher. Accordingly, a continuing whole body counting program to monitor cesium-137 uptake in the resettling population should be considered.

PLUTONIUM URINALYSIS (BIOASSAY) MONITORING

What is Plutonium Urinalysis Monitoring | Routes of Human Exposure | Purpose of Plutonium Urinalysis Monitoring | Methods of Detection | Methods Validation | Plutonium Urinalysis Monitoring on Rongelap | Plans for the Future



A schematic diagram of the systems configuration for detection and measurement of plutonium isotopes by Accelerator Mass Spectrometry (AMS). AMS is about 200 to 400 times more sensitive than standard techniques commonly employed in routine internal dosimetry programs, and far exceeds the standard requirements established under the latest United States Department of Energy regulation 10CFR 835, for in-vitro bioassay monitoring of plutonium-239.

What is Plutonium Urinalysis Monitoring?

Plutonium urinalysis is a very sensitive *in-vitro* bioassay measurement technique used to determine the amount of plutonium in human urine as a means of estimating the systemic burden (or total amount of plutonium) in the human body. Plutonium urinalysis tests are performed by collecting urine from individuals over a 24-hour period. Under the Marshall Islands Radiological Surveillance Program, we have developed a new state-of-the-art technology for measuring the amount of plutonium in urine based on Accelerator Mass Spectrometry. The test turns a urine sample into a powder which scientists analyze by counting the number of plutonium atoms contained in the sample.

Everybody has a small amount of plutonium in their bodies. Plutonium occurs in nature at very low concentrations but human exposure to plutonium increased dramatically through the 1950s as a result of global fallout from atmospheric nuclear weapons testing. Marshall Islanders are potentially exposed to higher levels of contamination in the environment as a result of exposure to close-in and regional fallout contamination.

Routes of Human Exposure

Plutonium is an important radioactive element produced in nuclear explosions. Plutonium emits alpha particles (or alpha-rays). Alpha-particles have a short range in tissue (about ~40 μm) and cannot be measured by detectors external to the body. However, as heavy slow moving charged particles they have a high relative effectiveness to disrupt or cause harm to biological cells. As a consequence, *in-vitro* bioassay tests have been developed to test for the presence of systemic plutonium in the human body based on measured urinary excretion patterns and modeled metabolic behaviors of the absorbed radionuclides.

The main pathway for exposure to plutonium in humans is inhalation of contaminated dust particles in the air that people breathe. Inhaled or ingested plutonium may eventually end up in various organs–especially the lung, liver and bone–resulting in continuous exposure of these tissues to alpha particle radiation. Plutonium remains in the body for a long time but the systemic uptake of plutonium in people living in the northern Marshall Islands is still expected to be very low (Robison *et al.*, 1980; 1982; 1997b).

Inhalation exposure can be estimated from the product of the soil concentration, resuspension enhancement factors and inhalation dose conversion factors for radionuclides of interest. These estimates show that the projected dose contribution from exposure to plutonium in the Marshall Islands is less that 5% of the total lifetime dose from exposure to residual fallout contamination in the environment (Robison *et al.*, 1980; 1982; 1997b). However, plutonium is a major concern to people living in the northern Marshall Islands because of its long half-life and persistence in the environment. Moreover, radioactive debris deposited in lagoon sediments of coral atolls formed a reservoir and potential long-term source for remobilization and transfer of plutonium through the marine food chain and potentially to man. Elevated levels of plutonium in the terrestrial environment represent potential inhalation and/or ingestion hazards. Early characterization of the terrestrial environment has also revealed the presence of hotspots containing milligram-sized pieces of plutonium metal that required some form of remediation (DOE, 1982). Consequently, dose assessments and atoll rehabilitation programs in the Marshall Islands have historically given special consideration to monitoring plutonium uptake in resettled and resettling populations.

What is the Purpose of Plutonium Urinalysis Monitoring in the Marshall Islands?

Plutonium urinalysis is a measurement technique that ultimately provides information on the amount of plutonium people have in their bodies. Although plutonium is expected to be a minor contributor to the total manmade dose, it is a concern to people living in the northern Marshall Islands who are potentially exposed to elevated levels of plutonium in the environment from close-in or regional fallout deposition. Consequently, the United States Department of Energy has agreed to monitor resettlement workers and perform a limited number of urinalysis tests on island residents using advanced measurement technologies available at the Lawrence Livermore National Laboratory. The measurement technique currently employed at the Lawrence Livermore National Laboratory is based on Accelerator Mass Spectrometry. AMS is about 200 to 400 times more sensitive than monitoring techniques commonly employed in occupational internal dosimetry monitoring programs within the United States, and far exceeds the standard requirements established under the latest Department of Energy regulation 10CFR 835 for *in-vitro* bioassay monitoring of plutonium-239.

The Marshall Islands Plutonium Urinalysis Monitoring Program was implemented under the following action plan:-

1) To provide more reliable and accurate data to assess *baseline* and potentially significant incremental uptakes of plutonium within resettled and/or resettling populations in the Marshall Islands.

2) To monitor plutonium exposure in critical population groups such as workers involved in soil remediation or agriculture.

3) To demonstrate and document that occupational and/or public exposures to plutonium in the Marshall Islands are below levels that will have an impact on human health.

4) To ensure that our plutonium bioassay data meet all applicable quality requirements through the use of standardized procedures and performance testing.

5) To document and test the reliability of using environmental data to assess human exposure (and uptake) to plutonium in coral atoll ecosystems, and predict future change.

Methods of Detection of Plutonium in Urine

Researchers from the Brookhaven National Laboratory (BNL) were the first to use whole body counting and plutonium urinalysis techniques to assess intakes of internally deposited radionuclides in Marshallese populations (Sun *et al.*, 1992; 1995; 1997a; 1997b; Conard, 1992; Lessard *et al.,* 1984; Miltenberger *et al.*, 1981; Greenhouse *et al.*, 1980). Classical methods for evaluating intakes of plutonium in bioassay samples include alpha-spectrometry and fission-track analysis. Alpha spectrometry cannot distinguish between plutonium-239 and plutonium-240, and results are normally reported for the sum of the two isotopes. Moreover, alpha spectrometry lacks the necessary detection sensitivity to accurately assess plutonium exposure in the Marshall Islands (Hamilton *et al.*, 2004). Fission Track Analysis is limited to the quantification of plutonium-239 but with a reported detection limit (MDA, Minimum Detectable Amount) of around 1 to 3 microBecquerel (μBq) of plutonium-239 offers a greatly improved potential for assessing uptakes associated with low-level chronic exposure to plutonium in the environment.

Under the Marshall Islands Plutonium Urinalysis Program, urine samples were initially sent to the University of Utah for analysis of plutonium using fission track analysis. Fission is a process where heavy nuclei such as plutonium and uranium break up into two large fragments. Fission may occur spontaneously or be induced by collisions with neutrons. During fission track analysis samples are exposed to a source of neutrons in a reactor while in contact with a quartz or plastic slide. Any resulting fission fragments will leave behind tracks on the slide that can be counted under an optical microscope to determine the amount of plutonium present. Historically, fission track analysis has been plagued with a number of deficiencies including the use of less than reliable and tedious preparative methods, low chemical yields, contamination issues and inaccurate quantification. The University of Utah and the Brookhaven National Laboratory improved on the fission track process methodology, and adopted a more rigorous approach to data reduction and quality assurance in support of urinalysis testing programs in the Marshall Islands.

More recently, scientists from the Lawrence Livermore National Laboratory have developed a low-level detection technique for determination of plutonium isotopes in bioassay samples based Accelerator Mass Spectrometry (Brown *et al.*, 2004; Hamilton *et al.*, 2004; Hamilton *et al.*, 2007). The technique has vastly improved the quality and reliability of assessments of urinary excretion of plutonium from Marshall Islanders, and avoids many of the disadvantages of using conventional atom counting techniques or other competing new technologies.

INFORMATION NOTE

There are two main isotopes of plutonium in the environment–namely plutonium-239 (^{239}Pu) and plutonium-240 (^{240}Pu). The isotopic composition of plutonium (i.e., the relative amounts of ^{239}Pu and ^{240}Pu) may vary significantly depending on the source of plutonium. For example, the $^{240}Pu/^{239}Pu$ content of nuclear fallout from high−yield atmospheric nuclear tests in the Marshall Islands produced $^{240}Pu/^{239}Pu$ atom ratio signatures of ~0.35 compared with that present in integrated global fallout deposition (~0.18) or unfissioned nuclear fuel (~0.05). Consequently, it may be possible to use bioassay testing and plutonium isotopic measurements as an investigative tool to assess source specific exposures to Bravo fallout as well as from other specific nuclear events.

Method Validation

Method validation is the process used to monitor and document the quality of the measurement data. Methods validation testing under the Marshall Islands Urinalysis Monitoring Program has included participation in an independent interlaboratory exercise organized by the United States National Institute of Standards and Technology (NIST). The results of this exercise clearly demonstrate that accelerator mass spectrometry is well suited for detection of μBq concentrations of plutonium-239 and plutonium-240 in urine (Figure 8) (Marchetti *et al.*, 2002). An independent report on the results of this intercomparison exercise was recently published in the open scientific literature (McCurdy *et al.*, 2005). This study demonstrated that accelerator mass spectrometry provided more precise and higher quality results than comparative methods.

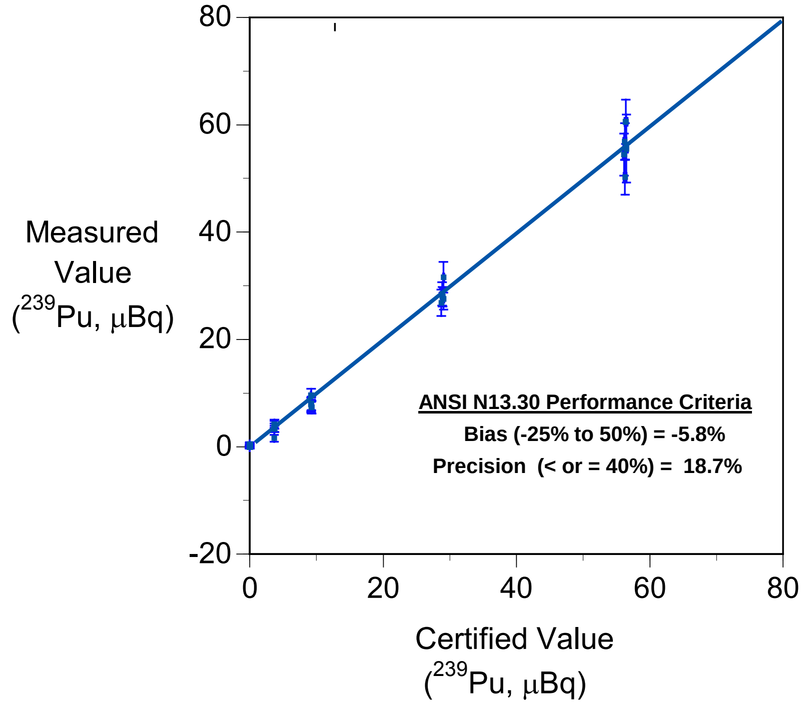


Figure 8. Results of an interlaboratory exercise conducted by National Institute of Standards and Technology (NIST) on determination of plutonium-239 in synthetic urine in the microBecquerel (μBq) range.

We also continue to test the performance of the technique by analyzing externally-prepared quality control natural urine samples artificially spiked with known amounts of plutonium. These quality control performance test samples are prepared under contract with the Oak Ridge National Laboratory and analyzed along with routine bioassay samples collected from the Marshall Islands. The activity concentration of plutonium-239 in the quality control samples is keep below 200 μBq in order to avoid possible cross-contamination problems, and the plutonium-240/plutonium-239 atom ratio approximates that observed in integrated worldwide fallout deposition, i.e., ~0.2. The results of the quality control sample analyses are sent to Oak Ridge National Laboratory researchers for review and, in return, they prepare a data quality assurance report. All quality control data must pass ANSI N13.30 performance criteria for accuracy and precision before acceptance of any routine bioassay measurement data. The average combined measurement bias and precision based on spiked quality samples analyzed under the Marshall Islands Program (2001-2006) were 1.1% and ±6.8% for plutonium-239, and 4.6% and ±11.1% for plutonium-240, respectively. The results of the plutonium-239 measurements are shown in Figure 9. Based on the results from these performance tests we consider that the methodologies employed under the Marshall Islands Urinalysis Monitoring Program represent the current state-of-the-art in the field for a routine plutonium bioassay program.

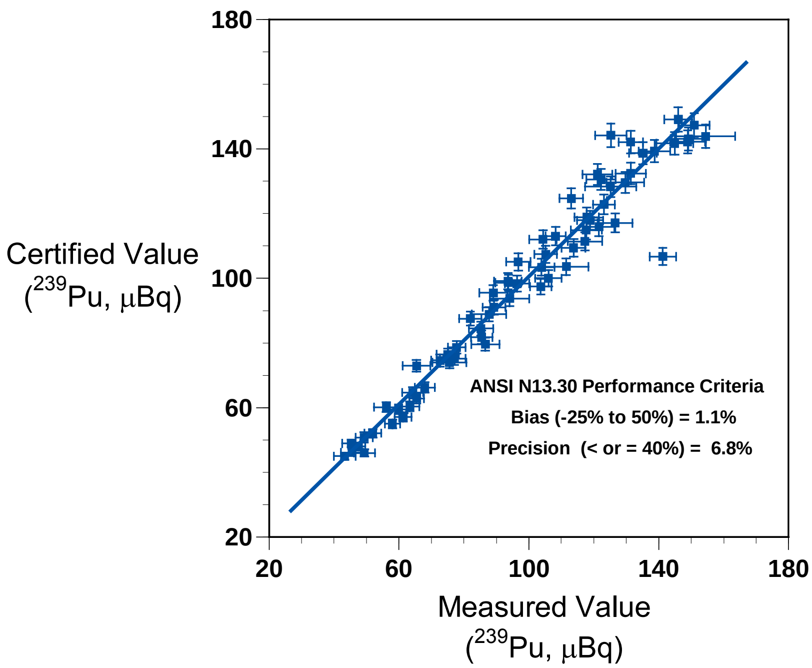


Figure 9. Analyses of externally prepared natural matrix spiked quality control performance evaluation test samples (2001–2006) prepared by the Oak Ridge National Laboratory.

Plutonium Urinalysis Monitoring on Rongelap

Individual measurement data from the Marshall Islands Plutonium Urinalysis Monitoring Program on Rongelap Atoll are available on the Marshall Islands web site (http://eed.llnl.gov/mi/).

The bioassay sampling program was originally designed to monitor the systemic uptake of plutonium in resettlement workers who were either actively involved in soil remediation or who lived on Rongelap Island for extended periods of time during the initial phase of the resettlement program. A total of 139 bioassay samples, 9 control samples and 21 procedural field blanks were analyzed under this program. The vast majority of these samples were collected between 2001 and 2004 (Appendix 1, Table 2).

The urinary excretion rate of plutonium from the Rongelap resettlement workers ranged from <<1 to 4 μBq per 24-h void (including all outliers) and is well below the occupational action level established under the latest Department regulation 10 CFR 835 in the United States for *in vitro* bioassay monitoring of plutonium-239 (Hamilton *et al.*, 2007). Moreover, the vast majority of the individual bioassay samples collected from the resettlement workers contained less than the critical level needed to accurately determine if plutonium was actually present in the sample or not (L_C ~0.25 μBq). As a consequence, the bioassay measurement data are characterized by high relative measurement uncertainties and are generally not conducive to performing detailed individual dose assessments. Nonetheless, we are able to make a number of important conclusions about the systemic uptake of plutonium and the associated dose delivered to Rongelap resettlement workers based on detailed statistical analyses of the combined dataset.

Urinary excretion of plutonium from Marshallese populations will consist of a long-term baseline component from residual systemic burdens acquired from all previous exposures plus any prompt (new) contributions (and eventual long-term excretion) resulting from recently acquired systemic burdens of plutonium. It is reported that people living in the Northern Hemisphere have acquired sufficiently high systemic burdens of plutonium from exposure to global fallout contamination to produce urinary excretion rates of plutonium of around 2-4 μBq per 24-h void (Boecker *et al.*, 1991). Based on fission track analysis of urine samples collected by scientists from Brookhaven National Laboratory, the systemic uptake of plutonium from exposure to global fallout contamination in the Marshall Islands is estimated to produce background urinary excretion rates of 1–2 μBq of plutonium per 24-h void (National Research Council, 1994) or about an order of magnitude higher than levels observed in our studies. Consequently, the more precise and higher quality bioassay data based on Accelerator Mass Spectrometry detection and measurement provide a much more accurate basis for assessing small incremental uptakes of plutonium associated with resettlement of the northern Marshall Islands. Similarly, the sensitivity of the method is such that we may be able to track long-term changes in the availability and transfer of plutonium through the marine and/or terrestrial pathways to man.

In general, the urinary excretion patterns of plutonium from Rongelap resettlement workers appear to be representative of world-wide background. Plutonium excretion is monotonically related to volunteer age although the trend is less evident than that observed for Enewetak. The population average urinary excretion of plutonium from Rongelap resettlement workers (median age = 35.4 years) of 0.11 μBq per 24-h void compares with a measurement background of 0.00 μBq observed in compatible sets of field blank samples. A more detailed statistical analysis of plutonium bioassay data from Rongelap Atoll will be given elsewhere (Bogen *et al.*, 2006) taking into account the uncertainty of the measurements. However, the age-related trend is supported heuristically based on Fisher exact, extended Fisher exact and Bartholomew's trend tests without regard to measurement error based on the proportion of plutonium values >0.35 μBq per 24-h void with increasing age of the program volunteers (Table 1). As shown, the proportion of values >0.35 μBq per 24-h void increases from 22 % in the <35 year age-group to 32 % in those workers who are 45 years of age or older. By comparison, none of the field blank samples contained >0.35 μBq of plutonium-239.

Table 1. Fraction of bioassay samples from Rongelap Atoll containing >0.35 μBq of plutonium-239.

Atoll	Sample group	N	Number of values >0.35 μBq
Rongelap Atoll (median age = 35.5 years)	field blanks	21	0%
	<35 y	65	22%
	35<45 y	45	30%
	> 45y	28	32%

N = number of field blank measures or the number of volunteers in each age-group.

As previously discussed, urinary excretion rates of plutonium from resettlement workers on Rongelap Atoll are at or below worldwide background levels. As such, there appears to be no discernible evidence of elevated levels of plutonium uptake associated with cleanup/resettlement activities on Rongelap Island. However, for completeness, we attempt to assign a dose to all the measurement data posted on the Marshall Islands web site using default assumptions as described by Daniels *et al.*, 2007.

Based on the error-weighted, average values in the urinary excretion of plutonioum-239, the population average committed effective dose equivalent delivered to Rongelap resettlement workers from internally deposited plutonium is around 1.3 mrem (or 13 μSv). The maximal dose delivered to Rongelap resettlement workers from internally deposited plutonium occurs in adult males in the 35 to <45 year age-group and averages around a committed effective dose equivalent of 1.8 mrem (or 18 μSv). Please note that the annualized dose criteria developed for remediation of radioactively contaminated sites (NCRP, 2004) is usually based on estimates of the total effective dose equivalent (TEDE) over 50 years and consists of the sum of the committed dose due to intakes of radionuclides (of which, plutonium is just one potential component) and the deep dose equivalent from external exposures experienced during the measurement year.

Plans for the Future

Some of the early urinary excretion data for plutonium in the Marshall Islands is of questionable quality because of the poor quantification sensitivity of the methods employed and/or from the general lack of adequate quality control. In addition to expanding on the plutonium bioassay database for Utrōk Atoll, we plan to develop comparative high-quality baseline data for other atoll population groups including those people who resettle Rongelap Atoll.

Such provisions should help provide assurances to resettled and resettling populations concerned about long-term exposure to residual fallout contamination in the Marshall Islands. Additionally, by establishing a well documented baseline for urinary excretion of plutonium from Marshallese populations, we will be better able to track and monitor potential long-term changes in exposure conditions on the atolls, especially in relation to assessing the remobilization and transfer of plutonium through the aquatic food chain or from potential increases in inhalation exposure associated with resettlement of island or atolls, remediation activities, commercial development and changing land-use patterns.

MEASUREMENT DATA FROM THE INDIVIDUAL RADIOLOGICAL SURVEILLANCE PROGRAM

Introduction | Individual Measurement Database

Introduction

The individual (de-identified) measurement data for Rongelap Atoll is accessible over the Marshall Islands web site (http://eed.llnl.gov/mi/) using menu driven routines (Figure 10).

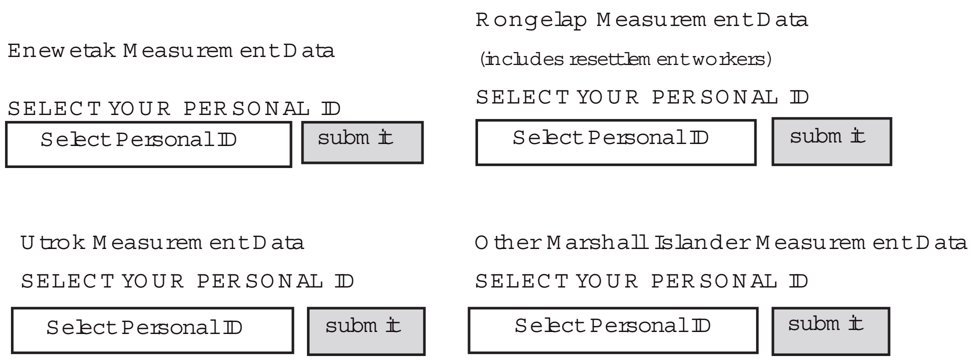


Figure 10. Layout of the menu structure used to access individual radiological protection monitoring data from the Marshall Islands web site (http://eed.llnl.gov/mi/).

Whole-body counting provides a direct measure of the total amount of cesium-137 present in the human body at the time of measurement. The amount of cesium-137 detected is usually reported in activity units of kilo-Becquerel (kBq), where 1 kBq equals 1000 Bq and 1 Bq = 1 nuclear transformation per second (t s^{-1}). The detection of plutonium-239 (^{239}Pu) and plutonium-240 (^{240}Pu) in bioassay (urine) samples indicates the presence of internally deposited (systemic) plutonium in the body. At Livermore, plutonium bioassay measurements are performed using a state-of-the-art technology based on Accelerator Mass Spectrometry (AMS) (Hamilton *et al.*, 2004, 2007; Brown *et al.*, 2004). Under the Marshall Islands Plutonium Urinalysis Program, the urinary excretion of plutonium from program volunteers is usually described in activity units, expressed as micro-Becquerel (μBq) of $^{239+240}$Pu (the sum of the ^{239}Pu and ^{240}Pu activity) excreted (lost) per day (d^{-1}); where 1 μBq d^{-1} = 10^{-6} Bq d^{-1} and 1 Bq = 1 t s^{-1}.

Individual Measurement Database

The Marshall Islands web site provides electronic access to verified whole body counting and plutonium urinalysis data developed under the Marshall Islands Individual Radiological Surveillance Program at the Lawrence Livermore National Laboratory

(1999–present). Please note that measurement data developed for Rongelap Atoll are given an RR prefix identification number and, in addition to resettlement workers from Pacific International Incorporate (PII), may include temporary visitors, tourists and non-nationals.

DOSIMETRIC DATA AND METHODOLOGY

Introduction | Dose Methodology

Introduction

The individual (de-identified) dosimetric data for Rongelap Atoll are accessible over the Marshall Islands web site (http://eed.llnl.gov/mi/) using menu driven routines (Figure 11).

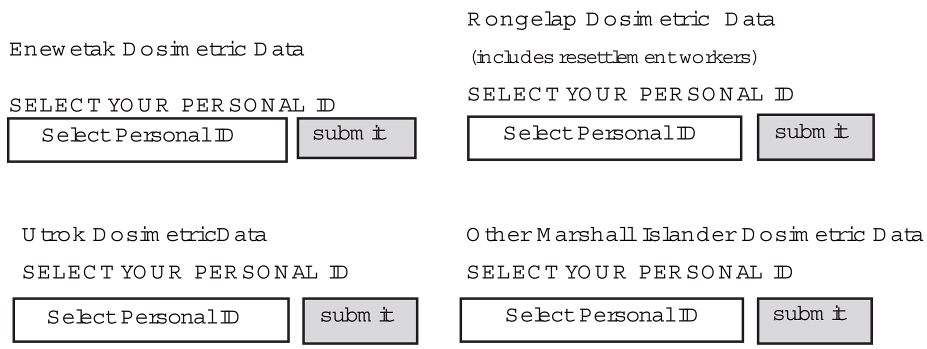


Figure 11. Layout of the menu structure used to access individual dosimetric monitoring data from the Marshall Islands web site (http://eed.llnl.gov/mi/).

In general, nuclear transformations emit energy and/or particles in the form of gamma rays, beta particles and alpha particles. Tissues in the human body may adsorb these emissions with the potential for any deposited energy to cause damage and disrupt biological function of cells. The general term used to quantify the extent of any health risk from radiation exposure is referred to as the dose. The equivalent dose is defined by the average absorbed dose in an organ or tissue weighed by the average quality factor for the type and energy of the radiation causing the dose. The effective dose equivalent (as applied to the whole body) is the sum of the average dose equivalent for each tissue weighted by tissue weighing factors. The International System (SI) unit of effective dose equivalent is the joule per kilogram (J kg^{-1}), named the sievert (Sv). The conventional unit often used by federal and state agencies in the United States is called a rem; 1 rem = 0.01 Sv.

Based on measurements of the internally deposited cesium-137 and/or the urinary excretion of plutonium, an estimate can be derived for either or both radionuclides of the annual number of nuclear transformations (t y^{-1}) that occurred in the body during the measurement year. For both radionuclides, this result is the time integral of activity in the body of an individual normalized over a one-year measurement period. In addition to nuclear transformations occurring during the year of measurement, additional transformations may occur in the future due to the presence of residual activity in the body at the end of the measurement year. The number of transformations derived from the residual radioactivity is usually evaluated up to 50 y in the future [a conservative maximum as defined by the United States Environmental Protection Agency (EPA) for members of the public] resulting in a committed dose. Accordingly, these future transformations will commit additional dose to the individual according to the biological half-life of the radioactive element of concern. For this reason, it is considered appropriate and conforming with the national and international recommendations of the U.S EPA and the International Commission on Radiological Protection (ICRP) that this additional dose commitment be assigned to the year of measurement. Consequently, dose reports issued under the Marshall Islands Radiological Surveillance Program are based on the Committed Effective Dose Equivalent (CEDE).

Dosimetric Methodology

The calendar year dose represents the sum of radionuclide-specific, age-dependent, committed effective dose equivalent for each monitored radionuclide. The total calendar year dose is calculated over a calendar year but only applies to the sum of the committed dose from cesium-137 and the 50-y integrated dose from plutonium (based on a time integral of any whole body counting and any available plutonium bioassay measurements performed during that year). When only one radionuclide is measured, the total dose assigned in a year and the CEDE for a specific radionuclide are identical. When more than one radionuclide is measured, the total annual 'calendar year' dose is the sum on the CEDE for each measured radionuclide. The calendar year dose estimates based on whole body counting and plutonium bioassay are conservative in nature, especially in relation to committed dose contributions from plutonium, but exclude dose contributions from external radiation exposure and from other internally deposited radionuclides such as strontium-90 (refer Daniels *et al.*, 2007).

For comparison, the Marshall Islands Nuclear Claims Tribunal has established a standard of 0.15 mSv (15 mrem) per year (EDE) for cleanup and rehabilitation of radioactively contaminated sites in the northern Marshall Islands.

PROVIDING FOLLOW-UP ON RESULTS

All volunteers participating in the Marshall Islands Radiological Surveillance Program are issued a preliminary copy of their dose report immediately after receiving a whole body count. Scientists from the Lawrence Livermore National Laboratory verify the measurement data and, if required, issue a revised measurement dose report. Statistically significant individual whole body counter or plutonium bioassay measurement data that yield computed doses of 10 mrem (0.1 mSv) or higher will normally evoke some type of pre-determined action or investigation (refer to the discussion outline below). These actions will nearly always lead to follow-up verification measurements but may also include a dietary evaluation and/or a work history review. Below the 10 mrem level, default assumptions for assigning doses (Daniels *et al.*, 2007) are assumed to be valid and no further action is taken. Data may be withheld from the web site or hard copy reports while these investigations are on-going. The Lawrence Livermore National Laboratory Marshall Islands Program action level (10 mrem) is one-tenth of the investigation level used for occupational workers throughout the U.S. Department of Energy and two-thirds of the U.S. Environmental Protection Agency guideline for cleanup of radioactively contaminated sites (15 mrem). In addition, at the end of each calendar year, all program volunteers receive a formal written report containing an estimate of their '*calendar year* dose' based on all available verified data for that year. Program volunteers are also invited to discuss their concerns with local technicians and/or to contact Dr. Terry Hamilton at Lawrence Livermore National Laboratory for more information.

Due to the very conservative nature of our dose methodology and preference not to trivialize doses no matter what the level, we anticipate that the default assumptions for calculating committed doses from low-level plutonium bioassay measurements will occasionally yield values that exceed the 10 mrem investigation level. In some cases, doses in excess of 10 mrem will not necessarily evoke a follow-up response. The reasoning for this is that the low-level plutonium bioassay measurements usually contain a relatively large uncertainty where the confidence level (nominally tested at 3 $\times$ measurement MDA) spans the investigation action level. As such, dose estimates are computed for all the measurement data but the scope of any follow-up action may be limited to those sample analyses that are clearly distinguishable from the measurement MDA or upon receiving specific requests from concerned individuals.

ACKNOWLEDGMENTS

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Figure 12. Rongelap Atoll Local Government whole body counting technicians; from left, Mr. Erickson Arelong (1999–2007) and Mr. Simon Langinbelik (2001–present).

REFERENCES

Bell, R.T., D. Hickman, L. Yamaguchi, W. Jackson, and T. Hamilton (2002). *A whole body counting facility in a remote Enewetak Island Setting, The Radiation Safety Journal, 83* (suppl. 1), S22–S26.

Boecker, B.B., R. Hall, K. Inn, J. Lawrence, P. Ziemer, G. Eisle, B. Wachholtz, and W. Bunn, Jr. (1991). *Current status of bioassay procedures to detect and quantity previous exposures to radioactive materials*, Health Phys., 60, 45–100.

Bogen, K.T., T.F. Hamilton, T. A. Brown, A.A. Marchetti, R.E. Martinelli, and S.R. Kehl (2007). *A Statistical Basis for Interpreting Urinary Excretion of Plutonium Based on Accelerator Mass Spectrometry (AMS) for Selected Atoll Populations in the Marshall Islands, Technical Basis Document,* Lawrence Livermore National Laboratory, Livermore CA, UCRL-MI-230705.

Brown, T.A., A.A. Marchetti, R.E. Martinelli, C.C. Cox, J.P. Knezovich, and T.F. Hamilton (2004). *Actinide Measurements by Accelerator Mass Spectrometry at Lawrence Livermore National Laboratory*, Nucl. Instr. Meth. B223–224, 788–793.

Conard R.A. (1992). *Fallout: The experiences of a medical team in care of a Marshallese population accidentally exposed to fallout radiation*, Brookhaven National Laboratory, Report BNL–46444, Upton NY.

Canberra Industries (1998a), Abacos-2000, Canberra Industries, Meriden, CT.

Canberra Industries (1998b), Genie-2000 Spectrometry System, Canberra Industries, Meriden, CT.

Daniels, J.I., D. P. Hickman, S. R. Kehl, and T.F. Hamilton (2007). *Estimation of Radiation Doses in the Marshall Islands Based on Whole Body Counting of Cesium-137 (^{137}Cs) and Plutonium Urinalysis*, Technical Basis Document, Lawrence Livermore National Laboratory, Livermore CA, UCRL-MI-231680.

DOE (1982). *Enewetak Radiological Support Project*, NVO–213, United States Department of Energy (DOE), Nevada Operation Office, Nevada, 158 pp.

Greenhouse N.A., P.P. Miltenberger, and E.T. Lessard (1980), *Dosimetric results for the Bikini population*, Health Phys., 38, 845–851.

Hamilton, T., S. Kehl, J. Brunk, F. Gouveia, and W. Robison (2001), *Rongelap Resettlement Support—Preliminary Report Part I. In-Situ Gamma Spectrometric Measurements around the Service and Village Area on Rongelap Island*, Lawrence Livermore National Laboratory, Livermore CA, UCRL-ID-143680-Pt 1.

Hamilton, T.F., T.A. Brown, D.P. Hickman, A.A. Marchetti, R.E. Martinelli, and S.R. Kehl (2004). *Low-Level Plutonium Bioassay Measurements at the Lawrence Livermore National Laboratory*, Lawrence Livermore National Laboratory, Livermore CA, UCRL-MI-232208.

Hamilton, T.F., T.A. Brown, R.E. Martinelli, S.R. Kehl, A.A. Marchetti, S.J. Tumey, and R. G. Langston (2007). *Low-Level Detection of Plutonium Isotopes in Bioassay Samples from the Marshall Islands using Accelerator Mass Spectrometry*, Health Phys. (in preparation).

ICRP (1977). International Commission on Radiological Protection, *Recommendations of the International Commission on Radiological Protection*, ICRP Publication 26, Annuals of the ICRP 3(1–4), Elsevier Science, New York.

ICRP (1991). International Commission on Radiological Protection, *1990 Recommendations of the International Commission on Radiological Protection*, ICRP Publication 60, Annuals of the ICRP 21(1–3), Elsevier Science, New York.

ISP (2005). Annual Performance Evaluation 2005 Whole Body Count, Intercomparison Studies Program (ISP), Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Kehl, S.R., T.F. Hamilton, T.M. Jue, and D.P. Hickman (2007). Performance Evaluation of Whole Body Counting Facilities in the Marshall Islands (2002–2005), Lawrence Livermore National Laboratory, Livermore CA, UCRL-TR-229724.

Lessard, E.T., R.P. Miltenburger, S.H. Cohn, S.V. Musolino, and R.A. Conrad (1984). *Protacted exposure to fallout: the Rongelap and Utirik experience*, Health Phys., 46, 511–527.

Marchetti, A.A., T.A. Brown, J.E. McAninch, J. Brunk, C.C. Cox, R. Martinelli, J.P. Knezovich, and T.F. Hamilton (2002). *Measurements of Plutonium Isotopes in Urine at MicroBecquerel Levels: AMS Results of a NIST Interlaboratory Exercise*, Lawrence Livermore National Laboratory, Livermore CA, UCRL-ID-147972.

McCurdy, D., Z. Lin, K. Inn, R. Bell, S. Wagner, D. Efurd, T. Hamilton, T. Brown, and A.A. Marchetti (2005). *Second Inter-Laboratory comparison Study for the Analysis of ^{239}Pu in Synthetic Urine at the microBecquerel (~100 aCi) Level by Mass Spectrometry*, J. Radioanal. Nuc. Chem., 263(2), 447–455.

Miltenberger, R.P., E.T. Lessard, and N.A. Greenhouse (1981). *Cobalt-60 and cesium-137 long-term biological removal rate constants for the Marshallese population*, Health Phys., 40, 615–623.

MOU (1999). Memorandum of Understanding by and between the Republic of the Marshall Islands, the Rongelap Atoll Local Government, and the U.S. Department of Energy, Office of Environmental Safety and Health.

National Research Council (2004), *Radiological Assessments for Resettlement of Rongelap in the Republic of the Marshall Islands*, National Research Council, National Academy Press, Washington DC, 108 pp.

NCRP (2004). *Approaches to Risk Management in Remediation of Radioactively Contaminated Sites*, National Council on Radiation Protection and Measurement, NCRP Report No. 146, Bethesia, MD 20814, 280 pp.

NRC (1994). U.S. Nuclear Regulatory Commission. "*10CRF part 20—Standards for protection against radiation,*" Proposed rule, 59 FR 43200, U.S. Government Printing Office, Washington DC**.**

Robison W.L., V.E. Noshkin, C.L. Conrado, R.J. Eagle, J.L. Brunk, T.A. Jokela, M.E. Mount, W.A. Phillips, A.C. Stoker, M.L. Stuart, S.E. Thompson, and K.M. Wong (1997a). The northern Marshall Islands radiological survey: data and dose assessments, Health Phys., Vol. 73(1), 37–48.

Robison W.L., K.T. Bogen and C.L. Conrado (1997b). *An updated dose assessment for resettlement options at Bikini Atoll-a U.S. nuclear test site*, Health Phys., Vol. 73(1), 100–114.

Robison W.L., M.E. Mount, W.A. Phillips, M.L. Stuart, S.E. Thompson, C.L. Conrado, and A.C. Stoker (1982). *An updated radiological dose assessment of Bikini and Eneu Islands at Bikini Atoll*, Lawrence Livermore National Laboratory, Livermore CA, UCRL-53225.

Robison W.L., W.A. Phillips, M.E. Mount, B.R. Clegg, and C.L. Conrado (1980). *Reassessment of the potential radiological doses for residents resettling Enewetak Atoll*, Lawrence Livermore National Laboratory, Livermore CA, UCRL-53066.

Sun L.C., J.H. Clinton, E. Kaplan, and C.B. Meinhold (1997c). *^{137}Cs exposure in the Marshallese populations: An assessment based on whole body counting measurements (1989–1994)*, Health Phys., 73(1), 86–99.

Sun L.C., C.B. Meinhold, A.R. Moorthy, E. Kaplan, and J.W. Baum (1997b). *Assessment of plutonium exposure in the Enewetak population by urinalysis*, Health Phys., 73(1), 127–132.

Sun L.C., A.R. Moorthy, E. Kaplan, J.W. Baum, and C.B. Meinhold (1995). *Assessment of plutonium exposures in Rongelap and Utrik populations by fission tracks analysis of urine*, Applied Radiat. Isotopes, 46, 1259–1269.

Sun L.C., C.B. Meinhold, A.R. Moorthy, J.H. Clinton, and E. Kaplan (1992). *Radiological dose assessments in the Northern Marshall Islands (1989–1991), In: Proceedings of the Eighth International Congress of the International Radiation Protection Association (IRPA–8),* Vol. II, IRPA, BNL–45868, 1320–1323.

United States Department of Energy (USDOE) (2000). *United States Nuclear Tests: July 1945 through September 1992,* United States Department of Energy, Nevada Operations Office, Las Vegas, NV, DOE/NV–209–REV.

GLOSSARY OF TERMS

Absorbed Dose

The absorbed dose is the energy deposited in an organ or tissue per unit mass of irradiated material. The common unit for absorbed dose is the rad, which is equivalent to 100 egs per gram of material. The international scientific community has adopted the use of different terms. The International System (SI) unit of absorbed dose is the joule per kilogram (J kg^{-1}) and its special name is the gray (Gy). One Gy is the same as 100 rad.

Activity

Activity is the rate of transformation or decay of a radioactive material. The International System (SI) unit of activity is the reciprocal second (s^{-1}) and its special name is the Becquerel. Federal and state agencies in the United States use conventional units where activity is expressed in curies (Ci); 1 Ci = 3.7 x 10^{10} Bq.

Alpha Particles

Alpha particles are one of the primary types of radiation associated with radioactivity and exist as energetic nuclei of helium atoms, consisting of two protons and two neutrons. Alpha rays are heavy, slow moving charged particles that travel only 2 to 5 cm in air, and can be stopped by a piece of paper or the outer dead layer of human skin.

Background Radiation

The average person in the United States receives about 3.6 mSv (360 mrem) of ionizing radiation every year. About 3 mSv (300 mrem) per year comes from natural background radiation including cosmic radiation and radiation emitted by naturally occurring radionuclides either in the environment (e.g., in air, water, soil and rock) or deposited in tissues inside the body. The other 0.60 mSv (60 mrem) is derived from man-made sources such as exposures to diagnostic X-rays, and consumer products such as smoking tobacco. The general worldwide contribution from radioactive fallout contamination is <0.3% of the average total annual effective dose. Exposures to natural background radiation vary depending on the geographic area, diet and other factors such as the composition of materials used in the construction of homes. The natural background radiation dose in the Marshall Islands is around 1.4 mSv (140 mrem) per year and is significantly less than what most people receive in most other parts of the world.

Baseline

We have all been exposed to some level of worldwide fallout contamination. In the United States, the general population receives up to 0.015 mSv (1.5 mrem) (0.3% of the average total annual effective dose) from exposure to worldwide fallout contamination resulting from atmospheric nuclear weapons testing and about 0.005 mSv (0.5 mrem) (or 0.1% of the average total annual effective dose) from operations related to nuclear power generation. Similarly, people living in the Marshall Islands will have very small quantities of internally deposited fallout radionuclides such as cesium-137, strontium-90 and plutonium in their bodies from worldwide contamination of food, air, water and soil.

Assessments of possible increases in radiation exposure from elevated levels of fallout contamination in the northern Marshall Islands can only be made on the basis of comparisons with residual systemic burdens of radionuclides acquired from previous exposures. Under the Marshall Islands Radiological Surveillance Program, efforts are being made to improve on the reliability of measurements of systemic plutonium in Marshallese populations using state-of-the-art methodologies in bioassay against which the results of future bioassay measurements can be compared to accurately assess the impacts of resettlement on radiation exposure and dose.

Becquerel (Bq)

A Becquerel (abbreviated as Bq) is the International System (SI) unit for activity of radioactive material. One Bq of radioactive material is that amount of material in which one atom is transformed or undergoes one disintegration every second. Whole body counting and plutonium bioassay measurements are usually reported in activity units of kBq (kiloBecquerel) (1000 Bq) and μBq (microBecquerel) (1×10^{-6} Bq), respectively.

Biokinetic

The word 'biokinetic' is used here to describe the absorption (uptake), distribution and retention of elements in humans.

Calibration

Calibration is the process of adjusting or determining the response or reading of an instrument to a standard.

Committed Dose Equivalent

The committed dose equivalent is the time integral of the dose-equivalent rate in a particular tissue that will be received by an individual following an intake of radioactive material into the body by inhalation, ingestion or dermal absorption. For adults, the committed dose is usually the dose received over 50 years. For children, the committed dose is usually calculated from the age of intake to age 70 years. For these age groups the term 'integrated dose equivalent' is used.

Committed Effective Dose Equivalent (CEDE)

The committed dose equivalents to various tissues or organ in the body each multiplied by an appropriate tissue-weighing factor and then summed. The conventional unit for committed effective dose equivalence (CEDE) used by federal and state agencies within the United States is the rem. The international scientific (SI) unit of committed effective dose equivalent is called a sievert (Sv). One Sv is the same as 100 rem. Chronic doses are usually reported in units of mSv (1×10^{-3} Sv) or mrem (1×10^{-3} rem)

Critical Level

The amount of a count (L_C) or final measurement of a quantity of an analyte at or above which a decision is made that the analyte is definitely present above background levels ($L_C \approx$ MDA/2).

Default Assumptions (used in assignment of dose)

The largest dose contributions attributable to exposure to residual nuclear fallout contamination in the Marshall Islands result from either internal exposure from intakes of radionuclides through ingestion, inhalation and/or absorption through the skin or external exposure from radionuclides distributed in the soil. External exposure rates can be measured directly using instrument surveys of the radiation field. The assignment of dose to internally deposited radionuclides is much more complicated. Biokinetic and dosimetric models developed by the International Commission on Radiological Protection (ICRP) are used to convert whole body burdens (from whole body counting or from *in vitro* bioassay tests such as urinalysis) into dose. In the case of chronic exposure, organ and body burdens continue to build up over time until a steady state is reached, and where losses due to decay and excretion are balanced by intake and absorption. Cesium-137 has an effective half-life in an adult of about 110 days, and under chronic exposure conditions reaches a maximal dose contribution after about 2 years. By contrast, plutonium absorbed from the gastrointestinal or respiratory tract enters the blood stream and deposits in liver and bone with an effective half-life of 20 to 50 years. Only a small fraction of plutonium entering the blood stream is excreted in urine with the long-term excretion rate approaching 2×10^{-5} of the systemic body burden per day. Knowledge of excretion rates and time of exposure are important when interpreting urinalysis data. A more detailed discussion of the dose calculation methodology employed under the Marshall Islands is given elsewhere (see under Daniels *et al.*, 2007).

Direct bioassay

The measurements of radioactive material in the human body utilizing instrumentation that detects radiation emitted from radioactive material in the body (synonymous with *in vivo* measurements).

Dose Assessment

The scientific process used to determine radiation dose and uncertainty in the dose.

Dose Equivalent

The dose equivalent is the adsorbed dose at a point in tissue multiplied by a biological effectiveness factor or quality factor for the particular types of radiation to cause biological damage. The conventional unit of dose equivalents used by federal and state agencies in the United States is the rem. A 100 rem dose to an adult will normally produce some clinical signs of radiation sickness and requires hospitalization. The International System (SI) unit for dose equivalent is the joule per kilogram (J kg^{-1}) and is called the sievert (Sv). One Sv is equal to 100 rem.

Effective Dose (ICRP 60)

The sum of the equivalent dose over specified organs and tissues weighted by the tissue weighing factor (ICRP, 1991). Supersedes the effective dose equivalent in ICRP and NCRP recommendations but is not used in current U.S. regulations.

Effective Dose Equivalent (ICRP 26)

The effective dose equivalent for the whole body is the sum of dose-equivalents for various organs in the body weighted to account for different sensitivities of the organs to radiation. It includes the dose from radiation sources internal and/or external to the body. Superseded by the effective dose in ICRP and NCRP recommendations but often used in current U.S. regulations. The effective dose equivalent is usually expressed in units of millirem (mrem). The International System (SI) unit for dose equivalent is the joule per kilogram ($J\ kg^{-1}$) and is called the sievert (Sv). One Sv is the same as 100 rem.

Dose (exposure) Assessment

A quantification of the magnitude, duration and timing of radiation exposures, and the resulting doses from such exposures, based on all possible types of radiological agents involved and their primary pathways and routes of exposure.

Exposure Pathway

The physical route a hazardous substance takes in leading to the exposure of an organism.

External Dose or Exposure or Radiation

That portion of the dose equivalent delivered by ionizing radiation originating from a source outside the body of an organism (e.g., also know as direct radiation).

Fission Track Analysis

During neutron irradiation heavy nuclei such as uranium and plutonium undergo nuclear fission with release of large fission fragments. This property has led to the development of a number of measurement techniques such as delayed neutron activation analysis and fission track analysis. Fission track analysis is a measurement technique commonly employed in plutonium urinalysis (bioassay) monitoring programs. Urine samples are chemically treated to remove plutonium. The plutonium is then mounted in contact with a special plastic or quartz slide known as solid-state nuclear track detector (SSNTD). The slide along with the sample is then irradiated in a reactor where neutron-induced fission of plutonium-239 (or uranium-235) causes emission of energetic fission fragments. Some of the fragments penetrate into the SSNTD damaging the integrity of the material before coming to rest. The SSNTD is separated from the sample and chemically etched to expose the damaged areas (known as fission tracks) on the detector surface. The fission tracks are then counted under an optical microscope. The amount of plutonium (and/or uranium) present in the sample is a function of the total number of tracks generated and the total irradiation neutron flux.

Gamma-rays

Gamma-rays are electromagnetic waves produced by spontaneous decay of radioactive elements during de-excitation of an atomic nucleus. Sunlight also consists of electromagnetic waves but gamma-rays have a shorter wavelength and much higher energy. High-energy gamma-rays such as those produced by decay of cesium-137 may penetrate deeply into the body and affect cells. Gamma-rays from a cobalt-60 source are often used for cancer radiotherapy.

Half-life

The time taken for the activity of a radionuclide to halve as a result of radioactive decay. Also used in more general terms to indicate the time taken for the quantity of a specified radionuclide in a specified place to halve as a result of any specified process or processes that follow similar exponential patterns (e.g., biological half-life or effective half-life).

High-End Health Risk

Use of the term 'high-end health risk' usually relates to the maximally exposed individuals in a population.

In-Vito

In vitro measurements are synonymous with indirect bioassay techniques, such as plutonium urinalysis.

In-Vivo

In vivo measurements are synonymous with bioassay techniques, such as whole body counting.

Indirect bioassay

Measurements to determine the presence of and/or the amount of a radioactive material in the excreta, urine or in other biological materials removed from the body (synonymous with *in vitro* measurements).

Individual

An individual is any human being.

Internal Dose or Exposure or Radiation

That portion of the dose equivalent delivered by ionizing radiation originating from a radiation source inside the body of an organism (e.g., from intakes of radionuclides by ingestion, inhalation or dermal adsorption).

Isotope

Atoms with the same number of protons but different numbers of neutrons are called isotopes of that element. We identify different isotopes by appending the total number of nucleons (the total number of proton plus neutrons in the nucleus of an atom) to the name of the element, e.g., cesium-137. Isotopes are usually written in an abbreviated form using the chemical symbol of the element. Two examples include ^{137}Cs for cesium-137 and ^{239}Pu for plutonium-239.

Minimum Detectable Amount (MDA)

The minimum detectable amount (MDA) is the smallest activity or mass of an analyte in a sample or person that can be detected with an acceptable level of uncertainty.

Quality Assurance

All those planned and systematic actions necessary to provide adequate confidence that an analysis, measurement or surveillance program will perform satisfactorily.

Quality Control

Those actions that control the attributes of an analytical process, system or facility according to predetermined quality requirements.

Radiation Dose (or mrem)

A generic term to describe the amount of radiation a person receives. Dose is measured in units of thousands of a roentegen equivalent man (rem). The millirem (normally abbreviated as mrem) is the preferred unit used by federal and state agencies in the United States. Dose is a general term used in the general field of radiological protection. The common International System (SI) unit for dose is the millisievert (mSv). One mSv is the same as 100 mrem.

Radiological Monitoring (Monitoring)

Radiological monitoring is the measurement of radiation levels or individual doses, and the use of the results to assess radiological hazards in the environment or workplace, or the potential and actual doses resulting from exposures to ionizing radiation.

Radioactivity

A natural and spontaneous process by which unstable atoms of an element emit energy and/or particles from their nuclei and, thus change (or decay) to atoms of a different element or a different state of the same element.

Remediation

Remediation is the actions taken to reduce risks to human health or the environment posed by the presence of radioactive or hazardous materials.

Risk

The probability of harm from the presence of radionuclides or hazardous materials taking into account (1) the probability of occurrences or events that could lead to an exposure, (2) probability that individual or populations would be exposed to radioactive or hazardous materials and the magnitude of such exposures, and (3) the probability that an exposure would produce a response.

Total Effective Dose Equivalent (TEDE)

The sum of the deep-dose equivalent (for external exposures) and the committed effective dose equivalent for external from intakes of radionuclides as described by the U.S. Nuclear Regulatory Commission under 10 CFR Part 20.1003.

Validation

Defining the process of the method capability and determining whether it can be properly applied as intended.

Whole Body

For the purposes of external exposure includes the head, trunk, the arms above and including the elbow, and legs above and including the knee.

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GENERAL STAFF PUBLICATIONS, PRESENTATIONS & INTERNAL REPORTS ARCHIVE (2002-2007)

Hamilton, T.F. (2007). *What can low-level plutonium bioassay measurements do for you*? Invited presentation, CIEMAT visit to the Lawrence Livermore National Laboratory, 30 April 2007, Lawrence Livermore National Laboratory, Livermore CA, UCRL-PRES-231910.

Hamilton, T.F., S.R. Kehl, T.A. Brown, R.E. Martinelli, D.P. Hickman, T.M. Jue, S.J. Tumey, and R.G. Langston (2007). *Individual Radiological Protection Monitoring of Utrōk Atoll Residents Based on Whole Body Counting of Cesium-137 (^{137}Cs) and Plutonium Bioassay,* Lawrence Livermore National Laboratory, Livermore CA, UCRL-MI-231678.

Brunk, J.L., S.R. Kehl, and T.F. Hamilton (2007), *Bikini Island Geographical Information System (GPS) Sample Site Mapping*, Field Operations Report (February-March 2006), Lawrence Livermore National Laboratory, Livermore CA, UCRL-MI-231650.

Brunk, J.L., S.R. Kehl, and T.F. Hamilton (2007), *Rongelap Island Information Positioning System (GPS) Sample Site Mapping*, Field Operations Report (March 2006), Lawrence Livermore National Laboratory, Livermore CA, UCRL-MI-231660.

Buchholz, B.A., T.A. Brown, T.F. Hamilton, I.D. Hutcheon, A.A. Marchetti, R.E. Martinelli, E.C. Ramon, S.J. Tumey, and R.W. Williams (2007). *Investigating Uranium Isotopic Distributions in Environmental Samples Using AMS and ICPMS*. Nucl. Instrum. Methods Phys. Res., Section B, 259, 733-738.

Hamilton, T.F., S.R. Kehl, D.P. Hickman, T.A. Brown, R.E. Martinelli, S.J. Tumey, T.M. Jue, B.A. Buchholz, R.G. Langston, S. Langinbelik, and E. Arelong (2007). *Individual Radiation Protection Monitoring in the Marshall Islands: Rongelap Atoll (2005–2006)*, Lawrence Livermore National Laboratory, Livermore CA, UCRL-TR-231414.

Hamilton, T.F., S.R. Kehl, D.P. Hickman, T.A. Brown, R.E. Martinelli, S.J. Tumey, T.M. Jue, B.A. Buchholz, R.G. Langston, K. Johannes, and D. Henry (2007). *Individual Radiation Protection Monitoring in the Marshall Islands: Enewetak Atoll (2005–2006)*, Lawrence Livermore National Laboratory, Livermore CA, UCRL-TR-231397.

Hamilton, T.F., S.R. Kehl, D.P. Hickman, T.A. Brown, R.E. Martinelli, S.J. Tumey, T.M. Jue, B.A. Buchholz, R.G. Langston, S. Tibon, and L. Chee (2007). *Individual Radiation Protection Monitoring in the Marshall Islands: Utrōk Atoll (2005–2006)*, Lawrence Livermore National Laboratory, Livermore CA, UCRL-TR-231415.

Kehl, S.R., T.F. Hamilton, T.M. Jue, and D.P. Hickman (2007). *Performance Evaluation of Whole Body Counting Facilities in the Marshall Islands (2002–2005)*, Lawrence Livermore National Laboratory, Livermore CA, UCRL-TR-229724.

Hamilton, T.F. (2007). *DOE-RMI Marshall Islands Program Review Briefing*, Invited presentation, Annual DOE-RMI Meeting on the Marshall Islands Program, Majuro 2526 April 2007, Lawrence Livermore National Laboratory, Livermore CA, UCRL-PRES-230112.

Robison, W.L., T.F. Hamilton, K.T. Bogen, C.L. Conrado, S.R. Kehl (2007). *^{137}Cs Inter-Plant Concentration Ratios for Tree Food Crops on Atolls Provide a Tool for Dose Predictions with Distinct Benefits Over Transfer Factors*, Submitted J. Environ. Radioact., April 2007.

Bogen, K.T., T.F. Hamilton, T. A. Brown, R.E. Martinelli, A.A. Marchetti, S.R. Kehl, and R.G. Langston (2006). *A Statistical Basis for Interpreting Urinary Excretion of Plutonium Based on Accelerator Mass Spectrometry (AMS) Data from the Marshall Islands*, Lawrence Livermore National Laboratory, Livermore CA, UCRL-MI-230705.

Daniels, J.I., D.P. Hickman, S.R. Kehl, and T.F. Hamilton (2007), *Estimation of Radiation Doses in the Marshall Islands Based on Whole Body Counting of Cesium-137 (^{137}Cs) and Plutonium Urinalysis*, Technical Basis Document, Lawrence Livermore National Laboratory, Livermore CA, UCRL-TR-231680.

Hamilton T.F., T.A. Brown, and R.L. Newmark (2006). *A Systematic Baseline Study of Internally Deposited Plutonium in Agricultural Workers and Local Residents of Palomares (Almeria District)*, Spain, Project Pre-Proposal, Lawrence Livermore National Laboratory CA, UCRL-PROP-225310.

Hamilton,T.F., T.A Brown, G. Bench, B.A. Buchholz, and K.W. Turteltaub (2006). *Baseline Measurements of Internally Deposited Radionuclides in the U.S. Population*, Project Pre-Proposal, Lawrence Livermore National Laboratory CA, UCRL-PROP-225308.

Hamilton,T.F., S.R. Kehl, D.P. Hickman, T.A. Brown, A.A. Marchetti, R.E. Martinelli, E. Arelong, and S. Langinbelk (2006), *Individual Radiation Protection Monitoring in the Marshall Islands: Rongelap Atoll (2002–2004)*, Lawrence Livermore National Laboratory, Livermore CA, UCRL-TR-220590.

Hamilton,T.F., S.R. Kehl, D.P. Hickman, T.A. Brown, A.A. Marchetti, R.E. Martinelli, K. Johannes, and D. Henry (2006). *Individual Radiation Protection Monitoring in the Marshall Islands: Enewetak Atoll (2002–2004)*, Lawrence Livermore National Laboratory, Livermore CA, UCRL-TR-220591.

Hamilton, T.F., S.R. Kehl, D.P. Hickman, T.A. Brown, A.A. Marchetti, R.E. Martinelli, S. Tibon, and L. Chee (2006). *Individual Radiation Protection Monitoring in the Marshall Islands: Utrōk Atoll (2003–2004)*, Lawrence Livermore National Laboratory, Livermore CA, UCRL-TR-220654.

Hamilton, T.F. (2006). *FY2005 Operational Activities in Support of the Marshall Islands Program*, Lawrence Livermore National Laboratory, Livermore CA, UCRL-PRES-219263.

Hamilton, T.F. (2006). *Marshall Islands Program Briefing*, Lawrence Livermore National Laboratory, Livermore CA, UCRL-PRES-219265.

Hamilton, T.F. (2006). *Plutonium Isotope Measurements in the Marshall Islands*, Lawrence Livermore National Laboratory, Livermore CA, UCRL-PRES-221266.

Hamilton, T.F. (2006). *Marshall Islands Program Logo*, Lawrence Livermore National Laboratory, Livermore, CA, UCRL-MI-220556.

Hamilton, T.F. (2006). *Radiological Surveillance Measures in Support of the Rongelap Atoll Resettlement Program*, Lawrence Livermore National Laboratory, Livermore CA, UCRL-PRES-220893.

Hamilton, T.F. (2006). *Continuation of the Marshall Islands Dose Assessment and Radioecology Program*, Lawrence Livermore National Laboratory, Livermore CA, UCRL-PRES-220894.

Hamilton, T.F. (2006). *Marshall Islands Program Advertisement*, Lawrence Livermore National Laboratory, Livermore CA, UCRL-POST-221208.

Hamilton, T.F. (2006). *Marshall Islands Program Advertisement*, Lawrence Livermore National Laboratory, Livermore, CA, UCRL-POST-MI-220556.

Hamilton, T.F., and S.R. Kehl (2006), *Marshall Islands Program Web Site*, Lawrence Livermore National Laboratory, Livermore CA, UCRL-WEB-220536; URL: http://eed.llnl.gov/mi/.

Hamilton, T.F., R.E. Martinelli, S.K. Kehl, and J.L. Brunk (2006). *Preconcentration of Cesium-137 (^{137}Cs) from Large Volume Water Samples Using Zirconium Ferrocyanide Embedded on Cartridge Water Filters*, Methods and Applications of Radioanalytical Chemistry, Kailue-Kona, HI, April 3–7, 2006, Lawrence Livermore National Laboratory, Livermore CA, UCRL-ABS-217452.

Hamilton, T.F., D. Dasher, T.A. Brown, A.A. Marchetti, R.E. Martinelli, and S.R. Kehl (2006), *Measurements of Plutonium Activity Concentrations and $^{240}Pu/^{239}Pu$ Atom Ratios in Brown Algae (Fucus distichus) Collected from the Littoral Zone of Amchitka Island Using Accelerator Mass Spectrometry (AMS)*, Methods and Applications of Radioanalytical Chemistry, Kailue-Kona, HI, April 3–7, 2006, Lawrence Livermore National Laboratory, Livermore CA, UCRL-ABS-217453.

Jernström J., M. Eriksson, R. Simon, G. Tamborini, O. Bildstein, R. Carlos Marquez, S.R. Kehl, T.F. Hamilton, Y. Ranedo, and M. Betti (2006), *Characterization and Source Term Assessments of Radioactive Particles From Marshall Islands Using Non-Destructive Analytical Techniques*, Spectrochim. Acta, Part B, 61, 971–979.

Jernstrom, J., M. Erilsson, R. Simon, G Tamborini, O. Bildstein, R. Carlos Marquez, S.R. Kehl, M. Betti, T.F. Hamilton (2006), *Characterization and Source Term Assessments of Radioactive Particles from Marshall Islands Using Non-Destructive Analytical Techniques,* Presented at the *Technical Meeting on Analytical Methods for Characterization of Hot Particles & their Impact on Environment*, March 610, 2006, ICTP, Trieste, Italy. Lawrence Livermore National Laboratory, Livermore CA, UCRL-PRES-220343.

Martinelli, R.E., T.F. Hamilton, T.A. Brown, A.A. Marchetti, R.W. Williams and S.J. Tumey (2006). Isolation and Purification of Uranium Isotopes for Measurement by Mass-Spectrometry ($^{233, 234, 235, 236, 238}U$) and Alpha-Spectrometry (^{232}U), Lawrence Livermore National Laboratory CA, UCRL-TR-232228.

Robison, W.L., T.F. Hamilton, R.E. Martinelli, F.J. Gouveia, T.R. Lindman, and S.C. Yakuma (2006). *The Concentration and Distribution of Depleted Uranium (DU) and Beryllium (Be) in Soil and Air on Illeginni Island at Kwajalein Atoll*, Lawrence Livermore National Laboratory, Livermore CA, UCRL-TR-222048.

Robison, W.L., T.F. Hamilton, C.L. Conrado, and S. Kehl (2006). *Uptake of cesium-137 by leafy vegetables and grains from calcareous soils*, In: Proceedings of a final research coordination meeting organized by the Joint FAO/IAEA Programme of Nuclear Techniques in Food and Agriculture, Chania, Crete, 22-26 September 2003, IAEA-TECHDOC-1497, Classification of soil systems on the basis of transfer factors of radionuclides from soil to reference plants, IAEA June 2006, pp. 179–190.

Robison, W.L., E.L. Stone, T.F. Hamilton and C.L. Conrado (2006). *Long-Term Reduction in Cesium-137 Concentration in Foodcrops on coral Atolls Resulting from Potassium Treatment*, J. Environ. Radioact*,* 88: 251–266.

Bogen, K.T., T.F. Hamilton, T. A. Brown, A.A. Marchetti, R.E. Martinelli, and S.R. Kehl (2005), *Age-related trend in elevated ^{239}Pu measured by AMS in urine samples collected in 1998-2003 from Enewetak residents and Rongelap resettlement workers*, Livermore National Laboratory, Livermore CA, UCRL-PRES-216780.

Bogen, K.T., D.P. Hickman, T.F. Hamilton, T. A. Brown, C.C. Cox, A.A. Marchetti, and R.E. Martinelli (2005), *AMS Analysis of ^{239}Pu in archived occupational samples*, Livermore National Laboratory, Livermore CA, UCRL-PRES-216781.

Bogen, K.T., T.F. Hamilton, T. A. Brown, A.A. Marchetti, R.E. Martinelli, and S.R. Kehl (2005), *Age-related trend in elevated ^{239}Pu measured by AMS in urine samples collected in 1998-2003 from Enewetak residents and Rongelap resettlement workers*, Livermore National Laboratory, Livermore CA, UCRL-ABS-213685-REV-1.

Buchholz, B.A., T.A. Brown, T.F. Hamilton, I.D. Hutcheon, A.A. Marchetti, R.E. Martinelli, E.C. Ramon, S.J. Tumey, and R.W. Williams (2005)., *Investigating Uranium Isotopic Distributions in Environmental Samples Using AMS and ICPMS*, Nuclear Instruments & Methods B , Lawrence Livermore National Laboratory, Poster presented at the *10th International Conference on Accelerator Mass Spectrometry*, September 5–9, 2005, Berkeley, CA.

Hamilton, T.F., (2005), *FY2005 Operations Activities in Support of the Marshall Islands Program*, Lawrence Livermore National Laboratory, Livermore CA, UCRL-PRES-329925.

Hamilton, T.F., (2005), *Individual Dose Reporting*, Lawrence Livermore National Laboratory, Livermore CA, UCRL-MI-217507.

Hamilton, T.F. (2005). *Continuation of the Marshall Islands Dose Assessment and Radioecology Program*, Lawrence Livermore National Laboratory, Livermore CA, UCRL-PRES-210283.

Hamilton T.F., and S.R. Kehl (2005). Individual Dose Reporting Form for the Marshall Islands Program, Lawrence Livermore National Laboratory, Livermore CA, UCRL-MI-217507.

Hamilton T.F., and R.L. Newmark (2005), *HOMEWARD BOUND: Radiological Surveillance Measures in Support of Rongelap Atoll Resettlement*, Lawrence Livermore National Laboratory, Livermore CA, UCRL-PRES-329925.

Hamilton, T.F., T.A. Brown, A.A. Marchetti, R.E. Martinelli, and S.R. Kehl (2005), *Determination of Plutonium Activity Concentrations and $^{240}Pu/^{239}Pu$ Atom Ratios in Brown Algae (Fucus distichus) collected From Amchitka Island, Alaska*, Final Report, Lawrence Livermore National Laboratory, Livermore CA, UCRL-SR-212129.

Hamilton, T.F., (2005), *Preconcentration of Cesium-137 (^{137}Cs) From Large Volume Water Samples Using Ferrocyanide Embedded on Cartridge Water Filters*, Lawrence Livermore National Laboratory, Livermore CA, UCRL-ABS-217452.

Hamilton, T.F., (2005), *Measurements of Plutonium Activity Concentrations and $^{240}Pu/^{239}Pu$ Atom Ratios in Brown Algae (Fucus Distichus) Collected from the Littoral Zone of Amchitka Island Using Accelerator Mass Spectrometry (AMS)*, Lawrence Livermore National Laboratory, Livermore CA, UCRL-ABS-217453.

Hamilton, T.F. (2005), *^{137}Cs and ^{210}Po in Pacific Walrus and Bearded Seal*, Lawrence Livermore National Laboratory, Livermore CA, UCRL-JRNL-211213, submitted Mar. Pollut. Bull.

Hamilton, T.F. (2005), *Validation Testing of Accelerator Mass Spectrometry Plutonium Bioassay Measurement Conducted at the Lawrence Livermore National Laboratory*, Lawrence Livermore National Laboratory, Livermore CA, UCRL-CONF-207648.

Hamilton, T.F. (2005), *Accelerator Mass Spectrometric Measurements of Uranium-236 Associated with Workplace Intakes of Anthropogenic Uranium*, Lawrence Livermore National Laboratory, Livermore CA, UCRL-CONF-207647.

Hamilton, T.F.(2005), *Radiological Surveillance Measures in Support of Rongelap Atoll Resettlement Minimizing Radiation Exposure from Residual Nuclear Fallout Contamination,* Lawrence Livermore National Laboratory, Livermore CA, UCRL-POST-207541.

McCurdy, D., Z. Lin, K. Inn, R. Bell, S. Wagner, D. Efurd, T. Hamilton, T. Brown, and A. Marchetti (2005). *Second Inter-Laboratory comparison Study for the Analysis of* ^{239}Pu *in Synthetic Urine at the microBecquerel (~100 aCi) Level by Mass Spectrometry*, J. Radioanal. Nuc. Chem., 263(2), 447–455.

Povinec, P.P., M.K. Pham, G. Barci-Funel, R. Bojanawski, T. Boshkova, W. Burnett, F. Carvalho, B. Chapeyron, I.L. Cunha, H. Dahlgaard, N. Galabov, J. Gaustaud, J.-J. Geering, I.F. Gomez, N. Green, T. Hamilton, F.L. Ibanez, M. Ibn Majah, M. John, G. Kanisch, T.C. Kenna, M. Kloster, M. Korun, L. Liong Wee Kwong, J. La Rosa, S.-H. Leee, I. Levy-Plaomo, M. Malatova, Y. Maruo, P. Michell, I.V.Murciano, R. Nelson, J.-S. Oh, B. Oregioni, G. Le Petit, H.B.L. Pettersson, A. Reineking, P.A. Smedley, A. Suckow, T.D.B. van der Struijs, P.I. Voors, K. Yoshimiza, and E. Wyse (2005). *Reference Material for Radionuclides in Sediment, IAEA–384 (Fangataufa Lagoon Sediment*), Lawrence Livermore National Laboratory, Livermore CA, UCRL-JRNL-218110, submitted *J. of Radioanal. Nucl. Chem.*

Robison, W.L., T. F. Hamilton, R. E. Martinelli, S. K. Kehl, T.R. Lindman (2005). *Concentration of Beryllium (Be) and Depleted Uranium (DU) in Marine Fauna and Sediment Samples from Illeginni and Boggerik Islands at Kwajalein Atoll*, Lawrence Livermore National Laboratory, Livermore CA, UCRL-TR-210057.

Brown, T.A., A.A. Marchetti, R.E. Martinelli, C.C. Cox, J.P. Knezovich, and T.F. Hamilton (2004). *Actinide Measurements by Accelerator Mass Spectrometry at Lawrence Livermore National Laboratory*, Nucl. Instrum. Methods, B223–224, 788–793.

Hamilton, T.F. (2004). *Radiation Fallout – Guam*, Lawrence Livermore National Laboratory, Livermore, CA, UCRL-TR-204361.

Hamilton T.F. (2004). *Linking legacies of the cold war to arrival of anthropogenic radionuclides in the oceans through the 20th century*, In: Radioactivity in the Environment, Vol. 6, Marine Radioactivity, H.D. Livingston (editor), Elsevier Science, Amsterdam, pp. 30–87.

Hamilton, T.F., T.A. Brown, D.P. Hickman, A.A. Marchetti, R.E. Martinelli, and S.R. Kehl (2004). *Low-Level Plutonium Bioassay Measurements at the Lawrence Livermore National Laboratory*, Lawrence Livermore National Laboratory, Livermore CA, UCRL-MI-232208.

Hamilton, T.F., T.A. Brown, A.A. Marchetti, G.P. Payne, R.E. Martinelli, S.R. Kehl, R.G. Langston, and J.M. Rankin (2004). *Validation Testing of Accelerator Mass Spectrometry Plutonium Bioassay Measurements Conducted at the Lawrence Livermore National Laboratory*, Lawrence Livermore National Laboratory, Livermore CA, UCRL-PRES-207648.

Hamilton, T.F., T.A. Brown, A.A. Marchetti, R.E. Martinelli, A. Wood-Zika, R.W. Williams, L. Johnson-Collins, Wm.G. Mansfield, and J.P. Knezovich (2004). *Accelerator Mass Spectrometric Measurements of Uranium-236 Associated with Potential Workplace Intakes of Anthropogenic Uranium,* Lawrence Livermore National Laboratory, Livermore CA, UCRL-PRES-207647.

Hamilton, T.F., and W.L. Robison (2004). *Overview of Radiological Conditions on Bikini Atoll*, Lawrence Livermore National Laboratory, Livermore CA, UCRL-MI-208228.

Hamilton, T.F., and W.L. Robison (2004). *Current Day Impact of Tracer Materials Associated with the U.S. Nuclear Test Program in the Marshall Islands*, Lawrence Livermore National Laboratory, Livermore, CA, UCRL-MI-204441.

Hamilton, T.F., and W.L. Robison (2004). *The effective and environmental half-life of cesium-137 at former U.S. nuclear test sites in the Marshall Islands*, Lawrence Livermore National Laboratory, Livermore, CA, UCRL-MI-206535.

Robison W.L., E.L. Stone, T.F. Hamilton, and C.L. Conrado (2004). *Long-term reduction in ^{137}Cs concentrations in food crops on coral atolls resulting from potassium treatment*, J. Environ. Radioactivity, 88, 251–266.

Robison W.L., E.L. Stone, and T.F. Hamilton (2004).*Large plate lysimeter collection efficiency for water being transported from soil to ground water*, Soil Sci., 758–764.

Bradsher, R.V., W.L. Robison, and T.F. Hamilton (2003). *The Marshall Islands Dose Assessment and Radioecology Program (1974–2003): A Bibliography of Lawrence Livermore National Laboratory Staff Publications*, Lawrence Livermore National Laboratory, Livermore CA, UCRL-ID-203184.

Hamilton, T.F. (2003), *Radiological Conditions on Rongelap Atoll: Perspective on Resettlement of Rongelap Atoll*, Lawrence Livermore National Laboratory, Livermore CA, UCRL-ID-151952.

Hamilton, T.F. (2003). *Radiological Conditions on Rongelap Atoll: Recommendations for Visiting and Food Gathering on the Northern Islands of Rongelap Atoll*, Lawrence Livermore National Laboratory, Livermore, CA, UCRL-ID-151953.

Hamilton, T.F. (2003), *Radiological Conditions on Rongelap Atoll: Diving and Fishing on and around Rongelap Atoll*, Lawrence Livermore National Laboratory, Livermore CA, UCRL-ID-151954.

Hamilton, T., C. Conrado, and W. Robison (2003). *The LLNL Environmental Program on Bikini Island: A Status Report Related to Resettlement of the Northern Marshall Islands*, Lawrence Livermore National Laboratory, Livermore CA, UCRL-MI-151707.

Hamilton, T., E. Arelong, and S. Langinbelik (2003). *LLNL/DOE Individual Radiation Protection Monitoring of Rongelap Resettlement Workers During 1999–2002: An Overview*, Lawrence Livermore National Laboratory, Livermore CA, UCRL-MI-150922, Rev. 1 (includes Marshallese translation).

Hamilton, T., E. Arelong, and S. Langinbelik (2003). *Perspective on Resettlement of Rongelap Island*, Lawrence Livermore National Laboratory, Livermore CA, UCRL-MI-151706 (includes Marshallese translation).

Robison W.L., C.L. Conrado, K.T. Bogen, and A.C. Stoker (2003). *The effective and environmental half-life of ^{137}Cs at coral islands at the former US nuclear test site*, J. Environ. Radioact., 69, 207–223.

Bell, R.T., D. Hickman, L. Yamaguchi, W. Jackson, and T. Hamilton (2002). *A whole body counting facility in a remote Enewetak Island setting*, The Radiation Safety Journal, 83 (suppl.1), S22–S26.

Gouveia, F., R. Bradsher, J. Brunk, W. Robison, and T. Hamilton (2002), *Meteorological Monitoring on Bikini Atoll: System Description and Data Summary (May 2000–April 2001)*, Lawrence Livermore National Laboratory, Livermore CA, UCRL-ID-147523.

Hamilton, T., K. Johannes, and D. Henry (2002). *LLNL/DOE Individual Radiation Protection Monitoring of Enewetak Island Residents during 2001–2002: An Overview*, Lawrence Livermore National Laboratory, Livermore CA, UCRL-MI-150970 (includes Marshallese translation).

Hamilton, T., D. Hickman, C. Conrado, T. Brown, J. Brunk, A. Marchetti, C. Cox, R. Martinelli, S. Kehl, E. Arelong, S. Langinbelik, R.T. Bell, and G. Petersen (2002), *Individual Radiation Protection Monitoring in the Marshall Islands: Rongelap Island Resettlement Support (1998–2001)*, Lawrence Livermore National Laboratory, Livermore CA, UCRL-LR-149600.

Hamilton, T., D. Hickman, C. Conrado, T. Brown, J. Brunk, A. Marchetti, C. Cox, R. Martinelli, S. Kehl, K. Johannes, D. Henry, R.T. Bell, and G. Petersen (2002), *Individual Radiation Protection Monitoring in the Marshall Islands: Enewetak Island Resettlement Support (May–December 2001)*, Lawrence Livermore National Laboratory, Livermore CA, UCRL-LR-149601.

Marchetti A.A., T.A. Brown, J.E. McAninch, J. Brunk, C.C. Cox, R. Martinelli, J.P. Knezovich and T.F. Hamilton (2002). *Measurements of Plutonium Isotopes in Urine at MicroBecquerel Levels: AMS Results of a NIST Interlaboratory Exercise*, Lawrence Livermore National Laboratory, Livermore CA, UCRL-ID-147972.

Appendix I

Individual Radiological Surveillance Monitoring Data Based on Whole Body Counting and Plutonium Urinalysis

The following tables provide full disclosure of measurement data developed from the whole body counting (2005–2006) and plutonium bioassay (2001–2004) program on Rongelap Atoll.

Table A1. Whole body count data developed for Rongelap Atoll (2005–2006).

ID#	Age Type	Gender	Count Date	Cs-137 (kBq) value		Cs-137 (kBq) MDA	Method Code	Notes
RR00025	Adult	Male	2006-03-27	0.18	± 0.03	0.13	NaI_WBC	
RR00025	Adult	Male	2006-08-21	0.59	± 0.05	0.20	NaI_WBC	
RR00026	Adult	Male	2005-03-22	0.48	± 0.04	0.19	NaI_WBC	
RR00029	Adult	Male	2005-03-22	0.41	± 0.04	0.19	NaI_WBC	
RR00029	Adult	Male	2005-06-17	0.43	± 0.04	0.17	NaI_WBC	
RR00029	Adult	Male	2005-04-07	0.47	± 0.04	0.19	NaI_WBC	
RR00029	Adult	Male	2005-10-10	0.57	± 0.05	0.20	NaI_WBC	
RR00029	Adult	Male	2005-09-13	0.61	± 0.05	0.21	NaI_WBC	
RR00030	Adult	Male	2005-01-31	0.48	± 0.05	0.20	NaI_WBC	
RR00030	Adult	Male	2005-07-12	0.57	± 0.05	0.20	NaI_WBC	
RR00030	Adult	Male	2005-03-10	0.58	± 0.04	0.19	NaI_WBC	
RR00030	Adult	Male	2005-06-26	0.60	± 0.05	0.20	NaI_WBC	
RR00030	Adult	Male	2005-09-20	0.94	± 0.05	0.21	NaI_WBC	
RR00050	Adult	Male	2006-05-30	0.08	± 0.03	0.12	NaI_WBC	
RR00053	Adult	Male	2006-07-29	0.00	± 0.00	0.07	NaI_WBC	
RR00054	Adult	Male	2005-08-19	0.00	± 0.00	0.07	NaI_WBC	
RR00054	Adult	Male	2005-09-15	0.31	± 0.05	0.21	NaI_WBC	
RR00054	Adult	Male	2005-10-21	0.35	± 0.04	0.18	NaI_WBC	
RR00054	Adult	Male	2006-03-30	0.36	± 0.04	0.18	NaI_WBC	
RR00054	Adult	Male	2006-07-29	0.61	± 0.05	0.18	NaI_WBC	
RR00054	Adult	Male	2006-08-21	0.62	± 0.05	0.20	NaI_WBC	
RR00066	Adult	Male	2005-03-22	0.00	± 0.00	0.07	NaI_WBC	
RR00066	Adult	Male	2005-08-20	0.00	± 0.00	0.07	NaI_WBC	
RR00072	Adult	Male	2005-04-05	0.12	± 0.03	0.13	NaI_WBC	
RR00072	Adult	Male	2006-05-30	0.12	± 0.03	0.13	NaI_WBC	
RR00072	Adult	Male	2005-09-20	0.58	± 0.05	0.21	NaI_WBC	
RR00072	Adult	Male	2005-08-13	0.68	± 0.04	0.18	NaI_WBC	
RR00073	Adult	Male	2006-05-29	0.11	± 0.03	0.12	NaI_WBC	
RR00073	Adult	Male	2006-01-26	0.13	± 0.03	0.12	NaI_WBC	
RR00073	Adult	Male	2006-10-16	0.17	± 0.03	0.15	NaI_WBC	
RR00073	Adult	Male	2006-04-10	0.28	± 0.04	0.17	NaI_WBC	
RR00073	Adult	Male	2005-04-08	0.31	± 0.04	0.17	NaI_WBC	
RR00073	Adult	Male	2006-03-17	0.31	± 0.04	0.18	NaI_WBC	
RR00073	Adult	Male	2005-03-07	0.33	± 0.05	0.21	NaI_WBC	
RR00073	Adult	Male	2006-10-02	0.35	± 0.05	0.21	NaI_WBC	
RR00073	Adult	Male	2005-01-29	0.37	± 0.04	0.20	NaI_WBC	
RR00073	Adult	Male	2006-08-22	0.39	± 0.05	0.19	NaI_WBC	
RR00073	Adult	Male	2005-09-20	0.44	± 0.05	0.21	NaI_WBC	

Table A1. Continued.

ID#	Age Type	Gender	Count Date	Cs-137 (kBq) value		Cs-137 (kBq) MDA	Method Code	Notes
RR00078	Adult	Male	2005-08-24	0.01	± 0.02	0.11	NaI_WBC	
RR00078	Adult	Male	2005-09-15	0.04	± 0.02	0.09	NaI_WBC	
RR00078	Adult	Male	2005-10-08	0.08	± 0.03	0.12	NaI_WBC	
RR00078	Adult	Male	2005-12-10	0.13	± 0.03	0.12	NaI_WBC	
RR00078	Adult	Male	2005-12-10	0.16	± 0.03	0.14	NaI_WBC	
RR00098	Adult	Male	2005-01-15	0.07	± 0.03	0.12	NaI_WBC	
RR00098	Adult	Male	2005-04-08	0.12	± 0.04	0.18	NaI_WBC	
RR00098	Adult	Male	2006-10-09	0.14	± 0.04	0.16	NaI_WBC	
RR00098	Adult	Male	2006-08-21	0.15	± 0.03	0.13	NaI_WBC	
RR00098	Adult	Male	2006-02-14	0.16	± 0.03	0.15	NaI_WBC	
RR00098	Adult	Male	2006-07-20	0.22	± 0.04	0.19	NaI_WBC	
RR00098	Adult	Male	2006-10-03	0.24	± 0.04	0.18	NaI_WBC	
RR00098	Adult	Male	2006-04-17	0.26	± 0.04	0.19	NaI_WBC	
RR00098	Adult	Male	2006-11-14	0.27	± 0.04	0.19	NaI_WBC	
RR00098	Adult	Male	2006-12-01	0.27	± 0.04	0.18	NaI_WBC	
RR00098	Adult	Male	2006-10-28	0.30	± 0.04	0.20	NaI_WBC	
RR00098	Adult	Male	2005-12-10	0.31	± 0.05	0.21	NaI_WBC	
RR00098	Adult	Male	2006-06-27	0.35	± 0.05	0.21	NaI_WBC	
RR00098	Adult	Male	2005-09-15	0.39	± 0.04	0.19	NaI_WBC	
RR00124	Adult	Male	2005-03-20	0.00	± 0.00	0.07	NaI_WBC	
RR00132	Adult	Male	2005-12-09	0.43	± 0.05	0.21	NaI_WBC	
RR00132	Adult	Male	2005-04-10	0.44	± 0.05	0.20	NaI_WBC	
RR00132	Adult	Male	2005-07-12	0.45	± 0.05	0.21	NaI_WBC	
RR00132	Adult	Male	2005-10-11	0.53	± 0.04	0.19	NaI_WBC	
RR00132	Adult	Male	2005-06-20	0.55	± 0.05	0.20	NaI_WBC	
RR00132	Adult	Male	2006-10-03	0.64	± 0.05	0.19	NaI_WBC	
RR00132	Adult	Male	2006-02-17	0.73	± 0.05	0.22	NaI_WBC	
RR00132	Adult	Male	2006-07-31	0.73	± 0.05	0.21	NaI_WBC	
RR00158	Adult	Male	2006-07-28	0.55	± 0.05	0.19	NaI_WBC	
RR00158	Adult	Male	2005-07-11	0.88	± 0.05	0.21	NaI_WBC	
RR00158	Adult	Male	2006-10-12	0.91	± 0.06	0.21	NaI_WBC	
RR00158	Adult	Male	2005-01-21	1.00	± 0.05	0.20	NaI_WBC	
RR00158	Adult	Male	2006-10-03	1.02	± 0.06	0.20	NaI_WBC	
RR00158	Adult	Male	2005-03-22	1.12	± 0.06	0.22	NaI_WBC	
RR00187	Adult	Male	2006-11-07	0.74	± 0.05	0.20	NaI_WBC	
RR00187	Adult	Male	2005-03-21	0.79	± 0.05	0.20	NaI_WBC	
RR00187	Adult	Male	2006-10-24	0.81	± 0.06	0.21	NaI_WBC	
RR00187	Adult	Male	2005-01-21	0.81	± 0.05	0.21	NaI_WBC	

Table A1. Continued.

ID#	Age Type	Gender	Count Date	Cs-137 (kBq) value		Cs-137 (kBq) MDA	Method Code	Notes
RR00187	Adult	Male	2006-11-16	0.84	± 0.06	0.21	NaI_WBC	
RR00187	Adult	Male	2006-08-21	0.85	± 0.06	0.22	NaI_WBC	
RR00187	Adult	Male	2005-07-11	0.86	± 0.05	0.20	NaI_WBC	
RR00187	Adult	Male	2005-04-09	0.87	± 0.05	0.21	NaI_WBC	
RR00187	Adult	Male	2006-07-29	0.95	± 0.06	0.20	NaI_WBC	
RR00187	Adult	Male	2005-11-29	0.99	± 0.06	0.22	NaI_WBC	
RR00187	Adult	Male	2005-10-10	1.19	± 0.06	0.22	NaI_WBC	
RR00203	Adult	Male	2006-01-23	0.00	± 0.00	0.07	NaI_WBC	
RR00252	Adult	Female	2006-12-13	0.00	± 0.00	0.06	NaI_WBC	
RR00256	Adult	Male	2005-01-21	0.67	± 0.05	0.20	NaI_WBC	
RR00256	Adult	Male	2005-01-29	0.92	± 0.05	0.22	NaI_WBC	
RR00256	Adult	Male	2005-04-13	0.96	± 0.06	0.22	NaI_WBC	
RR00256	Adult	Male	2005-03-21	0.96	± 0.05	0.21	NaI_WBC	
RR00264	Adult	Male	2006-01-23	0.00	± 0.00	0.07	NaI_WBC	
RR00266	Adult	Male	2006-01-23	0.00	± 0.00	0.07	NaI_WBC	
RR00267	Adult	Male	2005-03-20	0.00	± 0.00	0.07	NaI_WBC	
RR00272	Adult	Male	2006-01-23	0.00	± 0.00	0.07	NaI_WBC	
RR00273	Adult	Male	2005-03-20	0.00	± 0.00	0.06	NaI_WBC	
RR00276	Adult	Male	2005-01-14	1.01	± 0.06	0.22	NaI_WBC	
RR00276	Adult	Male	2005-04-13	1.13	± 0.06	0.22	NaI_WBC	
RR00276	Adult	Male	2005-03-22	1.26	± 0.06	0.20	NaI_WBC	
RR00276	Adult	Male	2006-07-28	1.49	± 0.07	0.19	NaI_WBC	
RR00276	Adult	Male	2006-08-22	1.53	± 0.08	0.22	NaI_WBC	
RR00276	Adult	Male	2005-08-19	1.59	± 0.07	0.24	NaI_WBC	
RR00276	Adult	Male	2005-10-12	1.69	± 0.07	0.23	NaI_WBC	
RR00276	Adult	Male	2005-09-15	1.76	± 0.07	0.23	NaI_WBC	
RR00276	Adult	Male	2006-10-16	1.83	± 0.09	0.24	NaI_WBC	
RR00276	Adult	Male	2006-10-28	1.99	± 0.09	0.23	NaI_WBC	
RR00276	Adult	Male	2006-10-02	2.02	± 0.09	0.23	NaI_WBC	
RR00276	Adult	Male	2006-12-06	2.08	± 0.11	0.31	NaI_WBC	
RR00279	Adult	Male	2005-03-07	0.00	± 0.00	0.07	NaI_WBC	
RR00279	Adult	Male	2005-01-15	0.22	± 0.04	0.17	NaI_WBC	
RR00284	Adult	Male	2006-10-12	0.18	± 0.04	0.17	NaI_WBC	
RR00284	Adult	Male	2005-03-21	0.24	± 0.04	0.18	NaI_WBC	
RR00284	Adult	Male	2005-01-20	0.28	± 0.04	0.20	NaI_WBC	
RR00284	Adult	Male	2006-07-17	0.32	± 0.04	0.19	NaI_WBC	
RR00284	Adult	Male	2005-09-16	0.35	± 0.04	0.19	NaI_WBC	

Table A1. Continued.

ID#	Age Type	Gender	Count Date	Cs-137 (kBq) value		Cs-137 (kBq) MDA	Method Code	Notes
RR00284	Adult	Male	2005-01-29	0.37	± 0.04	0.20	NaI_WBC	
RR00284	Adult	Male	2005-07-11	0.39	± 0.04	0.17	NaI_WBC	
RR00284	Adult	Male	2006-01-28	0.42	± 0.05	0.21	NaI_WBC	
RR00285	Adult	Male	2005-03-22	0.34	± 0.04	0.19	NaI_WBC	
RR00285	Adult	Male	2005-01-14	0.36	± 0.04	0.19	NaI_WBC	
RR00285	Adult	Male	2005-04-21	0.36	± 0.04	0.19	NaI_WBC	
RR00285	Adult	Male	2005-12-09	0.40	± 0.04	0.20	NaI_WBC	
RR00285	Adult	Male	2006-10-09	0.49	± 0.05	0.21	NaI_WBC	
RR00285	Adult	Male	2005-09-20	0.49	± 0.05	0.21	NaI_WBC	
RR00285	Adult	Male	2005-10-08	0.52	± 0.04	0.16	NaI_WBC	
RR00285	Adult	Male	2005-06-19	0.53	± 0.05	0.20	NaI_WBC	
RR00285	Adult	Male	2005-07-11	0.55	± 0.05	0.21	NaI_WBC	
RR00285	Adult	Male	2006-07-31	0.55	± 0.05	0.22	NaI_WBC	
RR00285	Adult	Male	2006-10-08	0.59	± 0.05	0.21	NaI_WBC	
RR00285	Adult	Male	2006-10-03	0.60	± 0.05	0.18	NaI_WBC	
RR00286	Adult	Male	2006-03-20	0.20	± 0.04	0.20	NaI_WBC	
RR00286	Adult	Male	2006-07-26	0.42	± 0.04	0.18	NaI_WBC	
RR00286	Adult	Male	2006-12-09	0.46	± 0.04	0.17	NaI_WBC	
RR00288	Adult	Male	2005-09-20	0.00	± 0.00	0.07	NaI_WBC	
RR00288	Adult	Male	2005-10-08	0.00	± 0.00	0.07	NaI_WBC	
RR00288	Adult	Male	2006-08-18	0.00	± 0.00	0.07	NaI_WBC	
RR00288	Adult	Male	2006-05-30	0.04	± 0.02	0.09	NaI_WBC	
RR00288	Adult	Male	2006-11-21	0.47	± 0.05	0.20	NaI_WBC	
RR00288	Adult	Male	2006-10-07	0.48	± 0.05	0.20	NaI_WBC	
RR00288	Adult	Male	2006-10-03	0.49	± 0.05	0.20	NaI_WBC	
RR00289	Adult	Male	2005-04-07	0.00	± 0.00	0.07	NaI_WBC	
RR00289	Adult	Male	2006-03-11	0.00	± 0.00	0.07	NaI_WBC	
RR00289	Adult	Male	2006-12-09	0.00	± 0.00	0.07	NaI_WBC	
RR00289	Adult	Male	2006-11-30	0.04	± 0.02	0.11	NaI_WBC	
RR00289	Adult	Male	2006-04-18	0.04	± 0.02	0.11	NaI_WBC	
RR00289	Adult	Male	2005-06-17	0.27	± 0.04	0.18	NaI_WBC	
RR00291	Adult	Male	2006-07-29	0.44	± 0.04	0.19	NaI_WBC	
RR00291	Adult	Male	2005-01-21	0.44	± 0.04	0.19	NaI_WBC	
RR00291	Adult	Male	2006-04-07	0.47	± 0.04	0.20	NaI_WBC	
RR00291	Adult	Male	2006-10-03	0.48	± 0.05	0.20	NaI_WBC	
RR00291	Adult	Male	2005-03-22	0.48	± 0.05	0.21	NaI_WBC	
RR00291	Adult	Male	2005-09-20	0.49	± 0.05	0.21	NaI_WBC	
RR00291	Adult	Male	2005-06-18	0.53	± 0.04	0.18	NaI_WBC	

Table A1. Continued.

ID#	Age Type	Gender	Count Date	Cs-137 (kBq) value		Cs-137 (kBq) MDA	Method Code	Notes
RR00291	Adult	Male	2005-08-12	0.54	± 0.05	0.22	NaI_WBC	
RR00294	Adult	Male	2005-01-29	0.43	± 0.04	0.17	NaI_WBC	
RR00294	Adult	Male	2005-11-29	0.45	± 0.04	0.16	NaI_WBC	
RR00294	Adult	Male	2005-03-22	0.84	± 0.05	0.20	NaI_WBC	
RR00294	Adult	Male	2006-04-11	0.84	± 0.05	0.22	NaI_WBC	
RR00294	Adult	Male	2005-04-22	0.92	± 0.05	0.20	NaI_WBC	
RR00294	Adult	Male	2006-07-08	1.08	± 0.06	0.22	NaI_WBC	
RR00294	Adult	Male	2006-08-22	1.21	± 0.07	0.23	NaI_WBC	
RR00294	Adult	Male	2005-09-20	1.21	± 0.06	0.24	NaI_WBC	
RR00294	Adult	Male	2006-10-03	1.32	± 0.07	0.21	NaI_WBC	
RR00294	Adult	Male	2005-06-20	1.34	± 0.06	0.21	NaI_WBC	
RR00294	Adult	Male	2006-12-04	1.37	± 0.08	0.22	NaI_WBC	
RR00294	Adult	Male	2006-10-17	1.38	± 0.07	0.24	NaI_WBC	
RR00294	Adult	Male	2006-10-31	1.40	± 0.08	0.24	NaI_WBC	
RR00295	Adult	Male	2005-04-22	0.00	± 0.00	0.07	NaI_WBC	
RR00295	Adult	Male	2006-04-10	0.35	± 0.04	0.17	NaI_WBC	
RR00295	Adult	Male	2006-07-29	0.42	± 0.05	0.19	NaI_WBC	
RR00295	Adult	Male	2006-06-30	0.45	± 0.04	0.18	NaI_WBC	
RR00295	Adult	Male	2006-10-17	0.50	± 0.05	0.19	NaI_WBC	
RR00295	Adult	Male	2005-07-11	0.51	± 0.04	0.18	NaI_WBC	
RR00295	Adult	Male	2006-10-02	0.53	± 0.05	0.19	NaI_WBC	
RR00295	Adult	Male	2005-08-26	0.62	± 0.04	0.18	NaI_WBC	
RR00298	Adult	Female	2005-03-11	0.00	± 0.00	0.06	NaI_WBC	
RR00298	Adult	Female	2005-03-15	0.00	± 0.00	0.06	NaI_WBC	
RR00299	Adult	Male	2005-03-20	0.00	± 0.00	0.07	NaI_WBC	
RR00300	Adult	Male	2005-03-20	0.00	± 0.00	0.07	NaI_WBC	
RR00301	Adult	Male	2005-03-20	0.00	± 0.00	0.07	NaI_WBC	
RR00302	Adult	Male	2005-03-20	0.00	± 0.00	0.07	NaI_WBC	
RR00303	Adult	Male	2005-03-20	0.00	± 0.00	0.07	NaI_WBC	
RR00304	Adult	Male	2005-03-21	0.00	± 0.00	0.07	NaI_WBC	
RR00307	Adult	Unknown	2005-08-24	0.00	± 0.00	0.07	NaI_WBC	
RR00307	Adult	Male	2005-10-24	0.48	± 0.05	0.20	NaI_WBC	
RR00308	Adult	Male	2005-08-26	0.07	± 0.03	0.12	NaI_WBC	
RR00308	Adult	Male	2006-11-03	0.09	± 0.03	0.13	NaI_WBC	
RR00308	Adult	Male	2005-09-15	0.11	± 0.03	0.12	NaI_WBC	
RR00308	Adult	Male	2006-02-21	0.26	± 0.04	0.19	NaI_WBC	
RR00308	Adult	Male	2006-04-07	0.34	± 0.04	0.19	NaI_WBC	
RR00309	Adult	Male	2005-09-15	0.31	± 0.05	0.23	NaI_WBC	

Table A1. Continued.

ID#	Age Type	Gender	Count Date	Cs-137 (kBq) value		MDA	Method Code	Notes
RR00309	Adult	Male	2006-03-28	0.32	± 0.04	0.19	NaI_WBC	
RR00309	Adult	Male	2005-08-26	0.32	± 0.05	0.23	NaI_WBC	
RR00309	Adult	Male	2005-10-06	0.34	± 0.04	0.18	NaI_WBC	
RR00309	Adult	Male	2006-01-28	0.38	± 0.04	0.19	NaI_WBC	
RR00309	Adult	Male	2006-04-07	0.38	± 0.05	0.21	NaI_WBC	
RR00310	Adult	Male	2005-03-21	0.24	± 0.04	0.18	NaI_WBC	
RR00310	Adult	Male	2005-01-31	0.29	± 0.04	0.19	NaI_WBC	
RR00311	Adult	Male	2006-01-20	0.35	± 0.04	0.19	NaI_WBC	
RR00311	Adult	Male	2005-07-11	0.36	± 0.05	0.21	NaI_WBC	
RR00311	Adult	Male	2006-04-08	0.40	± 0.04	0.18	NaI_WBC	
RR00311	Adult	Male	2006-02-15	0.41	± 0.05	0.21	NaI_WBC	
RR00311	Adult	Male	2006-03-20	0.46	± 0.04	0.17	NaI_WBC	
RR00311	Adult	Male	2005-09-17	0.50	± 0.04	0.19	NaI_WBC	
RR00311	Adult	Male	2005-10-11	0.51	± 0.04	0.18	NaI_WBC	
RR00311	Adult	Male	2006-08-21	0.53	± 0.04	0.18	NaI_WBC	
RR00311	Adult	Male	2006-10-02	0.54	± 0.05	0.21	NaI_WBC	
RR00311	Adult	Male	2006-07-08	0.55	± 0.05	0.21	NaI_WBC	
RR00312	Adult	Male	2005-07-11	0.00	± 0.00	0.07	NaI_WBC	
RR00312	Adult	Male	2005-09-18	0.11	± 0.04	0.19	NaI_WBC	
RR00312	Adult	Male	2006-04-08	0.12	± 0.03	0.13	NaI_WBC	
RR00312	Adult	Male	2006-03-20	0.17	± 0.03	0.14	NaI_WBC	
RR00312	Adult	Male	2006-10-17	0.19	± 0.03	0.14	NaI_WBC	
RR00312	Adult	Male	2006-07-28	0.27	± 0.04	0.16	NaI_WBC	
RR00312	Adult	Male	2006-08-22	0.29	± 0.04	0.18	NaI_WBC	
RR00312	Adult	Male	2006-10-03	0.38	± 0.05	0.20	NaI_WBC	
RR00312	Adult	Male	2006-12-04	0.43	± 0.05	0.20	NaI_WBC	
RR00313	Adult	Male	2005-07-11	0.12	± 0.03	0.12	NaI_WBC	
RR00313	Adult	Male	2005-09-20	0.35	± 0.05	0.21	NaI_WBC	
RR00314	Adult	Male	2005-08-26	0.11	± 0.03	0.13	NaI_WBC	
RR00314	Adult	Male	2005-09-18	0.27	± 0.04	0.19	NaI_WBC	
RR00314	Adult	Male	2006-02-14	0.42	± 0.05	0.21	NaI_WBC	
RR00314	Adult	Male	2006-08-21	0.42	± 0.05	0.20	NaI_WBC	
RR00314	Adult	Male	2006-07-29	0.53	± 0.05	0.21	NaI_WBC	
RR00315	Adult	Male	2005-09-03	0.00	± 0.00	0.07	NaI_WBC	
RR00315	Adult	Male	2005-10-24	0.23	± 0.03	0.16	NaI_WBC	
RR00315	Adult	Male	2006-05-23	0.39	± 0.05	0.21	NaI_WBC	
RR00315	Adult	Male	2006-10-02	0.60	± 0.05	0.21	NaI_WBC	
RR00315	Adult	Male	2006-10-31	0.65	± 0.05	0.18	NaI_WBC	

Table A1. Continued.

ID#	Age Type	Gender	Count Date	Cs-137 (kBq) value		Cs-137 (kBq) MDA	Method Code	Notes
RR00315	Adult	Male	2006-12-02	0.68	± 0.05	0.21	NaI_WBC	
RR00315	Adult	Male	2006-10-12	0.69	± 0.05	0.19	NaI_WBC	
RR00315	Adult	Male	2006-11-30	0.76	± 0.05	0.19	NaI_WBC	
RR00316	Adult	Male	2005-09-03	0.00	± 0.00	0.07	NaI_WBC	
RR00316	Adult	Male	2006-04-08	0.27	± 0.03	0.15	NaI_WBC	
RR00316	Adult	Male	2006-02-01	0.39	± 0.04	0.20	NaI_WBC	
RR00316	Adult	Male	2005-12-10	0.40	± 0.04	0.19	NaI_WBC	
RR00316	Adult	Male	2006-05-26	0.40	± 0.05	0.20	NaI_WBC	
RR00316	Adult	Male	2006-03-15	0.42	± 0.05	0.22	NaI_WBC	
RR00316	Adult	Male	2005-10-08	0.47	± 0.05	0.21	NaI_WBC	
RR00316	Adult	Male	2006-02-13	0.50	± 0.05	0.20	NaI_WBC	
RR00317	Adult	Male	2005-09-05	0.17	± 0.03	0.13	NaI_WBC	
RR00318	Adult	Male	2005-09-06	0.00	± 0.00	0.07	NaI_WBC	
RR00318	Adult	Male	2005-10-14	0.07	± 0.03	0.12	NaI_WBC	
RR00318	Adult	Male	2006-04-08	0.16	± 0.03	0.14	NaI_WBC	
RR00318	Adult	Male	2006-10-16	0.37	± 0.04	0.19	NaI_WBC	
RR00318	Adult	Male	2006-11-30	0.69	± 0.05	0.20	NaI_WBC	
RR00318	Adult	Male	2006-12-02	0.74	± 0.06	0.22	NaI_WBC	
RR00319	Adult	Male	2005-09-15	0.00	± 0.00	0.07	NaI_WBC	
RR00319	Adult	Male	2005-10-10	0.00	± 0.00	0.07	NaI_WBC	
RR00319	Adult	Male	2006-05-26	0.00	± 0.00	0.07	NaI_WBC	
RR00319	Adult	Male	2006-07-07	0.06	± 0.03	0.13	NaI_WBC	
RR00319	Adult	Male	2006-06-30	0.07	± 0.03	0.12	NaI_WBC	
RR00320	Adult	Male	2005-10-06	0.00	± 0.00	0.06	NaI_WBC	
RR00320	Adult	Male	2006-04-10	0.00	± 0.00	0.07	NaI_WBC	
RR00320	Adult	Male	2006-02-15	0.26	± 0.04	0.19	NaI_WBC	
RR00320	Adult	Male	2006-07-10	0.37	± 0.04	0.18	NaI_WBC	
RR00320	Adult	Male	2006-06-23	0.37	± 0.05	0.20	NaI_WBC	
RR00321	Adult	Male	2005-10-06	0.00	± 0.00	0.07	NaI_WBC	
RR00323	Adult	Male	2005-10-12	0.00	± 0.00	0.07	NaI_WBC	
RR00323	Adult	Male	2006-07-27	0.12	± 0.03	0.14	NaI_WBC	
RR00323	Adult	Male	2006-06-20	0.23	± 0.03	0.14	NaI_WBC	
RR00323	Adult	Male	2006-04-19	0.36	± 0.04	0.18	NaI_WBC	
RR00324	Adult	Male	2005-10-12	0.00	± 0.00	0.07	NaI_WBC	
RR00324	Adult	Male	2006-02-20	0.10	± 0.03	0.13	NaI_WBC	
RR00324	Adult	Male	2006-06-23	0.23	± 0.03	0.15	NaI_WBC	
RR00325	Adult	Male	2005-10-18	0.00	± 0.00	0.07	NaI_WBC	
RR00326	Adult	Male	2005-10-21	0.00	± 0.00	0.07	NaI_WBC	

Table A1. Continued.

ID#	Age Type	Gender	Count Date	Cs-137 (kBq) value		Cs-137 (kBq) MDA	Method Code	Notes
RR00326	Adult	Male	2006-02-21	0.42	± 0.04	0.20	NaI_WBC	
RR00326	Adult	Male	2006-03-19	0.43	± 0.04	0.20	NaI_WBC	
RR00326	Adult	Male	2006-07-28	0.52	± 0.05	0.19	NaI_WBC	
RR00326	Adult	Male	2006-06-22	0.52	± 0.05	0.20	NaI_WBC	
RR00327	Adult	Male	2005-10-22	0.00	± 0.00	0.07	NaI_WBC	
RR00327	Adult	Male	2006-04-14	0.08	± 0.03	0.12	NaI_WBC	
RR00327	Adult	Male	2006-07-27	0.50	± 0.05	0.19	NaI_WBC	
RR00328	Adult	Male	2006-01-20	0.00	± 0.00	0.07	NaI_WBC	
RR00329	Adult	Male	2006-01-21	0.00	± 0.00	0.07	NaI_WBC	
RR00329	Adult	Male	2006-02-11	0.00	± 0.00	0.07	NaI_WBC	
RR00329	Adult	Male	2006-08-19	0.05	± 0.02	0.12	NaI_WBC	
RR00330	Adult	Male	2006-01-21	0.00	± 0.00	0.07	NaI_WBC	
RR00330	Adult	Male	2006-02-14	0.00	± 0.00	0.07	NaI_WBC	
RR00330	Adult	Male	2006-07-25	0.76	± 0.05	0.21	NaI_WBC	
RR00331	Adult	Male	2006-01-21	0.00	± 0.00	0.07	NaI_WBC	
RR00331	Adult	Male	2006-02-11	0.05	± 0.02	0.11	NaI_WBC	
RR00332	Adult	Male	2006-01-23	0.00	± 0.00	0.07	NaI_WBC	
RR00332	Adult	Male	2006-02-17	0.00	± 0.00	0.07	NaI_WBC	
RR00332	Adult	Male	2006-03-20	0.00	± 0.00	0.07	NaI_WBC	
RR00332	Adult	Male	2006-12-04	0.00	± 0.00	0.07	NaI_WBC	
RR00332	Adult	Male	2006-06-16	0.08	± 0.03	0.12	NaI_WBC	
RR00332	Adult	Male	2006-07-08	0.10	± 0.03	0.15	NaI_WBC	
RR00332	Adult	Male	2006-08-19	0.24	± 0.04	0.16	NaI_WBC	
RR00332	Adult	Male	2006-10-11	0.24	± 0.04	0.18	NaI_WBC	
RR00333	Adult	Male	2006-01-23	0.00	± 0.00	0.07	NaI_WBC	
RR00333	Adult	Male	2006-04-10	0.06	± 0.02	0.11	NaI_WBC	
RR00333	Adult	Male	2006-07-29	0.25	± 0.04	0.16	NaI_WBC	
RR00333	Adult	Male	2006-03-20	0.27	± 0.04	0.19	NaI_WBC	
RR00333	Adult	Male	2006-10-28	0.43	± 0.04	0.18	NaI_WBC	
RR00334	Adult	Male	2006-01-23	0.06	± 0.03	0.12	NaI_WBC	
RR00335	Adult	Male	2006-02-11	0.00	± 0.00	0.07	NaI_WBC	
RR00336	Adult	Male	2006-03-19	0.03	± 0.02	0.10	NaI_WBC	
RR00336	Adult	Male	2006-04-08	0.51	± 0.04	0.18	NaI_WBC	
RR00336	Adult	Male	2006-06-20	1.07	± 0.06	0.21	NaI_WBC	
RR00337	Adult	Male	2006-03-19	0.00	± 0.00	0.07	NaI_WBC	
RR00337	Adult	Male	2006-04-06	0.45	± 0.05	0.20	NaI_WBC	
RR00337	Adult	Male	2006-06-22	0.79	± 0.06	0.22	NaI_WBC	
RR00337	Adult	Male	2006-07-26	0.80	± 0.05	0.20	NaI_WBC	

Table A1. Continued.

ID#	Age Type	Gender	Count Date	Cs-137 (kBq) value		Cs-137 (kBq) MDA	Method Code	Notes
RR00338	Adult	Male	2006-03-19	0.06	± 0.02	0.10	NaI_WBC	
RR00338	Adult	Male	2006-04-06	0.25	± 0.04	0.17	NaI_WBC	
RR00338	Adult	Male	2006-08-22	0.58	± 0.05	0.20	NaI_WBC	
RR00338	Adult	Male	2006-07-29	0.59	± 0.05	0.20	NaI_WBC	
RR00338	Adult	Male	2006-06-22	0.64	± 0.05	0.19	NaI_WBC	
RR00339	Adult	Male	2006-03-19	0.00	± 0.00	0.07	NaI_WBC	
RR00339	Adult	Male	2006-04-10	0.47	± 0.04	0.19	NaI_WBC	
RR00339	Adult	Male	2006-06-20	1.31	± 0.07	0.21	NaI_WBC	
RR00340	Adult	Male	2006-03-19	0.00	± 0.00	0.07	NaI_WBC	
RR00340	Adult	Male	2006-04-10	0.20	± 0.03	0.13	NaI_WBC	
RR00340	Adult	Male	2006-07-29	0.45	± 0.05	0.20	NaI_WBC	
RR00340	Adult	Male	2006-06-23	0.58	± 0.05	0.20	NaI_WBC	
RR00341	Adult	Male	2006-04-08	0.00	± 0.00	0.07	NaI_WBC	
RR00341	Adult	Male	2006-03-19	0.08	± 0.02	0.10	NaI_WBC	
RR00341	Adult	Male	2006-06-20	0.30	± 0.04	0.17	NaI_WBC	
RR00342	Adult	Male	2006-04-06	0.31	± 0.04	0.18	NaI_WBC	
RR00342	Adult	Male	2006-11-30	0.51	± 0.04	0.17	NaI_WBC	
RR00342	Adult	Male	2006-07-26	0.53	± 0.05	0.20	NaI_WBC	
RR00342	Adult	Male	2006-12-01	0.56	± 0.05	0.18	NaI_WBC	
RR00344	Adult	Male	2005-10-19	0.00	± 0.00	0.06	NaI_WBC	
RR00345	Adult	Male	2006-05-20	0.00	± 0.00	0.07	NaI_WBC	
RR00345	Adult	Male	2006-07-21	0.00	± 0.00	0.07	NaI_WBC	
RR00345	Adult	Male	2006-08-17	0.00	± 0.00	0.07	NaI_WBC	
RR00345	Adult	Male	2006-09-19	0.00	± 0.00	0.07	NaI_WBC	
RR00346	Adult	Male	2006-05-20	0.00	± 0.00	0.07	NaI_WBC	
RR00346	Adult	Male	2006-07-29	0.13	± 0.04	0.20	NaI_WBC	
RR00346	Adult	Male	2006-07-21	0.13	± 0.03	0.14	NaI_WBC	
RR00346	Adult	Male	2006-08-17	0.24	± 0.04	0.19	NaI_WBC	
RR00346	Adult	Male	2006-12-10	0.43	± 0.05	0.20	NaI_WBC	
RR00346	Adult	Male	2006-10-02	0.53	± 0.05	0.20	NaI_WBC	
RR00347	Adult	Male	2006-05-20	0.00	± 0.00	0.06	NaI_WBC	
RR00348	Adult	Male	2006-05-20	0.00	± 0.00	0.07	NaI_WBC	
RR00348	Adult	Male	2006-07-21	0.00	± 0.00	0.07	NaI_WBC	
RR00348	Adult	Male	2006-08-17	0.00	± 0.00	0.07	NaI_WBC	
RR00348	Adult	Male	2006-12-10	0.00	± 0.00	0.07	NaI_WBC	
RR00349	Adult	Male	2006-05-20	0.00	± 0.00	0.07	NaI_WBC	
RR00350	Adult	Male	2006-05-20	0.00	± 0.00	0.07	NaI_WBC	
RR00351	Adult	Male	2006-05-20	0.00	± 0.00	0.06	NaI_WBC	

Table A1. Continued.

ID#	Age Type	Gender	Count Date	Cs-137 (kBq) value		Cs-137 (kBq) MDA	Method Code	Notes
RR00351	Adult	Male	2006-08-17	0.00	± 0.00	0.07	NaI_WBC	
RR00351	Adult	Male	2006-07-21	0.07	± 0.03	0.12	NaI_WBC	
RR00352	Adult	Male	2006-05-20	0.00	± 0.00	0.06	NaI_WBC	
RR00352	Adult	Male	2006-06-20	0.00	± 0.00	0.07	NaI_WBC	
RR00353	Adult	Male	2006-05-23	0.00	± 0.00	0.07	NaI_WBC	
RR00354	Adult	Male	2006-05-23	0.05	± 0.02	0.10	NaI_WBC	
RR00354	Adult	Male	2006-08-22	0.93	± 0.06	0.21	NaI_WBC	
RR00354	Adult	Male	2006-07-07	0.94	± 0.06	0.20	NaI_WBC	
RR00355	Adult	Male	2006-05-26	0.00	± 0.00	0.07	NaI_WBC	
RR00355	Adult	Male	2006-07-13	0.32	± 0.04	0.17	NaI_WBC	
RR00355	Adult	Male	2006-08-19	0.32	± 0.04	0.18	NaI_WBC	
RR00357	Adult	Male	2006-05-26	0.00	± 0.00	0.06	NaI_WBC	
RR00358	Adult	Male	2006-05-26	0.00	± 0.00	0.07	NaI_WBC	
RR00358	Adult	Male	2006-07-27	0.37	± 0.04	0.18	NaI_WBC	
RR00358	Adult	Male	2006-08-21	0.42	± 0.05	0.21	NaI_WBC	
RR00359	Adult	Male	2006-05-26	0.00	± 0.00	0.06	NaI_WBC	
RR00360	Adult	Male	2005-12-10	0.08	± 0.02	0.10	NaI_WBC	
RR00361	Adult	Male	2006-05-26	0.00	± 0.00	0.07	NaI_WBC	
RR00362	Adult	Male	2006-07-06	0.13	± 0.03	0.16	NaI_WBC	
RR00362	Adult	Male	2006-08-17	0.41	± 0.04	0.19	NaI_WBC	
RR00363	Adult	Male	2006-07-21	0.00	± 0.00	0.07	NaI_WBC	
RR00363	Adult	Male	2006-08-17	0.00	± 0.00	0.07	NaI_WBC	
RR00364	Adult	Male	2006-07-21	0.00	± 0.00	0.07	NaI_WBC	
RR00364	Adult	Male	2006-08-17	0.06	± 0.03	0.14	NaI_WBC	
RR00366	Adult	Male	2006-10-11	0.00	± 0.00	0.07	NaI_WBC	
RR00367	Adult	Male	2006-10-28	0.00	± 0.00	0.07	NaI_WBC	
RR00367	Adult	Male	2006-10-31	0.00	± 0.00	0.07	NaI_WBC	
RR00369	Adult	Male	2006-12-09	0.22	± 0.04	0.16	NaI_WBC	
RR00400	Adult	Male	2006-11-29	0.00	± 0.00	0.06	NaI_WBC	
RR00402	Adult	Male	2006-11-29	0.00	± 0.00	0.06	NaI_WBC	
RR02426	Adult	Female	2006-07-15	0.00	± 0.00	0.07	NaI_WBC	

Table A2. Plutonium urinalysis data from Rongelap Atoll (2001–2004).

ID#	Age Type	Gender	Count Date	μBq per 24 h void				Notes
				^{239}Pu		^{240}Pu		
RR00007	Adult	Male	6/24/2003	0.60	± 0.36	0.71	± 0.77	
RR00007	Adult	Male	11/10/2003	-0.03	± 0.19	0.32	± 0.54	
RR00009	Adult	Male	11/20/2001	-0.11	± 0.27	0.00	± 0.87	
RR00026	Adult	Male	9/25/2002	0.11	± 0.21	0.66	± 0.71	
RR00026	Adult	Male	7/25/2003	0.34	± 0.32	-0.16	± 0.64	
RR00026	Adult	Male	11/10/2003	-0.05	± 0.40	-0.08	± 1.42	
RR00029	Adult	Male	7/26/2003	0.75	± 0.40	-0.16	± 0.60	
RR00029	Adult	Male	11/6/2003	-0.01	± 0.20	-0.16	± 0.60	
RR00030	Adult	Male	6/24/2003	0.52	± 0.32	0.63	± 0.70	
RR00030	Adult	Male	11/12/2003	0.16	± 0.24	-0.08	± 0.86	
RR00032	Adult	Male	4/30/2002	-0.11	± 0.25	0.00	± 0.82	
RR00032	Adult	Male	6/24/2003	0.55	± 0.27	0.00	± 0.51	
RR00034	Adult	Male	11/14/2001	-0.11	± 0.21	0.00	± 0.75	
RR00034	Adult	Male	4/10/2002	0.05	± 0.17	0.00	± 0.58	
RR00036	Adult	Male	11/10/2003	-0.03	± 0.19	-0.16	± 0.52	
RR00038	Adult	Male	7/25/2003	-0.05	± 0.18	-0.16	± 0.49	
RR00038	Adult	Male	11/7/2003	0.09	± 0.23	-0.16	± 0.52	
RR00051	Adult	Male	11/13/2003	0.13	± 0.22	-0.08	± 0.75	
RR00051	Adult	Male	12//02/05	0.03	± 0.16	0.46	± 0.53	
RR00054	Adult	Male	4/8/2002	0.25	± 0.27	0.00	± 0.64	
RR00057	Adult	Male	11/16/2001	-0.11	± 0.23	0.00	± 0.77	
RR00057	Adult	Male	4/9/2002	0.95	± 0.38	0.94	± 0.85	
RR00062	Adult	Male	5/30/2001	0.39	± 0.75	-0.03	± 2.21	
RR00062	Adult	Male	11/14/2001	-0.11	± 0.21	0.00	± 0.71	
RR00062	Adult	Male	1/17/2003	0.06	± 0.17	0.00	± 0.59	
RR00066	Adult	Male	7/12/2002	0.15	± 0.19	0.00	± 0.50	
RR00066	Adult	Male	10/21/2003	0.01	± 0.22	-0.16	± 0.69	
RR00069	Adult	Male	7/27/2003	0.27	± 0.26	-0.16	± 0.45	
RR00072	Adult	Male	7/27/2003	0.50	± 0.33	-0.16	± 0.55	
RR00073	Adult	Male	7/25/2003	0.73	± 0.34	-0.16	± 0.46	
RR00073	Adult	Male	11/11/2003	-0.05	± 0.23	-0.08	± 0.83	
RR00088	Adult	Male	7/24/2003	0.13	± 0.25	0.81	± 0.73	
RR00092	Adult	Male	7/24/2003	0.82	± 0.40	-0.16	± 0.56	
RR00095	Adult	Male	4/11/2002	-0.11	± 0.16	0.00	± 0.53	
RR00098	Adult	Male	1/17/2003	0.05	± 0.16	0.00	± 0.55	
RR00111	Adult	Male	1/17/2003	-0.08	± 0.14	0.00	± 0.49	
RR00111	Adult	Male	11/12/2003	-0.05	± 0.39	-0.08	± 1.42	
RR00121	Adult	Male	7/12/2002	0.43	± 0.27	0.44	± 0.52	
RR00122	Adult	Male	4/8/2002	-0.11	± 0.23	0.00	± 0.81	
RR00123	Adult	Male	11/14/2001	0.07	± 0.19	0.00	± 0.71	
RR00123	Adult	Male	7/28/2003	0.22	± 0.30	-0.16	± 0.73	

Table A2. Continued.

ID#	Age Type	Gender	Count Date	µBq per 24 h void ^{239}Pu		^{240}Pu		Notes
RR00123	Adult	Male	11/7/2003	-0.05	± 0.38	-0.08	± 1.38	
RR00124	Adult	Male	4/30/2002	0.07	± 0.20	0.00	± 0.67	
RR00124	Adult	Male	6/24/2003	0.00	± 0.18	0.00	± 0.60	
RR00124	Adult	Male	11/7/2003	-0.16	± 0.22	-0.16	± 0.64	
RR00125	Adult	Male	4/30/2002	0.56	± 0.31	0.00	± 0.56	
RR00125	Adult	Male	10/21/2003	0.06	± 0.26	0.66	± 0.86	
RR00126	Adult	Male	4/10/2002	0.07	± 0.19	0.00	± 0.68	
RR00128	Adult	Male	5/30/2001	-0.02	± 0.71	-0.03	± 2.82	
RR00128	Adult	Male	11/12/2003	-0.05	± 0.23	0.62	± 0.81	
RR00129	Adult	Male	5/30/2001	-0.37	± 1.07	-0.03	± 6.72	
RR00130	Adult	Male	4/30/2002	0.56	± 0.34	0.00	± 0.64	
RR00130	Adult	Male	1/28/2003	0.25	± 0.25	0.00	± 0.67	
RR00131	Adult	Male	5/30/2001	0.12	± 0.70	-0.03	± 1.88	
RR00132	Adult	Male	9/25/2002	0.26	± 0.26	0.64	± 0.69	
RR00132	Adult	Male	7/27/2003	1.74	± 0.62	1.81	± 1.16	
RR00132	Adult	Male	11/11/2003	-0.05	± 0.58	-0.08	± 2.04	
RR00133	Adult	Male	11/15/2001	0.29	± 0.29	0.00	± 0.68	
RR00134	Adult	Male	11/20/2001	0.37	± 0.35	0.00	± 0.81	
RR00136	Adult	Male	4/10/2002	0.39	± 0.36	0.00	± 0.93	
RR00136	Adult	Male	1/28/2003	0.62	± 0.32	1.53	± 0.92	
RR00137	Adult	Male	1/17/2003	0.06	± 0.16	0.00	± 0.56	
RR00141	Adult	Male	4/9/2002	0.42	± 0.32	0.00	± 0.66	
RR00141	Adult	Male	1/28/2003	0.18	± 0.20	0.00	± 0.54	
RR00143	Adult	Male	4/8/2002	0.19	± 0.30	0.00	± 1.02	
RR00143	Adult	Male	10/21/2003	-0.16	± 0.20	-0.16	± 0.54	
RR00144	Adult	Male	12/2/2005	-0.10	± 0.13	0.00	± 0.43	
RR00145	Adult	Male	11/16/2001	0.28	± 0.28	0.00	± 0.75	
RR00146	Adult	Male	7/16/2002	0.45	± 0.25	0.00	± 0.47	
RR00147	Adult	Male	11/14/2001	0.07	± 0.20	0.00	± 0.71	
RR00148	Adult	Male	11/14/2001	0.04	± 0.17	0.00	± 0.63	
RR00149	Adult	Male	11/20/2001	-0.11	± 0.20	0.00	± 0.73	
RR00150	Adult	Male	11/16/2001	4.13	± 0.95	0.00	± 0.72	
RR00150	Adult	Male	10/21/2003	0.00	± 0.21	-0.16	± 0.63	
RR00152	Adult	Male	7/16/2002	0.18	± 0.20	0.00	± 0.53	
RR00156	Adult	Male	7/12/2002	0.19	± 0.18	0.00	± 0.43	
RR00157	Adult	Male	4/10/2002	0.24	± 0.26	0.00	± 0.71	
RR00158	Adult	Male	11/19/2001	0.26	± 0.27	0.00	± 0.69	
RR00162	Adult	Male	7/16/2002	0.25	± 0.21	0.00	± 0.49	
RR00168	Adult	Male	7/16/2002	0.09	± 0.19	0.64	± 0.69	
RR00170	Adult	Male	8/1/2002	0.03	± 0.14	0.00	± 0.49	
RR00171	Adult	Male	11/15/2001	-0.11	± 0.18	0.00	± 0.68	

Table A2. Continued.

ID#	Age Type	Gender	Count Date	μBq per 24 h void				Notes
				^{239}Pu		^{240}Pu		
RR00172	Adult	Male	11/19/2001	0.11	± 0.24	0.00	± 0.84	
RR00173	Adult	Male	11/19/2001	0.46	± 0.57	0.00	± 1.98	
RR00174	Adult	Male	11/16/2001	-0.11	± 0.28	0.00	± 1.02	
RR00174	Adult	Male	4/12/2002	0.90	± 0.42	0.59	± 0.72	
RR00174	Adult	Male	7/1/2003	0.00	± 0.22	0.00	± 0.74	
RR00175	Adult	Male	11/20/2001	0.12	± 0.24	0.00	± 0.89	
RR00176	Adult	Male	11/19/2001	-0.11	± 0.25	0.00	± 1.02	
RR00177	Adult	Male	11/20/2001	0.35	± 0.33	0.00	± 0.89	
RR00178	Adult	Male	11/15/2001	0.67	± 0.35	0.00	± 0.62	
RR00179	Adult	Male	4/9/2002	0.40	± 0.31	0.65	± 0.88	
RR00180	Adult	Male	4/8/2002	-0.11	± 0.22	0.00	± 0.86	
RR00180	Adult	Male	3/11/2003	0.00	± 0.30	0.00	± 1.12	
RR00181	Adult	Male	11/16/2001	-0.11	± 0.17	0.00	± 0.65	
RR00182	Adult	Male	11/15/2001	0.08	± 0.20	0.00	± 0.71	
RR00184	Adult	Male	11/19/2001	0.08	± 0.20	0.00	± 0.74	
RR00185	Adult	Male	11/19/2001	-0.11	± 0.22	0.00	± 0.82	
RR00185	Adult	Male	3/11/2003	0.00	± 0.24	0.00	± 0.80	
RR00186	Adult	Male	4/9/2002	-0.11	± 0.21	0.00	± 0.73	
RR00187	Adult	Male	8/1/2002	0.33	± 0.25	0.00	± 0.57	
RR00187	Adult	Male	11/6/2003	0.31	± 0.31	-0.16	± 0.61	
RR00188	Adult	Male	11/15/2001	0.30	± 0.30	0.00	± 0.88	
RR00189	Adult	Male	8/1/2002	0.17	± 0.20	0.00	± 0.54	
RR00189	Adult	Male	3/11/2003	0.45	± 0.33	0.00	± 0.85	
RR00190	Adult	Male	3/11/2003	0.40	± 0.30	0.00	± 0.79	
RR00191	Adult	Male	10/14/2003	0.15	± 0.26	-0.16	± 0.59	
RR00193	Adult	Male	10/14/2003	0.58	± 0.36	-0.16	± 0.59	
RR00194	Adult	Male	8/1/2002	0.22	± 0.23	0.00	± 0.60	
RR00195	Adult	Male	11/15/2001	0.08	± 0.20	0.00	± 0.65	
RR00198	Adult	Male	7/1/2003	0.15	± 0.18	0.00	± 0.56	
RR00198	Adult	Male	11/6/2003	0.01	± 0.22	-0.16	± 0.66	
RR00203	Adult	Male	12/7/2002	0.18	± 0.21	0.00	± 0.56	
RR00206	Adult	Male	7/28/2003	0.17	± 0.27	-0.16	± 0.64	
RR00206	Adult	Male	11/10/2003	-0.05	± 0.39	-0.08	± 1.43	
RR00207	Adult	Male	9/25/2002	0.05	± 0.15	0.00	± 0.54	
RR00208	Adult	Male	10/14/2003	0.69	± 0.35	-0.16	± 0.50	
RR00211	Adult	Male	7/1/2003	0.25	± 0.21	0.00	± 0.53	
RR00211	Adult	Male	11/10/2003	-0.16	± 0.19	-0.16	± 0.53	
RR00212	Adult	Male	3/5/2003	0.80	± 0.42	0.00	± 0.76	
RR00213	Adult	Male	7/24/2003	0.09	± 0.29	0.76	± 0.96	
RR00213	Adult	Male	11/7/2003	0.11	± 0.30	-0.16	± 1.02	
RR00222	Adult	Male	4/11/2002	0.92	± 0.37	0.46	± 0.57	

Table A2. Continued.

ID#	Age Type	Gender	Count Date	µBq per 24 h void				Notes
				^{239}Pu		^{240}Pu		
RR00223	Adult	Male	4/11/2002	0.39	± 0.36	0.00	± 1.05	
RR00224	Adult	Male	4/11/2002	-0.11	± 0.15	0.00	± 0.57	
RR00225	Adult	Male	4/12/2002	0.15	± 0.27	0.00	± 1.02	
RR00226	Adult	Male	4/12/2002	0.05	± 0.18	0.59	± 1.05	
RR00227	Adult	Male	4/12/2002	0.03	± 0.16	0.00	± 0.56	
RR00233	Adult	Male	7/1/2003	0.38	± 0.24	0.44	± 0.54	
RR00234	Adult	Male	3/5/2003	0.22	± 0.24	0.00	± 0.85	
RR00237	Adult	Male	3/5/2003	1.90	± 0.68	2.49	± 1.47	
RR00243	Adult	Male	11/7/2003	-0.16	± 0.25	-0.16	± 0.78	
RR00253	Adult	Male	3/5/2003	0.41	± 0.30	0.00	± 0.80	
RR00256	Adult	Male	11/6/2003	0.40	± 0.31	-0.16	± 0.54	
RR00258	Adult	Male	7/24/2003	0.78	± 0.41	0.39	± 0.61	
RR00258	Adult	Male	11/13/2003	0.25	± 0.32	-0.08	± 1.15	
RR00259	Adult	Male	11/10/2003	-0.05	± 0.39	-0.08	± 1.42	
RR00260	Adult	Male	11/10/2003	-0.05	± 0.29	1.80	± 1.39	
RR00261	Adult	Male	11/13/2003	0.68	± 0.38	-0.08	± 0.77	
Control	Adult	Male	07/24/03	29.76	± 2.16	26.48	± 3.84	outlier value
Control	Adult	Male	3/7/2001	0.06	± 0.75	-0.03	± 3.36	
Control	Adult	Male	11/14/2001	0.27	± 0.23	0.00	± 0.51	
Control	Adult	Male	4/30/2002	0.05	± 0.18	0.00	± 0.64	
Control	Adult	Male	7/19/2002	0.96	± 0.40	0.55	± 0.61	
Control	Adult	Male	7/24/2003	1.35	± 0.44	0.26	± 0.49	
Control	Adult	Male	10/14/2003	-0.16	± 0.19	-0.16	± 0.52	
Control	Adult	Male	11/6/2003	1.18	± 0.47	-0.16	± 0.60	
Control	Adult	Female	2/13/2005	0.01	± 0.14	0.00	± 0.47	
Field Blank	–	–	5/30/2001	-0.20	± 0.64	-0.03	± 1.45	
Field Blank	–	–	11/21/2001	-0.11	± 0.32	0.00	± 1.15	
Field Blank	–	–	11/21/2001	-0.11	± 0.39	0.00	± 1.23	
Field Blank	–	–	11/21/2001	-0.11	± 0.21	0.00	± 0.84	
Field Blank	–	–	11/21/2001	-0.11	± 0.18	0.00	± 0.66	
Field Blank	–	–	4/14/2002	0.05	± 0.18	0.00	± 0.58	
Field Blank	–	–	4/14/2002	-0.11	± 0.18	0.00	± 0.68	
Field Blank	–	–	5/2/2002	-0.11	± 0.17	0.00	± 0.62	
Field Blank	–	–	7/19/2002	-0.08	± 0.16	0.00	± 0.58	
Field Blank	–	–	7/24/2003	0.00	± 0.17	0.00	± 0.58	
Field Blank	–	–	7/24/2003	0.11	± 0.15	0.00	± 0.50	
Field Blank	–	–	7/24/2003	0.13	± 0.16	0.00	± 0.53	
Field Blank	–	–	7/24/2003	0.00	± 0.16	0.00	± 0.52	
Field Blank	–	–	7/25/2003	0.06	± 0.21	-0.16	± 0.47	
Field Blank	–	–	10/21/2003	0.06	± 0.21	-0.16	± 0.48	
Field Blank	–	–	11/6/2003	0.25	± 0.27	0.31	± 0.53	

Table A2. Continued.

ID#	Age Type	Gender	Count Date	μBq per 24 h void				Notes
				^{239}Pu		^{240}Pu		
Field Blank	–	–	11/11/2003	-0.05	± 0.36	-0.08	± 1.28	
Field Blank	–	–	12/3/2003	0.11	± 0.20	0.55	± 0.64	
Field Blank	–	–	11/25/2003	0.11	± 0.20	0.00	± 0.63	
Field Blank	–	–	2/15/2005	-0.10	± 0.14	0.00	± 0.48	
Field Blank	–	–	2/15/2005	0.00	± 0.13	0.00	± 0.46	

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