Review of Radiation Exposures of Utrik Atoll Residents

Final Report

Prepared by

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Prepared for the people of Utrik Atoll
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Executive Summary

This report describes work performed by the Institute for Energy and Environmental Research based in Heidelberg, Germany (IFEU) under contract with S. Cohen & Associates, McLean Virginia. It was prepared for the people of Utrik Atoll for submission to the Nuclear Claims Tribunal (NCT) of the Republic of the Marshall Islands (RMI). The report presents:

- Estimates of radiation doses using the methodology employed in the Rongelap Resettlement Project;
- An evaluation of historical whole body counting data of Utrik residents; and
- An overview of year-by-year radiation exposures to Utrik residents since the onset of nuclear testing in the Pacific

Key findings include the following:

(1) Using the methodology employed in the Rongelap Resettlement Project, an upper limit (99-percentile) of radiation exposure to Utrik Island residents who live on a local-food-only diet was calculated to be 43 mrem/year in the year 2005. This dose includes a 2 mrem/year contribution from external gamma radiation.
(2) Based on historical whole body counting data of Utrik Island residents, the maximum credible dose due to the ingestion of Cs-137 was determined to be 42 mrem/year. The fact that the calculated value of 43 mrem/year is essentially identical to the empirical whole body count value of 42 mrem/year suggests that a local-food-only diet was the actual lifestyle for some individuals on Utrik Island in past decades.
(3) Residents of Utrik received significant doses from Zn-65 in fish the years in the years between 1954 and 1958. In 1955, the maximum dose to a Utrik resident as a result of incorporated Zn-65 was 24 rem.
(4) Operation Redwing in 1956 and Operation Hardtack in 1958 contributed significant gamma radiation doses to Utrik residents
(5) Between 1954 and 2001, radiation exposures to the reasonably maximally exposed individual (RMEI) residing on Utrik Island were not in compliance with applicable or relevant and appropriate requirements. The people of Utrik had no proper use of their home atoll for the time period 1954 to 2001, a total of 48 years.

Acknowledgement - The author is indebted to the people of Utrik who accepted the research team with great hospitality during the October 2001 field trip to Utrik and Taka Atolls. I particularly appreciate the support of the Honorable Hiroshi Yamamura, Member of the Nitijela, the Honorable Joe Saul, Mayor of Utrik and Mr. John E. Masek, Esq., Legal Counsel to the Utrik Atoll Local Government. I appreciate many suggestions and the in-depth review of my work by Dr. John Mauro and Dr. Hans Behling.

Contents

1 Introduction

This report was prepared for the people of Utrik under contract with S. Cohen & Associates, McLean, Virginia, USA for submission before the Nuclear Claims Tribunal of the Republic of the Marshall Islands.

It was drafted in close collaboration with Dr. John Mauro and Dr. Hans Behling, S. Cohen & Associates. The objectives of this report is to provide the following supplemental information:

1. to estimate radiation doses using the methodology employed in the Rongelap Resettlement Project;
2. to critically review historical whole body counting data of Utrik residents; and
3. to present a year-by-year estimate of radiation exposures to Utrik residents since the onset of nuclear testing in the Pacific.

Relevant information and key data are presented as follows:

Chapter 2 contains a summary of the qualifications of the principal investigator.

Chapter 3 summarizes of the methodology for dose assessment in the Rongelap Resettlement Project and the results of model calculations using data for Utrik Island. These results are compared with those from other models, including the one used by John Mauro and Hans Behling in the SC&A report concurrently submitted to the Nuclear Claims Tribunal.

Chapter 4 presents an analysis of whole body counting data of Utrik residents, which serve as empirical evidence of past exposures over time. The observed exposures can be directly compared with those estimated by model calculations.

Chapter 5 gives a brief overview of yearly radiation exposures to Utrik residents since the onset of nuclear testing in the Pacific.

Chapter 6 assesses doses to the reasonably maximum exposed individual (RMEI) in context with applicable regulations, and the loss-of-use of Utrik Atoll is determined.

2 Qualifications

Bernd Franke has the German equivalent of a master's degree in biology and geography from the University of Heidelberg. He has 25 years of professional experience in radioecology and environmental risk assessment. In 1978, he was a co-founder of the IFEU-Institut für Energie- und Umweltforschung Heidelberg GmbH (Institute for Energy and Environmental Research) in Heidelberg, Germany, where he currently holds the position of Scientific Director. He also was a co-founder of the US-based Institute for Energy and Environmental Research (IEER) in Takoma Park, Maryland, where he served as Executive Director from 1984 to 1998. In both Institutes, he was the principal investigator in a substantial number of radiation risk assessment projects for clients representing the public and private sector.

In 1982, he was responsible for the assessment of radiation exposures due to potential accidents in the proposed fast breeder reactor at Kalkar, a study funded by the Federal German Department of Research and Technology. In 1986, he evaluated radiation exposures and associated health risks for residents in Hamburg due to fallout from the Chernobyl nuclear accident, for the State of Hamburg Department for Environmental Protection. From 1992 to 1996, Mr. Franke was a member of the Scientific Management Team of the Rongelap Resettlement Project. The project was funded by the U.S. Department of Interior and administered by the Government of the Marshall Islands and the Rongelap Local Government. In this project, he was responsible for a detailed assessment of the diet for residents on Mejatto Island, Kwajalein Atoll, and the determination of plutonium content in the remains of deceased residents of Rongelap Atoll. Together with the other members of the team, he prepared the prospective dose assessment for residents of Rongelap Island after resettlement.

In recent years, Mr. Franke has conducted dose reconstructions for residents and workers in legal claims against U.S. nuclear plants (e.g. the Feed Materials Production Center (FMPC) in Fernald, Ohio; Hanford Site, Washington; the Apollo, Pennsylvania uranium fuel facility),;evaluated the risks after cleanup at a radioactive waste disposal site near Point Hope, Alaska, under contract with the North Slope Borough, Barrow, Alaska; monitored the Independent Audits of Los Alamos National Laboratory for Compliance with the Clean Air Act, 40CFR61, Subpart H, under contract with Concerned Citizens for Nuclear Safety, Santa Fe, NM; and reviewed properties of radioactive wastes shipped from Los Alamos National Laboratory (LANL) under contract with the Attorney General of New Mexico. Since the beginning of 2001, Mr. Franke has been a member of the German Radiation Protection Commission, an official body of experts advising the Federal Minister of the Environment in Germany with respect to many radiological issues.

3 Estimates of Cs-137 exposure to residents on Utrik Island using the methodology applied in the Rongelap Resettlement Project

The Rongelap Resettlement Project (RRP) resulted in a final report[1], which contains estimates of radiation doses to determine compliance with the predetermined dose limit specified in the Memorandum of Understanding.[2] The calculations therein were based on a protocol[3] (see Appendix A), which was adopted in consultation with the Rongelap community according to the following principles:

- the quantities calculated shall be relevant to the determination of compliance with criteria set out in the Memorandum of Understanding;
- the model shall make effective use of the data arising from RRP studies, and shall take into account other data of relevance, as appropriate;
- the model shall be so structured that the views of the Rongelap Community on key issues are properly taken into account; and
- the model and associated input data shall be documented in such a way that all the technical and social assumptions made in defining the assessment basis and undertaking the quantitative calculations are clearly and explicitly defined.

The Memorandum of Understanding stated that the primary condition for a determination to resettlement is that the calculated maximum whole-body radiation dose equivalent to the maximally exposed resident shall not exceed 100 mrem/year above natural background, based on a local food-only diet. In reality, the parameters for this model are not well defined, so the approach was directed to assessing the distribution of individual doses, which might be received by both external and internal exposure. This distribution of doses over the exposed population was then used to determine whether there exists a reasonable assurance of compliance with the given criterion.

Our adopted model considered the probability distribution functions for the following parameters:

- height and body weight;
- energy intake at a given weight and height as a function of lifestyle and the degree of physical activity, expressed as estimated mean basal metabolic requirement (BMR_{est}); and
- Cs-137 contamination of local food items.

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[1] Baverstock K., Franke B., Simon S.L., Rongelap Resettlement Project, Summary of First Phase: Determining Compliance with Agreed Limits for Total Annual Dose-Rate on Rongelap Island and Actinide Contamination of Soils on Rongelap Island and Neighbouring Islands, Rongelap Resettlement Project, P.O.Box 1766, Majuro, MI 96960, May 1994

[2] Republic of the Marshall Islands, Rongelap Atoll Local Government, U.S. Department of Energy and U.S. Department of Interior (1992), Memorandum of Understanding for the Rongelap Resettlement Project, February 1992

[3] M.C. Thorne (1994). The Protocol being Adopted for Assessment of Radiation Doses in the Rongelap Resettlement Project, as revised 28 March 1994, Appendix A2 to: Baverstock K., Franke B., Simon S.L., Rongelap Resettlement Project, Summary of First Phase: Determining Compliance with Agreed Limits for Total Annual Dose-rate on Rongelap Island and Actinide Contamination of Soils on Rongelap Island and Neighbouring Islands, Rongelap Resettlement Project, P.O.Box 1766, Majuro, MI 96960, May 1994

The results of the model have been peer reviewed by the National Academy of Sciences and compare well with other approaches.[4]

3.1 The diet model

For more than 100 years, the Marshallese diet has consisted of a mixture of imported and local foods. From the period of the Germans in the mid-1800s, the Japanese, and finally the Americans, the Marshallese people have subsisted on varying types and quantities of imported food as an adjunct to their abundant but monotonous marine-based diet. As atoll dwellers (and not agriculturists), the Marshallese and other people living in Pacific atolls have the most restricted diet of all oceanic peoples.

A local-food-only diet cannot be measured directly since there appears to be no population in the Marshall Islands that subsists for long periods of time on a diet exclusively of local food items. Even if one were to conduct a dietary survey on more traditional islands, the problem remains how to substitute imported food items, such as instant noodles or rice, for local food items.

A carefully conducted 24-hour recall gives a good estimate of the mean intake of nutrients in a population because people eating more or less than usual will balance each other out. However, this also leads to the variability (spread) of intakes on one day being wider than the variability if an average of many days were collected from each person. Given the small size of the Mejatto population and the desirability of including everyone in the survey, a single 24-hour recall from all Mejatto residents was considered suitable to determine the mean intakes. In addition, height and weight of the population were measured as an external verification check of the mean energy intakes. Since the main focus of the project was to determine the variability as accurately as possible, a repeat survey of women 18 years and older was conducted.

Table 3-1 shows the summary of results. The mean data for energy intake (EI) as well as consumption of protein, carbohydrates and fat are reasonable if compared, for example, with the reference data in ICRP Publication 23. The average protein intakes of men and women are substantially higher than the US Recommended Dietary Intakes whereas the energy intakes are slightly lower. As expected, intake rates for males are higher than for females. The distribution of body mass with mean values of 69.2 kg for males $\geq$18 yrs and of 63.6 kg for females $\geq$18 yrs closely follows a lognormal distribution with m_m=4.22 and m_f=4.14 and s_m=0.17 and s_f=0.18.

Table 3-2 provides an analysis of the observed energy intake rates in comparison to the estimated basal metabolic rate. The observed mean energy intake for men and women of 1.6 times the estimated mean basal metabolic requirement (BMR_{est}) is consistent with sedentary-light activity. As has been anticipated, the spread or range of values is wide, with a small number of individuals reporting energy intakes below their estimated basal metabolic rate, whereas the maximum reported energy intakes correspond to unrealistically high physical activity levels.

[4] Simon S.L.; Robison W.L., Thorne M.C., Toburen L.H., Franke B., Baverstock K.F., Pettengill H.J., A comparison of independently conducted dose assessments to determine compliance and resettlement options for the people of Rongelap Atoll, Health Physics 73(1):133-151, 1997

Since reasonable annual mean values are needed for the dose assessment, the variation in intake was assumed to represent a lognormal distribution of the ratio of EI/BMR_{est}, whereby the standard deviation *s* of the natural logarithm of the mean *m* is adjusted such that the 1st percentile of the distribution is equivalent with a ratio of $EI/BMR_{est} = 1$. Since very heavy physical activity is associated with an average daily energy intake of 2.3 EI/BMR_{est} for males and 2.0 for females, the 99th percentile reflects reasonable upper limits of EI/BMR_{est}.

Table 3-1 Summary of Selected Results from the Mejatto Diet Survey, May 1993[5]
(mean and one standard deviation)

Group	**Energy Intake** *(kcal/d)*	**Protein Intake** *(g/d)*	**Carbohydrate Intake** *(g/d)*	**Fat Intake** *(g/d)*
Boys, 10-17 years (N=43)				
mean	2,100 ± 690	87 ± 36	270 ± 100	72 ± 28
Girls, 10-17 years (N=26)				
mean	2,100 ± 570	87 ± 39	280 ± 64	75 ± 26
Men ≥ 18 yrs (N=68)				
mean	2,750 ± 1,200	110 ± 55	365 ± 170	94 ± 52
Women ≥ 18 yrs with one or two recalls (first recall only) (N=64)				
mean	2,000 ± 770	80 ± 43	270 ± 100	71 ± 32
Women ≥ 18 yrs with repeat recalls (N=48)				
1st recall	1,960 ± 690	77 ± 38	260 ± 94	68 ± 27
2nd recall	1,860 ± 590	67 ± 29	250 ± 87	64 ± 25
mean	1,900 ± 500	72 ± 27	255 ± 66	66 ± 21
ICRP 23 reference data for comparison				
adult man	3,000	95	390	120
adult woman	2,100	66	270	85
US RDA (10th edition)				
men 25-50 yrs	2,900	63		
women 25-50 yrs	2,200	50		

One of the greatest challenges in the diet study was the design of a "local food diet". Since there is no established methodology, and the composition of a "local-food-only" cannot be observed empirically, the following diet scenarios were selected after consultation with the Rongelap community:

(Diet 1) "Mejatto observed"
The current level of local food items as observed in the Mejatto survey (about 18% of total energy intake).

[5] Franke B. (1991). Study of Traditional or "Local Food Only" Diet. in: Baverstock K., Franke B., Simon S.L., Rongelap Resettlement Project Scientific Studies, Rongelap resettlement Project, P.O.Box 1766, Majuro, MI 96960, May 1994

(Diet 2) "Mejatto scaled"
Imported food items are replaced by local food items on a calorie-by-calorie basis in the same proportions as these local food items were consumed in the mean on Mejatto during the survey.

(Diet 3) "Mejatto scaled with rice"
Same as #2, but accounting for the same mean rice consumption as observed on Mejatto (between 25% and 30% of total energy intake).

(Diet 4) "Naidu et al., scaled"
Imported food items are replaced by local food items on a calorie-by-calorie basis in the same mean proportions as these local food items were reported in the Naidu et al. survey.[6]

(Diet 5) "Naidu et al., scaled with rice"
Same as #4, but accounting for same mean rice consumption as observed on Mejatto (between 25% and 30% of total energy intake).

Table 3-2 Energy Intake (EI) compared to the estimated basal metabolic rate (BMR_{est})

Parameter	Boys 10-17 yrs (N=35)	Girls 10-17 yrs (N=22)	Men ≥ 18 yrs (N=53)	Women ≥ 18 yrs (N=41)
observed data:				
EI/BMR_{est}, avg	1.6	1.7	1.7	1.4
EI/BMR_{est}, min	0.46	0.69	0.59	0.72
EI/BMR_{est}, max	2.4	2.5	3.5	2.3
m (EI/BMR_{est})	0.41	0.51	0.45	0.33
s (EI/BMR_{est})	0.33	0.32	0.39	0.28
adjusted data:				
m (EI/BMR_{est})	0.41	0.51	0.45	0.33
s (EI/BMR_{est})	0.18	0.22	0.19	0.14
EI/BMR_{est}, 01-percentile	1.0	1.0	1.0	1.0
EI/BMR_{est}, 50-percentile	1.5	1.7	1.6	1.4
EI/BMR_{est}, 95-percentile	2.1	2.6	2.3	1.8
EI/BMR_{est}, 99-percentile	2.3	2.8	2.4	1.9

BMR estimated based on equations by Schoffield et al.

The resulting diet models for consumption of local foodstuffs are shown in Tables 3-3 to 3-4. Table 3-5 provides key nutritional data on the diets.

[6] Naidu, J.R., et al. Marshall Islands: A study of diet and living patterns. Brookhaven National Laboratory, Upton, N.Y. July 1980, BNL 51313

Table 3-3 Food composition for local food diets (Males ≥ 18 yrs)

Description	**Energy content in food** *kcal/g*	**Diet 1 Mejatto observed** *g/d (avg)*	**Diet 2 Mejatto scaled w/o rice** *g/d (avg)*	**Diet 3 Mejatto scaled with rice** *g/d (avg)*	**Diet 4 Naidu et al. scaled w/o rice** *g/d (avg)*	**Diet 5 Naidu et al. scaled with rice** *g/d (avg)*
observed in Mejatto survey:						
Bananas (raw, peeled)	0.92	0.0	0.0	0.0	20.3	14.3
Bird, wild, roasted	2.1	14.0	84.7	59.7	5.5	3.9
Coconut Cream (solid)	3.5	64.2	389.1	274.3	0.0	0.0
Coconut Milk (i.e. diluted cream)	2.5	16.1	97.6	68.8	27.1	19.1
Coconut, drinking, NI	0.11	24.3	147.1	103.7	1014.8	715.5
Coconut Embryo, IU	0.83	1.5	9.0	6.3	330.9	233.3
Coconut hard, WAINI	4.1	5.3	32.3	22.8	176.8	124.7
Coconut soft, MEDE	1.1	5.3	32.1	22.6	256.7	181.0
Coconut crab, blue, boiled	0.85	1.3	7.7	5.4	12.2	8.6
JEKERU, incl. JEKMAI	0.48	83.5	506.5	357.1	372.7	262.7
JEMANIN, (fermented JEKERU)	0.51	3.7	22.4	15.8	0.0	0.0
Pandanus fruit, raw	0.64	12.7	77.2	54.5	135.9	95.8
Pandanus fruit, cooked	0.64	6.1	37.0	26.1	0.0	0.0
Papayas, raw	0.39	6.9	41.7	29.4	32.7	23.1
Pork	3.0	2.7	16.2	11.4	2.3	1.6
Pumpkin	0.20	1.5	9.0	6.3	5.4	3.8
Reef fish (boiled, poached)	1.1	12.9	78.3	55.2	248.2	175.0
Reef fish (grilled, bbq)	1.3	13.2	80.2	56.5	0.0	0.0
Reef fish (pan fried, no flour)	1.1	9.7	59.0	41.6	0.0	0.0
Salt fish (equiv. wet wt.)	1.1	1.6	9.8	6.9	0.0	0.0
Sashimi (tuna, trolling fish)	1.0	7.9	48.1	33.9	0.0	0.0
Tuna, trolling fish (cooked)	1.2	10.6	64.4	45.4	226.3	159.5
Watermelon (raw)	0.32	0.0	0.0	0.0	0.0	0.0
Breadfruit, incl. BWIRO	1.0	0.0	0.0	0.0	222.4	156.8
in Naidu et al. survey, but not observed on Mejatto:						
Coconut, KENAWE	0.1				23.8	16.7
Arrowroot flour	3.6				5.2	3.7
Sweet potatoes	1.1				0.7	0.5
Breadfruit seeds, roasted	2.1				4.0	2.8
Plantains (cooked)	1.2				20.3	14.3
Turtle	0.89				2.0	1.4
Lobster	1.0				1.6	1.1
Clams (giant)	1.5				2.1	1.5
Snails	0.90				30.9	21.8
Octopus	1.6				2.5	1.7
Clams (small)	1.5				5.8	4.1
Jankwon	2.9				32.1	22.6
Chicken	2.4				1.4	1.0
local vegetables	0.35				19.5	13.7

Table 3-4 Food composition for local food diets (Females ≥ 18 yrs)

Description	**Energy content in food** *kcal/g*	**Diet 1 Mejatto observed** *g/d (avg)*	**Diet 2 Mejatto scaled w/o rice** *g/d (avg)*	**Diet 3 Mejatto scaled with rice** *g/d (avg)*	**Diet 4 Naidu et al. scaled w/o rice** *g/d (avg)*	**Diet 5 Naidu et al. scaled with rice** *g/d (avg)*
observed in Mejatto survey:						
Bananas (raw, peeled)	0.92	2.4	12.9	9.7	14.1	10.6
Bird, wild, roasted	2.1	1.6	8.8	6.6	3.8	2.9
Coconut Cream (solid)	3.5	45.4	246.0	185.1	0.0	0.0
Coconut Milk (i.e. diluted cream)	2.5	7.6	40.9	30.8	18.8	14.2
Coconut, drinking, NI	0.11	37.1	200.9	151.1	702.6	530.5
Coconut Embryo, IU	0.83	0.5	2.8	2.1	229.1	173.0
Coconut hard, WAINI	4.1	6.0	32.7	24.6	122.4	92.4
Coconut soft, MEDE	1.1	0.4	2.2	1.6	177.7	134.2
Coconut crab, blue, boiled	0.85	0.0	0.0	0.0	8.5	6.4
JEKERU, incl. JEKMAI	0.48	53.4	289.5	217.8	258.0	194.8
JEMANIN, (fermented JEKERU)	0.51	0.0	0.0	0.0	0.0	0.0
Pandanus fruit, raw	0.64	24.2	130.9	98.4	94.1	71.0
Pandanus fruit, cooked	0.64	11.6	63.0	47.4	0.0	0.0
Papayas, raw	0.39	12.3	66.8	50.2	22.7	17.1
Pork	3.0	2.2	11.7	8.8	1.6	1.2
Pumpkin	0.20	2.1	11.6	8.7	3.8	2.8
Reef fish (boiled, poached)	1.1	10.3	55.8	41.9	171.9	129.8
Reef fish (grilled, bbq)	1.3	3.5	18.7	14.1	0.0	0.0
Reef fish (pan fried, no flour)	1.1	28.4	153.6	115.6	0.0	0.0
Salt fish (equiv. wet wt.)	1.1	3.7	19.9	15.0	0.0	0.0
Sashimi (tuna, trolling fish)	1.0	0.5	3.0	2.2	0.0	0.0
Tuna, trolling fish (cooked)	1.2	3.8	20.4	15.3	156.7	118.3
Watermelon (raw)	0.32	4.4	24.0	18.1	0.0	0.0
Breadfruit incl. BWIRO	1.0	22.6	122.3	92.0	153.9	116.2
in Naidu et al. survey, but not observed on Mejatto:						
Coconut, KENAWE	0.1				16.4	12.4
Arrowroot flour	3.6				3.6	2.7
Sweet potatoes	1.1				0.5	0.4
Breadfruit seeds, roasted	2.1				2.8	2.1
Plantains (cooked)	1.2				14.0	10.6
Turtle	0.89				1.4	1.1
Lobster	1.0				1.1	0.8
Clams (giant)	1.5				1.4	1.1
Snails	0.9				21.4	16.1
Octopus	1.6				1.7	1.3
Clams (small)	1.5				4.0	3.1
Jankwon	2.9				22.2	16.8
Chicken	2.4				1.0	0.7
local vegetables	0.35				13.5	10.2

Table 3-5 Key data for diet models used in Rongelap compliance assessment
(average data for females >18 yrs; *average data for males >18 yrs in italic*s)

Parameter	Diet 1 Mejatto	Diet 2 Mejatto scaled w/o rice	Diet 3 Mejatto scaled with rice	Diet 4 Naidu et al. scaled w/o rice	Diet 5 Naidu et al. scaled with rice
Total Energy Intake (kcal/d)	1,900 *2,750*	1,900 *2,750*	1,900 *2,750*	1,900 *2,750*	1,900 *2,750*
Energy Intake from Local Foodstuffs (Percent)	18% *17%*	100% *100%*	75% *70%*	100% *100%*	75% *70%*
Energy Intake from Rice (Percent)	25% *30%*	0% *0%*	25% *30%*	0% *0%*	25% *30%*
Protein Intake (g/d)	72 *110*	82 *130*	71 *110*	100 *150*	87 *120*
Carbohydrate Intake (g/d)	260 *360*	140 *130*	210 *260*	180 *260*	240 *360*
Fat Intake (g/d)	67 *95*	120 *200*	92 *130*	80 *120*	61 *83*

3.2 Radiological data

For the assessment of radiation doses among Utrik residents, a considerable amount of data is available both from Lawrence Livermore Laboratory (LLNL)[7] and the Nationwide Radiological Study (NWRS)[8]. The two data sets are in good agreement. Since the LLNL data set is much larger when compared to the NWRS one (e.g. 128 samples for coconut meat measured by LLNL compared to 3 samples by NWRS); the first one was used as a basis for the calculations. The data are summarized in Table 3-6. The NWRS data set, on the other hand, is more comprehensive regarding the external gamma dose from Cs-137; hence the NWRS data set was taken as the basis for the calculations of external doses.

The variability of the parameter was described by lognormal distributions, as shown in Table 3-6. The variability in the concentration of Cs-137 of all food items was assumed to be independent, i.e. no correlation between the radioactivity concentrations in the various food items was assumed. The calculations for ingestion doses were performed using 1,000 Monte Carlo simulations. The variability of external doses was calculated directly on the basis of the NWRS data. All values were corrected for radioactive decay, using the year 2005 as a reference. The results of the calculations are shown in Figures 3-1 to 3-3. The main contribution to variance (between 33%-43%) is due to the energy intake of the individuals, followed by the variability in Cs-137 concentration of coconut products.

[7] Robison W.L., Conrado C.L. and Bogen K.T. (1999). Utirik Atoll Dose Assessment. Lawrence Livermore Laboratoy, UCRL-LR-135953.
[8] Simon S.L. and Graham J.C. (1995). Findings of the Nationwide Radiological Study, Data Tables and Sampling Maps. Volume 3. Republic of the Marshall Islands, Majuro

Table 3-6 Radiological parameters used in ingestion dose calculations for Utrik Island in this assessment

Parameter	Unit	Distribution type	Minimum	Maximum	Median	Mean	Standard deviation	Source
Body mass, male	kg	lognormal	49.6	95.9		69.02	11.82	Franke, 1994
Body mass, female	kg	lognormal	41.1	87.9		63.83	11.58	Franke, 1994
EI/BMR male	-	lognormal	0.89	2.77		1.60	0.31	Franke, 1994
EI/BMR female	-	lognormal	0.92	2.11		1.40	0.20	Franke, 1994
Food items observed on Mejatto in 1993								
Banana	Bq/g wet	lognormal	1.40E-03	1.30E-02	7.80E-03	7.80E-03	8.30E-03	Robison et al, 1999
Bird[d)]	Bq/g wet	lognormal	9.70E-05	5.40E-04	2.60E-04	2.90E-04	2.10E-04	Robison et al, 1999
Coconut[a)]	Bq/g wet	lognormal	1.80E-03	8.00E-02	2.30E-02	2.80E-02	2.20E-02	Robison et al, 1999
Coconut milk [a)]	Bq/g wet	lognormal	1.80E-03	8.00E-02	2.30E-02	2.80E-02	2.20E-02	Robison et al, 1999
Coconut ni (drinking)	Bq/g wet	lognormal	3.40E-04	3.80E-02	6.40E-03	8.30E-03	6.50E-03	Robison et al, 1999
Coconut iu (embryo) [a)]	Bq/g wet	lognormal	1.80E-03	8.00E-02	2.30E-02	2.80E-02	2.20E-02	Robison et al, 1999
Coconut waini (copra)	Bq/g wet	lognormal	1.80E-03	8.00E-02	2.30E-02	2.80E-02	2.20E-02	Robison et al, 1999
Coconut mede (soft)	Bq/g wet	lognormal	1.50E-03	5.40E-02	1.40E-02	1.70E-02	1.20E-02	Robison et al, 1999
Coconut crab[b)]	Bq/g wet	lognormal	1.50E-03	5.40E-02	1.40E-02	1.70E-02	1.20E-02	Robison et al, 1999
Jekeru [a)]	Bq/g wet	lognormal	1.80E-03	8.00E-02	2.30E-02	2.80E-02	2.20E-02	Robison et al, 1999
Jemanin [a)]	Bq/g wet	lognormal	1.80E-03	8.00E-02	2.30E-02	2.80E-02	2.20E-02	Robison et al, 1999
Pandanus raw	Bq/g wet	lognormal	1.60E-03	1.30E-01	4.10E-02	4.50E-02	3.00E-02	Robison et al, 1999
Pandanus cooked	Bq/g wet	lognormal	1.60E-03	1.30E-01	4.10E-02	4.50E-02	3.00E-02	Robison et al, 1999
Papaya	Bq/g wet	lognormal	2.30E-02	8.40E-02	5.40E-02	5.40E-02	4.40E-02	Robison et al, 1999
Pork	Bq/g wet	lognormal	7.10E-02	8.70E-02	7.60E-02	7.80E-02	8.10E-03	Robison et al, 1999
Pumpkin[c)]	Bq/g wet	lognormal	2.30E-02	8.40E-02	5.40E-02	5.40E-02	4.40E-02	Robison et al, 1999
Reef fish boiled	Bq/g wet	lognormal	9.70E-05	5.40E-04	2.60E-04	2.90E-04	2.10E-04	Robison et al, 1999
Reef fish grilled	Bq/g wet	lognormal	9.70E-05	5.40E-04	2.60E-04	2.90E-04	2.10E-04	Robison et al, 1999
Reef fish fried	Bq/g wet	lognormal	9.70E-05	5.40E-04	2.60E-04	2.90E-04	2.10E-04	Robison et al, 1999
Salt fish [d)]	Bq/g wet	lognormal	9.70E-05	5.40E-04	2.60E-04	2.90E-04	2.10E-04	Robison et al, 1999
Sashimi [d)]	Bq/g wet	lognormal	9.70E-05	5.40E-04	2.60E-04	2.90E-04	2.10E-04	Robison et al, 1999
Tuna cooked [d)]	Bq/g wet	lognormal	9.70E-05	5.40E-04	2.60E-04	2.90E-04	2.10E-04	Robison et al, 1999
Watermelon [c)]	Bq/g wet	lognormal	2.30E-02	8.40E-02	5.40E-02	5.40E-02	4.40E-02	Robison et al, 1999
Breadfruit	Bq/g wet	lognormal	6.90E-03	3.00E-02	1.70E-02	1.80E-02	7.10E-03	Robison et al, 1999

a) same as Coconut waini (copra); b) same as Coconut mede; c) same as Papaya; d) same as reef fish

Table 3-6 (cont'd) Radiological parameters used in ingestion dose calculations for Utrik Island in this assessment

Parameter	Unit	Distribution type	Minimum	Maximum	Median	Mean	Standard deviation	Source
Food items not observed on Mejatto in 1993, but contained in BNL survey (Naidu et al., 1980)								
Coconut kenawe[a)]	Bq/g wet	lognormal	3.40E-04	3.80E-02	6.40E-03	8.30E-03	6.50E-03	Robison et al, 1999
Arrowroot flour[b)]	Bq/g wet	lognormal	2.30E-02	8.40E-02	5.40E-02	5.40E-02	4.40E-02	Robison et al, 1999
Sweet potatoes[c)]	Bq/g wet	lognormal	1.60E-03	1.30E-01	4.10E-02	4.50E-02	3.00E-02	Robison et al, 1999
Breadfruit seeds, roasted	Bq/g wet	lognormal	6.90E-03	3.00E-02	1.70E-02	1.80E-02	7.10E-03	Robison et al, 1999
Plantains (cooked) [c)]	Bq/g wet	lognormal	1.60E-03	1.30E-01	4.10E-02	4.50E-02	3.00E-02	Robison et al, 1999
Turtle[d)]	Bq/g wet	lognormal	9.70E-05	5.40E-04	2.60E-04	2.90E-04	2.10E-04	Robison et al, 1999
Lobster [d)]	Bq/g wet	lognormal	9.70E-05	5.40E-04	2.60E-04	2.90E-04	2.10E-04	Robison et al, 1999
Clams (giant) [d)]	Bq/g wet	lognormal	9.70E-05	5.40E-04	2.60E-04	2.90E-04	2.10E-04	Robison et al, 1999
Snails [d)]	Bq/g wet	lognormal	9.70E-05	5.40E-04	2.60E-04	2.90E-04	2.10E-04	Robison et al, 1999
Octopus [d)]	Bq/g wet	lognormal	9.70E-05	5.40E-04	2.60E-04	2.90E-04	2.10E-04	Robison et al, 1999
Clams (small) [d)]	Bq/g wet	lognormal	9.70E-05	5.40E-04	2.60E-04	2.90E-04	2.10E-04	Robison et al, 1999
Jankwon[e)]	Bq/g wet	lognormal	1.80E-03	8.00E-02	2.30E-02	2.80E-02	2.20E-02	Robison et al, 1999
Chicken[e)]	Bq/g wet	lognormal	1.80E-03	8.00E-02	2.30E-02	2.80E-02	2.20E-02	Robison et al, 1999
local vegetables[b)]	Bq/g wet	lognormal	2.30E-02	8.40E-02	5.40E-02	5.40E-02	4.40E-02	Robison et al, 1999

a) same as Coconut ni (drinking); b) same as Papaya; c) same as Pandanus; d) same as reef fish; e) same as Coconut waini (copra)

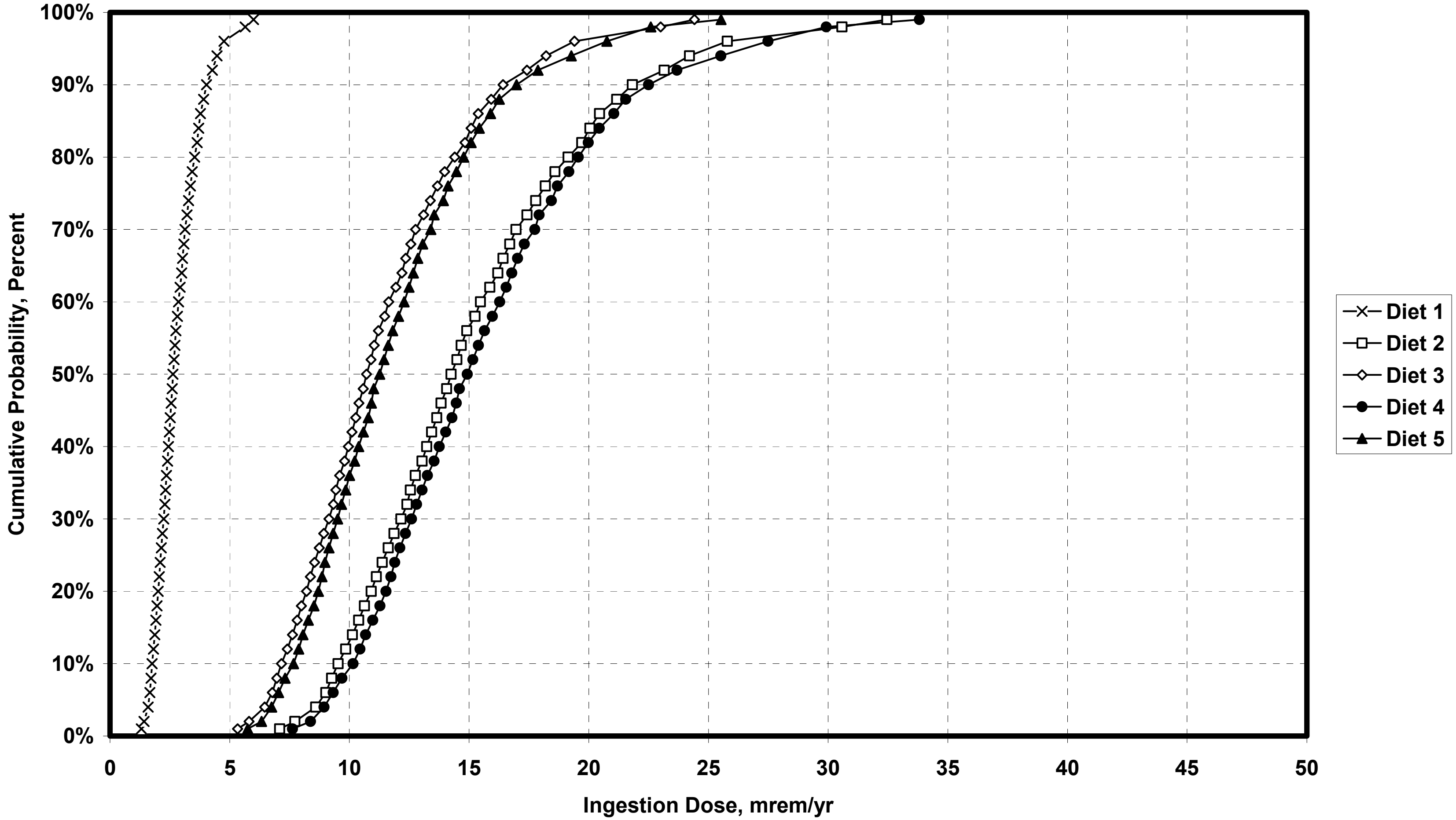

Figure 3-1 Predicted distributions of internal doses from Cs-137 for adult females residing on Utrik Island in 2005

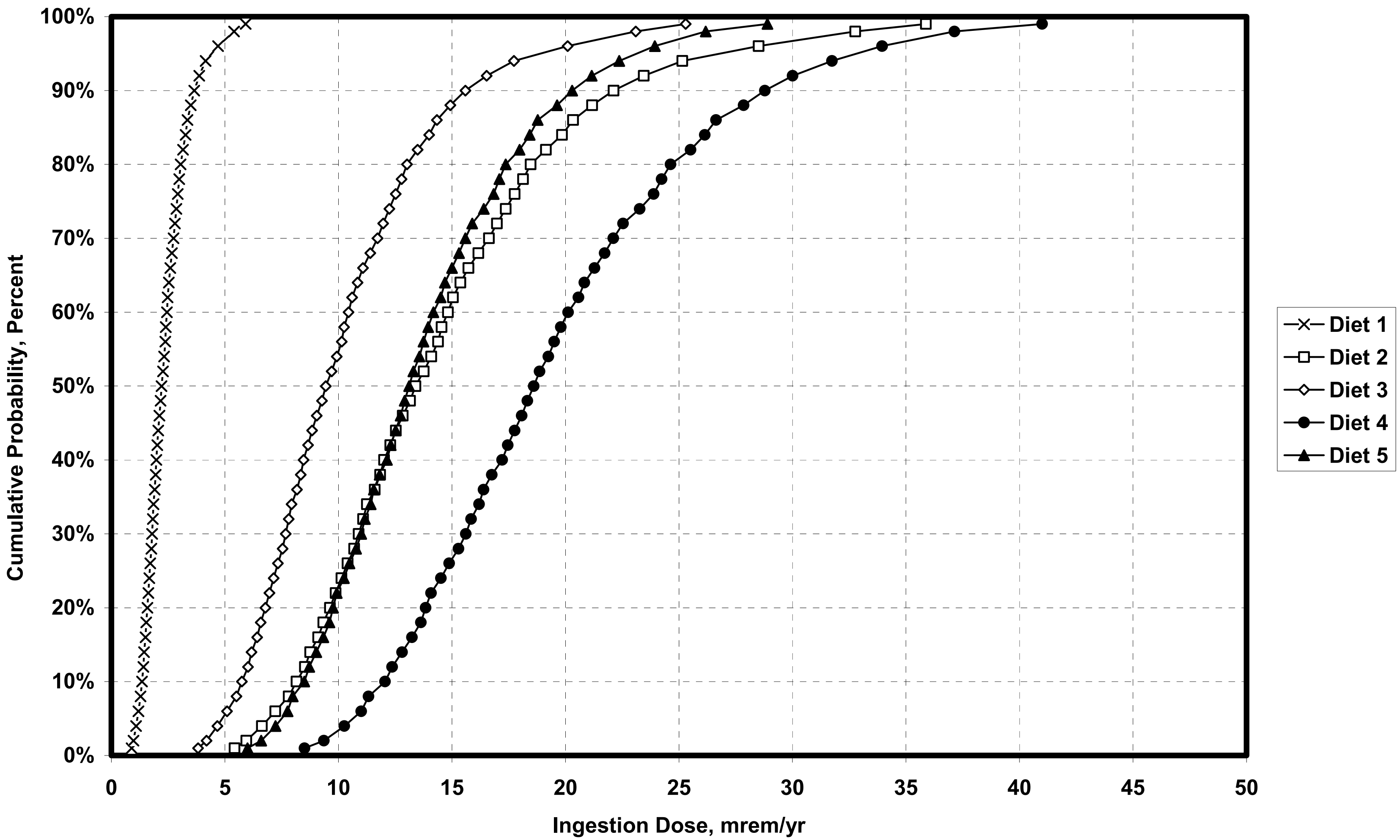

Figure 3-2 Predicted distributions of internal doses from Cs-137 for adult males residing on Utrik Island in 2005

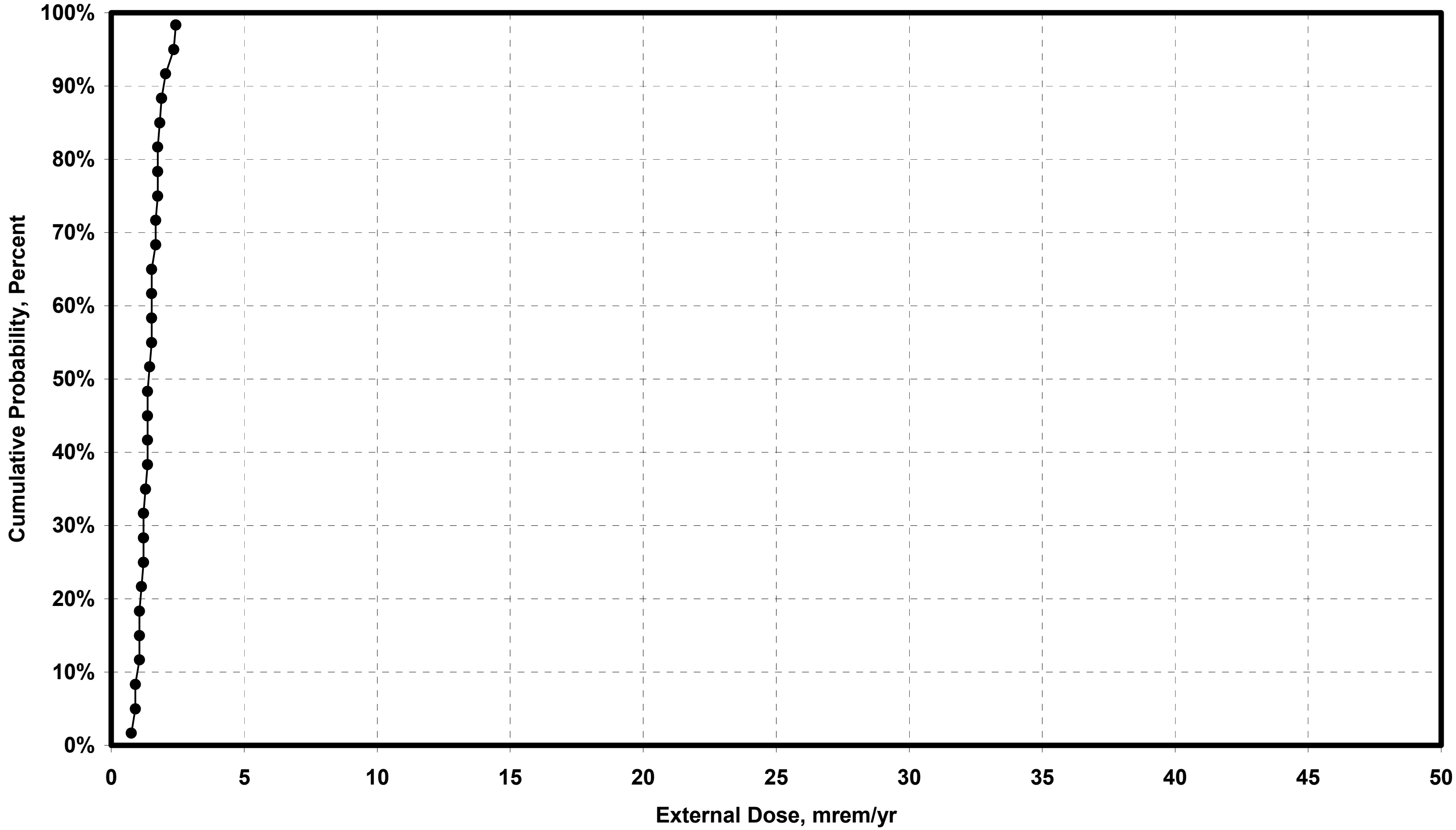

Figure 3-3 Predicted distributions of external doses from Cs-137 for adults residing on Utrik Island in 2005

3.3 Discussion

The results for the combined internal and external dose estimates are summarized in Tables 3-7 and 3-8 for adult females and males, respectively. The distribution of external doses was assumed to be positively correlated with the internal exposure. This assumption tends to maximize the calculated total exposure. The external dose contributes only about 10% for the diets with a large percentage of local foods (diets 2 to 5). For diet 1 with only a small percentage of local food items, the external dose plays a much larger role and amounts to approximately 37% of the total dose.

Table 3-7 Calculated total doses (in mrem/year) for female adults on Utrik Island as of 2005

Percentile	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5
1	2.1	7.8	6.1	8.4	6.5
5	2.5	10	7.6	10	7.8
10	2.8	11	8.2	11	8.7
25	3.3	13	10	13	10
50	4.1	16	12	16	13
75	5.1	20	15	20	16
90	6.1	24	18	25	19
95	7.0	28	21	29	22
99	8.4	35	27	36	28

Table 3-8 Calculated total doses (in mrem/year) for male adults on Utrik Island as of 2005

Percentile	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5
1	1.7	6.2	4.6	9.3	6.8
5	2.1	7.9	5.9	11	8.4
10	2.4	9.2	6.8	13	10
25	2.9	12	8.5	16	12
50	3.7	15	11	20	15
75	4.6	19	14	25	18
90	5.7	24	18	31	22
95	6.8	29	21	35	25
99	8.3	38	28	43	31

In Table 3-9, the results are compared to previous predictions by other investigators whose data are decay-corrected to the year 2005. For the scenario corresponding to imported foods are available, the calculations using the RRP model agree well with the numbers published by Lawrence Livermore National Laboratory (Robison et al., 1999). They also agree well with observations based on whole-body counting of Utrik adults made in 1993. Significant differences, however, are seen for the scenario “imports unavailable”. In this study, diet 4 is the most conservative. For the “imports unavailable” scenario, the dose estimate by Robison et al. appears to be too low with a maximum internal dose of 7.6 mrem/year. While the RRP model predicts the upper range (99-percentile) for males to be 41 mrem/year, this estimate appears even too low compared to decay-corrected empirical measurements of the whole body burden for the maximum female individual in the year 1977.

The WBC data suggest that in 1993, Utrik residents may have significantly changed their dietary habits and lived on a diet comparable to residents on Mejatto with a small percentage of local food items. (In the year 1977, their diet was quite different and contained much larger amounts of local food items and, therefore, Cs-137.) Thus, if the Utrik residents would adopt a diet pattern identical to the previous one in 1977, the resulting dose in the year 2005 would be 8.9 mrem/year for adult females with a range from 1.9 to 42 mrem/year.

Table 3-9 Comparison of internal doses from Cs-137 for adults on Utrik Island predicted for the year 2005

Dose prediction model	**Imports available**	**Imports unavailable**
LLNL (Robison et al.)[a)]	2.4 mrem/year	7.6 mrem/year
RRP model (this study)	2.6 mrem/year [b)] (range: 1.3 to 6 mrem/year)	19 mrem/year [c)] (range 8.5 to 41 mrem/year)
Extrapolated from whole body counting data in 1977[d)]	Females: 8.9 mrem/year (range: 1.9 to 42 mrem/year) Males: 8.3 mrem/year (range: 2.6 to 15 mrem/year)	
Extrapolated from whole body counting data in 1993[e)]	Females: 1.4 mrem/year (range: 0.2 to 3.0 mrem/year) Males: 1.9 mrem/year (range: 0.2 to 5.7 mrem/year)	
SC&A model[f)]	up to 6.1 mrem/year	up to 31.7 mrem/year

Notes: a) UCRL-LR-135953, Table 9, data decay corrected to 2005; b) Females Diet 1, range: 1-percentile to 99-percentile; c) males Diet 4, range: 1-percentile to 99-percentile; d) based on the following observations: 21 females and 27 males in 1977, data decay corrected to 2005; e) based on the following observations: 25 females and 31 males, data decay corrected to 2005; f) based on Table 6-9, page 6-27 in Draft Report entitled “Statement Before the Nuclear Claims Tribunal Regarding The Potential Radiation Doses and Health Risks to the Current and Future Population of Utrik, Taka, Bikar, and Taongi Atoll”; the data were decay corrected to 2005

4 Calculation of internal doses from Cs-137 for Utrik residents from whole body counting data

4.1 Introduction

A direct way to determine the magnitude of internal doses from ingested radionuclides on Utrik Atoll is the analysis of historical whole body counting data for Rongelap residents from eleven mission years for the time period 1957 through 1993. These data allow the determination of annual radiation doses under the following assumptions:

- the data are accurate (i.e. correct calibration);
- the body burden for a given individual is representative for the entire year in question; and
- the sample of monitored individuals is representative for the entire age and sex group.

Under these assumptions, the data allow to evaluate the variability of the radiation exposure, which reflects the diet pattern, as they existed in a particular mission year. The adjustment for radioactive decay also allows extrapolating the information for past years in which no measurements were taken and for future years in which Utrik people may exhibit the same dietary patterns as in past years.

4.2 Available data

The raw WBC data for a total of 2519 separate measurements was received from the U.S. Department of Energy at the request of the Marshall Islands Government in database format (file: DOE_BNL_WBC_PUBIOASSAY.mdb). The data included measurements for Utrik and Rongelap residents. The Rongelap resident data were evaluated as well because whole body counting was performed on Rongelap residents in years that Utrik people were not counted (1958, 1961 and 1965) and because of the similarity of living patterns between the two atolls. The number of records contained in the database is summarized in Table 4-1.

It appears that data for either body weight or age were entered incorrectly in a number of cases. Since the discrepancies could not be resolved, it was concluded that age data were more reliable because dose conversion factors are generally given only for adult body sizes. Hence only data for residents were analyzed for which the age was recorded to be greater than 15 years.

4.3 Dose estimation method

For a given activity in the body, the internal dose was calculated using the conversion factors for adults that were derived from ICRP 72 metabolic data. The effective dose per unit body burden is calculated to be 3.7×10^{-8} Sv/y per Bq (137 mrem/y per µCi). It was further assumed that the observed concentration in the body was representative for the entire year in question. Using the above assumptions, the doses to residents were calculated.

Table 4-1 Whole-body counting records for Utrik and Rongelap residents in DOE database

Year	Females<=15 yr		Females>15 yr		Males<=15 yr		Males>15 yr	
	Utrik	Rongelap	Utrik	Rongelap	Utrik	Rongelap	Utrik	Rongelap
1958	n.s.	0	n.s.	16	n.s.	4	n.s.	54
1959	6	8	16	49	8	7	13	56
1961	n.s.	5	n.s.	39	n.s.	4	n.s.	45
1965	n.s.	6	n.s.	71	n.s.	7	n.s.	72
1974	0	0	13	23	0	0	9	23
1977	4	4	21	22	5	7	27	29
1979	24	16	63	15	26	23	23	16
1981	35	21	n.s.	30	53	30	61	36
1982	n.s.	16	n.s.	18	n.s.	27	n.s.	29
1983	56	25	87	29	78	38	87	24
1984	51	36	85	37	74	43	81	44
1989	9		34		13		46	
1991	27		78		27		78	
1993	11		25		13		31	

Note: n.s. = no whole body counting performed on Utrik

It appears that each record represents a different person. Furthermore, the data were evaluated on an “as is” basis, which implies that any systematic bias could not be corrected.

4.4 Estimated radiation exposures from Cs-137 whole body counting data

The results of the analysis are summarized in Figures 4-1 and 4-2. For each year, the mean values for males and females above 15 years of age are indicated along with the minimum and maximum values. In order to allow a comparison between the years, two additional lines indicate the decay-corrected annual doses that one would expect from the maximum values observed for Utrik residents in the years 1974 and 1977. The solid line indicates the mean value, and the dotted line the maximum value. Both are corrected for radioactive decay. The use of these data allows estimating reasonable upper limits of radiation exposures to Utrik residents based on actual observations on Utrik. Non-radiological removal of Cs-137 from the environment and food items was ignored because it cannot be adequately quantified and its effect is considered to be small.

The data illustrates the significant differences among individuals in a given year, most likely due to different diet patterns and the origin of local food items within the atoll and/or island. The differences over the years most likely reflect the availability of imported food items. For example, the body burden in 1979 was much smaller than expected from radioactive decay alone and increased again in the early 1980s. This observation is in agreement with reports from the Utrik community that supplies from field trip ships decreased in the early 1980s. In the last year for which whole body counting data were available (1993), Cs-137 body burdens were almost an order of magnitude smaller than expected from radioactive decay alone. This suggests that the amount of local food items consumed by Utrik residents population has greatly decreased.

While doses to Rongelap residents are larger than for Utrik residents, the difference is smaller than one would expect based on the difference between the Cs-137 contamination in food at the two atolls, especially in the 1970s. The Cs-137 contamination in coconuts on Rongelap Island is between a factor of 3.3 and 3.8 larger than on Utrik Island, the difference in 1974 internal Cs-137 doses was only a factor of 2.3 for females and 1.8 for males. The ratios only reached expected values in the 1980s. This suggests that before 1980, relatively more local food items were consumed on Utrik compared to Rongelap.

Table 4-2 Ratio of mean internal doses from Cs-137 between Rongelap Island and Utrik Island residents compared with activity ratios of local food sources

Parameter	**Ratio (Rongelap Is./Utrik Is.)**
Mean internal Cs-137 doses (age >15 yrs)	
1958	females: 3.0; males: 3.0
1974	females: 2.3; males: 1.8
1977	females: 1.8; males: 2.9
1979	females: 3.4; males: 3.0
1981	females: 2.8; males: 1.8
1983	females: 4.3; males: 3.9
1984	females: 4.0; males: 2.9
Mean Cs-137 contamination of local food items*)	
Drinking coconut meat	3.8
Drinking coconut juice	3.5
Copra meat	3.3
Pandanus	5.7
Breadfruit	6.0

**) based on data in UCRL-LR-135953 (Utrik Is.) and UCRL-ID-123375 (Rongelap Island)*

The cumulative frequency distribution for the whole body counting data for Utrik Island residents is shown in Figures 4-3 using the years 1974 and 1977 in which maximum body burdens of males and females, respectively, were observed. The data illustrate that in the year 1977, a few individuals appeared to incorporate much larger amounts of Cs-137 than the remainder of the community. The maximum individual was a woman with a Cs-137 body burden of 22,000 Bq in the year 1977. This body burden is equivalent to an annual internal dose of 80 mrem/year if equilibrium is assumed for the entire year.

The uncertainty inherent in the assumption of body-burden equilibrium was explored by calculating the Cs-137 body burden for an extreme case with a varying intake that also results in a peak burden of 222,000 Bq in March 1977 (uptake of 40 Bq/d is from January 1975 to October 1976, 200 Bq/d from November 1976 to March 1977, and 40 Bq/d thereafter), using ICRP 72 dosimetry data. The change in the Cs-137 body burden over time body is shown in Figure 4-4. The annual dose is calculated as follows: 13 mrem in 1975, 26 mrem in 1976 and 54 mrem in 1977. This shows that the assumption of equilibrium conditions may overestimate the actual annual dose by a factor of ~1.5. Since the opposite may also be true (i.e. whole body counting at a low of the Cs-137 body burden), the actual dose may also be underestimated by a factor of ~1.5.

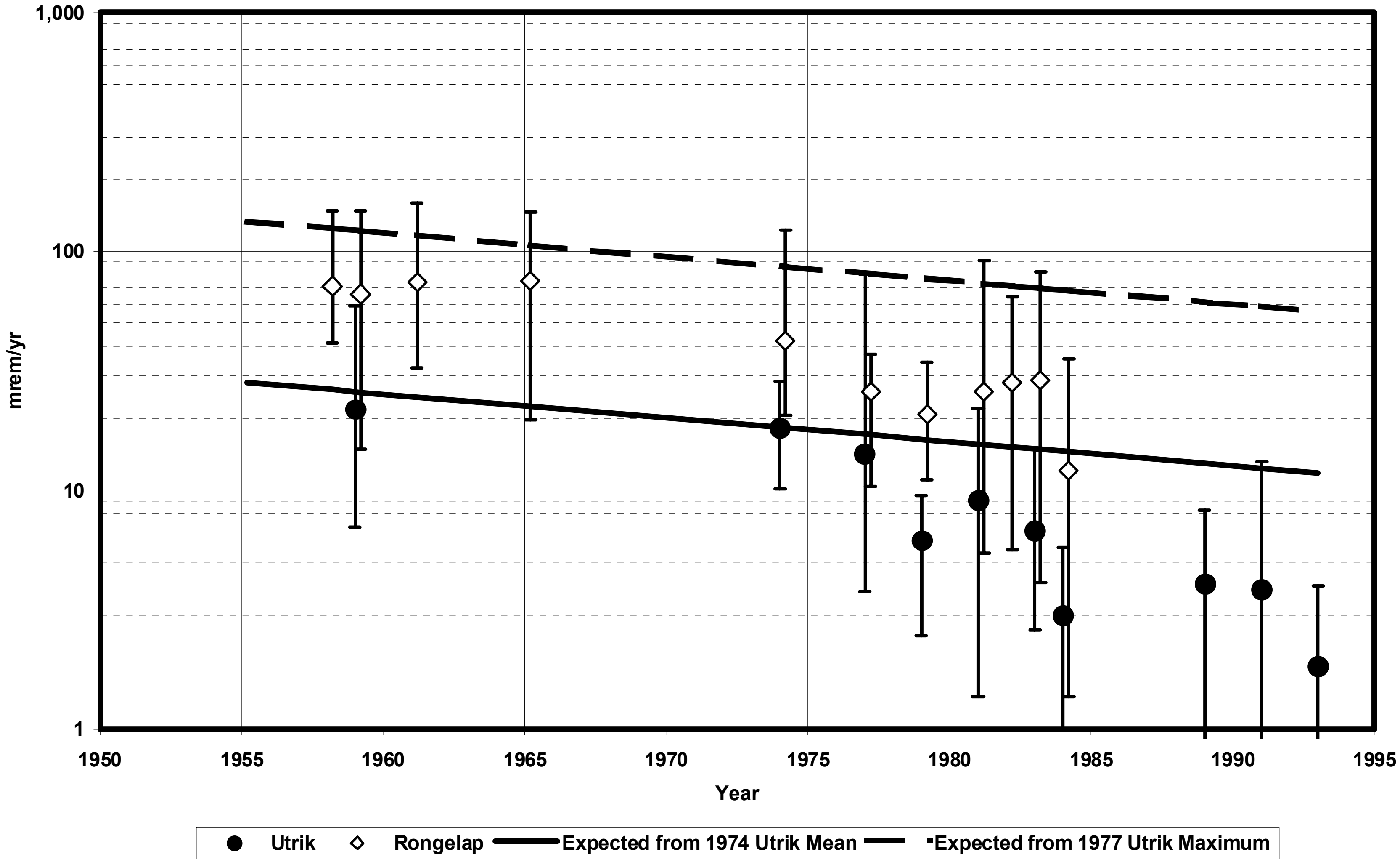

Figure 4-1 Estimated annual internal dose from Cs-137 among females > 15 years based on data provided by DOE for whole body counting missions (mean, minimum and maximum values for each year and atoll population in a given year)

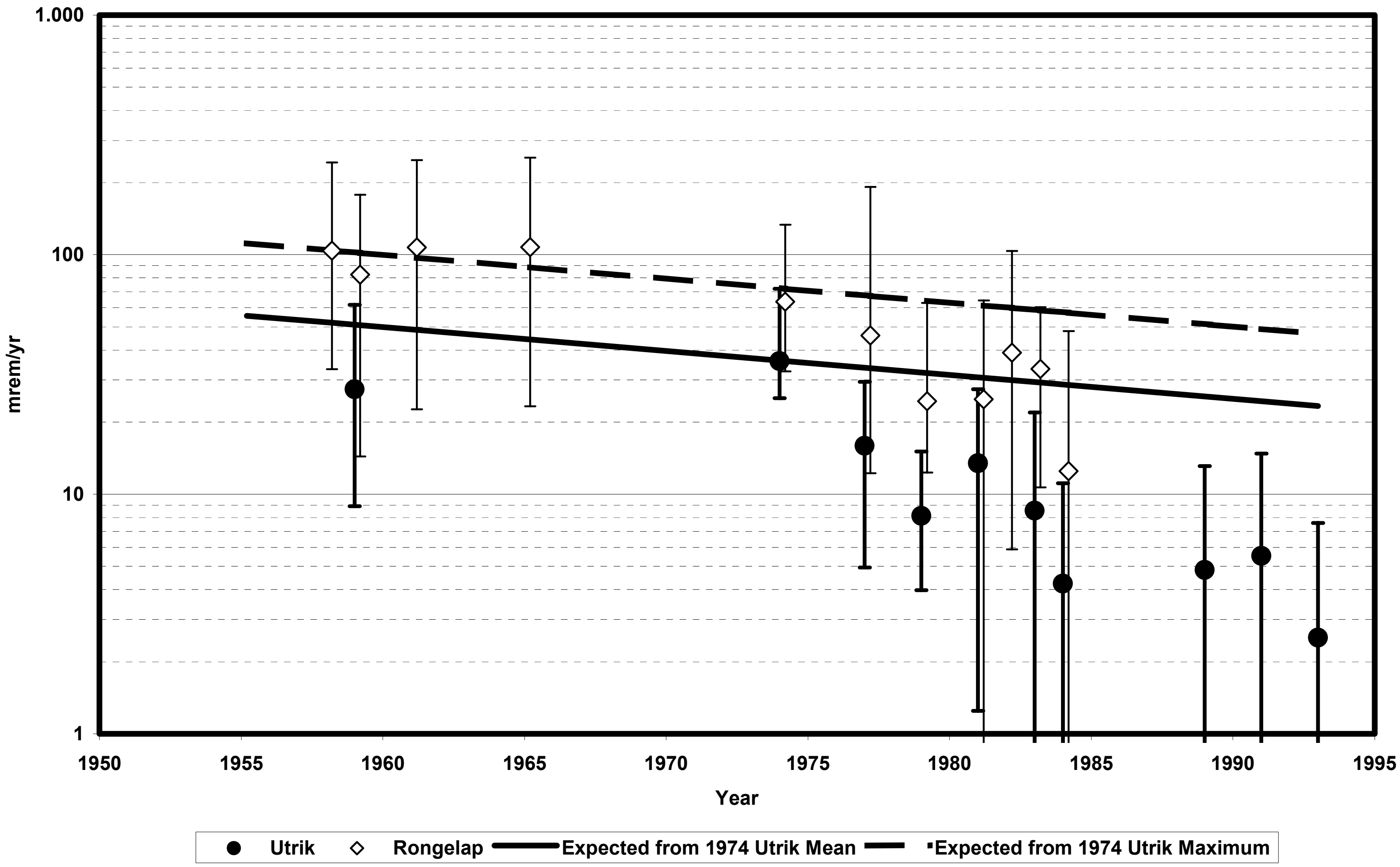

Figure 4-2 Estimated annual internal dose from Cs-137 among males > 15 years based on data provided by DOE for whole body counting missions (mean, minimum and maximum values for each year and atoll population in a given year)

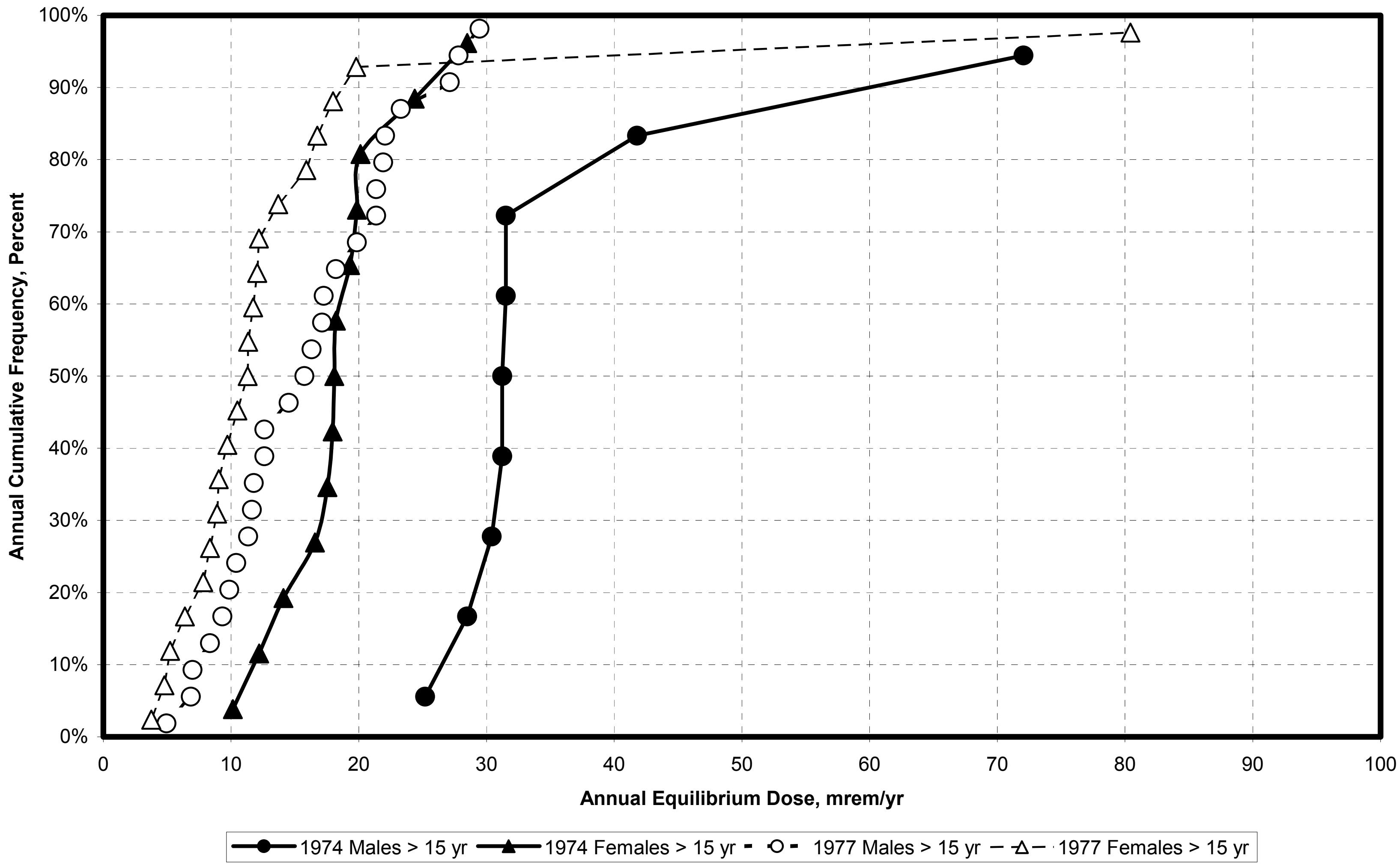

Figure 4-3 Cumulative frequency chart of 1974 and 1977 internal Cs-137 doses for Utrik residents estimated from whole body counting data

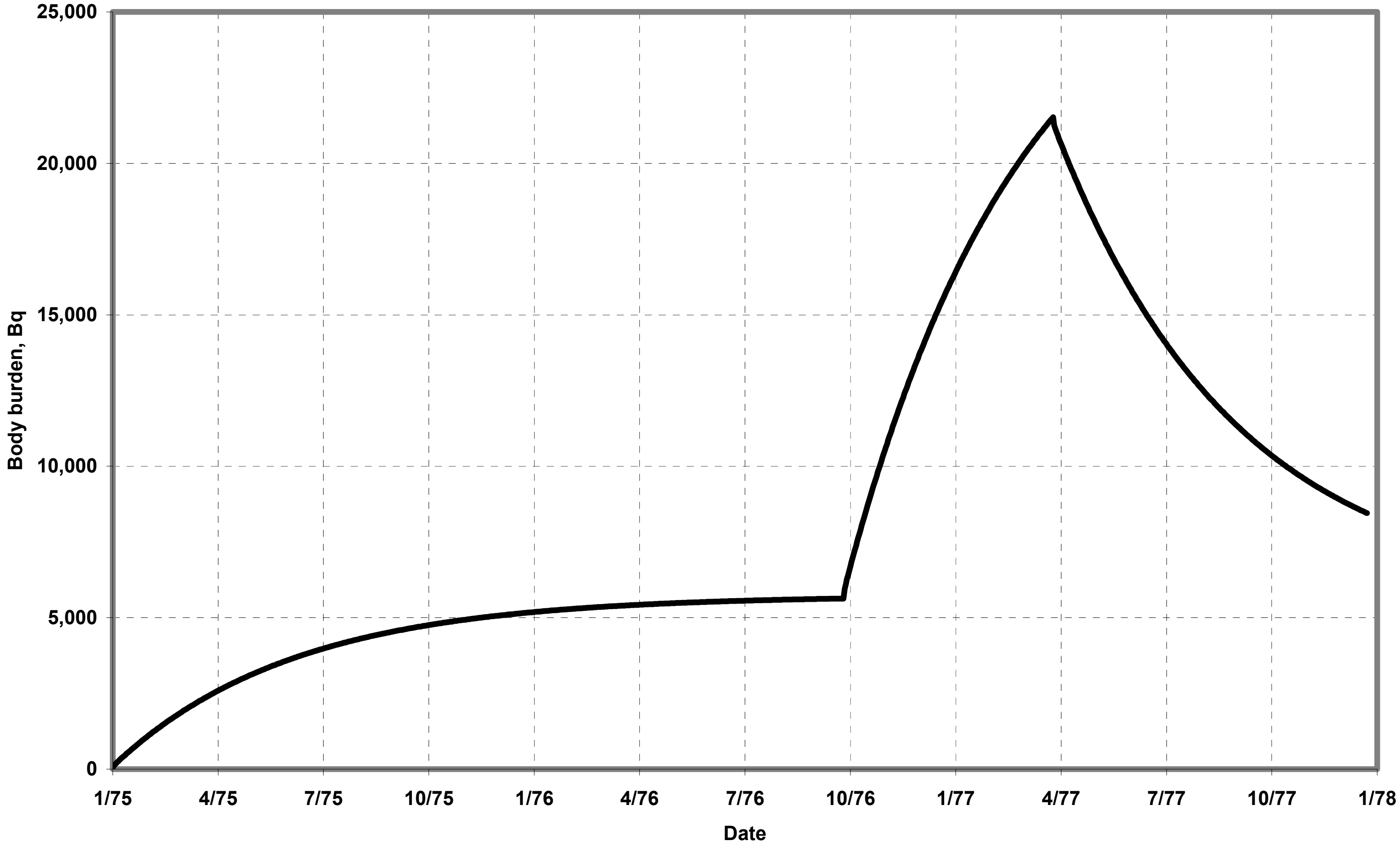

Figure 4-4 Estimated Cs-137 adult body burden assuming an uptake of 40 Bq/d from January 1975 to October 1976, 200 Bq/d from November 1976 to March 1977, and 40 Bq/d thereafter. The annual dose is calculated as follows: 13 mrem in 1975, 26 mrem in 1976 and 54 mrem in 1977. A continuous body burden of 22,000 Bq would result in an annual dose of 80 mrem.

Table 4-3 Internal Doses from Cs-137 among Utrik adults based on whole body counting data (age >15 yr), mrem/year[9]

Year	Observed from Whole Body Counting				Maximum Credible Based on Maximum Year			
	Average Females	**Average Males**	**Maximum Females**	**Maximum Males**	**Average Females**	**Average Males**	**Maximum Females**	**Maximum Males**
1955					2.8E+01	5.6E+01	1.3E+02	1.1E+02
1956					2.8E+01	5.4E+01	1.3E+02	1.1E+02
1957					2.7E+01	5.3E+01	1.3E+02	1.1E+02
1958					2.6E+01	5.2E+01	1.2E+02	1.0E+02
1959	2.2E+01	2.7E+01	5.9E+01	6.2E+01	2.6E+01	5.1E+01	1.2E+02	1.0E+02
1960					2.5E+01	5.0E+01	1.2E+02	9.9E+01
1961					2.5E+01	4.8E+01	1.2E+02	9.7E+01
1962					2.4E+01	4.7E+01	1.1E+02	9.5E+01
1963					2.3E+01	4.6E+01	1.1E+02	9.3E+01
1964					2.3E+01	4.5E+01	1.1E+02	9.1E+01
1965					2.2E+01	4.4E+01	1.1E+02	8.9E+01
1966					2.2E+01	4.3E+01	1.0E+02	8.7E+01
1967					2.1E+01	4.2E+01	1.0E+02	8.5E+01
1968					2.1E+01	4.1E+01	9.9E+01	8.3E+01
1969					2.0E+01	4.0E+01	9.7E+01	8.1E+01
1970					2.0E+01	3.9E+01	9.4E+01	7.9E+01
1971					2.0E+01	3.9E+01	9.2E+01	7.7E+01
1972					1.9E+01	3.8E+01	9.0E+01	7.5E+01
1973					1.9E+01	3.7E+01	8.8E+01	7.4E+01
1974	1.8E+01	3.6E+01	2.8E+01	7.2E+01	1.8E+01	3.6E+01	8.6E+01	7.2E+01
1975					1.8E+01	3.5E+01	8.4E+01	7.0E+01
1976					1.7E+01	3.4E+01	8.2E+01	6.9E+01
1977	1.4E+01	1.6E+01	8.0E+01	2.9E+01	1.7E+01	3.4E+01	8.0E+01	6.7E+01
1978					1.7E+01	3.3E+01	7.9E+01	6.6E+01

[9] Number presented in scientific notation format. The power of ten multiplying factor is indicated by the exponent. To convert from scientific notation, move the decimal point by the number of digits indicated after the "E". Move decimal point to the right for positive values, to the left for negative values. (e.g., 2.3E+02 = 230, 4.5E-01 = 0.45).

Table 4-3 (ct'd) Internal Doses from Cs-137 among Utrik adults based on whole body counting data (age >15 yr), mrem/year[10]

Year	Observed from Whole Body Counting				Maximum Credible Based on Maximum Year			
	Average Females	Average Males	Maximum Females	Maximum Males	Average Females	Average Males	Maximum Females	Maximum Males
1979	6.2E+00	8.1E+00	9.5E+00	1.5E+01	1.6E+01	3.2E+01	7.7E+01	6.4E+01
1980					1.6E+01	3.1E+01	7.5E+01	6.3E+01
1981	9.1E+00	1.3E+01	2.2E+01	2.7E+01	1.6E+01	3.1E+01	7.3E+01	6.1E+01
1982					1.5E+01	3.0E+01	7.2E+01	6.0E+01
1983	6.8E+00	8.5E+00	1.5E+01	2.2E+01	1.5E+01	2.9E+01	7.0E+01	5.9E+01
1984	3.0E+00	4.2E+00	5.8E+00	1.1E+01	1.4E+01	2.9E+01	6.8E+01	5.7E+01
1985					1.4E+01	2.8E+01	6.7E+01	5.6E+01
1986					1.4E+01	2.7E+01	6.5E+01	5.5E+01
1987					1.4E+01	2.7E+01	6.4E+01	5.3E+01
1988					1.3E+01	2.6E+01	6.2E+01	5.2E+01
1989	4.1E+00	4.8E+00	8.2E+00	1.3E+01	1.3E+01	2.5E+01	6.1E+01	5.1E+01
1990					1.3E+01	2.5E+01	6.0E+01	5.0E+01
1991	3.9E+00	5.5E+00	1.3E+01	1.5E+01	1.2E+01	2.4E+01	5.8E+01	4.9E+01
1992					1.2E+01	2.4E+01	5.7E+01	4.8E+01
1993	1.8E+00	2.5E+00	4.0E+00	7.6E+00	1.2E+01	2.3E+01	5.6E+01	4.7E+01
1994					1.2E+01	2.3E+01	5.4E+01	4.6E+01
1995					1.1E+01	2.2E+01	5.3E+01	4.4E+01
1996					1.1E+01	2.2E+01	5.2E+01	4.3E+01
1997					1.1E+01	2.1E+01	5.1E+01	4.2E+01
1998					1.1E+01	2.1E+01	5.0E+01	4.2E+01
1999					1.0E+01	2.0E+01	4.9E+01	4.1E+01
2000					1.0E+01	2.0E+01	4.7E+01	4.0E+01
2001					9.8E+00	1.9E+01	4.6E+01	3.9E+01

[10] Number presented in scientific notation format. The power of ten multiplying factor is indicated by the exponent. To convert from scientific notation, move the decimal point by the number of digits indicated after the "E". Move decimal point to the right for positive values, to the left for negative values. (e.g., 2.3E+02 = 230, 4.5E-01 = 0.45).

4.5 Conclusions

The maximum observations of Cs-137 body burdens among Utrik Island residents in the years 1974 and 1977 are considered to represent the "reasonably maximally exposed individuals", or RMEI. The values are taken as a reference point for other years in which no measurements have been taken in the past. They also represent a reasonable basis for estimating the radiation exposures in the future. Using these assumptions, Table 4-3 contains the extrapolated internal doses from incorporated Cs-137.

Estimates of internal doses from Cs-137 that are based on whole body counting of the Utrik population suggests the following:

- The maximum credible dose (RMEI) from incorporated Cs-137 for diet patterns that were prevalent among the Utrik population in mid-1970s exceed 15 mrem/year for all years between 1955 and 2005.
- If the Utrik population that currently lives on Utrik were to adopt the same diet patterns as they had in the mid-1970s, the maximum credible dose (RMEI) from incorporated Cs-137 would not fall below 15 mrem/year before the year 2050.

5 Summary of annual radiation exposures, 1946 - 2001

5.1 Introduction

Over a time span of thirteen years, from 1946 to 1958, a total of 67 nuclear weapons tests were conducted on Bikini and Eniwetak Atolls. Table 5-1 provides a summary that indicates the majority of the tests and especially those with a large yield were conducted in 1952, 1954, 1956 and 1958. About 14% of the total explosive yield of all tests was accounted for by BRAVO on March 1, 1954.

Table 5-1 Summary of U.S. nuclear tests in the Marshall Islands (after Simon and Robison, 1997)[11]

Year	Operation	Number of tests [a)]	Bikini yield, kt	Eniwetak yield, kt	Total yield, kt	Percent of Total
1946	Crossroads	2	42		42	< 0.1%
1948	Sandstone	3		104	104	0.1%
1951	Greenhouse	4		399	399	0.4%
1952	Ivy	2		10,900	10,900	10.0%
1954	Castle	6	48,200		48,200	44.4%
1956	Redwing	17	18,265	2,555	20,820	19.2%
1958	Hardtack I	33	12,900	15,126	28,026	25.8%
Total		**67**	**79,407**	**29,083**	**108,491**	**100.0%**

a) includes YUCCA on April 28, 1958 97 km W of Bikini at a height of 26 km and zero yield safety tests

Although the predominant radiation exposure for Utrik residents was caused by fallout from BRAVO, contribution from other tests need to be considered as well. In order to determine the compliance with historical and current dose limits, the fractionation of doses for each year is necessary which includes the combined exposure from all tests.

In this chapter, the following dose contributions are briefly summarized and quantified:

- External gamma radiation
- Internal dose from Zn-65 in fish
- Internal dose from Cs-137 incorporated with food
- Internal dose from ingested fresh fallout

[11] Simon S L, Robison W L. A Compilation of Nuclear Weapons Test Detonation Data for U.S. Pacific Ocean Tests. Health Phys. 73:258-264; 1997.

5.2 External gamma radiation

No data could be located regarding dose/dose-rates on Utrik Atoll for weapon tests conducted during Operations **Crossroads**, **Sandstone** and **Greenhouse,** which took place during 1946, 1948 and 1951. Owing to the small yield of these devices, the impact on Utrik Atoll can be expected to be small. However, in the absence of aerial survey data or fallout measurements, it is difficult to determine a reasonable upper range of the resulting radiation doses.

During **Operation Ivy** in 1952, two devices were detonated on Eniwetak, event Mike on November 1, 1952 with 10.400 Mt and event King on November 16, 1952 with 400 kt. The report by the Defense Nuclear Agency on this operation details radiological surveillance but contains no record of radiological contamination on Utrik.[12] The only information regarding Utrik was located in a report prepared under the supervision of Merril Eisenbud of the USAEC New York Operations Office.[13] The dose rate on day 2 after MIKE was reported to be 0.2 mR/hr; the dose rate on day 2 after KING was reported to be less than 0.05 mR/hr. If these dose rates are taken at face value, the associated cumulative external gamma dose would have been about 30 mrem in the year 1952, and less than 10 mrem in the year 1953. Uncertainties in aerial measurements, however, are evident from repeat measurements following BRAVO (see draft report by Hans Behling, 2001); hence the above estimates have a high degree of uncertainty.

The external gamma dose following **Operation Castle** was dominated by BRAVO. The external gamma doses following resettlement of the Utrik residents can be calculated using the information provided in the report by Hicks[14] based on an initial dose rate of 40 mR/hr at H+192 hours, the annualized results are shown in Table 5-3. The dose rates for 50% refractories were used in the calculations. This is appropriate given the distance between Utrik and Bikini Atolls. The dose rate calculations account for the radioactive decay but do not account for potential weathering of radionuclides and the shielding of gamma radiation in soil, which are difficult to reconstruct and validate.

A sampling report by the U.S. Naval Radiological Defense Laboratory[15] contains a total of only two gamma dose rate measurements on Utrik Island in subsequent years: 0.14 mR/hr after 11 months (February 1, 1955) and 0.05 mR/hr after 23 months (February 1, 1956). The dose rate extrapolated from 40 mR/hr at H+192 hours using the decay function provided by Hicks (1984) are 0.093 mR/hr for February 1, 1955 and 0.02 mR/hr for February 1, 1956. The measured dose rate 11 months after BRAVO was a factor of 1.5 higher than predicted from the decay function and is in general agreement with the expected value, given the spatial variability of fallout on the island. The measured dose rate 23 months after BRAVO was a factor of 2.5 smaller than predicted which could reflect leaching of fallout into deeper soil layers and/or washout.

[12] Gladeck F R, Hallowell J H, Martin E J, et al., Operation IVY, DNA 6036F, 1952

[13] U.S. Atomic Energy Commission, New York Operations Office (1953). Radioactive Debris from Operation Ivy. NYO-4522 (DEL). April 28, 1953

[14] Hicks H.G., Results of Calculation of External Gamma Radiation Exposure Rates from Local Fallout and the Related Radionuclide Compositions of Selected U.S. Pacific Events. UCRL-53505 (1984)

[15] Weiss HV, Cohn SH, Shipman WH, Gong JK. Residual Contamination of Plants, Animals, Soil, and Water of the Marshall Islands Two Years Following Operation Castle Fallout. U.S. Naval Radiological Defense Laboratory. Report NS-081-001. August 15, 1956

Operation Redwing consisted of 17 detonations in the Marshall Islands. The exposure records for Utrik are contained in a report by the Defense Nuclear Agency[16]. The reported gamma dose rates measured with survey meters during the months of April to July 1956 are shown in Figure 5-1 together with the yield and location of the detonations. It is evident that peak gamma dose rates are associated with tests ZUNI (5/28/56, 3500 kt) and DAKOTA (6/26/56, 1100 kt) on Bikini Atoll. The cumulative gamma dose rate for Utrik from the Redwing tests was estimated by extrapolation from dose rates on day 4.[17] Using the Hicks table decay function, a dose of 59 mR for the year 1956 is estimated. Combined with the contribution from BRAVO, a total dose of 210 mR is calculated for 1956. The cumulative dose based on measurements from April 26, 1956 to July 23, 1956 of 108 mR compares well to the calculated dose of 86 mR for the same time; differences can be assumed to be due to model and measurement uncertainties.

Operation Hardtack Phase I consisted of 33 detonations in the Marshall Islands. The exposure records for Utrik are contained in a report issued by the Public Health Service.[18] The gamma dose rates from survey meters are depicted in Figure 5-2 along with the place and yield of the detonations. It is likely that the event responsible for the observed peak dose rate was event FIR (5/12/58, 1360 kt), detonated on Bikini Atoll, rather than event KOA, which exploded on Eniwetak Atoll with a yield of 1370 kt.

The cumulative gamma dose on Utrik from the Hardtack/FIR detonation was estimated by extrapolation from the dose rate on day 4, using the Hicks table decay function. The external gamma radiation dose for Utrik Atoll residents for the Hardtack series was calculated to be 190 mR in 1958. For 1958, the total dose including the contribution by residual contamination prior to Hardtack is 270 mR.

The cumulative dose based on measurements for the time period May 6, 1958 to July 29, 1958 of 230 mR is comparable to the calculated dose of 200 mR; differences can be assumed to be due to model and measurement uncertainties.

Actual doses may have been larger than those calculated here because (a) of a potential low bias of survey meter data and (b) because dose rates varied over the Island of Utrik. This conclusion is supported by comparing the cumulative doses calculated from survey meter readings with the film badge data for the time period April 16 to July 30, 1958. Dose estimates based on film badge data were significantly larger, ranging from 307 to 524 mrem, with an average of 408 mrem (see Table 5-2). On average, film badge doses were a factor of 2.1 larger than the calculated cumulative dose based on survey meter readings. The PHS service report questions the reliability of the film badge data because it is claimed that additional exposure was received on Elmer (Medren Island on Eniwetak Atoll) prior to processing. However, this assertion could not be verified. Because film dosimeters provide an estimate of the integrated dose as compared to daily spot readings of survey meters readings, the film badge data can be generically considered to be more reliable. It is thus possible that the dose from Operation Hardtack I was a factor of 2.1 larger than the dose estimated here.

[16] Defense Nuclear Agency. 1956. DOE document number 93137
[17] The rate on day 4 was most consistent with the expected decay.
[18] AEC. Report of Public Health Service Off-Site Radiological Monitoring Data, Operation Hardtack Phase I, 1958. DOE document number 0410975. 1958

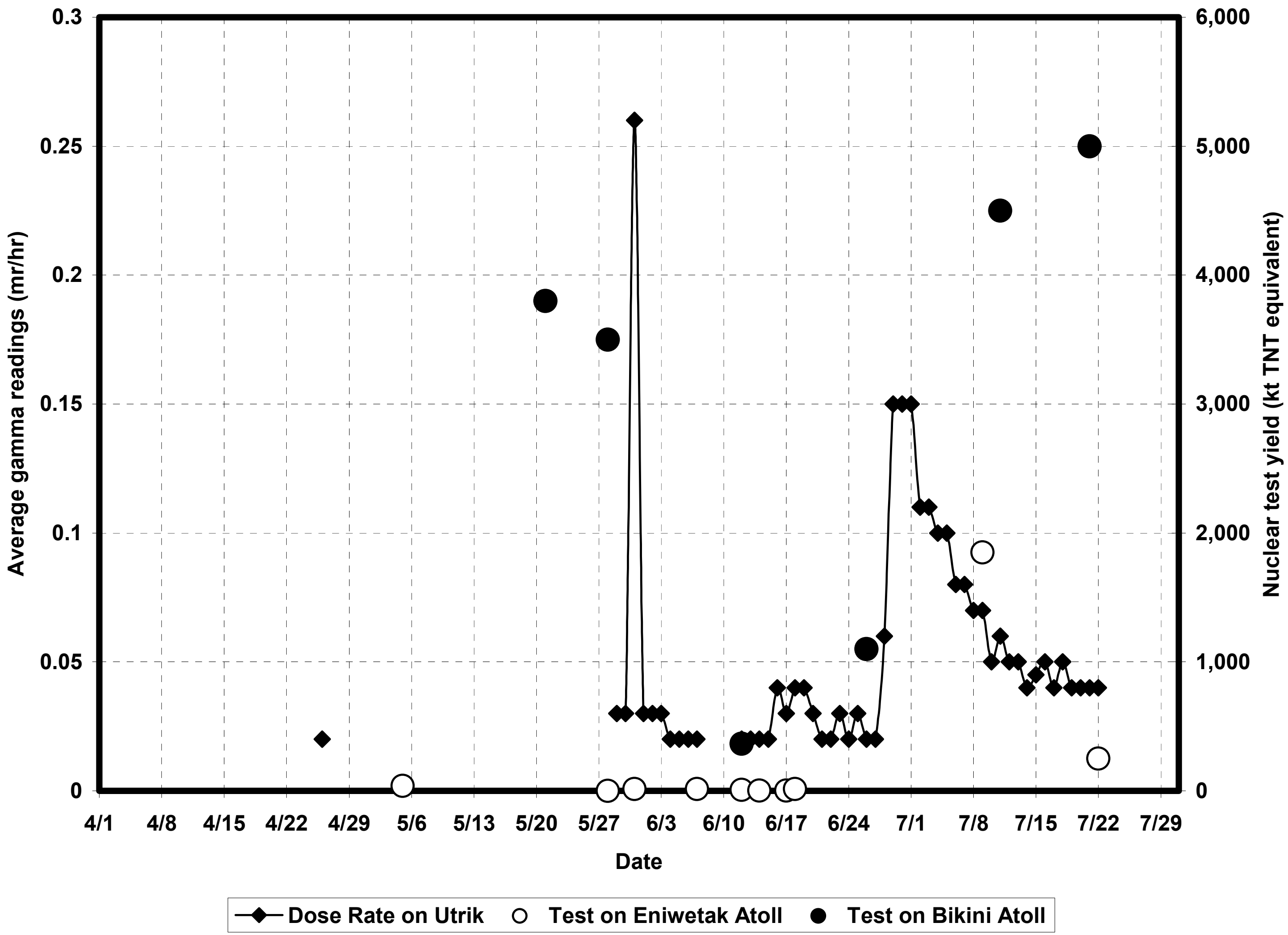

Figure 5-1 Reported dose rates on Utrik Island during Operation Redwing in 1956

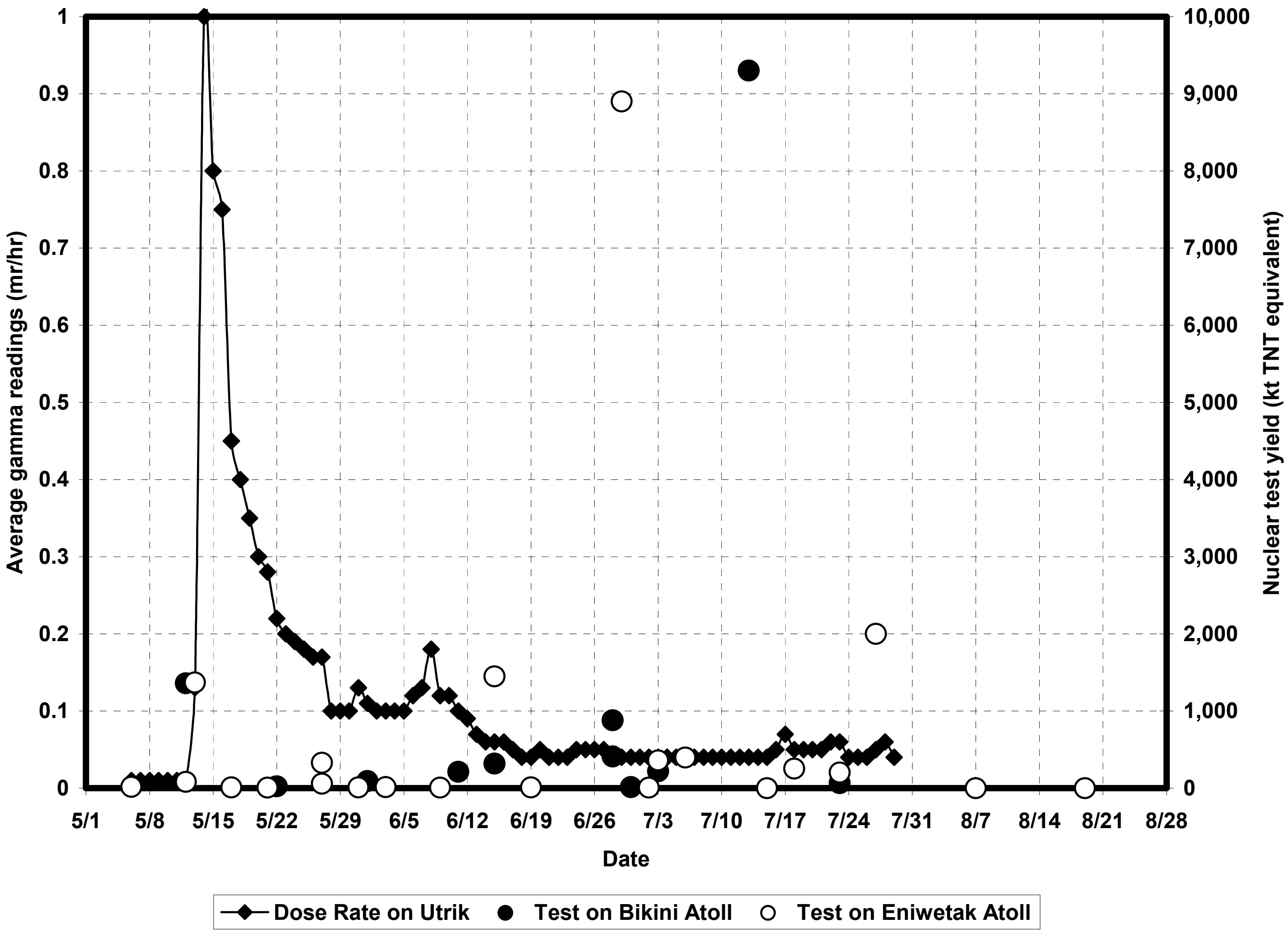

Figure 5-2 Reported dose rates on Utrik Island during Operation Hardtack I in 1958

Table 5-2 Film badge survey data for Utrik Island during Operation Hardtack I[19]

Station number	Exposure period (1958)	Cumulative dose, mR
1	4/16 to 4/29	--
2	4/16 to 5/13	670
3	4/16 to 5/28	133
4	4/16 to 6/12	121
5	4/16 to 7/30	307
6	5/14 to 7/30	259
7	4/16 to 7/30	351
8	4/16 to 7/30	397
9	4/16 to 7/15	258
10	4/16 to 7/30	380
11	4/16 to 7/30	398
12	4/16 to 7/30	348
13	4/16 to 7/30	427
14	4/16 to 7/30	424
15	4/18 to 7/30	524
16	4/18 to 7/30	412
17	4/18 to 7/30	399
18	4/18 to 5/15 and 6/12 to 7/15	352
19	4/18 to 7/30	402
20	4/18 to 7/30	436
Average	**4/16 to 7/30**	**408**

A further comparison of extrapolated external gamma doses with measurements on Utrik Island is possible with data collected by Greenhouse and Miltenberger in September of 1976[20]. The calculated average dose rate was based on nine measurements on the east-west transect of the island. External gamma doses ranged form 3.7±0.3 μR/hr to 4.5±0.9 μR/hr, with an average of 4.1±0.3 μR/hr. Background was assumed at 3.75 μR/hr, based on the average readings on Ailuk and Wotje Atolls. The net exposure for Utrik, decay-corrected to April 1977, was calculated to be 0.32 μR/hr. This dose rate compares well with the predicted dose rate of 3.6 μR/hr that one would expect if no non-radiological removal had occurred.

Lastly, Table 5-3 contains doses extrapolated both forward in time (based on dose-rate measurements 8 days after BRAVO and 4 days after the other tests) and backward calculations (from maximum gamma dose rate determined in the Nationwide Radiological Study in 1993).

[19] Public Health Service Report, DOE document number 0410975
[20] Greenhouse N A and Miltenberger R P. External Radiation Survey and Dose Predictions for Rongelap, Utirik, Rongerik, Ailuk, and Wotje Atolls. Brookhaven National Laboratories. 1977. BNL-50797.

Table 5-3 Calculated annual external radiation doses to Utrik Residents

Year	Extrapolated from BRAVO using data in Hicks (1984), mR/yr	Extrapolated from Redwing and Hardtack (see text), mR/yr	Backward extrapolation from 1995 maximum (NWRS study), mrem/year
1955	4.1E+02		6.5E+01
1956	1.5E+02	5.9E+01	2.3E+01
1957	1.0E+02	1.7E+00	1.6E+01
1958	7.8E+01	1.9E+02	1.2E+01
1959	6.6E+01	4.1E+00	1.0E+01
1960	5.9E+01	7.8E-01	9.3E+00
1961	5.4E+01	5.0E-01	8.4E+00
1962	5.1E+01	3.8E-01	7.9E+00
1963	4.8E+01	3.2E-01	7.5E+00
1964	4.6E+01	2.9E-01	7.2E+00
1965	4.4E+01	2.6E-01	6.9E+00
1966	4.2E+01	2.5E-01	6.6E+00
1967	4.1E+01	2.3E-01	6.4E+00
1968	4.0E+01	2.2E-01	6.2E+00
1969	3.8E+01	2.1E-01	6.0E+00
1970	3.7E+01	2.1E-01	5.8E+00
1971	3.6E+01	2.0E-01	5.7E+00
1972	3.6E+01	1.9E-01	5.6E+00
1973	3.5E+01	1.9E-01	5.4E+00
1974	3.4E+01	1.8E-01	5.3E+00
1975	3.3E+01	1.8E-01	5.1E+00
1976	3.2E+01	1.7E-01	5.0E+00
1977	3.1E+01	1.7E-01	4.9E+00
1978	3.0E+01	1.6E-01	4.7E+00
1979	2.9E+01	1.6E-01	4.6E+00
1980	2.9E+01	1.5E-01	4.5E+00
1981	2.8E+01	1.5E-01	4.4E+00
1982	2.7E+01	1.5E-01	4.3E+00
1983	2.7E+01	1.4E-01	4.2E+00
1984	2.6E+01	1.4E-01	4.1E+00
1985	2.6E+01	1.4E-01	4.0E+00
1986	2.5E+01	1.3E-01	4.0E+00
1987	2.5E+01	1.3E-01	3.9E+00
1988	2.4E+01	1.3E-01	3.8E+00
1989	2.4E+01	1.3E-01	3.7E+00
1990	2.3E+01	1.2E-01	3.6E+00
1991	2.3E+01	1.2E-01	3.5E+00
1992	2.2E+01	1.2E-01	3.5E+00
1993	2.1E+01	1.2E-01	3.4E+00
1994	2.1E+01	1.1E-01	3.3E+00
1995	2.0E+01	1.1E-01	3.2E+00
1996	2.0E+01	1.1E-01	3.1E+00
1997	1.9E+01	1.0E-01	3.0E+00
1998	1.9E+01	1.0E-01	3.0E+00
1999	1.9E+01	9.9E-02	2.9E+00

5.3 Internal doses from Cs-137

The internal doses from Cs-137 are best extrapolated from the whole body counting data analyzed in chapter 4 and summarized in Table 4-2. For the reasonably maximally exposed individual (RMEI), the data for the female adults were based on measurements in 1977. Backward extrapolation is possible for years prior to 1977 by accounting for Cs-137 decay.

5.4 Internal doses from Zn-65

The detonation of BRAVO on March 1, 1954 resulted in a severe contamination of the Utrik environment with zinc-65 (Zn-65), a radionuclide with a half-life of 243.9 days. Zinc-65 is an activation product generated from metals contained in nuclear bombs or from zinc in the ocean water and/or coral soil. The compilation of fallout from BRAVO by Hicks (1984)[21] contains no data for zinc-65. In addition, no fallout data regarding cobalt isotopes (Co-57, Co-58, Co-60) is provided, although contamination of the Rongelap and Utrik soils with cobalt-60 is well documented. This may either mean that this information was classified at the time of the preparation of the Hicks tables, or that the source of contamination with Co-57, Co-58, Co-60 and Zn-65 is due to neutron activation of sea water and/or coral soil.

The 1962 thesis of Timothy Joyner[22] provides a compilation of data on zinc-65 collected in the environment around Eniwetak, Bikini, and Rongelap. No data could be located regarding the zinc-65 contamination of Utrik Atoll soil. Data regarding Zn-65 contamination of fish caught near Utrik Atoll in 1956 provides direct evidence of its persistence in the environment.[23] It is, however, well established that although zinc-65 was present on atoll soils, the major route of uptake was from consumption of fish, because fish bio-accumulate the trace element zinc from its ocean environment. Internal exposure to Zn-65 is supported by measurements of diets among Rongelap residents in September of 1959, where 24-hour food rations were collected and analyzed[24]. After return to Utrik Atoll, residents had to rely on fish for their source of protein because U.S. servicemen prior to their return killed all livestock on Utrik Island.

A precise determination of the internal zinc-65 dose is not possible because of the absence of any measurements in 1954 and 1955, which represent the years of peak exposure. It is for this reason that Lessard et al. relied entirely on the results of whole body counting data in their reconstruction of chronic doses.[25] The raw data on whole body counting a total of 2519 separate measurements was received from the U.S. Department of Energy at the request of the Marshall Islands Government in database format (file: DOE_BNL_WBC_PUBIOASSAY.mdb).

[21] Hicks H G, Results of Calculation of External Gamma Radiation Exposure Rates from Local Fallout and the Related Radionuclide Compositions of Selected U.S. Pacific Events. UCRL-53505 (1984)

[22] Joyner T, Effects of the Biological Specificity of Zinc on the Distribution of Zinc-65 in the Fish Fauna of a Coral Lagoon. PhD Thesis. University of Washington. 1962

[23] Weiss HV, Cohn SH, Shipman WH, Gong JK. Residual Contamination of Plants, Animals, Soil, and Water of the Marshall Islands Two Years Following Operation Castle Fallout. U.S. Naval Radiological Defense Laboratory. Report NS-081-001. August 15, 1956

[24] Chakravarti D and Held E E. Chemical and Radiochemical Composition of the Rongelapese Diet. University of Washington. UWFL-77. 1961

[25] Lessard E T, Greenhouse N A and Miltenberger R P. A Reconstruction of Chronic Dose Equivalents for Rongelap and Utrik Residents – 1954 to 1980, BNL 51257, October 1980

The data in that file were evaluated for Utrik and Rongelap residents. The Rongelap resident data were evaluated as well because whole body counting was performed in years that Utrik people were not counted (1958, 1961 and 1965) and because of the similarity in living patterns between the two atolls. It appears that body weight and/or age data was entered incorrectly in a number of cases. Since the discrepancies could not be resolved, it was decided to rely primarily on age data. Hence, only data for residents of greater than 15 years were analyzed.

The whole body counting data for Zn-65 between Rongelap and Utrik residents are available for the time periods shown in Table 5-4. It is obvious that the lack of data for the time period where the Zn-65 activity was highest constitutes a major obstacle in any dose reconstruction efforts. The distribution of observed Zn-65 body burdens is shown in Figure 5-3.

Table 5-4 Adult (>15 yr) Zn-65 whole body burden of among Rongelap and Utrik residents

Date	Days post return	Zn-65 activity relative to March 1, 1954	Zn-65 body burden, Bq mean value and 95% confidence interval	N
Rongelap residents				
June 1, 1957	1	3.4 %	no data	
May 1, 1958	334	1.3 %	14,000 (4,600 – 26,000) min: 4,300; max: 31,000	70
March 1,1959	648	0.56%	12,000 (3,900 – 33,000) min: 1,800; max: 47,000	105
March 1, 1961	1,369	0.07%	3,000 (1.400 – 5.300) min: 730; max: 26,000	84
Utrik residents				
June 1, 1954	1	77%	no data	
March 1, 1959	1,734	0.59%	4,400 (1,100 – 11,000) min: 930; max: 17,000	43

The Zn-65 activity in fish is reduced by radioactive decay and non-radiological environmental removal. It is reasonable to assume that the environmental removal was not a constant over time but was higher in the early years post BRAVO. The reconstruction by Lessard et al. (1980) used the data collected on Rongelap to calculate the non-radiological removal function. The authors used the mean value body burden data from 1958, 1961, and 1961 ICRP 2 dosimetry and determined that about 0.31% of the Zn-65 was removed from the environmental per day by nonradiological removal. On this basis, Lessard et al. estimated the average cumulative dose to Utrik adults from Zn-65 to be 12.4 rem.

The distribution of doses over time as calculated by Lessard et al. is shown in Figure 5-4. Based on the data given by Lessard et al., the distribution of this dose over the years 1954-1961 is compiled in Table 5-5. The ratio of the dose to the maximum individual was assumed to be a factor of 3.9, which is based on the observed ratio from whole body counting among Utrik residents in 1959.

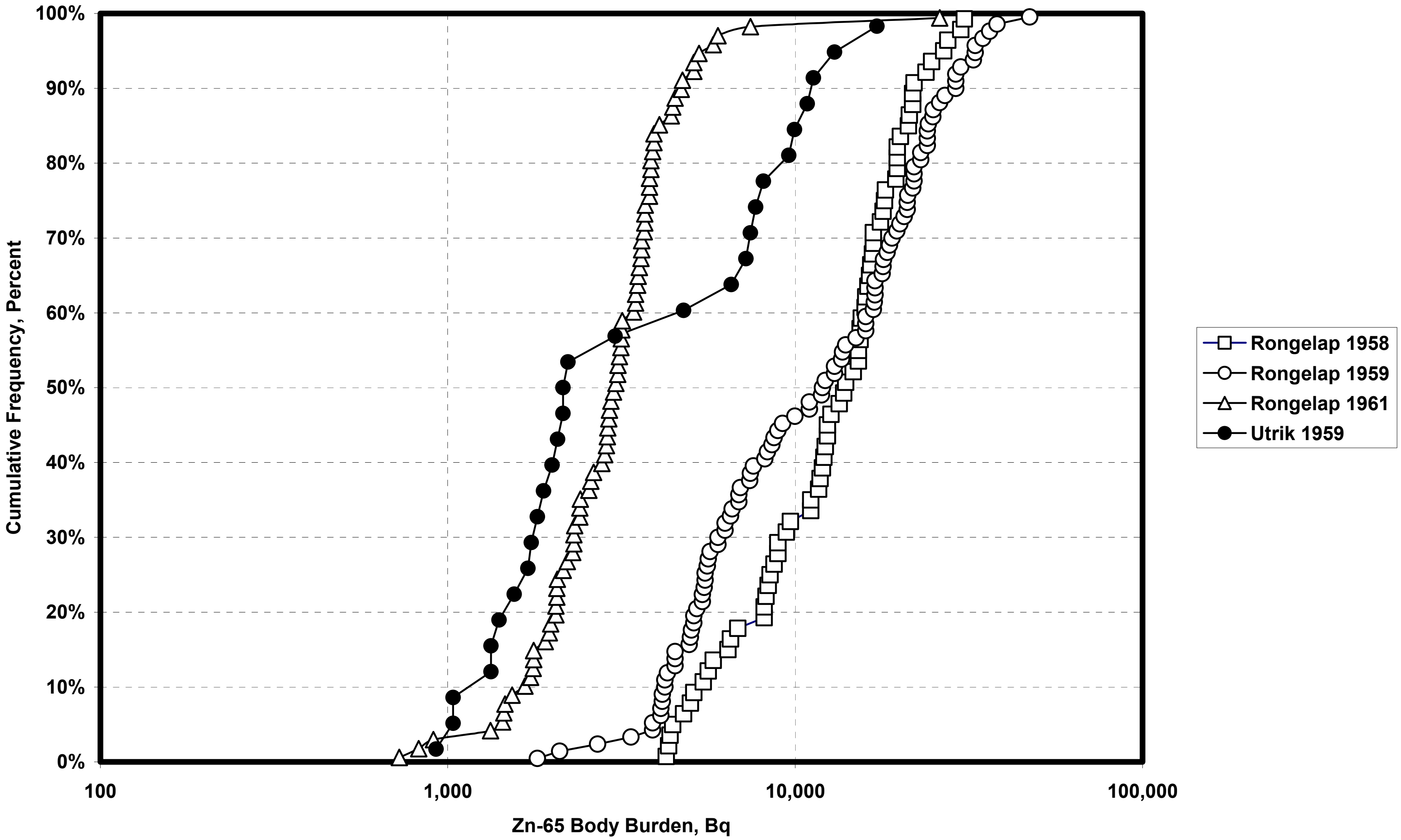

Figure 5-3 Distribution of Zn-65 body burden among monitored adults from Rongelap (1958, 1959, 1961) and Utrik (1959)

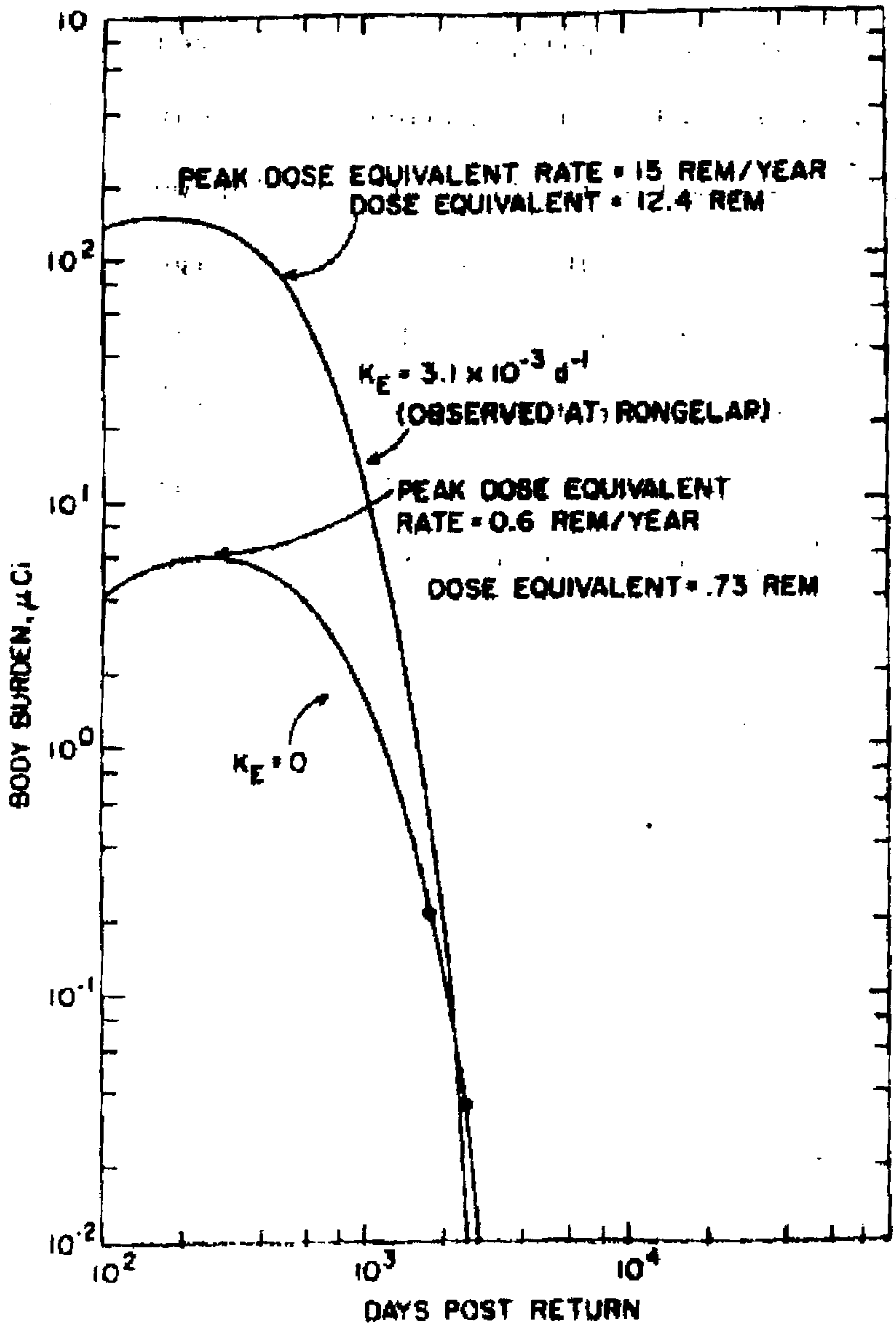

Figure 5-4 Mean adult Zn-65 body burden of Utrik residents according to estimates by Lessard et al. (1980)

Table 5-5 Annual radiation doses for Utrik adults as a result of incorporated Zn-65 based on data in Lessard et al. (1980)

Time period	Average individual	Maximum individual
1954 (June – December)	4.2 rem	17 rem
1955	6.1 rem	24 rem
1956	1.7 rem	6.6 rem
1957	0.35 rem	1.4 rem
1958	0.065 rem	0.25 rem
1959	0.011 rem	0.045 rem
1960	0.002 rem	0.008 rem
1961	<0.001 rem	<0.001 rem

In the absence of other data, it is reasonable to assume that the internal dose from Zn-65 was significant. Estimates by Lessard et al. for the average individual can be used to infer the doses among the RMEI using the observed variability of Zn-65 body burden among Utrik residents in 1959. An even greater variability (resulting in a larger range of estimated doses) could result if a different non-radiological removal function were to be selected.

5.5 Acute external and internal doses from short-lived fission and activation products

For Utrik residents, external whole-body and internal exposure to short-lived fission and activation products for the twelve-year testing program was overwhelmingly contributed by the March 1, 1954 BRAVO shot. With a yield of 15 megatons, heavy fallout was observed at several atolls east/northeast of ground-zero including Utrik.

Within hours of detonation, the radioactive cloud containing more than one-hundred different radionuclides arrived at Utrik where fallout contaminated all surfaces, inclusive of foods stored and/or prepared outdoors, cooking/eating utensils, drinking water in cisterns, etc. For more than 60 hours that elapsed between cloud arrival and evacuation, residents from Utrik Atoll were subject to external whole-body exposure and internal uptakes of radionuclides by a variety of pathways that are thought to have been dominated by the ingestion of contaminated food products. Among key radionuclides were several species of radioiodine and radio-tellurium, which resulted in large doses to the thyroid.

Many of the other ingested radionuclides were not metabolically assimilated in the human body but, in the process of passing through the gastrointestinal tract, resulted in large doses to the intestinal mucosa. Over the years, several reports have been issued that have attempted to estimate internal doses to the thyroid and other tissues to the exposed population groups of BRAVO shot. The most recent (and revised) DOE dose estimates are those reported by Lessard et al. 1985[26]. However, past DOE estimates inclusive of those reported by Lessard (1985) have been critically reviewed and contested in two reports issued by SC&A, Inc.:

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[26] Lessard, E. T., Miltenberger, R. P., Conard, R. A., Musolino, S. V., Naidu, J. R., Moorthy, A., and Schopfer, C. J. Thyroid Absorbed Dose for People at Rongelap, Utirik, and Sifo on March 1, 1954. BNL 51882. Brookhaven National Laboratory, Upton, NY. 1985.

- The first report (Behling et al. 2000[27]) was performed under contract to the Rongelap Atoll Local Government and was submitted to the RMI/DOE Nuclear Claims Tribunal.
- A more recent draft report (Behling et al. 2001[28]) was performed under contract to the Utrik Atoll Local Government. The draft report is currently under review by members of the Utrik Government Council. It is anticipated that a final report will be presented to the Nuclear Claims Tribunal in early 2002.

Because of the fact that SC&A's most recent report (which specifically contains revised internal and external dose estimates for Utrik Atoll residents) is still in draft form, dose estimates presented in Table 5-6 reflect values cited by both Behling et al. 2001 and Lessard et al. 1985. Inspection of Table 5-6 clearly shows that there are major discrepancies between the two sets of dose estimates.

Table 5.6 Acute external and internal doses to Utrik residents from BRAVO shot

Exposure	DOE[a)]	SC&A[b)]
External whole-body (rem)	11	50+
Internal Thyroid (rad) Adult Child Infant	 155 320 660	 2,700 3,400 5,900
Internal (Other than Thyroid) (rem-CEDE) Adult Child Infant	 7.6[c)] 13.7[c)] 31.7[c)]	 86 112 193

a) Source: Lessard et al. 1985 ; b) Source: Behling et al. 2001; c) These are implied fission product doses that were derived from data of ingested I-131 as cited by Lessard (1985).

In context with the restricted objectives of this report, however, these discrepancies have no significance for the following reason: The principal objective in this report was to identify yearly doses for Utrik residents that were in excess of regulatory limits and would, therefore, serve as basis for seeking compensation for loss of use. In fact, even the much lower dose estimates for (1) external, (2) thyroid, and (3) internal doses other than thyroid cited by the Lessard et al. independently exceed the regulatory dose limit for the year 1954.

Given that Redwing and Hardtack tests resulted in fallout on Utrik, it is likely that residents had significant radiation exposures to thyroid and other body tissues from ingestion of fresh fallout from these tests in the years 1956 and 1958 as well.

[27] Behling, U.H., Mauro, J.J., Behling, K. Reassessment of Acute Radiation Doses Associated with BRAVO Fallout. Prepared for William Graham, Public Advocate, Nuclear Claims Tribunal, Majuro, MH. 2000.

[28] Behling, U.H., Mauro, J.J., Behling, K. (Draft) Reassessment of Acute Radiation Doses Associate with BRAVO Fallout at Utrik Atoll. Prepared for Utrik Local Government Council, Republic of the Marshall Islands, Majuro, MH 2001.

6 Loss-of-use determination based on historical dose estimates

When land is contaminated radiologically, its full and unrestricted use by its owners may be lost. A claim for loss of use can be made in instances where resulting exposures to residents exceed levels prescribed by consensus dose standards and reflect health risks considered unsafe and/or unacceptable.

In a 1974 letter of the U.S. Environmental Protection[29], it was confirmed that the U.S. rules and regulations pertain to radiation protection apply to the Marshall Islands. The letter stated EPA's position as follows:

> *"These Trust Territory people are entitled to as much protection as that afforded residents of the U.S. by the Federal Radiation Protection Guides. Conversely, it might be argued that the degree of soil contamination and the doses expected to be received by the Marshallese are acceptable in the U.S."*

For Utrik Atoll residents and land owners, a subsistence lifestyle has and continues to be a tradition born out of necessity. It is the isolation and remoteness of the atoll and the near absence of an economic infrastructure that has forced the people of Utrik to be self sufficient for nearly all things considered vital to life inclusive of food items. The need for total self sufficiency imposes upper-bound limits for unrestricted land use.

The full and unrestricted use was lost with the heavy contamination of Utrik following Bravo shot in March of 1954, and the forced evacuation of its residents to Kwajalein. With few options and encouraged by the AEC, residents returned to their homeland in June of 1954 without any credible information and understanding of radiation exposures and risks that they would encounter as a result of living on Utrik and consuming contaminated local foods.

The safety of Utrik residents was clearly the sole responsibility of the U.S. Government, since the Marshall Islanders had been given no voice in anything related to the testing program. Moreover, in the intervening period that spans nearly half a century, attempts to assess their exposures have been tardy, sparse, incomplete, and inaccurate. In previous sections of this report, best estimates of annual internal and external radiation doses were derived by extrapolating/interpolating the limited number of available data points in time and space.

In this section, these annual dose data are assessed in context with radiation dose standards and regulatory limits. A claim for loss of use is made hereby for all years during which exposure must either have been considered unsafe or were ot in compliance with applicable dose standards and/or regulatory limits. A claim for loss of use must be considered even though the people of Utrik had assumed residency of their homelands and resumed their traditional lifestyle for most of the years. Legitimacy for this claim is based on the following:

(1) For residents of other contaminated atolls (i.e., Enewetak, Bikini, and Rongelap) who were denied residency and/or full use of their lands, compensation for loss of use has been granted or is currently under consideration by the Nuclear Claims Tribunal.

[29] Letter by William A. Mills, Criteria & Standards Division (USEPA) to Tommy McCraw, Division of Operational Safety (USAEC), dated February 28, 1974.

(2) On the basis of residual contamination and projected health risks (information only accessible to the AEC), residents should not have been permitted to return to Utrik Atoll under conditions of unrestricted use.

(3) Taking this line of reasoning one step further, a responsible effort by the AEC/DOE would have denied the return to Utrik in June 1954 until such time as the radioactive level and the resultant dose to any one person fell to a level considered safe.

Thus, by inverse logic, a claim for loss of use can be made in behalf of Utrik residents who in the absence of reasonable precautions, prematurely returned to their homelands in June 1954 and suffered substantial and avoidable radiation doses.

The period of time for which loss of use may reasonably be claimed is, therefore, dependent on establishing a date when return to their homeland would have been considered safe. The term "safe," however, is less than precise when used in context with our understanding of radiation health risks over the time period in question. Since the discovery of radiation and radioactivity 100 years ago, radiation protection standards and the philosophy governing those standards have evolved in somewhat discrete intervals. The changes have been driven by two factors – new information on the effects of radiation on biological systems and changing attitudes toward acceptable risk. The earliest limits were based on preventing the onset of such obvious effects as skin ulcerations that appeared after intense exposure to radiation fields. Later limits were based on preventing delayed effects such as cancer that had been observed in populations of people receiving medical exposures and from the atomic-bomb exposure in Hiroshima and Nagasaki.

In brief, our understanding of radiation health risks has changed dramatically over time. Concurrent with our improved understanding of radiation has been the steady decline in dose limits considered safe by prominent scientific committees and by policy makers who have promulgated Federal regulations. Thus, difficult questions that must be addressed in this claim for loss of use include the following:

- What is a safe level of radiation exposure and can it be properly quantified historically or even today?[30]
- Are historical recommendations by scientific committees and Federal regulatory limits applicable even though they are now clearly recognized as having been grossly inadequate?

In order to answer these questions, it is helpful to review the history of radiation standards and the scientific basis from which they evolved. Presented below is a brief citation of relevant milestones that characterize radiation protection standards.

[30] In spite of the vast amount of scientific data, there remain many unanswered questions pertaining to the mechanism(s) that produce biological effect. What are the relative risks of different types of radiation, different exposure pathways, acute versus chronic exposures, age of exposure, and chronic versus acute exposure? These and other concerns will likely affect future revisions to radiation standards.

6.1 A historical profile of radiation standards

Early Standards. Of significance is the fact that early limits on exposure to x-rays were not derived from quantitative measurements of dose but rather on judgment that was based on the absence of observed biological harm. Thus, in July 1896, only one month after the discovery of x-rays by Wilhelm Roentgen, a severe case of x-ray induced dermatitis was reported, and in 1902, the first dose limit estimated at about 10 rad per day (or 3000 rad per year) was recommended[31] (Kathren 1978[32]).

With the proliferation of x-ray devices and radioactive materials in medicine, physics, and chemistry in the next several decades, large numbers of individuals were exposed to high doses of radiation resulting in various biological effects. The most prevalent observable effect was that of skin reddening.

The early radiologists often used the image of their hands to focus the primitive fluoroscopic equipment, which resulted in very high doses. The dose of radiation sufficient to cause "reddening" of the skin, or erythema, was termed appropriately the "Threshold Erythema Dose" (TED) and was estimated at 700 roentgen (R).

The earliest efforts to set radiation standards were made by the American Roentgen Ray Society and the British Roentgen Society. Formed independently at the turn of the century, both groups included doctors, scientists, engineers, and manufacturers of x-ray equipment. Arthur Mutscheller, a German-American physicist, first attempted to establish a tolerance or maximum permissible dose in 1925. He developed a table made up from physical measurements of radiation transmitted through various thicknesses of lead. Based on these measurements, he recommended an annual maximum permissible dose equivalent to about one-tenth of a Threshold Erythema Dose; about 72 R per year or 6 R per month.[33]

The International Commission on Radiological Protection (ICRP), formed in 1928 at the Second International Congress of Radiology, provided additional guidelines on radiological protection. In 1934, the ICRP proposed a tolerance rate of exposure of 0.2 R per day, which was derived from the previous tolerance dose equivalent to 1/10th of a skin erythema dose or about 72 R spread over a one-year period.

In 1929, the Advisory Committee on X-ray and Radium Protection was founded in the United States and is now the National Council on Radiation Protection and Measurements (NCRP). This group of U.S. experts in radiological sciences was charged with developing and recommending radiation protection standards based on the best available scientific evidence. In 1933, this advisory committee developed a tolerance exposure level of 0.1 R per day. The ICRP and NCRP have the longest continuous experience in reviewing radiation health effects and recommending guidelines for radiological protection and radiation exposure limits.

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[31] At the time, this dose limit was defined in terms of x-ray tube current, voltage, distance, and exposure duration.

[32] Kathren, R.L. Historical Development of Radiation Measurement and Protection. In: CRC Handbook of Radiation Measurement and Protection., Section A, Volume I: Physical Science and Engineering Data. Brodsky A. Editor. CRC Press, Inc. 1978.

[33] Officially, the roentgen unit (R) was not established until 1928 by the Second International Congress of Radiology.

During this time, separate exposure limits were proposed for various parts of the body such as extremities. Because of the tragic consequences of radium ingested by the radium dial painters and of radium-bearing tonics and medicines that were imbibed, intake limits were also considered to deal with the problem of internal exposure from radium. A permissible body burden of 0.1 µCi was established in 1941 by the Advisory Committee on X-Ray and Radium Protection.

Post World War II. World War II led to the development and employment of the atomic bomb and the subsequent need for the large-scale production of fissile material. This provided new impetus for the development of standards and regulations to limit human exposure to internal and external sources of radiation and resulted in the formation of the Atomic Energy Commission (AEC) in 1946.

Almost immediately after the bombs were dropped over Japan, studies began on the human survivors as well as on the physical effects. The initial studies were concerned primarily with immediate clinical effects of radiation, as well as blast and other prompt effects. The limitations of these early studies performed by the U.S. Army with limited funding and personnel were of concern to the National Academy of Sciences in 1946. Thus, in early 1947, the National Academy of Sciences formed a committee, and with AEC funding and other support, began a long-range study of nearly 100,000 survivors of the Hiroshima and Nagasaki bombings. The formation of the Atomic Bomb Casualty Commission (ABCC) has carried on the study of survivors and their progeny for more than 50 years.

The ABCC had collected data on more than 150,000 persons by 1950. The early data revealed an increase in leukemia among survivors and a high incidence of cataracts among those receiving high doses. An early analysis of data from the Japanese atomic-bomb survivors also indicated an apparent change in the ratio of the number of males to females among infants born to survivors. At the same time, data from experiments on mammals and fruit flies demonstrated that genetic changes could be induced from very high radiation exposures. Thus, radiation-induced genetic effects became a dominant concern in the early 1950s and led to the first recommended standards for annual dose limits to the public.

For occupational exposure, the tolerance dose of 0.1 R/day proposed in the 1930s and used throughout the Manhattan District was reexamined in the early postwar period. In 1949, the National Committee (now Council) on Radiation Protection and Measurement (NCRP and formerly Advisory Committee on X-Ray and Radium Protection, ACXRP) put forth a recommended occupational exposure limit of 0.3 rem/week whole body and also introduced the benefit versus risk concept to radiation protection. The ICRP followed in 1950 as did the AEC. Later, these levels were incorporated into pertinent regulations (10 CFR 20).

In 1951, the 0.3 rem/week limit was reiterated by the U.S. National Bureau of Standards in NBS Handbook 47[34] and extended this dose limit to include internal exposure that result from the inhalation and/or ingestion of radionuclides. Based on dosimetric models available at the time,

[34] U.S. Department of Commerce, National Bureau of Standards. Recommendations of the International Commission on Radiological Protection and the International Commission on Radiological Units 1950. Issued June 29, 1951. Washington (DC): U.S. National Bureau of Standards Handbook 47

maximum permissible concentrations in air and water were published in 1952 in NBS Handbook 52[35] that are associated with this dose limit.

Non-Occupational Exposure Limits as of 1954. The first notion that doses to select members of public should be significantly lower than those to radiation workers is contained in Handbook 59 published by the U.S. National Bureau of Standards on September 24, 1954[36]. In Section 6.3 (Non-occupational Exposure), the NBS states:

> *"Therefore, it is recommended that in cases in which minors may be exposed to radiation in the course of their normal activities, protective measures be taken to make sure that no minor actually receives radiation at a weekly rate higher than one-tenth the respective basic permissible weekly doses for the critical organs and other body tissues, according to the basic dose distribution."*

One-tenth of the occupational dose limit of 0.3 rem/year is equivalent to 1,560 mrem/year (total body dose). Because the Utrik population contained minors of less than 18 years of age, the dose limit (conventionally rounded down) of 1,500 mrem/year should be selected. In addition, Section 5.2 of Handbook 59 stipulates that the doses from internal and external exposure have to be combined. This guidance in Handbook 59 builds on a provision of a "factor of safety that may be as large as ten be used in the design and operation of permanent installations where large quantities of radioactive materials are involved" that was already mentioned in the introduction section of Handbook 52[37].

This interpretation was also presented in the AEC Advisory Committee on Biology and Medicine (ACBM). In the 40th meeting that took place on October 9 and 10, 1953, one member (Claus) stated:

> *"Handbook 52 refers to internal emitters only, and there is not a factor thrown in there for external populations, but we have, by going through the context in the external report that there should be a factor of 10 for children. We can extrapolate that over internal emitters which are based on the .3 r per week calculation and therefore we should have a factor of 10% in internal emitters for children since environmental populations will contain a sizeable number of children. The only [way] you can limit their exposures is to limit the overall exposure."*[38]

This was reemphasized in the 53rd ACBM meeting that took place in December 1 and 2, 1955:

> *"[T]here is a problem concerning the NCRP recommendation regarding permissible levels of radiation for controlled areas and uncontrolled areas, permissible*

[35] U.S. Department of Commerce, National Bureau of Standards. Maximum Permissible Amounts of Radioisotopes in the Human Body and Maximum Permissible Concentrations in Air and Water. Issued March 20, 1953. Washington (DC): U.S. National Bureau of Standards Handbook 52

[36] U.S. Department of Commerce, National Bureau of Standards. Permissible Dose from External Sources of Ionizing Radiation. Issued September 24, 1954. Washington (DC): U.S. National Bureau of Standards Handbook 59

[37] U.S. Department of Commerce, National Bureau of Standards. Maximum Permissible Amounts of Radioisotopes in the Human Body and Maximum Permissible Concentrations in Air and Water. Issued March 20, 1953. Washington (DC): U.S. National Bureau of Standards Handbook 52

[38] AEC Advisory Committee on Biology and Medicine. Minutes of the 40th meeting. October 9 and 10, 1953, page 10

limits for occupational exposure, and nonoccupational exposure. The limits set for non-occupational exposure are ten percent of the others."[39]

Continued study and concern regarding exposure to radiation produced a joint recommendation by the National Academy of Sciences (NAS) and NCRP in 1957 to lower the basic permissible dose to radiation workers to 5 rem per year. Consistent with the 10 percent rule previously established by the NBS for minors, the NCRP also recommended an annual limit to the public of 500 mrem per year. Thus, 1957 marks the first time that an exposure limit to members of the public was identified; all previous dose limits pertained to individuals exposed occupationally.

In 1957, the National Bureau of Standards issued a Technical News Bulletin[40] in which the occupational dose limit is set as follows:

"The maximum permissible accumulated dose, in rems, ar any age, is equal to 5 times the number of years beyond age 18, provided no annual increment exceeds 15 rems."

It further defines the limit for internal emitters:

"Where the critical organ is the gonad or the whole body, the maximum permissible concentrations of radionuclides in air and water will be one-third the values hereto specified for radiation workers."

The maximum permissible concentrations that were referred to in 1957 Technical News Bulletin were those in Handbook 52 that were calculated on the basis of a 15 rem/yr limit to the whole body, hence the revised limit for internal emitters is equivalent to 5 rem/yr. For members of the public it is stipulated:

"For individuals outside the controlled areas, the maximum permissible concentrations should be one-tenth of those for occupational exposures."

Hence, as of 1957, the internal dose limit to a member of the public was one-tenth of 5 rem/year equaling 500 mrem/year.

As of 1959, the International Commission on Radiological Protection (ICRP)[41] suggested to set a limit for the total body dose of population groups to 2 rem over 30 years.

In 1960 the Federal Radiation Council of the U.S. set the limit of 500 mrem/year for an individual in the general public and a limit of 170 mrem per year as the average annual dose to a population group.[42]

[39] AEC Advisory Committee on Biology and Medicine. Minutes of the 53rd meeting. December 1 and 2, 1955, page 40

[40] U.S. Department of Commerce, National Bureau of Standards. Maximum Permissible Radiation Exposures to Man. Washington (DC): Technical News Bulletin Vol 41, No.2, February 1957

[41] ICRP Publication 2. Report of Committee II on Permissible Dose for Internal Radiation (1959) Recommendations of the International Commission on Radiological Protection, Pergamon Press, Oxford (1959).

[42] Federal Radiation Council. Radiation Protection Guidance for Federal Agencies. Federal Register, May 18, 1960

The current standard for limiting radiation exposure to the public was promulgated in 1991 in 10 CFR 20.1301 at 100 mrem per year TEDE with ALARA provisions and reflects earlier recommendations of the NCRP and the ICRP. These national and international experts in the fields of radiation protection and health effects also note and agree that although the limit for the public dose should be set at 100 mrem per year from all manmade sources combined, it would seem appropriate that the amount that a person would receive from a single source should be further reduced to be a fraction of the limit to account for the possibility that an individual may be exposed to more than one source of manmade radiation/radioactivity. As early as 1979, the U.S. EPA promulgated regulations that specified dose limits for all nuclear fuel cycle facilities under 10 CFR 190[43]. From any single source, annual dose limits to members of the public included 25 mrem to the whole body, 75 mrem to the thyroid, and 25 mrem to any other organ.

Other NRC and EPA regulations that are consistent with the 25 mrem/year limit for a single source are contained in regulations pertaining to low-level waste facilities (10 CFR 61 and 40 CFR 191), high-level waste facilities (10 CFR 60), and the decommissioning of nuclear power reactors (10 CFR 20).

Continued support for the 0.25 fraction of a single source has been voiced by the NCRP and NRC's Advisory Committee on Nuclear Waste (ACNW); NCRP Report No. 116, Chapter 15 notes that:

> *". . . no single source or set of sources under one's control should result in an individual being exposed to no more than 25 mrem/y. (…) The clear implication in this simple alternative is that, if individual sources are constrained to 25 mrem/y, NCRP believes it likely, given the low potential for multiple exposure, that the public close limits will be met."*

The Department of Energy is responsible for establishing basic radiation protection standards in behalf of its facilities that are consistent with regulatory standards and guidance issued by NRC and EPA as well as with the general recommendations published by the ICRP, NCRP, and other scientific committees. In 1993, the DOE promulgated primary standards for radiation protection of the public and environment and workers at its facilities by issuing regulations contained in 10 CFR 834 and 10 CFR 835, respectively. The issuance of 10 CFR 834 and 10 CFR 835 codified the 100 mrem/year dose limit to a member of the public that up to this time had been contained in DOE directives (i.e., DOE Order 5400.5 and DOE Order 5480.11).

A 100 mrem/year standard was formally acknowledged to apply for the resettlement of Rongelap Atoll. The Memorandum of Understanding (MOU) for the Rongelap Resettlement Project was signed on February 21, 1992 between the Republic of the Marshall Islands, the Rongelap Atoll Local Government, the U.S. Department of Energy and the U.S. Department of the Interior. It specifies that the dose limit applies to the "calculated maximum whole-body radiation dose equivalent to the maximally exposed resident (…) based on a local food only diet".

EPA's Regulatory Authority. Under authority derived from the Atomic Energy Act of 1954, as amended, and Reorganization Plan No. 3 of 1970, EPA is responsible for developing generally

[43] 40CFR190. Environmental Radiation Protection Standards for Nuclear Power Operations, effective December 1, 1979

applicable environmental standards for protection of the environment from radioactive material. As previously acknowledged, past regulations promulgated by EPA include 40 CFR 190, 40 CFR 191, and 40 CFR 192.

In general, EPA's dose limits for individual sources conform to the 25 percent of primary dose limit of 100 mrem per year from all sources and pathways. However, for select sources (e.g., HLW disposal) or when exposure is restricted to a specified pathway (e.g., airborne release, 40 CFR 61), respective dose limits of 15 mrem/year and 10 mrem/year have been established that are below the 25 percent level.

EPA's justification for lower dose limits is based on the disparity that exists when individual dose limits associated with radiation protection are compared to non-radiological hazards. Past and current EPA regulatory efforts focus on health-risk-based guidance and regulations with the objective of incorporating criteria that ensure protection of health and the environment With an ample margin of safety. EPA, the courts, and Congress have generally defined this as limiting the range of lifetime risk to 10^{-4} to 10^{-6} (40 CFR 300; FR55/46:8666 March 8, 1990). EPA's limits of lifetime risk apply to Superfund sites that include those with radioactive contamination. For reference purposes, the DOE Rocky Flats facility has adopted the EPA 15 mrem/year cleanup standard.

Although it has been a goal for radiation protection standards to limit lifetime risks to about 10^{-4}, application of current risk coefficients assumed by EPA and BEIR V to current dose limits are unlikely to meet that objective. For example, a limit of 100 mrem/year, as set forth in NRC and DOE regulations, cannot achieve this objective using EPA's risk coefficient of 5 x 10^{-4} fatal cancer per rem. Parity with EPA's radiation risk goals and the risks inherent in several radiation protection standards is only achieved through rigorous application of the ALARA process that reduces actual exposures well below regulatory limits as explained in Section 6.1 above.

For example, even the 1997 EPA Superfund cleanup limit of 15 mrem/year (OSWER No. 9200.4-18, August 20, 1997 - "Establishment of Cleanup Levels for CERCLA Sites with Radioactive Contamination"), results in a risk that is too high in comparison with risk goals in the range of 10^{-4} to 10^{-6} normally employed under CERCLA for non-radiological contamination. Based on the current risk coefficient, constant exposure over a 30-year time period to dose levels of about 15 mrem/year results in an estimated lifetime fatal cancer risk of about 2.3 x 10^{-4}, which exceeds EPA's upper end of the acceptable risk range by more than a factor of two.

ALARA as a Supplement to Dose Limits. While in the early years, radiation dose limits had historically focused on the avoidance of deterministic (i.e., threshold) health effects, an emphasis of maintaining exposure “as low as is reasonably achievable” (ALARA) was incorporated in pertinent documents as early as 1950. Over the years, it has changed mainly in the terminology used to express the concept, and there has been a continued effort to quantify whenever possible the ALARA process.

The underlying reason is that any radiation exposure, no matter how small, may carry with it some degree of detriment or risk for causing certain types of injury. Although the level of risk associated with radiation exposure limits is very small, it is prudent to keep exposure, thus risks, as low as is reasonably achievable and to assure that this risk is assumed only if comparable benefit is achieved.

The principles of minimizing dose that would ultimately be termed ALARA were stated as early as 1950 in Handbook 47 of the U.S. National Bureau of Standards notes the following precautionary principle[44]:

> *"While the values proposed for maximum permissible exposures are such as to involve a risk that is small compared to the other hazards of life, nevertheless in view of the unsatisfactory nature of much of the evidence on which our judgments must be based, couple with the knowledge that certain radiation effects are irreversible and cumulative, it is strongly recommended that every effort be made to reduce exposures to all types of ionizing radiations to the lowest possible level".*

In Handbook 52 which was published by the U.S. National Bureau of Standards on March 20, 1953[45] the recommendations is reiterated that:

> *"exposures be kept at a minimum insofar as it is practical".*

In 1959, National Bureau of Standard published Handbook 69[46] that superseded Handbook 52. The introduction section states:

> *"When radioactive contaminants are deposited in the body, it is often difficult to make an accurate estimate of the total body burden or its distribution in the body. In most cases, even when the fact is established that a person carries a large internal burden of a radionuclide, little can be done to hasten its elimination from the body. According to one theory, any dose of ionizing radiation, no matter how small, may produce some genetic or somatic damage; and thus, it is considered wise to avoid all unnecessary exposure to radionuclides."*

The recommendation is in accordance with an ICRP recommendation that all doses be kept

"as low as practicable"

(ALAP) that can be found in ICRP Publication 1, published in 1959[47].

A further step in the standard setting system of the United States occurred in 1960, when the Federal Radiation Council (FRC), which was formed in 1959, issued the "Radiation Protection Guidance for Federal Agencies"[48], containing the following statements:

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[44] U.S. Department of Commerce, National Bureau of Standards. Recommendations of the International Commission on Radiological Protection and the International Commission on Radiological Units 1950. Issued June 29, 1951. Washington (DC): U.S. National Bureau of Standards Handbook 47

[45] U.S. Department of Commerce, National Bureau of Standards. Maximum Permissible Amounts of Radioisotopes in the Human Body and Maximum Permissible Concentrations in Air and Water. Issued March 20, 1953. Washington (DC): U.S. National Bureau of Standards Handbook 52

[46] U.S. Department of Commerce, National Bureau of Standards. Maximum Permissible Body Burdens and Maximum Permissible Concentrations of Radionuclides in Air and Water for Occupational Exposure. Issued June 5, 1959. Washington (DC): U.S. National Bureau of Standards Handbook 69

[47] ICRP Publication 1. Recommendations of the International Commission on Radiological Protection, Pergamon Press, Oxford (1959).

"There should not be any man-made radiation exposure without the emanation of benefit resulting from such exposure"; and further:

"There can be no single permissible or acceptable level of exposure without regard to the reason for permitting the exposure. It should be general practice to reduce exposure to radiation, and positive effort should be carried out to fulfill the sense of these recommendations. It is basic that exposure to radiation should result from a real determination of necessity."

The Federal Report No. 1[49] that was published at the same time with the Guidance clarifies that:

"Radiation Protection Guide (RPG) is the radiation dose which should not be exceeded without careful consideration of the reasons doing so; every effort should be made to encourage the maintenance of radiation dose as far below this guide as practical."

In 1964, the ICRP stated (ICRP 1964)[50]:

"as any exposure may involve some degree of risk, the Commission recommends that any unnecessary exposure be avoided, and that all doses be kept as low as reasonably achievable (ALARA), economic and societal consideration being taken into account"

The NCRP in Report No. 39 issued in 1971[51] further described ALARA as "a concise summary of the intention to encourage protection practices that are better than any prescribed minimal level, and this is the basic criterion for all cases in which a non-threshold dose-effect relationship either exists or is assumed."

Further reference to the principles of ALARA was introduced in Title 10 of the Code of Federal Regulations Part 20, in January 1971. Upon recommendation by the Federal Radiation Council and approval by the President on December 3, 1970, wording was added charging licensees to:

"make every reasonable effort to maintain radiation exposures and releases of radioactive materials in effluents to unrestricted areas as far below limits specified in this part as practicable. The term 'as far below limits specified in this part as practicable' means as low as is practicably achievable taking into account the state of technology and the economics of improvement in relation to benefit to the public health and safety and in relation to the utilization of atomic energy in the public interest."

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[48] Federal Radiation Council. Radiation Protection Guidance for Federal Agencies. Federal Register, May 18, 1960

[49] Federal Radiation Council. Federal Guidance Report No. 1. Background Material for the Development of Radiation Protection Standards (Federal Radiation Council May 13, 1960)

[50] ICRP Publication 6. Recommendations of the International Commission on Radiological Protection, Pergamon Press, Oxford (as Amended 1959 and Revised 1962) (1964).

[51] National Council on Radiation Protection. NCRP Report No. 39, Basic Radiation Protection Criteria. 1971. Bethesda, MD

In the 1976 revision of 10 CFR Part 20, the wording was changed to *"as low as is reasonably achievable"* and the definition included reference to *"the economics of improvements in relation to benefits to the public health and safety, and other societal and socioeconomic considerations"*. It is important to point out that under §20.1(c) ALARA was not a regulatory requirement but only a recommendation.

In 1977, the ICRP issued Publication 26[52]. In paragraph 12, the Commission stated its recommendation for a system of dose limitations that incorporate the ALARA concept. The system has three components, which are necessarily interrelated:

(1) No practice shall be adopted unless its introduction produces a positive net benefit.
(2) All exposures shall be kept as low as reasonably achievable, economic and social factors being taken into account.
(3) The dose equivalent to individuals shall not exceed the limits recommended for the appropriate circumstances by the Commission.

This system of radiological protection recommended by the ICRP incorporates the concept of optimization, which is based on the following three principles:

(1) The justification of a practice: No practice involving exposure to radiation should be adopted unless it produces significant benefit to the exposed individuals or to society.
(2) The optimization of protection: The magnitude of the individual doses, the number of people exposed, and the likelihood of incurring exposures should be kept as low as is reasonably achievable, economic and social factors being taken into account.
(3) Individual dose and risk limits: The exposure of individuals resulting from the combination of all the relevant practices should be subject to dose limits, or to some control of risk in the case of potential exposures.

On May 21, 1991, the NRC issued a revision to its standards for protection against ionizing radiation, 10 CFR Part 20. Of significance were the regulatory requirement for ALARA and the specific approaches for its implementation. 10 CFR 20.1003 defines ALARA as follows:

> *"ALARA (acronym for "as low as is reasonably achievable") means making every reasonable effort to maintain exposures to radiation as far below the dose limits in this part as is practical consistent with the purpose for which the licensed activity is undertaken, taking into account the state of technology, the economics of improvements in relation to benefits to the public health and safety, and other societal and socioeconomic considerations and in relation to utilization of nuclear energy and licensed materials in the public interest."*

6.2 Determination of loss-of-use of Utrik Atoll

The evolution of radiation standards over time reflects our understanding of the complex nature of radiation and its ability to induce biological harm. Even today, the etiologic mechanism(s) of radiation in the induction of cancer are poorly understood and the dose-response for chronic low-dose exposure remains a topic of intense debate among scientists.

[52] ICRP Publication 26, Recommendations of the ICRP. Annals of the ICRP 1(3) 1977.

Early standards focused on the prevention of acute health effects, which required large doses of radiation experienced primarily by workers. Significant reductions in radiation dose standards emerged in response to studies that firmly linked radiation exposure to various forms of human cancers. With the development of nuclear weapons, commercial nuclear power and other sources capable of exposing large numbers of people, separate standards and regulatory limits were established for the protection of the general public. A generic approach to the protection of the public was to set dose limits that were 10 percent of occupational limits. With further revisions to Japanese A-bomb dosimetry and cancer-risk coefficients, public dose limits were further reduced to their current level of 100 mrem/year from all man-made sources and to fractions of the limit for any single source. While some regulatory limits for a single source correspond to 25 mrem/year, others including DOE sites are restricted to 15 mrem/year.

In summary, dose standards for the whole body exposure of members of the public have declined over the past from 1,500 mrem/year in 1954 to the current 15 mrem/year. In addition, the provisions of ALARA in its various forms are an integral part of pertinent regulations. For a loss-of-use determination, several critical questions must be answered that include the following:

- Which (if any) of these standards may serve as an appropriate reference value?
- What is the appropriate time frame for applying a given dose limit?
- What dose limit applies to those years that predate any standard for members of the public?
- What is the legal limitation of a past dose standard that has since been revised and is now considered "unsafe"?

These are questions that involve the combined scientific and legal evaluation of the available information. In Figure 6-1, an overview is provided of the RMEI dose for each year as well as various standards that were used in loss-of-use determination. Based on the forgoing sections, the following approach was taken:

- With regard to dosimetric data, emphasis was placed on observed data. Since for most years the doses were dominated by internal exposure to Cs-137, the estimates for RMEI doses in chapter 4 were used. Only a small number of individuals were monitored in the years of maximum reliance on local food and is quite possible that non-monitored individuals have a higher Cs-137 body burdens. The maximum observed levels reflect data from a real person, hence the maximum measurement is a sound basis to estimate the dose to the “reasonably maximally exposed individual” (RMEI).
- With regard to applicable dose limits, appropriate limits were selected taking into account the principles of ALARA and justification, if applicable.
- Compliance determination is thus a two-step process. First, the RMEI dose is compared with numerical limits; non-compliance is given if the limit is exceeded. Second, applicable ALARA principals are tested; non-compliance is given if the exposure is incompatible with such principles.

In the following, a variety of criteria are used for loss-of-use determination:

Criterion A: Compliance with current NCT cleanup criterion of 15 mrem/year
Criterion B: Compliance with regulations that limit the genetic dose to populations

Criterion C: Compliance with the the numerical limits in applicable and relevant regulations (ARAR) supplemented with non-numerical provisions such as justification of the exposure and ALARA

Loss-of-use determination using criterion A: Compliance with current NCT cleanup criterion of 15 mrem/year

The RMEI dose for Utrik Atoll exceeds the NCT cleanup criterion[53] of 15 mrem/year for the entire time period. If a piece of property is deemed unsuitable for continued residence without remediation today, it is difficult to conceive that residents enjoyed a full and unrestricted use of of their atoll in past years.

If the NCT cleanup criterion of 15 mrem/year is used as criterion, it is concluded that the Utrik residents had no full and safe use of their Atoll from 1954 to 2001, for a total of 48 years.

Loss-of-use determination using criterion B: Compliance with regulations that limit the genetic dose to populations

As of 1959, the International Commission on Radiological Protection (ICRP)[54] suggested a limit for the total body dose of population groups to 2 rem over 30 years due to concerns regarding the genetic effects of ionizing radiation. Given the magnitude of the initial whole body exposure of greater than 50 rem and the substantial exposures after resettlement. The average dose to Utrik residents exceeded 2 rem over 30 years. If the residents received exposures which were considered unsuitable for population groups, it is difficult to conceive that residents enjoyed a full and unrestricted use of their atoll in such years.

If the ICRP population dose limit of 2 rem in 30 years (IRCP 2, 1959) is used as criterion and the initial 1954 BRAVO exposure and substantial exposures after resettlement is accounted for in determining compliance with the criterion, it is concluded that the Utrik residents had no full and safe use of their Atoll from 1954 to 2001, for a total of 48 years.

Loss-of-use determination using criterion C: Compliance with the numerical limits in applicable or relevant and appropriate requirements (ARAR)

For this determination, the use of ARAR (applicable or relevant and appropriate requirements) was used. The ARAR concept is defined in section 121(d) of the Comprehensive

[53] Nuclear Claims Tribunal (NCT) of the Republic of the Marshall Islands. Memorandum of Decision and Order, NCT No. 23-0902. December 21, 1998

[54] ICRP Publication 2. Report of Committee II on Permissible Dose for Internal Radiation (1959) Recommendations of the International Commission on Radiological Protection, Pergamon Press, Oxford (1959).

Environmental Response, Compensation, and Liability Act (CERCLA) as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA). Subpart E, Section 300.400(g) “Identification of applicable or relevant and appropriate requirements,” of the National Oil and Hazardous Substance Pollution Contingency Plan (NCP) (55 FR 8666) describes the process for attaining these ARAR requirements. “Applicable requirements mean those cleanup standards, standards of control, or other substantive environmental protection requirements, criteria, or limitations promulgated under Federal environmental or State environmental or facility siting law that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance found at a CERCLA site” (55 FR 8814). If a requirement is not applicable, it still may be relevant and appropriate. “Relevant and appropriate requirements mean those cleanup standards [that] … address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site” (55 FR 8817).

If the exposure of Utrik residents was not in compliance with applicable or relevant and appropriate requirements regulations, it is difficult to conceive that residents enjoyed a full and unrestricted use of their atoll. For this assessment, the ARARs applied are described in further detail above.

Compliance with ARARs for the years 1954 to 1956

In 1954, the numerical limit for compliance is 1,500 mrem/year (whole body dose), based on National Bureau of Standards Handbook 59[55]. The RMEI exposure to BRAVO and after resettlement resulted in whole-body dose to the RMEI far in excess of 1,500 mrem/year in 1954, 1955 and 1956. Hence, the decision to resettle Utrik Atoll in June of 1954 was woefully inadequate.

-> Because the RMEI dose exceeded the limit of 1,500 mrem/year to the whole body dose it is concluded that the Utrik residents had no full and safe use of their Atoll from 1954 to 1957 (4 years).

Compliance with ARARs for the years 1957 to 1959

In 1957, the numerical limit for compliance was changed by to 500 mrem/year (whole body dose) by the National Bureau of Standards[56]. The RMEI exposures in 1957 and 1958 clearly exceeded the level of 500 mrem/year. In 1959, the RMEI dose was below 500 mrem/year. However, the ALARA-like provisions in pertinent regulations were not met. Measures to reduce exposures such remedial action and supply of uncontaminated food as well as adequate monitoring were not provided by the U.S. AEC. It cannot be ascertained that “*every effort be*

[55] U.S. Department of Commerce, National Bureau of Standards. Permissible Dose from External Sources of Ionizing Radiation. Issued September 24, 1954. Washington (DC): U.S. National Bureau of Standards Handbook 59

[56] U.S. Department of Commerce, National Bureau of Standards. Maximum Permissible Radiation Exposures to Man. Washington (DC): Technical News Bulletin Vol 41, No.2, February 1957

made to reduce exposures to all types of ionizing radiations to the lowest possible level" [57] and that *"exposures be kept at a minimum insofar as it is practical"* [58].

-> Because the RMEI dose exceeded the dose limit of 500 mrem/year to the whole body dose in 1957 and 1958 the absence of adequate dose reduction and monitoring efforts by the U.S. AEC, it is concluded that the Utrik residents had no full and safe use of their Atoll from 1957 to 1959 (3 years).

Compliance with ARARs for the years 1960 to 1991

In 1960, the dose limit of 500 mrem/year (whole body dose) to members of the public was reaffirmed by the Federal Radiation Council (FRC) and published in the "Radiation Protection Guidance for Federal Agencies"[59]. The Guidance further limited the average annual dose to a *"suitable sample of the exposed population"* to 170 mrem/year (whole body dose) and further required that *"[t]here should not be any man-made radiation exposure without the emanation of benefit resulting from such exposure".* The FRC Guidance even goes so far as to stipulate that *"[t]here can be no single permissible or acceptable level of exposure without regard to the reason for permitting the exposure*" and that *"exposure to radiation should result from a real determination of necessity".* The Federal Report No. 1[60] that was published at the same time with the Guidance further clarified that "*every effort should be made to encourage the maintenance of radiation dose as far below this guide as practical*".

While the exposure to the Utrik RMEI did not exceed the 500 mrem/year limit set for exposure to individuals set in the FRC 1960 Radiation Protection Guidance, three non-numerical provisions that are necessary for compliance with the guidance were not met: (a) there was clearly no benefit from this exposure, (b) there was no real determination of necessity, and (c) not every effort was made to keep the RMEI dose on Utrik below the guide levels. The simple fact that Utrik residents could remain on their home atoll does not serve as a proper justification for the exposure and is not a benefit from the exposure. Measures to reduce exposures such remedial action and supply of uncontaminated food as well as adequate monitoring were not provided by the U.S. AEC. The fact that the Utrik residents were considered suitable study objects by some AEC scientists (see quotes in section 6.3) does not provide proper justification for resettlement and is further proof for non-compliance with ARARs.

-> The dose to the RMEI was not in compliance with the 1960 Federal Radiation Council (FRC) "Radiation Protection Guidance for Federal Agencies" due to the lack of benefit from the exposure and adequate and feasible dose reduction efforts. It is therefore concluded that the Utrik residents had no full and safe use of their Atoll from 1960 to 1990 (31 years).

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[57] U.S. Department of Commerce, National Bureau of Standards. Recommendations of the International Commission on Radiological Protection and the International Commission on Radiological Units 1950. Issued June 29, 1951. Washington (DC): U.S. National Bureau of Standards Handbook 47

[58] U.S. Department of Commerce, National Bureau of Standards. Maximum Permissible Amounts of Radioisotopes in the Human Body and Maximum Permissible Concentrations in Air and Water. Issued March 20, 1953. Washington (DC): U.S. National Bureau of Standards Handbook 52

[59] Federal Radiation Council. Radiation Protection Guidance for Federal Agencies. Federal Register, May 18, 1960

[60] Federal Radiation Council. Federal Guidance Report No. 1. Background Material for the Development of Radiation Protection Standards (Federal Radiation Council May 13, 1960)

Compliance with ARARs for the years 1991 to 1997
The year 1991 marks the year in which the limit of radiation dose to individuals to 100 mrem/year above background including the requirement to comply with ALARA principle was implemented in US regulations (in 10 CFR 20.1301) following earlier recommendations by International Commission on Radiological Protection. This limit was furthermore acknowledgement by U.S. DOE and U.S. DOI in 1992 applicable for the resettlement of Rongelap Atoll. The RMEI for Utrik residents was below 100 mrem/year in the time period. However, the criteria necessary for compliance with the ALARA provisions were not met: (a) exposures could have been reduced using state of technology available at the time, (b) there was clearly no demonstrated benefit from the exposure, and (c) societal and socioeconomic considerations were not properly addressed.

-> Because the RMEI dose was not in compliance with the ALARA principles because of lack of benefit and necessity and absence of dose reduction efforts, it is concluded that the Utrik residents had no full and safe use of their Atoll from 1991 to 1997 (7 years).

Compliance with ARARs for the years 1998 to 2001
In 1998, the Nuclear Claims Tribunal (NCT) of the Republic of the Marshall Islands adopted a dose limit of 15 mrem/year (whole body) to the maximum individual in the public from residual contamination[61]. The RMEI estimated dose for 1998 is estimated to be greater than 50 mrem/year in 1998 and would remain above 15 mrem/yr until about 2050 unless remedial activities are performed.

-> Because the RMEI dose on Utrik Atoll is not in compliance with the criterion set by the Nuclear Claims Tribunal (NCT) of the Republic of the Marshall Islands, it is concluded that the Utrik residents had no full and safe use of their Atoll for every year since 1998 until about 2050 unless remedial activities are performed. Up and including the year 2001, this amounts to 4 years of loss-of-use.

If compliance with dose relevant and appropriate requirements (ARAR) is defined to mean that the dose to the RMEI did neither exceed the numerical limit in such requirements and that that non-numerical criteria such as justification of the exposure and ALARA requirements were met even if the dose was below the numerical limit, it is concluded that the Utrik residents had no full and safe use of their Atoll from 1954 to 2001, for a total of 48 years.[62]

[61] Nuclear Claims Tribunal (NCT) of the Republic of the Marshall Islands. Memorandum of Decision and Order, NCT No. 23-0902. December 21, 1998
[62] If one were to considered for the loss-of-use determination only those years in which the RMEI dose exceeded the numerical limit, disregarding non-numerical criteria such as justification of the exposure and ALARA requirements, loss-of-use would be determined from 1954 to 1958 and from 1998 to 2001, for a total of 9 years.

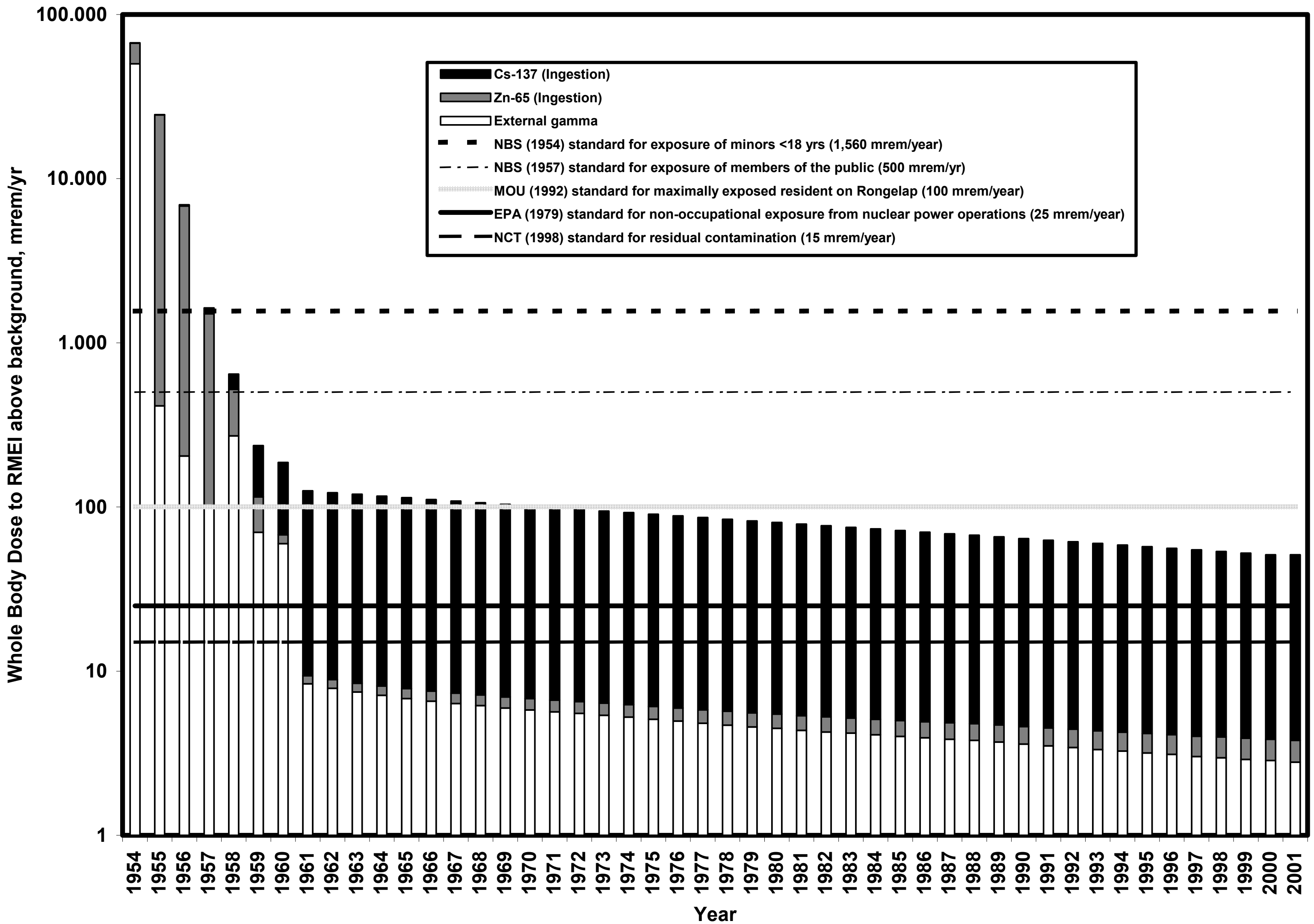

Figure 6-1. Comparison of radiation exposures to the whole body of the reasonably maximally exposed individual (RMEI) on Utrik Island with various limits for members of the public, 1954 to 2001

Conclusion regarding loss-of-use

It is the opinion of the author that the most appropriate basis for the loss-of-use determination is criterion C, compliance with the numerical limits in applicable and relevant requirements (ARAR) supplemented with non-numerical provisions such as justification of the exposure and ALARA. Because the exposure of the Utrik residents was not in compliance with ARAR requirements for all years from 1954 to 2001, it is concluded that the Utrik residents had no full and safe use of their Atoll for the entire time period from 1954 to 2001, for a total of 48 years.

6.3 Summary conclusions

The legal basis for a loss of use claim rests on the full and unrestricted land use. Due to geographic, economic and cultural factors, full and unrestricted land use demands that Utrik and its three neighboring atolls be sufficiently safe from radiological risks that result from the residential use of these atolls and a total reliance on locally grown foods.

In this report, historical data were used to reconstruct exposure to Utrik residents since the time of the U.S. Nuclear Testing Program in the Marshall Islands. Of greatest significance to the issue of loss of use was the contamination of Utrik, Taka, Bikar, and Taongi Atolls following the March 1, 1954 BRAVO shot.

For nearly three days, the residents of Utrik lived with and ingested the fallout that had contaminated their lands. After some delays, they were last to be evacuated on March 4, 1954 to Kwajalein where they were studied by American scientists, who were interested in understanding the effects of fallout on humans. At the time, they were told that their evacuation was a precautionary measure because “the ash that fell on them was poison and very dangerous.”

In the following three months, the United States detonated five more thermonuclear weapons as part of the Castle series tests. After only three months following BRAVO shot and a mere seven days after the last of the Castle series tests, the people were returned to Utrik in June 1954 and were told that their homelands were once again “safe” for habitation. A thorough review of DOE documents shows no evidence that any meaningful survey studies had been conducted at Utrik to support the claim of a “safe” resettlement. The only available measurements on which this decision could have been made were ambient dose-rate measurements, which at best provided the means for estimating external body radiation.

What was woefully missing in this decision process to resettle Utrik were environmental survey data, which would have provided a reasonable approach for estimating internal radiation doses from the ingestion of contaminated terrestrial foods, marine species, and drinking water. (On the basis of current knowledge, external exposure constitutes less than 10 percent of total exposure for any individual consuming local foods.)

Such studies, however, were only performed years to decades later and yielded some unexpected if not startling results. For example, it was not until 1957 that survey data unexpectedly showed high levels of Zn-65 in fish harvested from the lagoons of Rongelap and Utrik. As an activation product with a physical half-life of only 245 days, the residual high presence of Zn-65 in the marine environment years after BRAVO implies concentration levels in fish that were one to two orders of magnitude higher at time of resettlement. The importance of Zn-65 must be further viewed in context with the fact that upon return to Utrik in June of 1954, residents almost exclusively relied on fish for dietary proteins since their livestock had been destroyed following BRAVO.

Equally unknown at time of resettlement were the unique characteristics of atoll coral soils with respect to Cs-137. For nearly all soils in the United States and the world, the presence of Cs-137 in soil has only a limited ability to contaminate food crops. Referred to scientifically as the soil-to-plant transfer factor, only small fractions of Cs-137 are transferred from soil to plants in normal soils containing significant amounts of clay. Unique to coral soils of the Marshall Islands is the total absence of mineralized clay and a soil-to-plant transfer factor that is two to three orders of magnitude higher (i.e., 100 to 1000 times higher) than conventional soils.

In summary, survey data and information needed to declare Utrik "safe" did not exist at the time a decision was made to resettle Utrik in June 1954. In fact, it may have been the very absence of such data that served as the impetus for resettlement. Thus, "survey data" following resettlement could in fact be more accurately termed experimental study data. This might be explained by the following.

A 1954 telex[63] illustrates a primary motive of the AEC in support of the resettlement of Marshallese residents:

> *"After talking to the Marshallese, I feel that they are not as concerned with the explosions as they are that the tests might force them to lose their home lagoons. The fate of the Bikinians 'evicted in 1946 and now on isolated Kili' stands like a ghost over these people. Find a solution to their lot and what dissension has risen here against the tests will disappear."*

During a closed-door meeting held by the U.S. AEC Committee on Biology and Medicine on January 13 and 14, 1956, the following statement was made by one of the committee's leading scientists[64]:

> *"We have a few things that we are thinking about for the immediate future and would like to mention a few of these.*
>
> *We think that one very intriguing study can be made and plans are on the way to implement this -- "Uterik" Atoll is the atoll furtherest from the March 1st shot where people were exposed got initially about 15 roentgens and then they were evacuated and they returned.*
>
> *They had been living on that Island; now that Island is safe to live on but is by far the most contaminated place in the world and it will be very interesting to go back and get good environmental data, how many per square mile; what isotopes are involved and a sample of food changes in many humans through their urines, so as to get a measure of the human uptake when people live in a contaminated environment.*
>
> *Now, data of this type has never been available. While it is true that these people do not live, I would say, the way Westerners do, civilized people, it is nevertheless also*

[63] Reproduced in Appendix B
[64] Cover page and the select passage reproduced in Appendix B.

> *true that these people are more like us than the mice. So that is something which will be done this winter."*

In the 56th meeting of the U.S. AEC Committee on Biology and Medicine on May 26 and 27[65], 1956 one member stated that the return of the Rongelap community to their home atoll *"is an ideal situation to make your genetic study. Its is far more significant than anything you could get out of Hiroshima and Nagasaki"*.

On November 16 and 17, 1956, after discussing the means of *"continuing the monitoring of these natives and also those from the Island of Uterick for comparison purposes"*, the U.S. AEC Committee on Biology and Medicine[66] approved the proposal to return the Rongelapese to their native atoll. That easy access to valuable scientific data was considered a major benefit of the resettlement of Utrik and Rongelap Atoll after BRAVO is documented also in a 1958 report by Brookhaven National Laboratories[67]:

> *"Even though, as pointed out, the radioactive contamination is considered perfectly safe for human habitation, the levels of activity are higher than those found in other inhabited locations in the world. The habitation of these people on the island will afford most valuable ecological radiation data on human beings."*

From the above it is clear that the decision to return Utrik residents to their home atoll in 1954 and leave in their contaminated home atoll was not made out of consideration to keep their radiation exposures as low as reasonable. In particular, the following provisions for radiation protection that were clearly spelled out in pertinent regulations at the time were not followed:

1. No efforts were made to reduce exposures to all types of ionizing radiations to the lowest possible level;
2. Exposures to Utrik residents were not kept at a minimum;
3. Unnecessary exposure to radionuclides were not avoided; and
4. There was no demonstrated benefit for Utrik residents as the result of the exposure.

In contrast to the above, there is ample evidence that the resettlement of Utrik Atoll in June of 1954 was driven in part by the quest for scientific studies. On the basis of available documents, it therefore appears that the decision to return Utrik residents to their home atoll in 1954 and leave in their contaminated home atoll was designed not to disturb the continuation of the testing program and to provide radiation data on human beings. The Utrik resident were largely kept uninformed about important issues regarding the radioactive contamination of their home atoll.

A claim for loss of use can be made in behalf of Utrik residents who in the absence of reasonable precautions, prematurely returned to their homelands in June 1954, suffered substantial and avoidable radiation doses without proper justification and benefit from 1954 to 2001 and therefore had no full and safe use of their Atoll, for a total of 48 years.

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[65] Cover page and the select passage reproduced in Appendix B.
[66] Cover page and the select passage reproduced in Appendix B.
[67] Conard R.A., Meyre L.M., Rall J.E., Lowery A., Suen A.B., Cannon B., Carter L.E., Eicher M. and Hechter H. (1958). March 1957 Medical Survey of Rongelap and Utrik People Three Years after Exposure to Radioactive Fallout. Brookhaven National Laboratory, Upton NY, BNL 501, p.22