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RONGELAP REASSESSMENT PROJECT

REPORT

July 22, 1988

Pursuant to the Compact of Free Association Act of 1985, Public Law 99-239, January 14,1986 (99 Stat. 1783-84) and administered by the Republic of the Marshall Islands.

Rongelap Reassessment Project
1203 Shattuck Ave., Berkeley, CA 94709
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JULY 22, 1988

TO: The President and Congress of the United States

FROM: Henry I. Kohn, Referee

Pursuant to the Compact of Free Association Act of 1985, Public Law 99-239, January 14, 1986 (99 Stat. 1783-84) and administered by the Republic of the Marshall Islands.

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I must ask the Government's indulgence for not having finished this document sooner. My decision was based on waiting for two sets of critical data which are important in helping to provide insight and orientation -- which otherwise would have been lacking -- with respect to two major problems.

Henry I. Kohn

Corrected edition, August 12, 1988

ABSTRACT

The task has been to determine whether or not DOE's 1982 Report proved that Rongelap Island is safe for habitation. The island was contaminated in 1954 during the testing of nuclear weapons.

It should be borne in mind that the dosage under discussion is current dosage, e.g., from 1990 to 2020, and not that from exposure in 1954. The current dosage over a 30-year period is a matter of 3 rem, whereas the original exposure was one of 190 rem in 2 days.

The evidence used by DOE plus additional and more recent information have been reviewed.

Rongelap Island is safe for habitation by adults provided that the diet is equivalent to that formerly used. I do not believe that such a diet would present any difficulty.

Measurement of plutonium excretion in the urine of Rongelap residents (1981) shows very great variation. The matter is a potential cause of concern and should be studied although it is not associated with overexposure.

The dose to infants and small children is another potential cause of concern. Preliminary findings from a diet survey indicate, however, that the dosage is not excessive. This study should be continued.

The whole-body counting for cesium should be resumed to establish a base line for later work at the time of resettlement.

In the course of planning for atoll resettlement, the fact that Rongelap Island appears safe for resettlement now should not be lost sight of.

Planning for atoll resettlement should consider the possible use of potassium-salt treatment of the soil and soil removal as studied at Bikini.

To obtain a brief summary of the key facts of dosage and the more general, but important human factors that will affect decision-making, the reader is referred to Section 4.5 (Dose Summary) and to Section 5 (Discussion and Recommendations.)

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(cont.)

7. NOTES

1. INTRODUCTION

1.1 Task

Rongelap Atoll was contaminated with radioactive fallout in 1954 as a result of the Bravo thermonuclear test-shot at Bikini, 130 miles away. In 1978, to inform the people of the Northern Marshall Islands of the extent of residual contamination 24 years later, and of its potential effects upon their health, DOE (Department of Energy) surveyed the region and subsequently issued a specially prepared book report in Marshallese.

The book was entitled, The Meaning of Radiation for Those Atolls in the Northern Part of the Marshall Islands that were Surveyed in 1978, and was published in 1982. (We shall refer to it as DOE-1982.) The first part dealt in general with radiation and fallout, and how they might affect plants, animals and man. The situation at Rongelap was dealt with specifically on pages 38 - 39. (Note 1)

DOE's assessment of Rongelap Island was not accepted by the Rongelap people, so much so that in 1985 the residents abandoned their homes and moved to Majieto in Kwajalein Atoll.

The U. S. Congress, therefore, provided for an independent assessment of DOE's conclusions for Rongelap Island in the Compact of Free Association Act of 1985 (U.S. Public Law 99-239, section 103(i); see Note 2). The functions of the present report are therefore as follows:

> "[The referee shall] review the data collected by the Department of Energy relating to the radiation levels and other conditions on Rongelap Island resulting from the thermonuclear test...The purpose...shall be to establish whether the data cited in support of the conclusions as to habitability of Rongelap Island as set forth in the [book] ...are adequate and whether such conclusions are supported by the data....If...the data are inadequate to support...habitabilty...the government of the Marshall islands shall contract...[for]...a complete survey...[and for recommendations of]...the steps needed to restore habitability..."

It should be noted that the law is quite specific in referring to Rongelap Island, not Atoll, and accordingly this Report concentrates on that Island, the chief residence of the Rongelap people. However, data and comments on other islands of the Atoll are included.

1.2 Procedure

The sections of DOE-1982 that deal with Rongelap and are now under review were discussed with DOE-1982's senior author, Dr. William Bair (Pacific Northwest Laboratories, Richland, WA 99352), and Dr. Bair has read, especially, the parts of the Report referring to them. It should be noted that DOE-1982 is a statement by DOE and is always referred to as such in this Report.

Dr. William Robison (Lawrence Livermore National Laboratory, Livermore CA 94550), who supplied the field data and the dose calculations for DOE-1982, has provided additional data for the present report, and has discussed his findings with me.

Relevant Rongelap studies that were supported by DOE at Brookhaven National Laboratory (Upton, New York 11973), were discussed with Dr. William H. Adams, (Medical Department), Dr. Robert Conard and Mr. E. Lessard (Safety & Environmental Protection Division).

It was considered important and efficient to bring together all of the data that are now available rather than to restrict this report to the limited data on which DOE-1982 was based. With the concurrence of the Marshallese Government, therefore, additional information from DOE-supported laboratories, that became available after DOE-1982 had been written, was made available to us by Adams, Lessard and Robison. Also, we have taken a number of samples in the field and have had them analyzed independently, in accordance with the wishes of the Rongelap people.

Other sources of information in the international literature have been used and are cited in the text.

We have also discussed from time to time various matters relating to the Report, or the progress made in developing it, with Rongelap Senator Jeton Anjain, P.O. Box 1006, Majuro, Republic of the Marshall Islands, 96960.

The task has been greatly facilitated by Mr. Peter Oliver, Special Assistant for Compact Affairs, Republic of the Marshall Islands, P.O. Box 15, Majuro, 96960.

The Reassessment Report (the present document) was written by Henry I. Kohn in his capacity as Referee under contract with RepMar. The opinions and statements made are therefore his responsibility. The task, however, was greatly facilitated by discussions with members of an international panel of consultants, selected to represent a variety of overlapping specialties that would cover the problems under examination. Owing to time constraints, none of the consultants has read the final version of this Report. All have read the Preliminary Report (April 20, 1988), and I have discussed various parts of the present document with various consultants by correspondence and especially by telephone.

The following scientists participated in the Project.

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UTE BOIKAT, M.Sc., Ph.D. (radioecology), Executive of the Department of Public Health, Freie und Hansestadt Hamburg, Tesdorpfstr.8, D-2000 Hamburg 13, Federal Republic of Germany. ((011-49)40-44195334). Dr. Boikat has been a member of the consulting firm of Kollert, Donderer and Boikat of Bremen which assisted in some of the analytical work.

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2. BACKGROUND -- THE RONGELAP EXPERIENCE

Rongelap Atoll is located about 2,500 miles southwest of Hawaii, at 12°N, 167°E (Fig. 2 #1). It comprises more than 50 low-lying islands and islets, total area 3.07 sq. miles, which bound a lagoon of 400 sq. miles. The largest and by far the most important island, Rongelap, has an area of 0.3 sq. miles.

The geological structure is that of a coral reef atoll resting on a submerged volcanic mass. The islands are made of reef debris, primarily of sand and gravel size, and reef organisms.

The atoll is typical in appearance, and the islands are covered with vegetation. However, a major factor limiting the kinds of plants that can be grown as staples is the long dry season.

The Marshall Islands Statistical Abstract of 1986, issued by the Republic, lists the population of the atoll as totalling 235. Previously, it was 165 in 1973, 189 in 1967, 264 in 1958. In 1954 at the time of the Bravo incident, 84 persons were evacuated. (These fluctuations reflect the need to work elsewhere.) Earlier records for Japanese and German periods of control are: 99 in 1945, 98 in 1935, 110 in 1920, 100 in 1906, 120 in 1860.

However, Mr. Peter Oliver, the Republic's Special Assistant for Compact Affairs, has informed me that the Rongelap Distribution Authority now makes per capita payments from its Nuclear Claims Fund to 1,578 individuals. Currently, these amount to $1480 per year to those exposed to fallout in 1954, and $480 to others. The Council has also determined that 2,277 individuals qualify for the benefits of the Section 177 Health Care Program as a result of their ties to Rongelap.

2.1 Bravo test -- 1954

The initial event occurred on March 1, 1954, when a 17-megaton-yield thermonuclear device was set off at Bikini Atoll, the Bravo test. The device was 1000 times as powerful as the bombs that destroyed Nagasaki and Hiroshima; its cloud rose 25 miles above the earth, and after 10 minutes had a diameter of 70 miles.

It had been planned that the "cloud" would be blown to the west and north (Fig. 2.1 #1). Unexpectedly for whatever reason (Note 3), it was blown to the east so that at about 5 hours after detonation fallout began at Rongelap Atoll, and during the ensuing 7 hours fell in such quantities as to suggest to Rongelapese, who had never seen snow, that it was snowing (Sharp & Chapman, 1957). Rather than avoiding contact, children played in the powdery, finely granular fallout, and no particular effort was made to separate it from food or clothing. No warning was or had been issued by the military.

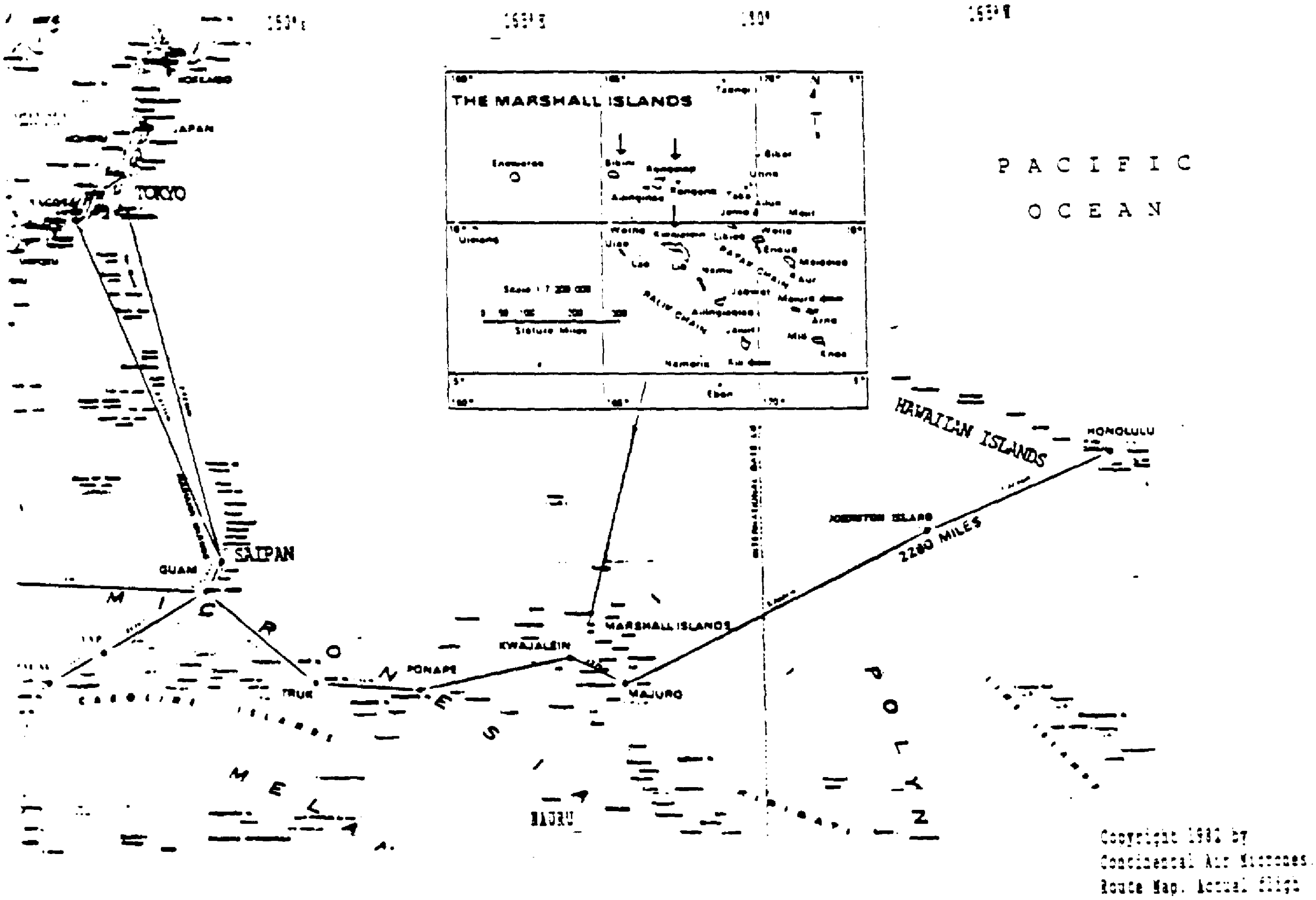

Fig. 2.1 LOCATION OF THE MARSHALL ISLANDS

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About 50 hours after the "shot", the Navy removed the 64 Rongelap residents from the Atoll to the medical base at Kwajalein (Sharp & Chapman, 1957; Cronkite et al, 1956) Also, eighteen visiting Rongelapese were removed from Sifo Island, Ailingnae Atoll, and 157 Utirik people from Utirik Atoll. It was immediately recognized that the surveillance and care of these people required far more professional staff than the base could supply, and a special medical team hurriedly organized for this purpose in the United States, utilizing naval and AEC personnel, reached the base 8 days after the detonation.

Consistent with a whole-body dose of 190 rem (over two days), two-thirds of the Rongelap group experienced nausea, 10% with vomiting and diarrhea, which cleared within three days or so, and all showed depressed white-blood-cell counts (Cronkite et al, 1956). As a result of the skin dose from physical contact with fallout, about 70% developed skin lesions of widely varying severity after a latency period of two to three weeks. Most of these were to heal successfully but a few developed significant scarring. There were no deaths within 60 days of exposure.

The most "significant" part of the initial exposure produced no immediate signs or symptoms. A half-dozen thyroid-seeking radionuclides entered the body through fallout-contamination of food and water. Over the course of the following weeks these iodine and tellurium radionuclides delivered doses that eventually caused thyroid hypofunction and the appearance of thyroid tumors.

The Bravo test posed new dosimetry problems, only vaguely sensed before. Owing to the gigantic energy-yield at ground level, great quantities of coralloid radioactive material were generated (Hiroshima and Nagasaki had involved high air-bursts): 142 radionuclides were involved whose radiations and rates of decay varied greatly, and whose eventual effects depended on the weather conditions and the living habits of the exposed population.

At the time of evacuation, the exposure rate in Rongelap village was 1.2 - 2.3 R/hour. The whole-body dose of "175 R in air" reported in 1956 was approximately correct. The dose estimate for the thyroid gland, however, was much too low because only iodine-131 had been considered in the calculation. As a result, the appearance of thyroid disease later on was quite unexpected.

An upwards revision of thyroid dose was reported in 1964 when iodine-133 and iodine-135 were included. (James, 1964). The revisions of 1984 (Lessard et al, 1985; Lessard, 1984a), based on a comprehensively planned attack on the problem (Bond et al, 1978), put the mean adult whole-body dose at 190 rem. The revised total dose to the thyroid gland, including contributions from all seven important radionuclides was greatly increased and varied significantly with age at exposure in 1954 -- from 5,200 rem for a one-year old to 1,600 rem at age 14, and 1,200 rem for the adult male. It was estimated that 95% of the thyroid dose was received during the first three post-exposure weeks, and 100% within three months (Note 4).

2.2 Return to Rongelap - 1957

The AEC (Atomic Energy Commission)[1/] decision that Rongelap had become safe was based on field data by the Radiation Ecology Laboratory, University of Washington College of Fisheries, and dose calculations by AEC staff._ For 1957 the annual external gamma"dose" at Rongelap Island was estimated to be less than 0.5 roentgen, the maximum permissible for the general population, and it was expected to decline owing to physical decay. However, the AEC assessment was inadequate with respect to internal dosage resulting from contaminated food (Note 5).

In 1957, therefore, the Rongelap people returned to Rongelap Island. In March 1958 there were 81 persons there who had been exposed on Rongelap or Ailingnae, and approximately 100 others who had not.

To anticipate any late effects that might follow the acute exposures of 1954, the AEC commissioned Brookhaven National Laboratory's Medical Division to establish the Marshall Islands Medical Program, whose staff has visited the Rongelap people once or twice a year since 1957 (Note 4). Since Rongelap soil still contained low levels of radionuclides which might enter the body through the food chain, the program included equipment to measure radionuclides within the human body (whole-body counting). Since 1978 the counting program has been operated by Brookhaven's Safety & Environmental Protection Division.

2.3 Rongelap: 1957-1987

The medical findings were summarized or updated by R. A. Conard, who led the whole program for many years (Conard et al. 1958; 1975; 1980) and more recently by Adams et al (1984). The status of the dosimetry, originally included in the Conard reports, has been more recently reported on by Lessard et al (1984; 1985). In brief, on the basis of these reports, the following sequence of health-related events occurred over the past 30 years.

1957-63. Among the usual problems in the Marshall Islands were parasitism, chronic skin disease, diabetes adult-onset type II, and bad teeth in adults, and a variety of infant and childhood diseases including infant diarrhea.. The vast majority of skin reactions to radiation had disappeared without sequelae, except for scarring in the most heavily irradiated cases. No skin cancers were observed. Two possible examples of radiation effects occurred. First, it was reported that about twice as many abnormally terminated pregnancies occurred among the exposed parents as would be expected normally. Second, two boys showed markedly stunted growth, suggesting thyroid deficiency.

[1/] The AEC was the predecessor of DOE.

1964-75. Unquestionable damage to the thyroid gland, especially to those exposed below the age of 10, made its appearance. A reexamination of earlier estimates of dose to the thyroid gland led to their elevation by a factor of about 2 for adults, and 5 or more for children. The administration of thyroid hormone (interrupted on occasion) to the entire exposed population was begun in 1965 as a prophylactic measure against thyroid neoplasia (nodules, cancer), and also to correct for possible losses in thyroid function.

By the end of 1974 (Fig 2.3 # 1), the thyroid tumor record was as follows:

Age below 10 in 1954: 17 tumors in 19 persons examined, including 1 cancer.

Age 10-18 years in 1954: 2 tumors in 12 persons examined.

Age above 18 years in 1954 : 3 tumors in 33 persons examined, including 2 cancers.

Almost all persons with thyroid nodules were sent for surgical treatment to the Cleveland Metropolitan Hospital, Cleveland, Ohio. Each one was compensated at the rate of $25,000 per surgery.

The occurrence of thyroid disease as well as a case of acute leukemia worried the Rongelap people. The medical team was accused of having deceived the Rongelap people and of using them as guinea pigs. The Brookhaven medical services were boycotted during 1972, but they were accepted later in the year after a favorable report on the matter by an international committee.

1976-79. More thyroid nodules appeared. The Rongelap people continued to be worried. They asked for an independent health review which was not granted. A group of Brookhaven scientists proposed a comprehensive dosimetry review (Bond et al, 1978), which DOE then funded (Lessard, 1984a; Lessard et al, 1984c; Lessard et al, 1985). Independently, DOE initiated a "Northern Marshall's Survey" based on an aerial survey by EG&G and some terrestrial work by Lawrence Livermore National Laboratory (Robison et al, 1980; Robison et al, 1982b; Tipton & Meibaum,1981).

1980-84. DOE summarized its survey results in 1982 with a report in Marshallese, embellished with colored illustrations. (This is the book, DOE-1982, under review in the present report. See Note 1.) DOE-1982 stated that the U. S. radiation guide was 5 rem in 30 years, and that the current whole-body dosage at Rongelap Island was 2.5 rem in 30 years. On some other Rongelap-Atoll islands not used for permanent residence the dose might be 2 to 5 times as much. The Rongelap people requested the Government to transfer them to another atoll. Significant parts of the anti-nuclear documentary film, Half-Life, were filmed at Rongelap. The film suggested that the people had been used as "guinea pigs".

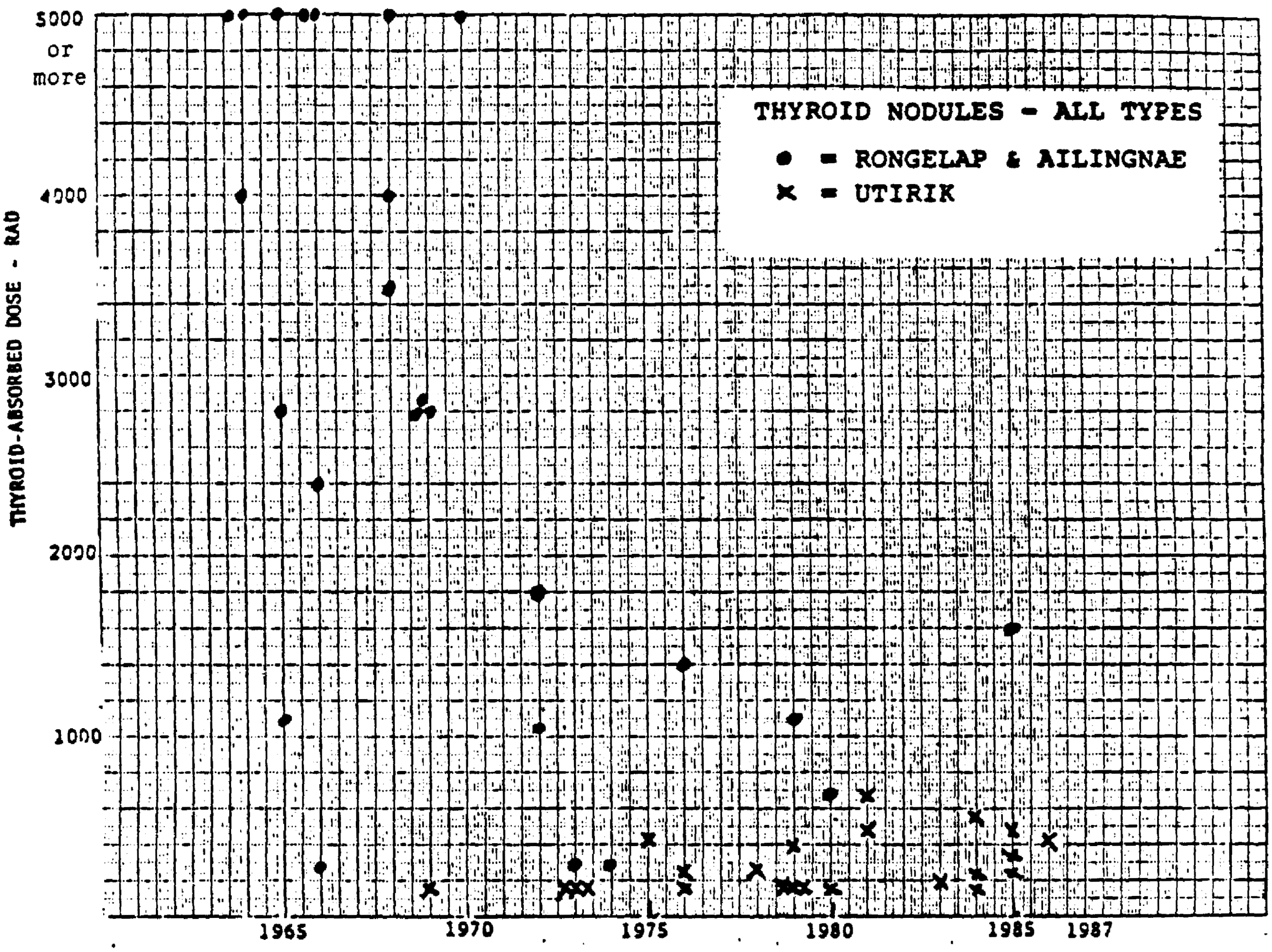

Figure 2.3 #1. Latency period for appearance of thyroid nodules related to thyroid dose received in 1954 at Rongelap & Ailingnae, and Utirik. Details on thyroid dosage are given in Table N.4 #2.

(Figure courtesy of W. H. Adams, Brookhaven National Laboratory)

1985. The Rongelap people abandoned Rongelap and sailed for Majieto Island in Kwajalein Atoll. The U. S. Congress passed the Compact of Free Association Act of 1985 (Public Law 99-239) of which Section 103(i) is the basis for the present inquiry (Note 2).

1987 The following points are of major interest for the present report.

(a) A clear distinction should be made between the late effects of the large acute exposure in 1954 (190 rem whole-body) and the possible (but as yet undetermined) effects of the much smaller chronic dose since resettlement in 1957-1978 (~3.5 rem or less).

(b) The original dose estimates for the 1954 exposure were much too low for the thyroid gland (Cronkite,1954; Dunning, 1957). The necessity for major correction later on weakened or destroyed Rongelap confidence in DOE. The annual radiation doses during the first years of resettlement may also have been underestimated, but the corrections would be very much smaller.

(c) The occurrence of thyroid tumors (~ 30%) 10 years or later after returning to Rongelap (Fig. 2.3 #1; Note 4B) has been a confusing experience for the Rongelap people. In addition, eight cases of hypothyroidism have been observed (Adams 1988).

(d) No significant increase in tumors outside of the thyroid gland has been seen (Adams et al, 1984), except for 1 basal cell epithelioma in 1987 (Adams 1988) in the 81 persons at risk.

(e) No obvious gross difference in survivorship between 1954-exposed and 1954-unexposed groups has occurred (Fig. 2.3 #2). Although statistically significant decreases in some blood-cell types have been noted (Adams et al, 1982), none has been clinically significant.

(f) Based on four parameters (longevity, thyroid nodules, carcinoma, blood counts), there is no evidence of effects from the chronic low-level exposure associated with length of residence on Rongelap since 1957 (Note 4(b)). These studies are admittedly exploratory. However, the average dose over the period 1957-78 is quite small (3.5 rem or less), and will be accumulated at much lower rates in the future.

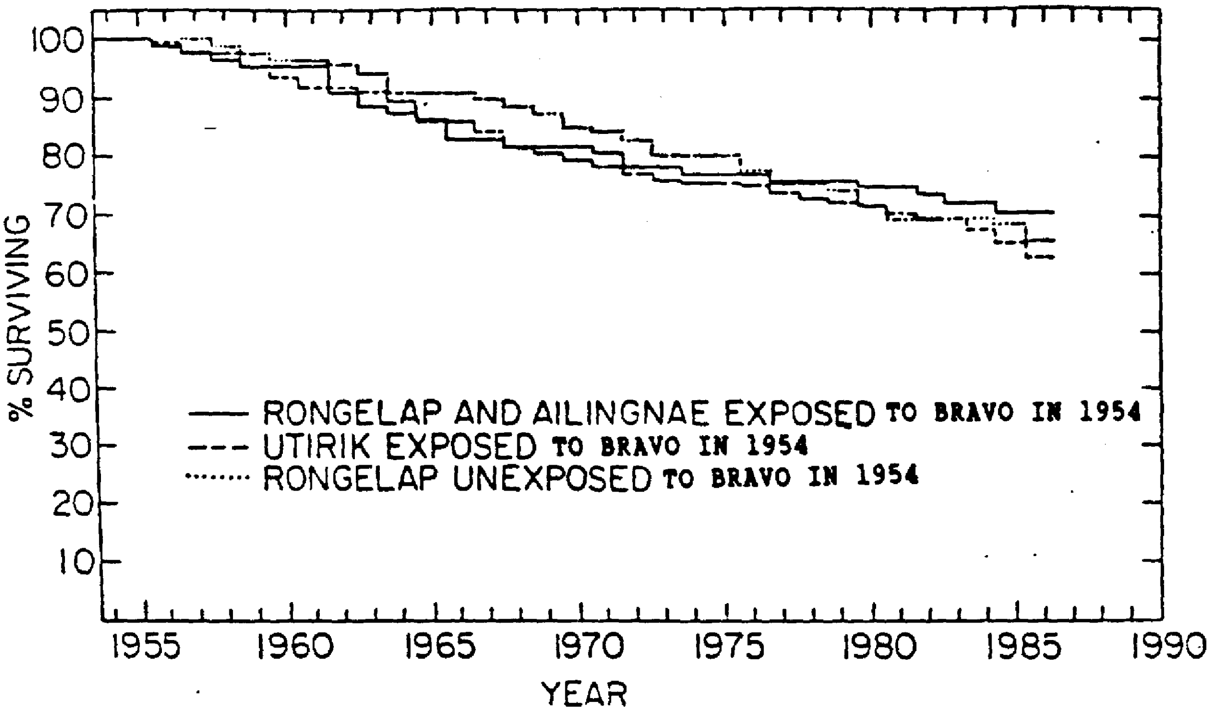

FIGURE 2.3 #2 Survival as a function of time after 1954.

The numbers exposed and whole-body doses were: Rongelap, 67 persons, 190 rem; Ailingnae, 19 persons, 110 rem; Utirik, 167 persons, 11 rem. The unexposed group of 86 Rongelapese was matched (age, sex) in 1957 to the Rongelap-Ailingnae group and has been followed for survival annually.

(Figure courtesy of W. H. Adams, Brookhaven National Laboratory.)

3. REASSESSMENT

With the foregoing as background, let us now attempt to answer the questions which the Congress has asked: Were the doses used by DOE-1982 correct (Robison 1982b)? Does it follow that Rongelap is habitable? If not, what should be done?

It should be noted that the technical position has changed since 1982. More data have been accumulated so that the original meager sampling has become more robust. In addition, we shall consider the findings of the Brookhaven National Laboratory, using an important method which DOE-1982 did not consider, and also our own findings.*

The data base employed by DOE-1982 comprised the results of the Northern Marshall Islands Survey of 1978 (September-November) which had been planned as an aerial reconnaissance to map external gamma-ray exposure rates (normalized to 1 meter above ground level) (Tipton & Meibaum,1981). Two helicopters were employed, operating from a major support vessel, the U.S.N.S. Wheeling.

Subsequently the Livermore Laboratory program was added to obtain soil, water, vegetation and fish samples at each atoll "as time and facilities might permit" (Robison et al, 1981, Part 1). The time spent at Rongelap Atoll permitted 7 days for 9 islands, of which the major one was Rongelap. Operating from a large ship that had to cruise at a considerable distance offshore, and whose primary function was aerial reconnaissance, restricted the terrestrial work significantly.

The radionuclides dealt with were five: cesium-137, which is distributed throughout the body; strontium-90, a bone seeker; and the very poorly absorbed plutonium-239.-240 and americium-241, which have very long half-lives and which are tightly bound by bone, liver and testes (Table 3: #1).

The Livermore group took soil samples from some 25 scattered locations on Rongelap Island whose averages (picocuries/gram) for 0-10 cm depth were: cesium-137, 12; strontium-90, 7.1; plutonium-239,-240, 2.6; americium-241, 0.9 (Table 3: #2). These 1978 levels were about twice those for Eneu, Bikini Atoll.

This soil contamination provided the basis for human exposure in two ways. Radiations that emanated from the ground or standing vegetation led to external dose. Radiations that emanated from food and water after entering the human body were responsible for internal dose.

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* B. Franke states that the enabling legislation calls for study of only the original findings and report. A second committee should consider subsequent findings, and a third group should execute its recommendations.

The total dose received was the sum of the external and internal doses. The external whole-body dose was estimated by measuring the exposure in air (e.g., at 1 meter above ground) and applying a factor based ultimately on measurements with phantoms to the meter reading. The internal dose was estimated by the Livermore group on the basis of an assumed diet and the analysis of the radionuclide contents of Rongelap food products in it.

The lagoon and its fish were found to be a trivial source of dose. Ground water (well water) was an unimportant source, since its activity was very low and, in any case, the people relied heavily on catchment of rain rather than wells (Noshkin et al 1981).

Before considering the data, the nonprofessional reader may wish to consult Note 6 which explains the radiological usage of such terms as exposure and dose, and the definition of their units. It may also be noted here that my use of the term whole-body dose (internal) usually signifies the committed effective dose equivalent; the tissue dose (internal) is usually the committed dose equivalent. DOE-1982 used integral doses calculated by the Livermore group, i.e., the annual dose (not committed dose) for each year was summed for the period of exposure.

TABLE 3. #1

SOURCES OF FALLOUT RADIATION

Radionuclide	Half-life[a]	Principal Radiations[a]			Fraction absorbed from gut in adults[e]	Annual dose (rem) per pCi/g in tissue[f]	
		[b] α	[c] β	[c,d] γ		soft tissue	bone marrow
	Years	MeV	MeV	MeV			
Cesium-137	30	-	0.187	.66	1.0	.010 (muscle)	.009
Strontium-90	29	-	1.13	-	.3	-	.005
Plutonium -239	24,065	5.23	-	-	.001	1.93 (liver)	0.63
-240	6,537	5.24	-	-	.001	1.93 (liver)	0.63
Americium -241	432	5.57	-	-	.001	2.06 (liver)	0.68

a/ ICRP Publication 38. (Radionuclide transformations)
b/ Quality factor, 20.
c/ Quality factor, 1.

d/ X and gamma rays are omitted whose total contribution to dose would be less than 10%.

e/ ICRP Publication 30. Supplement to Part 1. (1980), and ICRP Publications 48 and 51 for transuranics. The half-retention time in liver is 20 years, in skeleton 50 years for the transuranics.

f/ Dose in 1 year for an activity of 1 pCi/g maintained for that year in the tissues which receive the highest dose when the radionuclide is ingested. (Reference, See Footnote e/.)

TABLE 3 #2

RONGELAP ISLAND: RADIONUCLIDE SOIL PROFILES[a] (1978)

Depth (cm)	Average specific activity for dry soil (pCi/g)			
	Cesium-137	Strontium -90	Plutonium -239,-240	Americium -241
0-5	15	6.9	3.2	1.0
5-10	9	7.7	2.0	.78
10-15	5.4	6.7	1.1	.41
15-25	2.6	4.5	.35	.18
25-40	1.8	2.1	.07	.08
0-40	5.0	4.6	.89	.35
Number of profiles	27	20	18	17

[a] The 1978 profiles are from Robison et al, 1982, Part 4, Appendix B.

4. DOSE

DOE-1982 reported doses for persons living on Rongelap Island for the period 1978-2008; for the corresponding period 1990-2020, they would be 25% less:

(a) The "highest average amount of radiation the people might receive in any part of the body" was 2.5 rem (over 30 years). I take this to be Livermore's "integral dose" in which each year's delivery is summed for 30 years (Robison et al, 1982b, Table 17). I will compare it to the committed whole-body dose (rem) for 30 years (i.e., the committed effective dose equivalent for a standard man).

(b) The corresponding bone marrow average would be 3.3 rem (Robison et al, 1982b, Table 14). I take this to be the marrow "tissue dose" and it is approximately equal to the committed dose equivalent.

DOE-1982 stated that the doses are based on the condition of "local food only from Rongelap Island" (Note 1). However, the doses in fact had been calculated by the Livermore team (Robison, 1982b) for the community type B diet (Naidu et al, 1980). That diet involves the use of imported foods brought in on a regular basis by supply ship to supplement local produce. Without such imports, the doses would be higher.

DOE-1982 used the Livermore findings, but failed to utilize those of Brookhaven National Laboratory. These included whole-body counting to determine cesium-137, a method superior to that which calcultates dose from the diet.

More recently, Brookhaven's results with the fission track method to determine plutonium in urine, and from it the committed effective dose equivalent, have yielded doses which disagree with those of the Lawrence Livermore Laboratory based on diet. This will be discussed.

4.1 External Dose

The 1978 aerial survey (Tipton & Meibaum, 1981) provided DOE with important information on exposure to fallout in the Northern Marshall Islands. As the survey proceeded south and east from Bikini Atoll, the seat of the Bravo shot, the external exposure rate fell (Table 4.1 #1). It was calculated for 1 meter above ground level.

At Rongelap Atoll (Figure 4.1 #1), the islands fell into four exposure groups (microroentgens per hour) from north to south: Naen, Yugui, Lomuilal (28-43 μR/h), Eniaetok, Kabelle, Gogan (10-27 μR/h); Busch, Borukka, Gabelle, Tufa (5-9 μR/h); Rongelap and Arbar (4.1-4.5 μR/h).

The external dose (whole-body), was calculated from exposure by my assuming 1 roentgen = 0.7 rem tissue dose (Kerr, 1980; U.N. 1982). For Rongelap Island the annual dose was .028 rem, well below the EPA guide of .170 rem/year; 8 other major islands were also below the guide (Table 4.1 #1). The factor of 0.7 rem per roentgen was used to allow for the smaller size of the Rongelap people and the many children. The conventional value for the 70 kg standard man is 0.61.

There is also a shallow dose to be considered, that due to beta rays which travel for short distances ($<$ 1 cm) into those parts of the body that are near or in close contact with the soil and that are unshielded. Their contribution is considered to be negligible (Note 7).

These estimated external gamma-ray dose rates are maximal ones. Indoors the rate is reduced by about 50%. Likewise, the rate is reduced by about 50% in the immediate vicinity of houses owing to the coral gravel that is spread around them (Shingleton et al, 1987 and Robison et al, 1982b). This, of course, is important in the case of infants and small children.

Other annual contributions to external dosage which are not included come from cosmic radiation (.028 rem) and medical exposure.

In summary, the contribution of fallout to the total external radiation dose at Rongelap Island in 1978 was approximately .028 rem per year uncorrected for the shielding within or around buildings, which would decrease the rate by 50%. The 30-year whole-body dose would be .590 rem allowing for spontaneous decay, but not shielding. Environmental decay such as leaching of radionuclides from the soil would reduce this estimate still more, but was not allowed for.

RONGELAP ATOLL

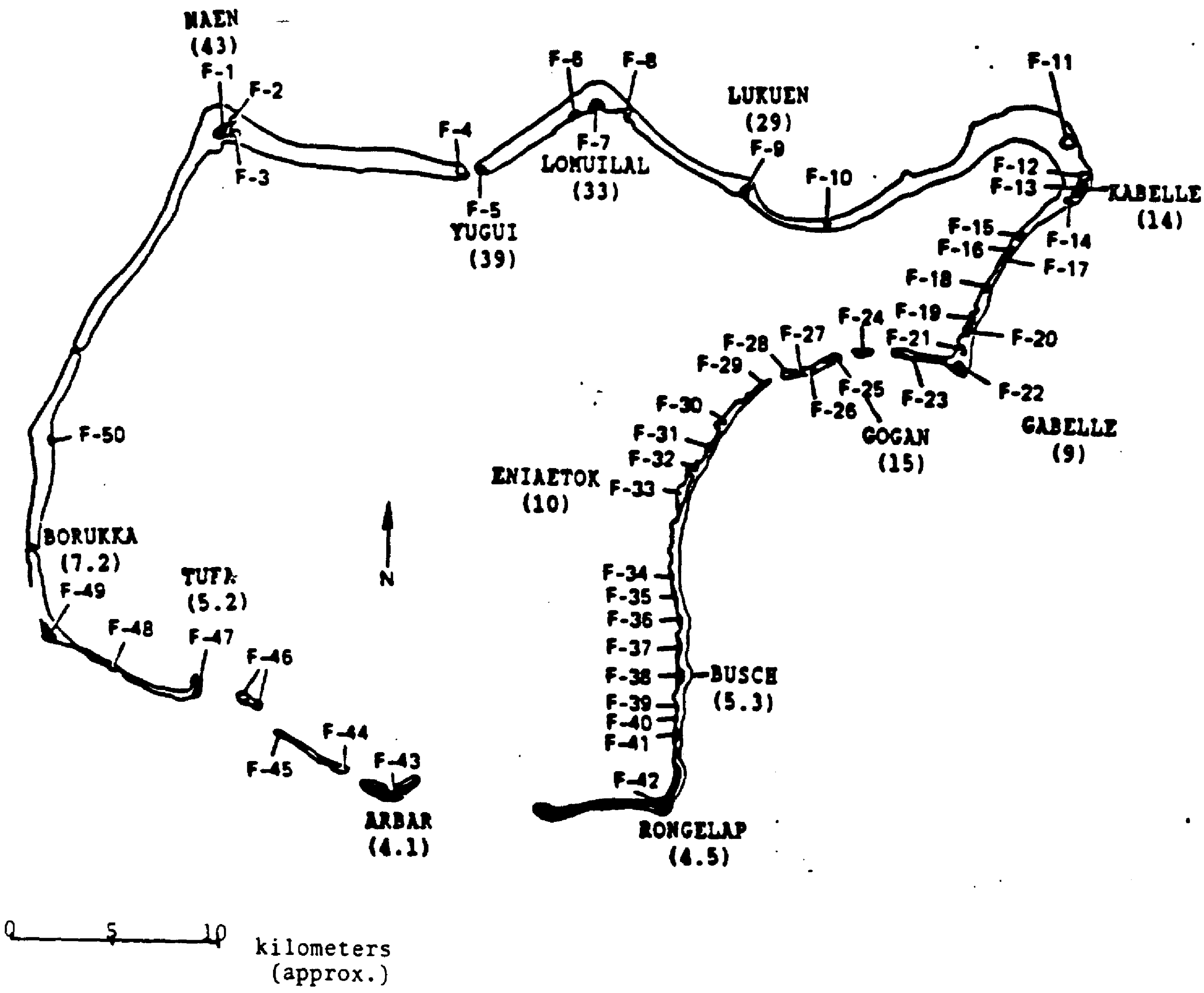

Figure 4.1 PRINCIPAL ISLANDS OF RONGELAP ATOLL

The numbers in parentheses are the external whole-body exposure-rates in microroentgens/hour, corrected for cosmic radiation, as determined in 1978 by aerial survey (Tipton & Meibaum, 1981).

TABLE 4.1 #1 AVERAGE EXTERNAL EXPOSURE AND EXTERNAL DOSE RATES (gamma ray) FOR ISLANDS AFFECTED BY BRAVO FALLOUT

(The 1990 doses will be approximately 75% of those for 1978.)

Atoll and Reference	Island	Year	a/ Exposure (gamma)	b/ Dose (whole-body)
			microroentgens/hour	rem/year
Bikini Atoll				
Tipton & Meibaum (1981)	Eneu	1978	2.7	.017
	Bikini		35.0	.215
Shingleton et al (1987)	Eneu	1986	--	.018
	Bikini		--	.160
Rongelap Atoll				
Tipton & Meibaum (1981)	Rongelap	1978	4.5	.028
	Arbar		4.1	.025
	Busch, Tufa, Borukka, Gabelle		5-9	.031-.055
	Eniaetok, Kabelle, Gogan		10-27	.061-.166
	Lukuen, Naen, Yugui, Lomuilal		28-43	.172-.264
Paretzke (Note 8)	Rongelap	1987	4.1 (7)[cd]	.025
Greenhouse & Miltenberger (1977)	Rongelap	1977	3.6-4.5	.022-.028
Ailingnae Atoll				
Tipton & Meibaum (1981)	Sifo	1978	1.4	.009
Paretzke (Note 8)	Mogiri	1987[d]	1.3 (1)	.008
	Enibuk		2.2 (1)	.013
Utirik Atoll				
Tipton & Meibaum (1981)	Utirik	1978	0.8	.005

a/ Measured at 1 meter above ground level, corrected for cosmic rays.

b/ Annual, whole-body dose (millirem/year) calculated as equal to $6.13 \times 10^{-3} \times \mu R$/hour. For the epidermal dose, see Note 7.

c/ The average of 7 locations ranging from 2.2 to 4.6 μR/hour.

d/ Corrected for decay back to 1978. See Note 9.

4.2 Internal Dose - Lawrence Livermore National Laboratory

Lawrence Livermore attacked the problem by determining what went into the body by ingestion and inhalation (picocuries per day), and then applying appropriate factors to such input (exposure) to obtain the dose in rem. The particular ones I have used are given in Table 4.2 #1.

The major uncertainty of the "input" method lies in the diet--no one knows precisely what it is, although several attempts have been made to define it. DOE-1982 used the BNL community B diet, i.e., one involving a greater amount of food and also a greater input of contaminated food (Note 8). Naidu et al (1980) who originally described it commented that the diet represented prepared, not eaten food, and that in fact it was more than a person could eat. This results in overestimation of dose. The Lawrence Livermore group that used it for dose calculations concurred.

The 1978 specific activities measured by the Livermore team were made on 21 samples of coconut, 5 of Pandanus, 1 of breadfruit, 1 chicken, 2 pigs and 98 fish, on the whole a barely adequate number (Robison et al, 1981a, 1982b). In 1986, however, that Laboratory took for analysis more than 75 samples of coconut, more than 10 of breadfruit and some others; the results were in agreement with the earlier ones, and a summary of all data is shown in Table 4.2 #1, calculated for 1990.

Since the Rongelap people have expressed doubt about the reliability and honesty of Department of Energy scientists (e.g., those from Brookhaven and Livermore), a comparison trial was carried out in December 1987 in which samples collected at Rongelap and Ailinginae in the presence of Senator Anjain and others were divided among several laboratories for analysis (Livermore, Bremen, Neuherberg (Munich) and Berkeley). The results demonstrated agreement (Note 9).

Cesium. I am taking 3,400 pCi/d (in 1990) as the exposure due to cesium-137, based on a total for foods listed in Table 4.2 #2 plus a 10% allowance for a miscellaneous variety of others (Note 8, Table #1). The whole-body, red marrow and bone surface doses are just about equal, 1.26 rem (Table 4.2 #1).

Strontium. The strontium-90 estimates for 1990 are based on the 1978 samples; I have been unable to learn how much more work has been done since then. I am therefore taking 21.8 pCi/d based on field samples plus a 25% increment for other miscellaneous foods. The total exposure is 27.3 pCi/d. The 30-year doses are: whole-body, .025 rem; red marrow, .137 rem; bone surfaces, .300 rem. (Scaled back to 1978, they would be 33% more.)

Transuranics. Based on Table 4.2 #1, the plutonium-239,-240 exposure is 0.293 pCi/d, and the 30-year doses are: whole-body, .011 rem; red marrow, .017 rem; bone surfaces, .014 rem. The americium doses will be 35% of the plutonium-239,-240 ones. The total transuranic dosage is therefore .015 rem, whole-body.

Water. In the case of catchment water (Noshkin et al 1981), the radionuclide levels are no higher than 3% of the guides. In the case of ground water, the same is true except for strontium-90, whose level is about 25% of the guide (8 pCi/liter). (These levels have been scaled to 1990.)

Inhalation. It is the transuranics that are of consequence. The original estimates of respired dust were very much too high (Shinn et al 1980) and they have been reduced to make them more realistic (Robison 1988). The matter is discussed in Note 10. Taking the daily intake to be 0.006 pCi/d, the 30-year adult dose is .027 rem whole-body, .041 to the red marrow, and .005 rem to the bone surfaces.

Summary. The individual doses have been multiplied by 1.33 to scale them back from 1990 to 1978, the year in which DOE-1982's samples were collected. It should be recalled that the following estimates depend directly on the assumed diet.

Livermore Adult 30-year Dose
(type B community diet) for 1978-2008*

Source	Whole-body dose (rem)	Red marrow dose (rem)
Inhalation	.027	.041
Internal dose		
-cesium-137	1.673	1.673
-strontium-90	.033	.182
-transuranics	.015	.023
External dose	.590	.590
Totals	2.34 **	2.513***
DOE-1982	2.500	3.300

* To convert 1990 to 1978, multiply by 1.33
** Committed effective dose equivalent
*** Committed dose equivalent

TABLE 4.2 #1A

INGESTION

FACTORS TO CONVERT ADULT "INITIAL DAILY INTAKE (pCi/d)" TO COMMITTED "WHOLE-BODY" OR "TISSUE" DOSE (rem) FOR DIFFERENT PERIODS OF DAILY INTAKE [a]

Radionuclide & period	C.E.D.E.[b]	Red marrow	Lungs	Bone surfaces	Liver
CESIUM-137					
initial year	1.7 E-5[c]	1.7 E-5	Like C.E.D.E		
0-30 year	3.7 E-4	3.8 E-4			
30-70 year	2.2 E-4	2.4 E-4			
STRONTIUM-90					
initial year	4.7 E-5	2.4 E-4	1.8 E-6	5.3 E-4	1.8 E-6
0-30 year	9.2 E-4	5.0 E-3	3.6 E-5	1.1 E-2	3.6 E-5
30-70 year	5.6 E-4	3.0 E-3	2.2 E-5	6.6 E-3	2.2 E-5
PLUTONIUM-239.-240					
initial year	1.3 E-3	1.9 E-3	1.0 E-8	2.4 E-2	4.2 E-3
0-30 year	3.9 E-2	5.7 E-2	3.1 E-7	7.3 E-1	1.3 E-1
30-70 year	5.1 E-2	7.4 E-2	4.1 E-7	9.6 E-1	1.7 E-1
AMERICIUM-241					
initial year	1.3 E-3	Like plutonium			
0-30 year	3.9 E-2	5.7 E-2	1.6 E-6	7.3 E-1	1.3 E-1
30-70 year		Like plutonium			

a/ It is assumed that the daily diet remains constant, but that the radionuclides in it decay spontaneously. The table provides dose factors in rem/picocuries/day. It is based on NRPB (1987) which provides factors in Sv/Bq (= 3.8 x rem/picocurie), and is consistent with ICRP recommendations (ICRP 1986, 1987). These factors allow for the fraction of radionuclide absorbed from the gut, its distribution and residence time in the body, the absorption and effectiveness of its radiation in the body, and its rate of physical decay.

b/ Committed effective dose equivalent (whole-body dose). Other doses are committed dose equivalents (tissue dose). The C.E.D.E. is the sum of the dose equivalents to 11 tissues of the body of a standard man, each weighted by the risk resulting from a unit dose to that tissue as compared to the risk from a unit dose to the whole body.

c/ E-5 signifies: $\times 10^{-5}$.

TABLE 4.2 #1B

INHALATION

FACTORS TO CONVERT ADULT "INITIAL DAILY INTAKE (pCi/d") TO COMMITTED "WHOLE BODY" OR "TISSUE" DOSE (rem) FOR DIFFERENT PERIODS OF DAILY INTAKE [a]

Radionuclide & period	C.E.D.E.[b]		Red marrow		Lungs		Bone surfaces		Liver	
CESIUM-137										
initial year	1.0	E-5[c]	9.9	E-6	1.1	E-5	9.4	E-6	1.0	E-5
0-30 year	2.2	E-4	2.0	E-5	2.2	E-4	2.0	E-4	2.2	E-4
30-70 year										
STRONTIUM-90										
initial year	7.7	E-5	4.2	E-4	4.6	E-6	9.2	E-4	3.1	E-6
0-30 year	1.6	E-3	8.7	E-3	9.5	E-5	1.9	E-2	6.4	E-5
30-70 year										
PLUTONIUM-239.-240 & AMERICIUM-241										
initial year	1.5	E-1	2.3	E-1	2.3	E-2	2.8	E-0	5.	E-1
0-30 year	4.5	E-0	6.9	E-0	6.9	E-1	8.4	E-1	1.5	E-1
30-70 year	6.0	E-0	9.2	E-0	9.2	E-1	1.12	E-2	2.0	E-1

[a] It is assumed that the radionuclides in soil decay spontaneously. The table provides dose factors in rem/picocuries/day. It is based on NRPB (1987) which provides factors in Sv/Bq (= 3.8 x rem/picocurie), and is consistent with ICRP recommendations (ICRP 1986, 1987). These factors allow for the fraction of radionuclide absorbed, its distribution and residence time in the body, the absorption and effectiveness of its radiation in the body, and its rate of physical decay. See p. 24.

[b] Committed effective dose equivalent (whole-body dose). Other doses are committed dose equivalents (tissue dose). The C.E.D.E. is the sum of the dose equivalents to 11 tissues of the body of a standard man, each weighted by the risk resulting from a unit dose to that tissue as compared to the risk from a unit dose to the whole body.

[c] E-5 signifies: x 10^{-5}.

TABLE 4.2 #2

FOOD SPECIFIC ACTIVITY IN 1990 [a/]

(Multiply the cesium and strontium values by 1.33 to scale them for 1978.)

Item	gm/d	pCi/gm wet Cs-137	Sr-90 x 10^{-2}	Pu-239, -240 x 10^{-4}	Amer-241 x 10^{-5}	pCi/day Cs-137	Sr-90	Pu-239 -240	Amer-241
Arrowroot	0	3.2							
Breadfruit	36	2.71	7.3	1.24	7.34	97.6	2.6	.045	.003
Banana	19	1.1	2.64	1.05	6.2	20.9	.502	.002	.001
Coconut									
Drinking meat	100	1.81	.39	.51	4.82	181	.39	.005	.005
Drink. fluid	514	1.07	.11	.27	2.52	550	.571	.014	.013
Copra	68	4.65	1.7	.56	6.32	316	1.16	.004	.004
Milk	125	4.65	1.7	.56	6.32	581	2.13	.007	.008
Sprouting	100	4.65	1.7	.56	6.3	465	1.70	.006	.006
Papaya	0								
Pumpkin	0								
Pandanus	96	8.63	11.8	.60	2.65	828	11.33	.006	.003
Fish	194	.0192	.065	2.40	4.22	3.73	.126	.047	.008
Poultry	3	1.95	.45	.1	85	5.85	.014	0	.003
Wild birds	9	?							
Domestic meat	0								
Pork	1.4	6.5	.27	.36	2.5	9.1	.004	0	0
Clams	15	.0012	.41	100	314	.02	.061	.15	.047
Crabs	0								
Octopus	20	.0106	.16	2.64	4.64	.212	.032	.005	.001
Turtle	.1								
Snails	12	?							
Coconut crab	1	2.71	118	19.4	62.4	2.71	1.18	.002	.0006
Lobster	.14								
Shellfish	-								
TOTALS	1310					3060	21.8	.293	.102

[a/] These data for the type B community diet (Naidu et al, 1980) were supplied through the courtesy of Dr. William L. Robison, Lawrence Livermore National Laboratory.

4.3 Internal Dose - Brookhaven National Laboratory

Cesium. It is a curious fact that Brookhaven's studies were not utilized by DOE-1982. Brookhaven had chosen whole-body counting, a definitive method independent of assumptions concerning diet, to follow cesium in the Rongelap population (Conard et al 1980; Lessard 1984 b,c; Miltenberger et al 1980), and one of primary importance in the present case where cesium accounts for 95% of the dose.

The cesium-137 body burden fell from about 670,000 pCi in 1958-65 to about 175,000 pCi in 1979. It is of interest that body burden fell by 75% in 20 years, whereas the half-life of cesium is 30 years. Perhaps a change in eating habits or a larger degree of environmental loss of the radionuclide than has been established were at work.

In any event, the Brookhaven estimates for whole-body dose (1978) are .027 rem, and for the ensuing 30-year period .245 rem (Note 11, Tables 1,2). The 30-year dose was calculated by extrapolating the curve for the previous dozen years.

A more conservative assumption would be that the dose will fall only as a result of spontaneous decay by cesium-137. In this case, the 30-year dose would be .56 rem for whole-body, red marrow and bone surfaces.

We do not have an independent field check on the accuracy of the whole-body field measurements. The point may be made, however, that it was this team that discovered the precipitous rise in body-burden of the Bikini settlers in 1977-78 and who therefore called for their removal from Bikini Atoll (Conard et al, 1980; Miltenberger et al, 1980).

Strontium. Strontium-90 daily excretion was determined by urine analysis and the committed effective dose equivalent calculated therefrom. Three autopsies have confirmed such calculations (Conard et al 1980, p. 115). The annual whole-body dose for 1978 was less than .001 rem (Note 11, Table 2); the subsequent 30-year committed effective dose based on spontaneous decay alone whould be .015 rem. The corresponding tissue doses are: red marrow, .079 rem; bone surfaces, .179 rem.

Transuranics. Although only 104 of some 270 determinations have been looked at, it is clear that the results cannot be used as they stand now. A full discussion is presented in Note 12; here we deal briefly with the conclusions.

Plutonium-239 was measured in urine samples, collected in 1981 at Rongelap, using the fission track method (ORAU, 1987). The data appear to be bimodally distributed over a range extending from 1 x 10^{-5} pCi/d (the practical limit of detection) up to 5 x 10^{-3} pCi/d. Neither sex nor age appears to play a primary role in determining this result.

The oral intake associated with the maximum urinary output would be 38 pCi/d of plutonium-239, or 76 pCi/d of the three transuranics (plutonium-239,-240; americium-241). It would seem impossible to eat this much; the minimum quantity would be 5.6 kg of clams every day (Table 4.2 #2). The 30-year whole-body dose from 76 pCi/d would be 2.96 rem.

On the other hand, the median excretion of about 1 x 10^{-4} pCi/d would require eating 1.2 pCi/d of all three transuranics. This would be about 3 times the currently estimated oral input used by Livermore, based on the community type B diet, and presumably would be possible. The 30-year whole-body dose would be .045 rem. It is curious and may be of some significance that the median of such an extended distribution should be within a factor of three of the diet method's single estimate.

Summary. In summarizing the Brookhaven results, two estimates have been made to cover the uncertainties surrounding the transuranic determinations, one based on the median, the other based on the range from minimum to maximum.

Source	Brookhaven 30-year (1978-2008)* Adult doses Whole-body** (rem)	Red marrow*** (rem)
Cesium-137:	.560	.560
Strontium-90:	.015	.079
Transuranics		
- median	.045	.068
- range	.005 - 2.96	.008 - 4.33
External dose:	.59	.59
Total:	1.21	1.30
- range	1.17 - 4.13****	1.24 - 5.49

* Not including inhalation
** Committed effective dose equivalent
*** Committed dose equivalent.
**** The estimate falls below the 5 rem guide for 30 years, even when the maximum transuranic estimate is used - one which would appear to be dietetically impossible.

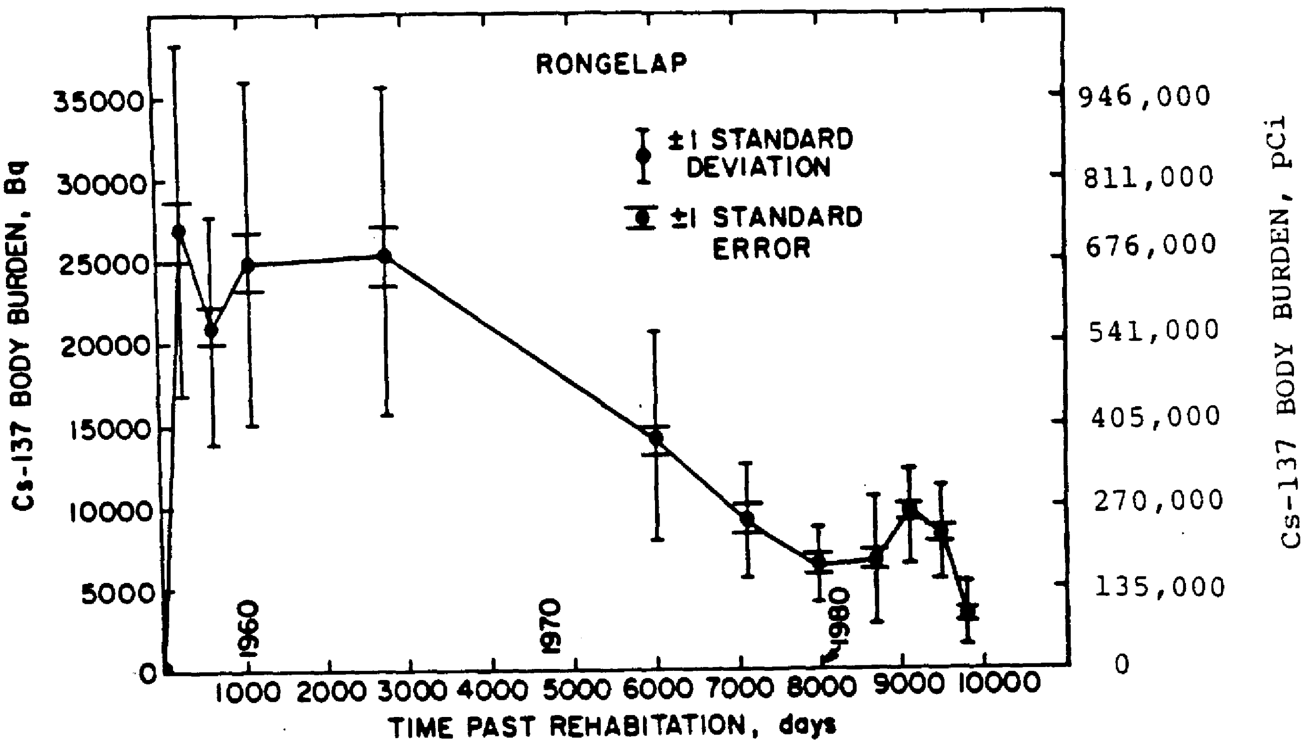

Figure 4.3 #1. Adult cesium-137 body burden as a function of time since resettlement of Rongelap Island in 1957.

The maintenance of the body content depends on the radionuclide intake from the diet. The physical half-life is 30 years; the physiological half-life is 110 days in men, 80 days in women, and less in youths and children. (1 Bequerel = 27 picocuries; 1 nanocurie = 1,000 picocuries) The maintenance of the specific activity of 1 pCi/g in soft tissue for 1 year gives rise to a dose of .01 rem.

(Figure courtesy of E.T. Lessard, Brookhaven National Laboratory.)

4.4 Infant Dosage

The doses that have been under consideration are for adults. In the case of children and infants, the doses might be different owing to variations in (1) physical and physiological processes and (2) dust and diet.

Physical and physiological factors. These variables affect the conversion factors in Tables 4.2 #1A & #1B. For example, the smaller size of children can diminish the fraction of gamma ray energy absorbed in the body; the residence time of the radionuclide in the body may be less than in adults; the fraction absorbed from the gut might be much more. Furthermore, a long-lived radionuclide deposited in the body at age 6 months will be diluted by growth so that its "picocuries per gram of tissue", on which a dose depends, will fall significantly with time.

Table 4.4 #1, based on the United Kingdom NRPB report (1987b), and consistent with the recommendations of the ICRP (International Commission on Radiological Protection), shows that the corrections for children are well on their way to disappearing by age 10 y, but are important in the first year or so of life. The correction for cesium-137 is an increase of not more than 20%, but that for strontium is about 3.6-fold. For the transuranics, it is 2.4-fold for inhalation during the first year, but for ingestion it is 22-fold for months 0-6, and 2.1-fold thereafter in that year.

These factors are for committed doses which in the case of children aged 10 and less are calculated to age 70 years rather than for the standarized period of 50 years in adults. For radionuclides with short physiological half-lives such as cesium-137 (less than 110 days), this is of no consequence. But for the transuranics with half-lives in liver and bone marrow of 20 and 50 years, respectively, the extra residence time adds to the 50-year committed dose.

In general, it would be expected that the smaller intake of children and infants will compensate for the increased size of their dose-factors compared to the adult ones in Tables 4.2 #1A & #1B.

Since there are almost no directly pertinent Rongelap data on such inputs, we have approached the problem in two ways. First, we have made some calculations aimed at setting upper bounds.
Second, we have attempted to obtain information from the Marshall Islands on infant and small child diets.

Table 4.4 #1

CHILDREN: FACTORS TO CONVERT ANNUAL OR 30-YEAR CONSTANT INTAKE(pCi/d) TO DOSE (rem)

(The factors for adults in Tables 4.2 #1A & #1B are to be multiplied by the relative values in this table)

Nuclide and route		Age at Exposure ≥ 20 yr[a]	10 yr[b]	1 yr[b]	0-6 mo[b]	30-year exposure[c]
Cs-137	Ingestion	1	1	1.1	1.1	1.02
	Inhalation	1	1	1.2	1.2	1.03
Sr-90	Ingestion	1	1.4	3.6	3.6	1.54
	Inhalation	1	1.4	3.7	3.7	1.56
PU-239 [d]	Ingestion	1	1.3	2.1	22.	1.63
	Inhalation	1	1.3	2.4	2.4	1.35

[a] Adult. The adult dose commitment is for 50 years.

[b] For children the commitment is until age 70.

[c] 30 years of constant "adult" intake, beginning at age 0. Since the intake of children in fact is much smaller than of adults, the true value will be much closer to 1.

[d] Also plutonium-240 and americium-241.

Cesium-137 in mothers' milk. The cesium content of mothers' milk was determined on samples from three Bikini women in 1979, nine months after leaving Bikini where they had been resident for 3-8 years (Miltenberger et al, 1981). The mean body burden of cesium-137 was .13 uCi (.09 - .18); the specific activity of the milk averaged .40 pCi/ml (.26 - .53); the mean specific activity of milk was therefore 3.3×10^{-6} times the body burden.

In 1977 on Rongelap the mean body burden of cesium-137 in women was .251 uCi. Applying the Bikini factor gives .83 pCi/ml for the specific activity of cesium-137 in Rongelap milk. Taking milk consumption to be 2 liters per day, the committed dose generated in months 0 - 12 would be

$$(2{,}000 \times .83) \times (1.1 \times 1.7 \times 10^{-5}) = .030 \text{ rem.}$$

Transuranics. We have no data for the consumption by children of plutonium-239,240 and americium-241 and therefore estimate their dosage as follows:

(a) For ingestion, suppose that infants and children eat as much of the transuranics as do adults. Taking the worst case of no supply ships for the entire year, so that only locally produced foods are consumed, Livermore now estimates an adult intake of 1.8 pCi/d (Ref. Robison).

For intake during the period 0-12 months of age the estimated committed effective dose equivalent would be:

$$(1.8) \times [(2.1 + 22)/2] \times (1.3 \times 10^{-3}) = .028 \text{ rem (1st y, ingestion)}$$

Of this committed dose, not more than .019 rem would in fact be received during the first year.

(b) To this would be added the dose from inhalation (Section 4.2). Taking .024 pCi/d as the adult exposure, which would be a liberal allowance for the infant, the committed whole-body dose would be:

$$(.024) \times (2.4 \times .15) = .009 \text{ rem} \quad \text{(0-1 year, inhalation)}$$

On this somewhat special basis, the committed effective transuranic doses would be 0.037 rem (1st year). The dose absorbed during the first year presumably would be no more than .025 rem.

<u>Diet.</u> We have also attempted through the assistance of the Peace Corps to find out quantitatively what infants and small children eat. (Such information will be of value to the professional nutritionists in the Marshall Islands as well as to ourselves.) The Corps volunteers, all of whom speak Marshallese, carried out inquiries on their own islands of residence where they are familiar with the local scene and people, and have lived for at least one year. The diets were ascertained by living with a family for one day on two separate occasions and recording what was eaten by the child (Note 13).

At present we have only the returns from 5 islands of 4 atolls, comprising 21 children, 7 months to 4 years of age (but chiefly below 1 year). The principal finding, as might have been expected, is that children are breast fed until well past 6 months of age, in fact often into the first year.

A second important finding appears to be that additional foods during the weaning period are often, if not usually, imported. The diet, however, varies greatly from family to family, as well as from day to day (to judge by these two-day samplings).

I have used Table 4.2 #2 and related material in calculating the daily intake of cesium-137, from the individual diet reports. The two reports for each child were averaged, and then an average obtained for the island. In the summary below, the island mean is followed by the range, followed by the number of children, in parentheses.

1.	Ine Island, Arno:	128 pCi/d (0-210; 3)
2.	Buoz Island, Ailinglaplap:	113 pCi/d (0-215; 5)
3.	Kaven Island, Maloelap:	212 pCi/d (58-343; 3)
4.	Woja Island, Ailinglaplap:	405 pCi/d (7-995; 9)
5.	Wotje Island, Wotje:	500 pCi/d (215-785; 2)

The maximum individual daily intake of cesium-137 indicated by these samples was not a constant one, but may be used to estimate what is probably an upper bound for daily consumption. For 1000 pCi/d of cesium-137, the dose would be (1990):

$$(1000) \times (1.1 \times 1.7 \times 10^{-5}) = .019 \text{ rem (committed first year dose)}$$

Scaled to 1978, it would be .025 rem. The strontium-90 dose would be less than 5% of this.

It is not claimed that these results are definitive. Nontheless, I believe that these data do provide at the very least significant orientation to the problem. Accurate data are very hard to obtain, according to the volunteers, and the investment in time -- about 2 days per child -- has been a very large one, indeed. One difficulty encountered was getting the mothers to understand what kind of information was wanted and why. No brief interrogatory visits could obtain reliable data. The study is still going on, and it is hoped that more information will be available by October.

Summary. A maximum type of internal dose estimate for age 0-12 months (1978) can be made by adding the three doses just developed:

Cesium-137 in breast milk (2 liters/d)	.03 rem
Transuranics (intake equal to that of adults):	.04 rem
Peace Corps cesium-137 estimates:	.025 rem
Total:	.095 rem

The estimate is therefore about .095 rem/day. However, it must be recalled that infants do not drink 2 liters of breast milk per day -- a better average might be 1 liter; the transuranic dose during the first year (not committed dose) would be closer to .025 rem; the daily average of non-milk cesium intake could be materially less than that stated. A maximum total of .05 rem seems more likely at present.

Until we have a more extensive appraisal of what the infant and small child diet is, it would be wise to withhold final judgement. The information in hand, however, does provide specific orientation to the methodology of the problem and the magnitude of the doses involved.

4.5 Dose Summary

The dosage problem as developed in this Report breaks down into three parts: the adult dose, the uncertainty introduced into the adult dose by the transuranics; the infant dose.

(a) Adult dose. For the 30-year period 1990-2020, the one of current interest, the following tabulation shows that all three estimates of the adult dose meet the 5 rem guide (community type B diet).

Rongelap: 30-year Adult Exposure (1990-2020)

Source	Whole-body (rem)	Red marrow (rem)
Livermore	1.80*	1.88**
Brookhaven****	.91* (.88 - 3.1)	.98** (.93 - 4.1)
DOE-1982***	1.9	2.9

* Committed effective dose equivalent
** Committed dose equivalent
*** Integral doses
**** The median transuranic dose was employed.

The Brookhaven doses are about half the others; cesium-137 was measured with the whole-body counter, the preferred method for its determination.

DOE-1982 stated that the diet on which its reported doses were based consisted only of local foods from Rongelap Island. That statement is incorrect. Lawrence Livermore calculated the cited dose on the basis of the community type B diet, and that diet (for comparability) has been used for the calculation of all doses above.

The cancer risk for 500 persons settled on Rongelap Island and receiving 1.9 rem over the next 30 years would be:

$$500 \times 1.9 \times 2.5 \times 10^{-4} = .24 \text{ cases}$$

The risk factor used here is 2.5 times that advocated in the National Academy of Science (1972) report. It is lower than what is being used for the Japanese survivors (Shimuzu et al 1987; Preston & Pierce 1987), but they experienced high-dose and high-dose-rate exposure whereas the Rongelap exposure would be low and at an extremely low dose-rate.

The risk factor for first generation genetic defects is smaller than that for cancer mortality (National Academy of Sciences, 1972; NCRP, 1987a), being approximately 1 x 10^{-4}. Furthermore, since no genetic effects have been recorded as yet for the Japanese (Radiation Effects Research Foundation, 1987), it is unlikely that any would be found here.

(b) Transuranics. The Brookhaven dose estimates vary significantly, reflecting the transuranic data which may vary by a factor of 1,000. Could this be "real"? Probably not. To supply the transuranic oral input necessary to maintain the maximum urinary output recorded, it would be necessary to eat 5 kg of clams every day -- or even larger amounts of other foods.

Obviously, something is radically wrong, technically or physiologically. Contamination is one possibility (urine collection in the Marshalls is difficult). Or conceivably, an inborn error of metabolism allows certain individuals in the general population to absorb 100 times as much from the gut as that which the ICRP recognizes as normal.

It is therefore essential, as emphasized in the Preliminary Report, that the problem be studied immediately. As a start, additional urines should be collected repeatedly from the same individuals under rigorously controlled conditions to determine the reproducibility of results, and which simple changes in life style might affect them.

(c) Infant dose. The question of infant and childhood dosage has been raised, and is a sensitive issue. The maximum internal dose for months 0-12 appears to be 0.1 rem. More information should become available by October. According to the ICRP tables, the dose per unit intake is 2 - 3 times higher for small children than for adults, but children eat less so that the two factors tend to cancel one another out. In any case, the observations thus far should not give rise to alarm, but they must be followed up.

(d) The foregoing comments apply to the future. But what about the influence of the past? The Rongelap residents exposed to the Bravo shot received an acute dose of 190 rem in 1954; during 1957-1978 they received a chronic dose of 3 rem. My opinion is that the addition to these past doses of something like 3 rem during the next 30 years will not appreciably increase detectable health and genetic risks in a way that should preclude return to Rongelap Island.

5. DISCUSSION AND RECOMMENDATIONS

5.1 Comment

Section 4.5 summarizes the basic results of this report. They must be viewed from two angles.

First, from a technical point of view, they provide a reasonable basis for assessing the Rongelap dosage problem. It seems clear that under the ordinary conditions of Rongelap life, there is no significant radiation danger associated with residence on Rongelap Island for adults. The implicit assumption in this statement is that the diet will be equivalent to that of the past. To what extent that will be true after resettlement can only be learned by monitoring the inhabitants with whole-body counting equipment, as done by Brookhaven, supplemented as necessary by urine analysis. Any other method such as that used by the Livermore groups must assume a diet in order to calculate the dose.

In the case of infants during the first six months, while they are breast-fed, it will be the mother's diet that ultimately determines the dose. However, knowing the mother's body burden by whole-body counting will make possible a prediction of her milk's specific activity. Or direct measurements can be made on the milk itself. Presumably, a "safe" mother should be associated with a "safe" baby.

On general grounds one can estimate the dosage to infants and children. Whole-body counting can be done only if the child will be quiet. My interest in enlisting the help of Peace Corps Volunteers (who speak Marshallese) was to see if the data obtained within the home would make it obvious that the children were receiving obviously excessive exposure. The result has been negative, at least thus far.

These negative findings with respect to radiation hazards are unpopular ones, at least for some of the Marshallese (and their advisors), and understandably so. Their history of irradiation without warning, and the subsequent development of thyroid disease (although originally told nothing would happen) initiated a distrust of the Federal Government which has never left them, and feelings of uncertainty as to the nature of their environment.

The second point of view is therefore that of the Rongelap person who does not have a grasp of technical matters, but who for one reason or another distrusts the establishment with which he or his representatives must deal. This situation is often if not always complicated by the fact that the concept of "objective" judgement is a foreign one. The judge is either for them or against them, but he cannot give a divided opinion.

During the course of this work, I have had criticism from Senator Anjain and from two of the consultants who regard themselves as working for him. It would be fruitless to answer their comments one by one (two letters from them were attached to the Preliminary Report). Here I attach a letter from Senator Anjain of June 25, 1988, in order to present his views and reactions to this project. The letter is best judged by comparing it to the contents of this Report. Note 15.

5.2 Recommendations

However the program is set up, I recommend that it cover the following items.

(1) Reinstitute whole-body counting for cesium-137 now to establish a base line of comparison to be used when the people return to Rongelap. We know, of course, that their counts have not been excessive.

2) Study the plutonium excretion in urine now as a research project to determine the reproducibility of the fission track method and how environmental factors might influence the results.

(3) Extend the study of infant diets and those of small children. This will be much more time consuming than foreign consultants might suppose.

(4) Develop a plan to control contamination to the extent necessary to make the Rongelap people feel comfortable with their Atoll. Two methods developed at Bikini Atoll might be adapted for use here -- soil removal or soil treatment with potassium salt. The plan would be a graded one in which the northern islands would receive more treatment than Rongelap itself (which would receive little, if any).

(5) The prelude to such planning would include contamination surveys on the important islands where food is produced.

(6) For the present, at least, I recommend no food gathering on islands north of Borukka and Eniaetok.

(7) The fact that Rongelap appears suitable for resettlement now should not be lost sight of. The Rongelap people should ask themselves what further evidence do they want, or what steps taken, to make them feel comfortable about this. Will they ever feel comfortable about it?

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NOTES CITED IN THE TEXT

N.1

The following is quoted from "The Meaning of Radiation for Those Atolls in the Northern Part of the Marshall Islands That Were Surveyed in 1978", U. S. Department of Energy, Washington, D.C., November 1982, page 39:

Information That Has Been Obtained from the Measurements Made in 1978

If 233 people live on Rongelap Island and eat local food only from Rongelap Island

Scientists estimate that the largest amount of radiation a person might receive in one year from radioactive atoms that came from the U S bomb tests is 400 millirem But usually the largest amount a person might receive would be less than this This amount of radiation decreases every year however, it decreases very slowly

The highest average amount of radiation people might receive in the coming 30 years is 2500 millirem in any part of the body and 3300 millirem in just the bone marrow

In the coming 30 years, scientists estimate that 10 people may die from cancers caused by things other than radiation from the atomic bomb tests In addition to this, from 0.1 to 0.6 people may die in the future from cancers caused by radiation received in the coming 30 years from the atomic bomb tests

In the coming 30 years, scientists estimate that 80 children could be born with health defects caused by things other than radiation from the atomic bomb tests In addition to this, 0.007 to 0.1 children may eventually be born with health defects caused by radiation their parents receive in the coming 30 years from the atomic bomb tests

If people live on Eneaetok and not on Rongelap Island, and eat local food only from Eneaetok, the amount of radiation they receive would be about the same

If people go to Naen from Rongelap Island, and eat food from Naen they might receive about five times more radiation while they are there

If people go to Namen or Melu from Rongelap Island, and eat food from those two islands they could receive about two times more radiation while they are there department or agency of the United States or by contract with a United States firm) shall continue to provide special medical care and logistical support thereto for the remaining 174 members of the population of Rongelap and Utrik who were exposed to radiation resulting from the 1954 United States thermonuclear "Bravo" test, pursuant to Public Laws 95-134 and 96-205. Such medical care and its accompanying logistical support shall total $22,500,000 over the first 11 years of the Compact. 91 Stat. 1159. 94 Stat. 84.

(2) AGRICULTURAL AND FOOD PROGRAMS.—Notwithstanding any other provision of law, upon the request of the Government of the Marshall Islands, for the first five years after the effective date of the Compact, the President (either through an appropriate department or agency of the United States or by contract with a United States firm) shall provide technical and other assistance— President of U.S.

(A) without reimbursement, to continue the planting and agricultural maintenance program on Enewetak;

(B) without reimbursement, to continue the food programs of the Bikini and Enewetak people described in section 1(d) of Article II of the Subsidiary Agreement for the Implementation of Section 177 of the Compact and for continued waterborne transportation of agricultural products to Enewetak including operations and maintenance of the vessel used for such purposes. *Post*, p. 1812.

(3) PAYMENTS.—Payments under this subsection shall be provided to such extent or in such amounts as are necessary for services and other assistance provided pursuant to this subsection. It is the sense of Congress that after the periods of time specified in paragraphs (1) and (2) of this subsection, consideration will be given to such additional funding for these programs as may be necessary.

(i) RONGELAP.—(1) Because Rongelap was directly affected by fallout from a 1954 United States thermonuclear test and because the Rongelap people remain unconvinced that it is safe to continue to live on Rongelap Island, it is the intent of Congress to take such steps (if any) as may be necessary to overcome the effects of such fallout on the habitability of Rongelap Island, and to restore Rongelap Island, if necessary, so that it can be safely inhabited. Accordingly, it is the expectation of the Congress that the Government of the Marshall Islands shall use such portion of the funds specified in Article II, section 1(e) of the subsidiary agreement for the implementation of section 177 of the Compact as are necessary for the purpose of contracting with a qualified scientist or group of scientists to review the data collected by the Department of Energy relating to radiation levels and other conditions on Rongelap Island resulting from the thermonuclear test. It is the expectation of the Congress that the Government of the Marshall Islands, after consultation with the people of Rongelap, shall select the party to review such data, and shall contract for such review and for submission of a report to the President of the United States and the Congress as to the results thereof. Hazardous materials. Contracts. *Post*, p. 1812. Report.

(2) The purpose of the review referred to in paragraph (1) of this subsection shall be to establish whether the data cited in support of the conclusions as to the habitability of Rongelap Island, as set forth in the Department of Energy report entitled: "The Meaning of Radiation for Those Atolls in the Northern Part of the Marshall Islands That Were Surveyed in 1978", dated November 1982, are Report.

adequate and whether such conclusions are fully supported by the data. If the party reviewing the data concludes that such conclusions as to habitability are fully supported by adequate data, the report to the President of the United States and the Congress shall so state. If the party reviewing the data concludes that the data are inadequate to support such conclusions as to habitability or that such conclusions as to habitability are not fully supported by the data, the Government of the Marshall Islands shall contract with an appropriate scientist or group of scientists to undertake a complete survey of radiation and other effects of the nuclear testing program relating to the habitability of Rongelap Island. Such sums as are necessary for such survey and report concerning the results thereof and as to steps needed to restore the habitability of Rongelap Island are authorized to be made available to the Government of the Marshall Islands.

(3) It is the intent of Congress that such steps (if any) as are necessary to restore the habitability of Rongelap Island and return the Rongelap people to their homeland will be taken by the United States in consultation with the Government of the Marshall Islands and, in accordance with its authority under the Constitution of the Marshall Islands, the Rongelap local government council.

Hazardous materials.

Ante, p. 1781.

91 Stat. 1159.
94 Stat. 84.

(j) Four Atoll Health Care Program.—(1) Services provided by the United States Public Health Service or any other United States agency pursuant to section 1(a) of Article II of the Agreement for the Implementation of Section 177 of the Compact (hereafter in this subsection referred to as the "Section 177 Agreement") shall be only for services to the people of the Atolls of Bikini, Enewetak, Rongelap, and Utrik who were affected by the consequences of the United States nuclear testing program, pursuant to the program described in Public Law 95-134 and Public Law 96-205 and their descendants (and any other persons identified as having been so affected if such identification occurs in the manner described in such public laws). Nothing in this subsection shall be construed as prejudicial to the views or policies of the Government of the Marshall Islands as to the persons affected by the consequences of the United States nuclear testing program.

(2) At the end of the first year after the effective date of the Compact and at the end of each year thereafter, the providing agency or agencies shall return to the Government of the Marshall Islands any unexpended funds to be returned to the Fund Manager (as described in Article I of the Section 177 Agreement) to be covered into the Fund to be available for future use.

(3) The Fund Manager shall retain the funds returned by the Government of the Marshall Islands pursuant to paragraph (2) of this subsection, shall invest and manage such funds, and at the end of 15 years after the effective date of the Compact, shall make from the total amount so retained and the proceeds thereof annual disbursements sufficient to continue to make payments for the provision of health services as specified in paragraph (1) of this subsection to such extent as may be provided in contracts between the Government of the Marshall Islands and appropriate United States providers of such health services.

Hazardous materials.

Post, p. 1812.

(k) Enjebi Community Trust Fund.—Notwithstanding any other provision of law, the Secretary of the Treasury shall establish on the books of the Treasury of the United States a fund having the status specified in Article V of the subsidiary agreement for the implementation of Section 177 of the Compact, to be known as the

N-3 The following comments relate to the timing of the evacuation of the Rongelap people.

(a) According to C. L. Dunham, Director of the AEC Division of Biology and Medicine, (Cronkite et al, 1956), "unexpected changes in the wind structure deposited radioactive materials on inhabited atolls and on ships of Joint Task Force 7, which was conducting the tests. Radiation surveys of the areas revealed radiation levels above permissible levels: therefore evacuation was ordered, and was carried out as quickly as possible with the facilities available to the Joint Task Force".

(b) According to Merril Eisenbud (personal communication, see references) a scientific member of the Task Force, "There are many unanswered questions about the circumstances of the 1954 fallout. It is strange that no formal investigation was ever conducted. There have been reports that the device was exploded despite an adverse meterological forecast. It has not been explained why an evacuation capability was not standing by, as had been recommended, or why there was not immediate action to evaluate the matter when the Task Force learned (seven hours after the explosion) that the AEC Health & Safety Laboratory recording instrument on Rongerik was off scale. There was also an unexplained interval of many days before the fallout was announced to the public".

(c) Since the Rongelapese had been evacuated prior to previous tests, it is not clear why the usual procedure was changed. In February 1954, Dr. Bertell has told me, Magistrate John Anjain of Rongelap was told about the Bravo test, but was not given the date. He said that "there are no orders from Washington to evacuate the people".

(d) Rongelap was evacuated on March 3, 1954, approximately 50-55 hours after the shot.

N-4

This note deals with the mission of the medical program at Rongelap (letter from W.H. Adams, M.D.), some medical findings at the time of the relocation of the Rongelap people in 1985 (letter from Dr. Adams to Mr. Roger Ray), and a detailed summary of the thyroid dosage from exposure to fallout in 1954.

NOTE 4: INTRODUCTION - THE MISSION OF THE MEDICAL PROGRAM.

BROOKHAVEN NATIONAL LABORATORY
ASSOCIATED UNIVERSITIES, INC.

Upton, Long Island, New York 11973

Medical Department

(516) 282
FTS 666

April 28, 1988

Henry Kohn, M.D.
Rongelap Reassessment Project
1203 Shattuck Ave.
Berkeley, California 94709

Dear Dr. Kohn,

Let me state briefly what the Brookhaven National Laboratory Marshall Islands Medical Program is and what it is not.

The medical program is mandated by Congress under Public Law 95-134 to provide for diagnosis and treatment of radiation-related disease among the populations of Rongelap and Utirik exposed to Bravo fallout radiation in 1954. The U.S. Department of Energy fulfills this mandate by contracting with the medical department, Brookhaven National Laboratory, to provide said care. The Department of Energy has permitted, by providing the necessary operating funds, an extension of the program to cover many aspects of health care unrelated to radiation exposure and to offer medical services to a great number of unexposed persons. No funds are made available for research because Congress did not intend the medical program to carry out research; clinical care of the injured parties is the program's sole purpose. Therefore, all activities of the medical program have a clinical goal, that being improvement of the health of the population identified in PL 95-134. The ability to disseminate the capabilities of the medical program among the general Marshallese population represents the natural tendency of any health care organization. It is to the great credit of U.S. Department of Energy personnel responsible for carrying out the Congressional mandate that this expansion of coverage has been warmly supported.

Sincerely yours,

W.H. Adams

William H. Adams, M.D.
Director, Marshall Islands
Medical Program

N-4A

The following letter is from Dr. W. H. Adams of Brookhaven National National Laboratory to Dr. Roger Ray of DOE.

2108

July 18, 1985

Mr. Roger Ray
Deputy for Pacific Operations
Nevada Operations Office
Department of Energy
P.O. Box 14100
Las Vegas, NV 89114

Dear Roger:

In view of the recent evacuation of Rongelap, which appears to have been precipitated by concern about harmful residual radioactivity on the atoll, we have reviewed our medical records to see if there is any clinical evidence that supports this conclusion and course of action.

Since 1957 an unexposed population of Marshallese of Rongelap ancestry has been examined periodically by the Brookhaven medical team. This population (the Comparison group) is similar in age and sex distribution to the exposed people of Rongelap. The reason for examination of the unexposed group has been to obtain baseline incidences of diseases in the general Marshallese population as an aid in detection of previously unidentified radiation hazards which might affect the exposed group.

Collected data on the unexposed people are sufficient to assess the effect of residence on Rongelap (since 1957) on longevity, thyroid neoplasia, and blood counts. We have done a retrospective analysis of their medical records; 133 of the group are living and 54 are deceased. We have arbitrarily selected for analysis the following divisions of years of residence on Rongelap:

Short-term - <3 years (average, 1.0 years)
Intermediate - 4 - 14 years (average, 7.5 years)
Long-term - >15 years (average, 20.9 years)

The place of residence for a given year is defined as the place where an individual received his medical examination. Since there is considerable migration of Marshallese among the atolls, the site of examination may not always be the same as the site of residence. Overall, however, there should be a good correlation between the two.

Mr. Roger Ray
July 18, 1985
Page 2

Effects on Longevity

There is no evidence that prolonged residence on Rongelap since 1957 has resulted in a shortening of life expectancy:

Residence Category		Number of Deaths		Mean age at Death
Short-term		20		61.4 years
Intermediate		27		66.6 years
Long-term		5		70.0 years
	Total	52*	Average	64.9 years

* Does not include 2 accidental deaths.

Effects on Thyroid Neoplasia

There is no evidence that prolonged residence on Rongelap since 1957 has resulted in an increase in thyroid neoplasia. Nine unexposed persons in the Comparison group have had surgery for thyroid nodules:

Residence Category	Number of Persons	Mean Age in 1985 (yr)	Number with Thyroid Nodules Removed	Number of Thyroid Cancers
Short-term	58	47.1	4 (7%)	1
Intermediate	46	46.4	3 (7%)	0
Long-term	29	46.9	2 (7%)	1
Total	133		9	2

These figures apply to the 133 unexposed persons in the Comparison group who are living. All of the 9 persons who had thyroid nodules removed are still alive.

Effects on Blood Counts (1985 data)

There is no detectable effect of residence on Rongelap on blood counts:

Residence Category	Number Tested	Neutrophils/ul ±SD	Lymphocytes/ul ±SD	Platelets/ul$\times10^3$ ±SD
Short-term	24	4851±2089	2754±1006	279±111
Intermediate	40	3838± 992	2835± 908	292± 59
Long-term	26	4366±1551	2612± 787	262± 51

A test of equality of means showed no statistically significant differences among the three categories. Note that the number of blood tests performed (90) is less than the number of persons in the Comparison group. This is because not all were seen in the March-April, 1985, survey.

We have also considered thyroid nodules and current blood cell counts as they may relate to early residence on Rongelap, since a greater radiation risk would have existed during the early years after the 1954 fallout. Thirty-four persons in the Comparison group resided in Rongelap for 4-6 years commencing with the return to the atoll in 1957. Only 1 nodule, an "occult carcinoma",, has occurred in this subgroup (3.0%), whereas the other 8 nodules, including the two true thyroid carcinomas, occurred in the other 99 persons in the Comparison group (8.1%). There was also no difference in blood cell counts:

Time of Residence	Number Tested (1985)	Neutrophils/ul ±SD	Lymphocytes/ul ±SD	Platelets/ul$\times 10^3$ ±SD
Early	29	4032±1543	2713±836	267±57
Late	77	4349±1599	2756±951	264±80

If you wish us to examine any other parameters do not hesitate to ask.

Sincerely yours,

William H. Adams, M.D.

WHA/elr

TABLE N.4B #1 THYROID DOSE FROM INDIVIDUAL RADIONUCLIDES IN FALLOUT TO THE ADULT MALE [a] [b]

Source	Half-life	Per cent physical decay in 3 weeks	Dose rads
Internal exposure			
Iodine-135	6.6 h	100%	190 rad
Iodine-134	53.2 min	100%	3
Iodine-133	21 h	100%	550
Iodine-132	2.3 h	100%	7
Iodine-131	8.04 d	84%	130
Tellurium-131	30 h + 8.04 d	79%	120
Tellurium-131m	25 min + 8.04 d	84%	13
External exposure			190
Total dose			1203

a/ Lessard et al, (1985)

b/ Exposure to the fallout on Rongelap Island occurred for about 45 hours. The fallout fell for about 7 hours.

TABLE N-4 B #2 **Total Thyroid Absorbed-Dose Estimate (1954)**

Age	Rongelap Island			Sifo Island			Utirik Island		
	Internal	External	Total	Internal	External	Total	Internal	External	Total
				Average Estimate, rad[a]					
Adult Male	1000	190	1200	280	110	400	150	11	160
Adult Female	1100	190	1300	290	110	410	160	11	170
Fourteen-Year-Old	1400	190	1600	410	110	530	220	11	230
Twelve-Year-Old	1600	190	1800	450	110	570	240	11	250
Nine-Year-Old	2000	190	2200	540	110	660	300	11	310
Six-Year-Old	2400	190	2600	640	110	760	340	11	350
One-Year-Old	5000	190	5200	1300	110	1400	670	11	680
Newborn	250	190	440	-	-	-	48	11	59
In Utero, 3rd tri.	680	190	870	-	-	-	98	11	110
In Utero, 2nd tri.	-	-	-	490	110	610	260	11	270
				Maximum Estimate, rad					
Adult Male	4000	190	4200	1120	110	1200	600	11	610
Adult Female	4400	190	4600	1160	110	1300	640	11	650
Fourteen-Year-Old	5600	190	5800	1600	110	1700	880	11	890
Twelve-Year-Old	6400	190	6600	1800	110	1900	960	11	970
Nine-Year-Old	8000	190	8200	2200	110	2300	1200	11	1200
Six-Year-Old	9600	190	9800	2600	110	2700	1400	11	1400
One-Year-Old	20000	190	20000	5200	110	5300	2700	11	2700
Newborn	1000	190	1200	-	-	-	190	11	200
In Utero, 3rd tri.	2700	190	2900	-	-	-	390	11	400
In Utero, 2nd tri.	-	-	-	2000	110	2100	1000	11	1000

[a]Multiply by 0.01 to obtain Gy.

Source: Lessard et al, 1985, p.61

N-5

The sequence of safety recommendations and guides has run as follows.

(a) In 1954 the National Bureau of Standards Handbook 59 presented the recommendations of the NCRP. The maximum permissible dose to the bone marrow (and hence to the entire body) was 0.3 rem per week.

(b) In January, 1957, the whole-body dose for the general population was lowered to .5 rem per year by the NCRP. This was published as an insert into the Bureau's Handbook 59. The AEC also published this and other recommendations in Appendix 10, p. 400 of its 22nd Semiannual Report to the Congress.

(c) In 1960, the Federal Radiation Council defined two guides for the general population. (Federal Register, May 22, 1965, pp. 6953-55)

The "radiation protection guide" for the general population under normal circumstances was .170 rem per year.

The "protective action guide (category 3)" was defined to cover the long-term harm by cesium-137 and strontium-90 acting through the food web after the first year of a contaminating event. The FRC recognized the great diversity of such situations. It concluded that protective action must be determined on a case-by-case basis when the annual dose to the bone marrow after the first year would exceed 0.5 rem to individuals or 0.2 rem to a suitable sample of the population.

(d) In 1979, ICRP Publication 30 subsequently modified for the transuranics in Publication 48, 1986, provided annual limits for the intake of radionuclides by workers. Divided by 30, they are equal to a committed effective dose equivalent per year of .170 rem.

For the nonprofessional reader, the following is an explanation of the specific radiological meaning of the terms, exposure and dose. Very simply, the medical analogy would be this. A patient takes a spoonful of heart medicine -- radiologically considered, that is his exposure.

Of the swallowed medicine, three-quarters are eliminated but one-quarter passes from the intestine into the circulation and is absorbed by the heart -- that one-quarter is the dose. It would be expressed per gram of heart tissue.

For exposure to radiation per se, the unit is the roentgen (R), measured in air. For radionuclides (atoms which spontaneously decay and emit radiation), the units are the bequerel (Bq), equal to 1 atomic disintegration per second, or the curie (Ci), 3.7×10^{10} disintegrations per second. The microcurie (μCi) and the picocurie (pCi) are respectively 1 millionth of a curie, and 1 millionth of a microcurie (27 pCi equal 1 Bq).

The units of dose are the rad (for any type of ionizing radiation: 100 ergs absorbed per gram of tissue); the rem (dose equivalent in biological effect to 1 rad of standard radiation). The particular point to remember about radiation dose is that it is per gram of tissue. A whole-body dose of 100 rad means that every gram (on average) received 100 rad; it does not mean that the entire body received 100 rad to be distributed throughout the tissues.

Both exposure and dose are referred to as resulting from external or internal sources. An external exposure or external dose is the result of a radiation source outside of the body, e.g., fallout contaminated soil. An internal dose would result from a source inside of the body, e.g., radioactive iodine due to the use of fallout-contaminated drinking water.

In the case of radionuclides, we shall use the term "whole-body dose" in the technical sense of "committed effective dose equivalent". Committed means the dose delivered to the body over the next 50 years from the amount of radionuclide under discussion (e.g., the amount I eat today). Effective signifies corresponding to whole-body exposure (e.g., 1 rem to the entire lungs corresponds to .12 rem whole-body). Dose equivalent in rem signifies that whatever kind of radiation is being used, its dose in rem gives the same effect as that of any other type of radiation expressed in rem.

The "tissue dose" is the committed dose equivalent.

N-7 The external gamma-ray exposures of Table 4.1 #1 affect all of the tissues of the body. In addition, beta rays (cesium-137 and strontium-90) emanate from soil, but have only a limited range in air and very poor penetration into the body; they might affect the body's surface in those regions which are closest to or are actually touching the ground. Shoes and clothing provide complete or almost complete protection.

External beta-ray dose is considered to be unimportant on the basis of the following. For gamma rays, the Rongelap Island/Eneu Island external-dose ratio is 1.7 (Table 4.1 #1. The beta-ray dose ratio at .007 mm depth (basal cell layer, skin) should be approximately the same. Therefore, by extrapolation from the determinations at Eneu (Shingleton et al, 1987) the Rongelap basal-cell dose would be 46 mrem/y, and at 1 cm depth practically zero (ICRP 51, Table 26). Since the radiation protection guide for skin is 5 rem/y (NCRP 1987b), the skin dose is a trivial one.

Diet. The major uncertainty in estimating the dose is the diet - no one knows precisely what it is. Two efforts have been made to delineate it. The first by Naidu et al (1980) (BNL 51313) was based on living experiences over the years on various Northern Marshallese Atolls and clearly demonstrated the effects of living patterns on it. Rongelap fell into their B class, one in which there was a low availability of local foods (excepting fish), overpopulation, and a good supply of imported foods (supply boat comes in regularly, say, every three weeks). Naidu et al reported the quantities of food prepared, but emphasized that they did not know how much was eaten. In any event, Robison and DOE-1982 used this estimate as the maximum level of consumption for a population.

The MLSC diet was elaborated by M. Pritchard of the Micronesian Legal Services Corporation in 1979 when he visited the Enewetak people for 2.5 weeks on Utirik Atoll (Robison et al, 1982a, His diets assumed that the supply ship came regularly, making it possible for the people to eat relatively large amounts of imported foods (rice, flour, sugar, canned goods, etc.), or that the ship did not come at all. Robison selected the adult female subgroup of the population for calculation because its consumption was greatest. DOE-1982 took this calculation for the minimal level of contaminated-food consumption.

For the MLSC diet (supply ship on schedule) it has been found that cesium-137 accounts for about 95% of the whole-body dose and 85% of the bone marrow dose. Strontium-90 accounts for 5% and 15%, respectively, and the transuranics for less than 1% during the first 70 years. When the supply ship is on schedule, coconut accounts for 80% or so of the radionuclide intake.

In summary, then, DOE-1982 used the Naidu type B commuunity diet for its dose calculations. When it wished to indicate a range, it used both the type B community (high) and the MLSC diet (low). The diets are given in Table N-8 #1.

One additional fact about the preparation of fish. The skin and bones of fish may have 50-100 times the strontium-90 specific activity of the meat. Also, the contents of the intestinal tract may be high. What is the effect of all this on dosage? First, Noshkin et al (1981) found the strontium-90 specific activities of all tissues to be below 1 pCi/g. Robison et al (personal communication, 1988), have confirmed this for mullet caught off the reef of Bikini Island (contamination levels 5-10 times those at Rongelap Island). Roast mullet and stewed mullet were tested. For stew, neither the meat, nor broth, nor skin and bones exceeded .01 pCi per gram (Table N 8.# 2). The cooking was done by Marshallese in the customary way (the intestines were discarded).

TABLE N- 8 #1 DAILY FOOD CONSUMPTION -- TWO DIETS [a/]

Food	Community B (adult) grams/day	MLSC Diet (adult female) grams/day
Arrowroot	0	3.9
Breadfruit	36	27.2
Banana	19	0.02
Coconut		
Drinking meat	100	--
Drinking fluid	514	--
Copra	68	--
Milk	125	--
Sprouting	100	--
Coconut "fluid"	--	142
Coconut "meat"	--	63.3
Papaya	0	6.6
Pumpkin	0	1.2
Pandanus	96	9.2
Fish	194	41.5
Eggs	--	10.7
Poultry	3	--
Wild birds	9	4.2
Domestic meat	--	21.2
Pork	1.4	--
Clams	15	8.9
Crabs	--	3.1
Octopus	20	4.5
Turtle	.1	4.3
Snails	12	--
Coconut crab	1	--
Lobster	.14	--
Shellfish	--	5.1
Total	1313.64	356.92

[a/] Imported foods are not included in the lists. The data are from Tables 4 and 11 in Robison et al, UCRL 52853 (1982b). Imported staples include rice (especially), sugar, flour, canned meat, canned drinks, and baby foods.

TABLE N-8 #2

STRONTIUM-90 DISTRIBUTION IN MULLET; FRESH, ROASTED, AND AS A STEW[a]

	Strontium-90, pCi/g wet weight		
	Roast mullet	Mullet stew	Fresh mullet[b]
Muscle (meat)	9.5 E-4	--	5.2 E-4
Bones	5.4 E-2	4.2 E-2	1.8 E-2
Duplicate bones	6.0 E-2	--	--
Skin	8.0 E-2	--	2.7 E-2
Broth	--	4.5 E-4	--
Skin + meat	--	1.8 E-3	--

[a] The table was supplied by Dr. W. L. Robison of the Lawrence Livermore National Laboratory.

[b] From V. Noshkin et al, UCID-20754, 1986, "Concentrations of Radionuclides in Fish Collected from Bikini Atoll between 1977 and 1984".

N-9

To determine whether or not the determination of specific activity of soil and plants made by the Livermore Laboratory was correct, a field trip took place in December 1987 during which samples were collected at 7 locations running the length of Rongelap Island and on 3 islands of Ailingnae Atoll. The samples were collected under the supervision of Dr. H. Paretzke by Livermore technicians and Rongelap men. Senator Anjain and other Rongelap citizens were present. The results show that the Livermore technique is an acceptable one.

At each location, the external exposure rate was measured. The mean for seven locations on Rongelap was 3.4 (2.2-4.6) μRh. Corrected back to 1978, it becomes 4.3 μR/h, in excellent agreement with previous determinations (Table 4.1 #1).

The samples of soil and vegetation were frozen and shipped back to the Livermore Laboratory where they were divided so that one-half of each was sent to Dr. Paretzke in Neuherberg (Munich), the other being retained for analyses in this county by Dr. Robison (Livermore) and Dr. Kohn (Berkeley). Dr. Paretzke shared his samples with Dr. Boikat (Bremen).

Each laboratory prepared its own material for analysis and then analyzed it without knowledge of the results from elsewhere.

In general, the various laboratory results agreed well with one another for field sampling (Table N 9# 1-4).

The radionuclide levels on Ailininae Atoll were found to be no more than one-third those on Rongelap Island.

Among the radionuclides themselves, the extremely low levels of the transuranics in vegetation and meat compared to soil demonstrate the operation of biological selection against these elements (5,000 to 10,000-fold). This effect is amplified by further negative selection in the gut; absorption in adults is about 0.1% compared to 100% for cesium. During the first month of life, however, absorption from the gut might be 10 to 100 times greater than in adults.

The radionuclide levels are also in general agreement with the most recent summary of the Lawrence Livermore Laboratory (Table 4.2 #2).

These comparisons are of more than routine importance, since many Rongelap people have stated that DOE laboratory results cannot be trusted and that the DOE scientists are liars.

TABLE N-9 #1

CESIUM-137 COMPARISONS (1987)

Item	Island [a] (No. samples)	LLNL [b]	P & B [c]
		pCi/g	pCi/g
Drinking	A (3) [d]	.47	.60
coconut meat	R (6)	4.5	3.4
Drinking	A (3)	.22	.19
coconut juice	R (6)	1.25	1.45
Soil: 0-10 cm	A (3)	3.31	2.43
	R (7)	11.5	8.7
10-20 cm	A (1)	.48	.30
	R (1)	1.30	.97
Lime meat	R (2)	2.2	1.9
Coconut crab muscle	A (2)	1.09	.96
Breadfruit	R (1)	3.8	4.38
Arrowroot	R (1)	17.1	20.7
Pandanus	R (1)	21.3	26.2
Pig muscle	R (1)	14.7	13.9
Chicken muscle	R (1)	6.2	6.3

[a] A is Ailinginae, R is Rongelap.

[b] Lawrence Livermore National Laboratory

[c] Dr. Paretzke (Munich) and Dr. Boikat (Bremen)

[d] 1 each from Mogiri, Enibuk and Gerea-Knox

TABLE N-9 #2

STRONTIUM-90 COMPARISONS (1987)

Item	Island (No. samples)	P & B [a]	HIK [b]
		pCi/g	pCi/g
Drinking coconut meat	R (1)	.0054	.0061
Breadfruit meat	R (1)	.035	.052
Soil: 0-10 cm	R (1)	6.2	10.1
Arrowroot	R (1)	.068	.076
Coconut crab muscle	A (1)		.35

[a] Dr. Paretzke (Munich) and Dr. Boikat (Bremen)
[b] Dr. Kohn (Berkeley)

TABLE N-9 #3

PLUTONIUM-239,-240 COMPARISONS (1987)

Item	Island (No. samples)	P & B [a]	HIK [b]
		pCi/g	pCi/g
Drinking coconut meat	R (2)	.000016 < .0032	.000069
Soil: 0-10 cm	R (1)	2.46	7.7
Arrowroot	R (1)	.0046	.00065
Breadfruit meat	R (1)		.000018
Pig muscle	R (1)		.00001
Chicken muscle	R (1)		.00011

TABLE N-9 #4

AMERICIUM-241 COMPARISONS (1987)

Item	Island (No. samples)	LLNL [c,d]	P & B [d]	HIK [e]
		pCi/g	pCi/g	pCi/g
Drinking	A (2)			.00002
coconut meat	R (6)			.00005
Soil: 0-10 cm	A (3)	0.69	< .33	.61
	R (7)	1.43	1.19	1.54
10-20 cm	A (1)	.19	< .12	.19
	R (1)	.074	< .11	.076
Breadfruit	R (1)			.000013
Arrowroot	R (1)			.00038
Pandanus	R (1)			.000025

a/ Dr. Paretzke (Munich) and Dr. Boikat (Bremen)
b/ Dr. Kohn (Berkeley)
c/ Lawrence Livermore National Laboratory
d/ Gamma counting.
e/ Alpha counting

N-10

INHALATION DOSE

The inhalation of dust can vary tremendously depending on activity. On Bikini Island ploughing an open field in the dry season would represent the high end of the spectrum; resting quietly at home or sailing on the lagoon would be near the low end. Robison (Ref. UCRL 53805, p. 9) has revised his earlier excessive estimate of 5 hours per day of ploughing. As an average now throughout the year, he takes 1 hour per day plus 23 hours under normal conditions, resulting in a daily intake at Bikini of .017 pCi of plutonium-239,-240 and .0071 pCi/d of americium-241, totalling .024 pCi/d.

To obtain the Rongelap dose, it was assumed that the distribution of particle sizes and of radionuclides was practically the same on Bikini and Rongelap Islands. Therefore, the inhalation dose on Rongelap would be to that on Bikini as the transuranic specific activity of Rongelap soil (0-5 cm) was to that of Bikini Island. The plutonium level on Rongelap was 29% of that on Bikini, and the americium level 12% (Robison 1982a, pp. 8, 12, 44, 56; 1982b, pp. 12, 14, 47, B10, B13).

The daily transuranic exposures for adults on Rongelap were therefore:

plutonium-239,-240,	29% of .017 pCi	= .005 pCi/d
americium-241,	12% of .00071 pCi	= .0009 pCi/d
Total		.006 pCi/d

The adult 30-year inhalation doses are estimated to be (Table 4.2 #1B):

Tissue	Plutonium-239,-240 (rem)	Americium-241 (rem)
Whole-body	.023	.004
Red marrow	.035	.006
Bone surfaces	.004	.0007

For the infant (to be on the safe side) we have assumed exposure to be the same as for an adult. Therefore, taking the total daily transuranic exposure as .006 pCi/d, we find the whole-body dose for the first year to be (Table 4.4 #1):

.006 x (2.4 x .15) = .002 rem (1st year),

and for the period 0-30 years of age,

.006 x (1.35 x 4.5) = .036 rem (0-30 years).

In other words, for the first year of age, the doses will be 2.4 times the adult, and for the period 0-30 years of age they will be 1.35 times the adult ones. This is on the conservative assumption that infants and children inhale as much radionuclide as do adults.

N-11

BROOKHAVEN RESULTS - Cesium-137 and Strontium-90

The whole-body counter measures the quantity and the energy of the gamma ray photons that have been emitted by cesium-137, or other radionuclides, and that escape from the body. In principle, the machine is calibrated by measuring the escape of gamma rays from a phantom which has been loaded with the radionuclides in question. Obviously, the whole-body counter comes closest to giving a direct measurement of the body-content.

The Brookhaven Laboratory team has visited Rongelap periodically since the time of resettlement in 1957 in order to perform whole-body counts for cesium-137, and some other radionuclides, for which the results are summarized in Tables N.11 #1 and #2. The actual data are shown in Table 1, and the annual estimates of body burden based on curves fitted to the data of Table 1 are shown in Table 2. These tables have been provided through the courtesy of Dr. E. T. Lessard.

TABLE N.11 #1

AVERAGE RADIONUCLIDE CONTENT AND TIME SINCE REHABILITATION FOR RONGELAP ADULTS

	Adult Males (>15a)		Adult Females (>15a)		Adults (>15a)			
	Body Burden Bq	Number of Individuals	Body Burden Bq	Number of Individuals	Body Burden Bq	Number of Individuals	Time Post Rehabitation Days	Year
^{60}Co	1.1×10^{0}	(A)	6.3×10^{-1}	(A)	9.3×10^{-1}	(A)	0	1957
	3.7×10^{2}	37	2.9×10^{2}	37	3.3×10^{2}	74	1370	196
	9.3×10^{1}	45	7.4×10^{1}	45	8.1×10^{1}	90	2831	1965
^{65}Zn	1.9×10^{3}	4(B)	(C)	(C)	(C)	(C)	0	195
	2.3×10^{4}	17	6.4×10^{3}	8	1.8×10^{4}	25	244	195
	1.6×10^{4}	30	1.4×10^{4}	12	1.5×10^{4}	42	304	19
	2.3×10^{4}	32	1.9×10^{4}	27	2.1×10^{4}	59	639	1959
	3.5×10^{3}	38	3.1×10^{3}	23	3.4×10^{3}	61	1370	196
^{55}Fe	1.6×10^{4}	28	1.5×10^{4}	32	1.5×10^{4}	60	4626	1970
^{90}Sr	7.0×10^{0}	(A)	5.2×10^{0}	(A)	6.3×10^{0}	(A)	0	195
	1.7×10^{1}	11	1.1×10^{1}	4	1.4×10^{1}	15	304	195
	4.7×10^{1}	24	2.9×10^{1}	16	4.1×10^{1}	40	639	1959
	6.3×10^{1}	9	2.5×10^{1}	4	5.1×10^{1}	13	1370	1961
	3.0×10^{2}	13	1.8×10^{2}	15	2.4×10^{2}	28	1696	196
	2.1×10^{2}	12	1.9×10^{2}	13	1.9×10^{2}	25	2100	196
	2.1×10^{2}	11	2.0×10^{2}	7	2.1×10^{2}	18	2466	196
	7.7×10^{1}	12	1.6×10^{2}	12	1.3×10^{2}	24	3561	1967
	1.5×10^{2}	11	1.2×10^{2}	11	1.3×10^{2}	22	3927	196
	1.6×10^{2}	11	1.3×10^{2}	13	1.5×10^{2}	24	4292	196
	5.5×10^{1}	9	1.5×10^{2}	11	1.1×10^{2}	20	4657	1970
	1.4×10^{2}	8	1.2×10^{2}	7	1.3×10^{2}	15	5022	197
	9.6×10^{1}	5	8.7×10^{1}	7	9.6×10^{1}	12	5388	197
	3.2×10^{2}	4	2.1×10^{2}	7	2.5×10^{2}	13	5753	197
	1.7×10^{2}	10	8.5×10^{1}	4	1.5×10^{2}	14	6118	1974
	2.5×10^{2}	26	(C)	(C)	(C)	(C)	7579	197
	3.7×10^{1}	25	2.8×10^{1}	19	3.3×10^{1}	44	8057	197
^{137}Cs	5.2×10^{2}	(A)	3.1×10^{2}	(A)	4.1×10^{2}	(A)	0	1957
	2.9×20^{4}	38	1.9×10^{4}	13	2.7×10^{4}	51	304	195
	2.9×10^{4}	47	1.5×10^{4}	49	2.1×10^{4}	96	639	195
	3.5×10^{4}	37	1.7×10^{4}	37	2.5×10^{4}	74	1370	196
	3.5×10^{4}	44	1.8×10^{4}	45	2.5×10^{4}	89	2831	196
	1.8×10^{4}	22	1.1×10^{4}	24	1.4×10^{4}	46	6118	197
	1.1×10^{4}	30	7.0×10^{3}	21	9.3×10^{3}	51	7213	197
	6.7×10^{3}	19	5.6×10^{3}	18	6.3×10^{3}	37	8057	19
	6.7×10^{3}	36	7.0×10^{3}	30	6.7×10^{3}	66	8813	198
	1.0×10^{4}	29	7.8×10^{3}	18	9.4×10^{3}	47	9180	198
	8.9×10^{3}	23	7.8×10^{3}	29	8.3×10^{3}	52	9540	198
	3.9×10^{3}	43	3.4×10^{3}	35	3.7×10^{3}	78	9910	198

A = Number of individuals not recorded.
B = Measured at Argonne National Laboratory.
C = No females measured.

(This table was supplied by Dr. E. T. Lessard, Brookhaven National Laboratory)
(1 bequerel = 27 picocuries)

TABLE N.11 # 2

BROOKHAVEN DATA FOR INTERNAL DOSE & EXTERNAL EXPOSURE

Rongelap Adult Committed Effective Dose Equivalent,(1)
Average Value Committed Each Year

Year Post BRAVO	Year	^{60}Co	^{137}Cs	^{65}Zn	^{90}Sr	^{55}Fe	mR/year 2 Average Annual External Exposure Rate	
		mrem y^{-1}						
3	1957	19.8	199	151	4.32	10.9	290	
4	1958	8.35	181	33.8	3.97	8.44	210	
5	1959	3.53	164	7.56	3.64	6.51	170	
6	1960	1.49	149	1.69	3.34	5.02	140	
7	1961	0.63	136	0.38	3.06	3.88	120	
8	1962	0.27	123	0.08	2.81	2.99	100	
9	1963	0.11	112	0.02 195	2.58	2.31	90	
10	1964	0.05	102		2.37	1.78	80	
11	1965	0.02 34	92.4		2.17	1.38	73	
12	1966		83.9		1.99	1.06	66	
13	1967		76.2		1.83	0.82	61	
14	1968		69.2		1.68	0.63	56	
15	1969		62.9		1.54	0.49	52	
16	1970		57.2		1.41	0.38	49	
17	1971		51.9		1.29	0.29	46	
18	1972		47.2		1.19	0.22	43	
19	1973		42.9		1.09	0.17	41	
20	1974		38.9		1.00	0.13	38	
21	1975		35.4		0.92	0.10	36	
22	1976		32.1		0.84	0.08	35	
23	1977		29.2		0.77	0.06	33	
24	1978		26.5 1911		0.71 45	0.05 47.6	32	1302
25	1979		24.1		0.65	0.04	30	
26	1980		21.9		0.60	0.03	29	millire
27	1981		19.9		0.55	0.02	28	
28	1982		19.1		0.50	0.02	27	
29	1983		16.4		0.46	0 01	26	
30	1984		14.9		0.42	0.01	25	
31	1985		13.5		0.39	0.01 .14	24	
32	1986		12.3		0.36		23	
33	1987		11.2		0.33		23	
34	1988		10.2		0.30		22	
35	1989		9.22		0.28		21	
36	1990		8.38		0.25		21	
37	1991		7.61		0.23		20	
38	1992		6.92		0.21		19	
39	1993		6.28		0.20		19	
40	1994		5.71		0.18		18	
41	1995		5.19		0.16		18	
42	1996		4.71		0.15		17	
43	1997		4.28		0.14		17	
44	1998		3.89		0.13		16	
45	1999		3.53		0.12		16	
46	2000		3.21		0.11		15	
47	2001		2.92		0.10		15	
48	2002		2.65		0.09		15	
49	2003		2.41		0.08		14	
50	2004		2.19		0.08		14	
51	2005		1.99		0.07		14	
52	2006		1.80		0.06		14	
53	2007		1.64		0.06		13	
54	2008		1.49 245		0.05 7		13	410
55	2009		1.35		0.05		13	millir

1 Multiply by 10^{-5} to convert to Sv.
2 Multiply by 0.7 to obtain ~~mrem~~ (whole-body).

Σ to 1978 = 2233 + 1302 = 3535
Σ 1979-2008 = 252 + 410 = 662

This table was supplied by Dr. E. T. Lessard of the Brookhaven National Laboratory.

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Note 12

PLUTONIUM ANALYSIS

In the case of radionuclides that emit beta rays (strontium-90) or alpha particles (transuranics), and whose range in tissue is at most a centimeter down to some micrometers, two methods have been used for assay.

(a) Knowing the daily urinary excretion, the body content of radionuclide is calculated from knowledge of its metabolism. The method has worked for strontium-90 (e.g., 3 Rongelap cases at autopsy confirmed urinary analysis (Ref. Conard 1980, Appendix, p. 115), but not so far with plutonium where extremely small quantities are involved.

(b) The dose can also be calculated from the diet. The primary obstacle here is that the diet is difficult to ascertain accurately. The Livermore results are based on this method.

For Rongelap, diet and urine methods are in frank disagreement. The Livermore diet method finds the daily intake of plutonium-239 to be .18 pCi/d (Section 4.2: plutonium-239 is 60% of the -239,-240 mixture).

On the other hand, the current analysis of urine at Brookhaven gives plutonium-239 excretion values which range from less than 1×10^{-5} to about 5×10^{-3} pCi/d. These correspond to a range of intake from less than .07 pCi/d to about 38 pCi/day.

The doses (30-year, whole-body) calculated from these estimates for plutonium-239 are as follows:

Livermore: .007 rem

Brookhaven: >.003 rem - 1.48 rem

The total dose for the three transuranics (two plutoniums plus americium) would be twice these figures.

The problems implicit in this comparison require some detailed discussion.

Brookhaven results. Historically, we may begin with Conard's twenty-year Rongelap review of 1975 (Ref. BNL 50424) in which the results of urine analysis for 10 Rongelap persons were reported (Appendix 12, p. 147). One result seemed much too high; the average of the other nine was 58×10^{-3} pCi/liter/d, twice the maximum found in the current series. Conard did not discuss this result, but it was reviewed by an ad hoc group which suggested contamination as a likely cause of the high values (Lessard 1984).

Urines were again collected on a much larger scale in 1981. The PARALS method was applied, but abandoned owing to inherent contamination with polonium. The fission track method was then adopted and a method to separate plutonium for such analysis worked out. It should be recognized that the very small quantities of plutonium involved make the operation of the method a very difficult task (ORAU). The cost per sample is about $1,000.

Some 270 samples of urine have been analyzed. Owing to a reorganization at Brookhaven, the work for this project was stopped (no funds), and the results were neither tabulated nor analyzed. For the Rongelap Preliminary Report of April 26, 1988, the Brookhaven Laboratory gave Dr. Lessard, the former manager of the program, two days of free time and he reported on some details.

Since then, starting in June a summer student, Mr. George Taylor, has been extracting data from the notebooks and should be able to tabulate a summary by the end of summer. Meanwhile, Mr. Taylor has sent me some results for the first 104 cases, which are displayed in Table N.12 #1.

(a) As noted above, the range of excretion is very large -- from less than 1 x 10^{-5} pCi/d to 5 x 10^{-3} pCi/d. The significance of this range is not known.

(b) The distribution of the data appears to be logarithmic and bimodal. Thus it may be suggested that two populations are at risk. The populations might differ physiologically (one absorbs transuranics much more readily than the other); environmentally (diet, contamination of samples); or technically (a change in technique or technician). Of these, contamination might be the most likely; it is very difficult to collect good urine samples in the Marshalls. But any or all of these variables may have played a role.

(c) The results are not primarily dependent on sex or age, although these factors may play a role.

(d) The youngest group appears to have a somewhat higher excretion rate than the oldest one, at least in males. This could be due to a more rapid metabolic turnover of the radionuclides. Tritium and iodine, for example, have half-residence times in infants of 3 days and 30 days respectively, but in adults 10 days and 100 days (Hoenes, et al 1977). The long-term compartments of plutonium have an average half-time in the body of about 35 years, which could be much less in infants and children. The higher outputs of the children might therefore represent faster metabolism rather than greater intake.

Although the arithmetic in the foregoing calculations may be correct, we may ask, "Are they consistent with what we know?" As a matter of judgment, I think the answer is, "No.". The maximum urinary output of plutonium-239 corresponds to 76 pCi/d for the three transuranic elements. Looking over the data in Table 4.2 #1, it is difficult to see how anyone could eat sufficient food to accomplish this. Clams have the highest specific activity of the transuranics -- 131 x 10^{-4} pCi/g -- a specific activity that is about 50 times greater than the nearest competitor. One would therefore have to eat 5.8 kilograms per day, every day in the year, to satisfy the predictions of the Brookhaven analyses.

<u>Dose calculations</u>. The Moss (Moss 1988) factors in Table N.12 #2, supplied through the courtesy of Dr. E. T. Lessard of Brookhaven, permit the calculation of plutonium-239 oral intake from urinary excretion, or vice versa. The factors vary about 3-fold in the present case where the periods of exposure are from about 5 to 25 years.

Of the 104 cases in Table N.12 # 1, all had lived on Rongelap since birth or for at least 7 years with four exceptions. One other exception was the case of a 12 year-old female who first arrived in 1980; her output of 2.34 pCi/d was practically identical to that of an 11 year-old (2.18 pCi/d) who had always lived on the island.

For orientation, let us use a factor of 1.5×10^{-4}, corresponding to about 7 years of plutonium exposure. Then for the maximum urinary output, the intake would be 38 pCi/d [$(5 \times 10^{-3}) / (1.5 \times 10^{-4})$].

The corresponding whole-body dose (30 year) would be 1.5 rem for plutonium-239, and 3 rem for the three transuranics. (The corresponding Livermore diet estimate would be .014 rem.) Three rem of course, is relatively a sizable dose. However, it is of interest that when combined with the rest of the Brookhaven estimates, the total dose of rem does not exceed the 5 rem limit. For exposure from birth to age 30 years, the dose would be 1.63 times greater (Table 4.4 #1).

TABLE N.12 #1

RONGELAP: PLUTONIUM-239 URINARY EXCRETION (1981)[a,b]

Age	No.	Below detectible limit	1 - 9 x 10^{-5} pCi/d	1 - 9 x 10^{-4} pCi/d	1 - 5 x 10^{-3} pCi/d
Males					
5 - 10 y	24	6 (25%)	-	17 (71%)	1
10 - 20 y	27	9 (33%)	7 (25%)	9 (33%)	2
21+ y	17	12 (71%)	1	3 (18%)	1
TOTAL MALES	68 (100%)	27 (40%)	8 (12%)	29 (43%)	4 (6%)
Females					
5 - 10 y	9	2 (22%)		4 (44%)	3 (33%)
10 - 20 y	10	4 (40%)		5 (50%)	1 (10%)
21+ y	17	8 (47%)	1	6 (35%)	2 (18%)
TOTAL FEMALES	36 (100%)	14 (39%)	1 (3%)	15 (42%)	6 (17%)
TOTALS	104 (100%)	42 (40%)	9 (9%)	44 (42%)	9 (9%)

[a] 1981 collection, determined by fission track method at Brookhaven National Laboratory. All subjects had been in continuous residence (or practically so) for their life span or for more than 7 years. The urine volumes were standardized to 700 ml for age 10 and below; 1 liter for females above 10; 1.2 liters for males 10 - 16, and 1.4 liters for males over 16 (per day).

[b] Analyses on another 160 or so subjects are now being taken from the records for tabulation and analysis. We are indebted to the Radiological Sciences Research Division for this material, and to Messrs. Lessard and Taylor.

TABLE N.12 #2

PLUTONIUM-23[illegible]: FRACTION OF ORAL DAILY INTAKE EXCRETED IN URINE [a/][b/]

It is assumed that the daily intake is constant over the period specified. F_1 = .001.

Duration of exposure (years)	Jones (old)	Moss (new)
1	3.62×10^{-5}	5.42×10^{-5}
5	6.2×10^{-5}	--
10	8.61×10^{-5}	1.71×10^{-4}
20	1.31×10^{-4}	2.3×10^{-4}
29	1.67×10^{-4}	2.92×10^{-4}

[a/] The table's data were supplied by Dr. E. T. Lessard of the Brookhaven National Laboratory. I have used the Moss factors (Moss, 1988).

[b/] The intake can be calculated by dividing the urinary excretion by the factors given. For example, after 20 years of intake, the daily excretion is found to be 3×10^{-5} picocuries. Then the intake is: $(3 \times 10^{-5}) / 2.3 \times 10^{-4}$ = .13 picocuries/day.

NOTE 13. PEACE CORPS

Through the essential help of Mr. Jack Maykoski (Peace Corps Headquarters, P.O. Box 5, Majuro, Marshall Islands 96960) and Mr. Peter Oliver, Special Assistant for Compact Affairs of the Government (P.O. Box 15, Majuro 96960), a number of Volunteers are making diet surveys of their islands. The study is still in progress, but some results have been reported at this time for inclusion in this report by: Mike Flaherty, Buoj Island, Ailinglaplap Atoll; Judi Hinshaw, Woja Island, Ailinglaplap Atoll; Hali Robinette, Ine Island, Arno Atoll, Serena Weihl, Kayen Island, Maloelap Atoll; Ellen Opie, Wotje Island, Wotje Atoll.

The Volunteers have standardized measuring equipment and reporting sheets. Data are gathered by staying with a family for one day on two separate occasions. The task is not an easy one, and we are greatly indebted to these workers for taking on an extra and difficult duty.

NOTE 14

RISK FACTORS

The recent revisions in dosimetry for Japanese bomb survivors have indicated that the risk factor for cancer mortality of 1×10^{-4} should be raised 2 - 10-fold (Shimizu et al 1987; Preston and Pierce 1987). The Japanese experience, however, was based on high dose, high dose-rate exposure, whereas the Rongelap experience under discussion is very low dose and very low dose-rate. The difference in dose-rate involves a factor downwards of 3 - 10-fold, and as a result the two changes cancel one another. To be on the safe side, however, I have chosen to raise the old BEIR factor from 1 to 2.5×10^{-4}. The matter is presently under discussion by the United Nations Scientific Committee on the Effects of Atomic Radiations, which is preparing a report for the International Committee on Radiation Protection.

Note 15: Senator Anjain's letter

The letter from Senator Anjain speaks for itself. It should be compared with the body of the text of the present Report.

I would, however, like to comment on one point, namely, my failure to transmit Dr. Bertell's letter to the Congress immediately on receiving it. The reason was this: I did not consider her report good enough to be transmitted by me as part of my work as Referee. I may add that Dr. Bertell had testified before the Congress at the April 26, 1988, hearing, at the invitation of Senator Anjain.

Her letter (as did her testimony) dealt with two major topics. First, an attempt to show that somehow living on Rongelap per se affected the blood cell counts. I enclose my letter to Dr. Muckle, a pathologist she consulted about this work. Dr. Muckle agreed that when all of the data were reviewed, no tangible results were evident.

Second, the survey of child health led to suggestions that something was radically wrong and that radiation would be the presumptive cause, owing to currently living on Rongelap. I do not consider the data convincing. No mention is made of the usual levels of infant and child health in the Marshalls, and how difficult it would be against such a background to establish radiation as a cause. On this score I quote from the Report of the Task Force on Health (December 17, 1985), chaired by Mrs. Carmen Bigler, RepMar Secretary of Interior and Outer Island Affairs:

> The task force believes that the central problem facing the health care system is a reversal of priorities;...an appropriate medical system must provide first the essentials of health through public health education, immunization, clean water, sanitation, family planning, community-based dispensary system, and infectious disease control.

For more specific information, I suggest reading "Current Living Conditions of Children in the Marshall Islands", a Report of general information for submission to UNICEF, Republic of the Marshall Islands, June 1984.

> Because Rongelap was directly affected by fallout from a 1954 United States thermonuclear test and because the Rongelap people remain unconvinced that is safe to continue to live on Rongelap Island, it is the intent of Congress to take such steps (if any) as may be necessary to overcome the effects of such fallout on the habitability of Rongelap Island, and to restore Rongelap Island, if necessary so that it can be safely inhabited.

The fears that swept through our people were justified in the eyes of Congress. The 1982 DOE report and revelations contained in it terrified our people. More information was needed and Congress established a process by which it would be obtained.

Your Preliminary Study, as the Mayor and I said to you in April, "for the first time, contains important and significant revelations about the radiation contamination to which we have been exposed."

The disclosures in 1982 made it evident that DOE was not truthful with the Rongelap people from 1957 to 1982 regarding the level of atoll contamination. As alarming as the 1982 DOE Report was, the Rongelap people didn't believe that DOE told the full story regarding atoll contamination or health impacts.

Your study has substantiated our concerns. DOE did not tell the truth and we now know it.

Since the April 26 hearing at which time your Preliminary Study was released, the nature of your undertaking has changed. Many things you have done or are in the process of doing are not understood. The manner in which this study is now being conducted is unacceptable.

The following is a list of major problems with the study:

(1) <u>DOE Plutonium Studies Withheld.</u> When DOE's Harry Brown testified before the Appropriations Committee, he indicated that DOE had published a study in 1986 concerning plutonium and the Rongelap people. He further stated that the study was provided to you and your consultants. It was not. You were provided information and data from DOE which was not shared with your consultant working on this very issue. Despite repeated requests for these documents and materials, they remains unavailable.

(2) <u>Bertell Report Completed, But Withheld From Congress.</u> On June 1, Dr. Bertell completed her report evaluating medical and health data, including impacts on the children of Rongelap.

She submitted it to you with the request that you immediately forward it to Congress as the deadline for action was only a few days away. This was not done. Despite the fact that the impacts on children was the primary reason for extending your report by several months, you did not submit this new material to the Yates Committee. The Bertell report concludes, among other things, that the data from blood samples taken from the Rongelapese was never analyzed, that the control group used in DOE studies was abnormal, and that the impacts on children and mothers indicate serious problems. DOE says it's safe and you advise us to return to Rongelap. We do not understand. Mostly, we don't understand why this report is being withheld beyond critical deadlines in Congress.

(3) Kohn Study Consultant Participated in Cover-up of Nuclear Radiation Accident. You selected Dr. John Dunster as one of your consultants. I have just learned of Dr. Dunster's personal and direct role in covering up the October, 1957 "Windscale" accident in Britian. Documents declassified early this year finally reveal the nature and extent of the willful withholding of information from the affected British people, both at the time of the accident and over the years since it occurred. That you would select such a person to participate in the Rongelap Reassessment Project is unthinkable.

(4) Independence of Rongelap Reassessment Project Undermined -- DOE Now Controls Release of Documents. Following the April hearing, and the disclosure that the DOE undertook a special review of the plutonium problem only two years ago, requests for information by one of your study consultants were referred to DOE. In early May, Mr. Franke sent written requests to you for the materials referenced at the hearing, and to Brookhaven National Laboratories, for additional materials relating to the plutonium problem. You wrote to Mr. Franke on May 7, stating, "the material you want should be obtained from Harry Brown (DOE). I am sorry that I have forgotten to send you his address." On May 9, Edward T. Lessard writes, "please forward your request to Mr. Harry Brown."

Requests for this information were then immediately sent to Brown, but as of today, none of the information has been received.

This study is not supposed to be "cleared" by DOE. It was supposed to be independent of DOE. Is this the independence we were promised?

(5) Study Work Plan Altered. The study mandated by Congress was to review the DOE data in the 1982 report and to determine its accuracy. Early in the study, you were highly critical of a work plan advanced by consultants who recommended gathering new data. Now however, you are embarking on such

actions. As I understand it, you have recently decided to undertake certain nutritional studies. In furtherance of this effort, instead of having trained nutritional experts, you have recruited untrained peace corp volunteers to do this work.

Throughout the study, I have been reminded that the purpose of the study is to review the 1982 report. To have untrained volunteers gathering new health-nutrition data at this point in the process is not understood.

(6) Kohn Study Needs to Add Section on DOE Omissions. As a result of your study, we have learned that DOE and its laboratories have urine and blood samples from Rongelap citizens which have either not been measured, or, if measured, not analyzed. My people have participated in medical testing with the understanding that these samples would be fully analyzed. There is now considerable evidence that at least some of these samples have never been evaluated. To be punctured with needles drawing blood or filling little cups with our urine -- to find out that DOE then fails to fully evaluate these samples -- is insulting. Your study needs to indicate this problem.

I returned to Washington from the Marshall Islands expecting to find answers to problems, not more problems. But, what have I learned? I have learned that:

* DOE is now controlling all or part of this study;

* DOE plutonium reports and other materials have not been released by DOE;

* Brookhaven National Laboratories has not released bioassay reports or other requested materials;

* The children's medical study was completed, submitted to you, but not forwarded to Congress;

* One of the study consultants, recruited by you, actively participated in a cover-up of a nuclear accident and further, participated in the willful withholding of information to the affected citizens;

* Unqualified peace corps volunteers have been retained or recruited to undertake "fast" nutritional studies of the Rongelap people;

* The scope and purpose of the study appear to have been altered with a new purpose beyond that of examining and evaluating the accuracy of the DOE data in the 1982 report and now the direction of the study is no longer clear.

Dr. Kohn, the people of Rongelap are the reason for this study. We are the central figures. Or, stated another way, we are the clients. We were sent back to Rongelap Atoll in 1957 and over the years we were repeatedly told that it was safe to live, to gather and consume food -- from all the islands.

We are the most exposed group of people in the Marshalls to radiation.

We are the subject of and the reason for this study.

Yet, when you completed your study, no effort has been made to communicate with our people. No briefings were held. We didn't know your study would be preliminary and that it would be extended for several months. You never told us. This delay has removed us from congressional consideration during this current budget cycle.

Last December, you sent a video message to the people of Rongelap. You indicated that you'd keep the Rongelap people informed. This is not being done.

Over these many months, disclosure after disclosure has come forth. Most involve what DOE didn't do, what they didn't say, what they didn't analyze, and what they didn't tell us. The 1982 DOE report is riddled with errors.

Congress established a two-part process. First, review the report to determine if it was accurate. Second, if not, then a comprehensive review should be undertaken.

DOE was not accurate. The comprehensive report is justified. We urge you to make that recommendation, and to make it in clear and unmistakable terms.

Correct the deficiencies in your study. Make it credible in our eyes. Let it become a stepping-stone in a process to properly restore and rehabilitate Rongelap Atoll.

Dr. Kohn, let me state it this way. Had the 1982 DOE report not been issued, obviously we would still be living on Rongelap Atoll. However, on the basis of the Kohn Report and its revelations, we would be packing our belongings and preparing to leave today.

The Rongelap people today live in deplorable circumstances. Above all, we seek resolution of this matter. We have become pacific nomads, not out of choice, but out of fear. In your hands is a decision to take steps toward resolution or to prolong this agony.

We are human beings and we seek only simply dignity and truth.

Sincerely,

Willie Mwekto

Mayor Willie Mwekto

Jeton Anjain

Senator Jeton Anjain

cc: Rongelap Atoll Local Government

Henry I. Kohn, MD, PhD
RONGELAP REASSESSMENT PROJECT

June 28, 1988

Dr. T. J. Muckle
Director of Laboratories
Chedoke Hospital Division
Box 2000, Station A
Hamilton, Ontario L8N 3Z5

Dear Dr. Muckle,

I have done some more thinking about the blood-cell counts of the Rongelap people, a matter which Dr. Rosalie Bertell asked you to comment on.

You will recall that 82 Rongelap people were exposed to fallout in 1954, were then moved to Majuro Atoll where they remained until 1957, and were then moved back to Rongelap.

During this period (1954-57), non-exposed Rongelap people were also living on Majuro and their blood counts are therefore of interest as controls. In addition, blood counts on the Majuro people themselves and on people living on Rita (an island in Majuro Atoll) are also of interest as controls.

The enclosed table shows blood cell counts for these control groups during the period 1954-57 (before return). You will note that the monocyte count of the Rongelap controls was low prior to return, but after return rose to the normal range. Radiation, therefore, had nothing to do with this change. The monocyte count was also somewhat low in the other two control groups.

You also commented on a difference in lymphocyte count between the first years on Rongelap and 1982-86. Please look again at the data including the Majuro controls in 1982-86. They show a similar change, but were never on Rongelap.

Looking over all of the results in this table leads me to suggest that the fourth paragraph of your letter (which has been quoted by Dr. Bertell) is not warranted now. I refer to the sentence, "I think what may be shown here is the effect of long-continued exposure, which may indeed be quite different from the late effects of acute but transient exposure."

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When reviewed with a bit of perspective, including bearing local conditions in mind, and the fact that 1982-86 counting techniques differed from earlier ones, I don't believe one can say that this collection of counts establishes anything specific in a positive sense.

What do you think now?

I feel somewhat hesitant to involve you in all of this, since it takes time. However, I excuse myself with the thought that you were involved already.

Sincerely yours,

Henry I. Kohn

Henry I. Kohn

cc: Dr. Rosalie Bertell

Over for Blood Count Table

25 June 88
HIK

WHITE BLOOD CELL COUNTS IN UNEXPOSED CONTROL GROUPS [a/]

Date	Group [b/]	Cells per mm^3 Neutrophils	Lymphocytes	Monocytes	Platelets per mm^3 x 10^{-3}
3'54	"Majuro" (115)	4800	4100	200	310
9'54	"Rita" (82)	5200	3700	180	290
3'56	"Rita" (57)	3600	4400	150	275
3'57	"Rongelap"	While living on Majuro, before return:			
	(86)	3400	2900	70	280
3'58	"Rongelap"	After return to Rongelap Island in 1957:			
	(80)	3600	3700	110	320
3'59	(75)	5200	4100	240	310
3'61	(-72)?	4200	3100	120	300
3'62	(70)?	4200	2900	190	350
3'63	(70)?	3900	3100	250	310
3'64	(70)?	4800	3500	240	370
'82-'86	(70)	4200	2800	330	--
'82-'86	"Majuro" (61)	3900	2800	320	--

a/ Brookhaven National Laboratory reports: BNL 384 (T-71), 412 (T-80), 501 (T-119), 534 (T-135), 609 (T-179), 727 (T-260), 780 (T-296), 908 (T-371), and the 1982-86 statistics from BNL Medical Division averaged by Dr. R. Bertell. The reports are available from the Technical Service Information Bureau. The earlier Brookhaven statistics were supplied by Brookhaven National Laboratory.

b/ All of these groups were unexposed to the fallout of 1954. The Majuro and Rita groups were living on those islands of Majuro Atoll. The Rongelap group was living on Majuro until 1957 when almost all of its members returned to Rongelap. The number examined per year is given in parentheses.