RADIOLOGICAL DOSE ASSESSMENTS IN THE NORTHERN MARSHALL ISLANDS (1989-1991)[a]

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Introduction

The Republic of the Marshall Islands (RMI) is located in the central Pacific Ocean about 3,500 km southwest of Hawaii and 4,500 km east of Manila, Philippines. It consists of 34 atolls and 2 coral islands, having a total land area of about 180 km^2, distributed over more then 2.5 x 10^6 km^2 of ocean. Between 1946 and 1958 the United States conducted nuclear tests there: 43 at Enewetak and 23 at Bikini. Thirty-three years after the cessation of nuclear testing in the RMI, the impact of these operations on the health and radiological safety of the people living in or planing to return to their contaminated homelands is still an important concern[(1)(2)].

The present Brookhaven National Laboratory (BNL) Marshall Islands Radiological Safety Program (MIRSP) began in 1987 with funding from the U.S. Department of Energy (DOE). The objectives of the MIRSP are to determine the radionuclides present in the bodies of those people potentially exposed to residual radionuclide from weapon tests and fallout, and to assess their present and lifetime dose from external and internal sources. Field bioassay missions involving whole body counting (WBC) and urine sample collection have, therefore, been important components of the program. WBC is used to measure γ-emitters, such as ^{40}K, ^{60}Co and ^{137}Cs, present in individuals. Urine samples are used to measure α and β-emitting nuclides, such as ^{239}Pu and ^{90}Sr, that are undetectable by WBC routine methods.

Whole-Body Counting Program

Whole-body counting measurements are conducted on a voluntary basis. Two complete counting systems are operated simultaneously and independently during daily WBC operations. The counting time is 15 minutes per measurement. About 50 to 60 measurements could be obtained in a working day. A total of 916 persons were counted in 1989. This group included 216 the people of (dri-) Enewetak, 258 dri-Rongelap, and 414 dri-Utirik. Also included were 28 visitors, workers, and DOE personnel, listed as "Others". A total of 1051 persons participated in the WBC in 1991; 311 dri-Enewetak,

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272 dri-Utirik, 427 dri-Rongelap, and 41 Others. Since 1985, when dri-Rongelap self-exiled to Mejatto Island, all Rongelap measurements were obtained at Mejatto.

^{137}Cs is the only fallout nuclide detected in the WBC. The highest WBC measured individual on any of the three missions was 14 kBq from Enewetak. Except at Enewetak, all WBC measurements showed a decrease from 1989 to 1991. This increase at Enewetak suggests the possibility that coconuts planted there during the cleanup, and just now beginning to bear fruit, are providing a source of cesium.

Dose calculations from the ^{137}Cs body counts were based on an ICRP-56 tabulation of conversion factors[3] used to compute the committed effective dose equivalents (CEDE) following acute exposures to cesium at different ages. The conversion factor of 1.4×10^{-8} Sv/Bq for 15 year old was used for conservative reasons. The ICRP-30 retention function[4] indicates that 90% of the CEDE is received within the first year of exposure, and that a 2.8 ratio exists if a constant level of ^{137}Cs is maintained as opposed to its being eliminated from the body in one year. Therefore, the annual effective dose equivalents (AEDE) were calculated by multiplying the CEDE by factors of 0.9 and 2.8. Table 1 shows the AEDE that an individual would receive due to uniform chronic exposure throughout an entire year.

Table 1, Average AEDE [μSv] from WBC Measurements

Population	1989	1991
Enewetak	11 ± 3	22 ± 4
Rongelap	3 ± 2	2 ± 2
Utirik	39 ± 2	35 ± 3

Plutonium Measurements and Urinalysis Program

In 1983, Photon Electron Rejection Alpha Liquid Scintillation (PERALS) system was used for ^{239}Pu urinalysis for the Marshallese. Unexpectedly high apparent ^{239}Pu activities (130 μBq) in samples collected from a location that should not have been affected by the Bravo fallout were obtained. It was subsequently shown that most of the measured ^{239}Pu was actually ^{210}Po which could not be differentiated by the PERALS system. These findings prompted development of a fission track analytical (FTA) technique[5] that would be capable of detecting very low-levels of ^{239}Pu without interference from ^{210}Po. By 1987, FTA was capable of measuring 4 μBq per sample of ^{239}Pu. With further improvements, a sensitivity of about 2 μBq was achieved in 1989.

As of December 1988, a total of 195 Rongelap and 300 Utirik urine samples were analyzed at BNL. These 495 samples were collected from volunteers during field missions conducted between 1981 to 1984. The frequency distribution for the ^{239}Pu values from the Marshallese urine were log-normal with the 50 percentile (geometric

mean) at about 9 μBq per sample for Rongelap and 4 μBq for Utirik. The 95% level of the distribution is at about 37 μBq for both sample sets. The highest value measured was 174 μBq.

Among the 195 Rongelap FTA results, 22 cases were found with inconsistent results from individuals who participated in the urine program more than once during the 1981-1984 missions. Three potential causes for these disparities were investigated: (1) was it possible that small amounts of contaminated soil were getting into the urine samples and thereby resulting in false estimates of plutonium excreted by the individual? (2) were the 24-h urine volumes used in the calculations appropriate and did each sample contain the entire 24 hour urine output as required for a proper systemic burden estimate? (3) were the other metabolic parameters used in this calculation appropriate for the Marshall Islanders?

In September 1988, urine samples were collected from individuals residing on Mejatto, Utirik, and Majuro. FTA values from the 146 urine measurements (67 Rongelap and 79 Utirik) and urine-blanks (26 synthetic and 76 composite human urine from a BNL employee) are shown in Table 2. For dri-Utirik, the values of mean (μ) mean) and standard deviation (σ) were higher than those of Rongelap because of one sample containing 742 tracks (about 50 μBq of ^{239}Pu). Since samples collected from this same person in 1981 and 1989 were both less than MDL, we concluded that the 1988 reading was due to contamination.

Table 2, Statistical Summary of the 1988 Data (Tracks)

	n	μ	σ	median
Dri-Rongelap	67	59	34	56
Dri-Utirik	79	64	82	54
BNL-Employee	76	54	29	49
Synthetic-Urine	26	42	13	42

The MDL ($\mu+3\sigma$) derived from the synthetic urine data was 81 tracks. All samples greater than 81 tracks are considered to have statistically significant levels of ^{239}Pu activity. Otherwise, less than MDL was reported.

In 1989, a new urine collection protocol was developed which approximates the precision and accuracy obtainable in a hospital. Collection bottles were no longer distributed to participants for use at their homes. Instead, all samples were taken on the mission vessel over a controlled 24-h period, and were acidified (16N HNO_3, 10% by volume) within 24 hours of the collection period. A group of 32 individuals who previously had ^{239}Pu readings greater than 11 μBq were resampled in 1989. Only two of these samples were above the MDL of 2 μBq (i.e., 2.8 and 2.4 μBq). These data lead to the conclusion that soil contamination was the cause of earlier abnormally high readings,

and provided confidence in the new urine collection protocol. The 2.8 μBq is equivalent to a CEDE of 0.4 mSv.

Interlaboratory Comparison of ^{137}Cs and ^{239}Pu Data

In 1990, a two order of magnitude dose discrepancy between BNL and Lawrence Livermore National Laboratory (LLNL) for dri-Rongelap[2] was resolved. For ^{137}Cs, BNL whole-body counts yielded an average of 3.7 kBq in 1984; LLNL estimated 5.9 kBq could be expected using their environmental sample measurements and availability of imported foods. For ^{239}Pu, BNL estimated an CEDE of 0.40 mSv from the interpretation of Rongelap urine data; and LLNL estimated 0.46 mSv from dietary assumptions, intake pathway analysis, and Pu activities measured in foods, dust and soil[6].

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