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RADIOACTIVE CONTAMINATION

OF CERTAIN AREAS IN THE

PACIFIC OCEAN

FROM NUCLEAR TESTS « « «

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FROM NUCLEAR TESTS

AUGUST 1957

A Summary of the Data from the Radiological Surveys and Medical Examinations

Edited by

GORDON M. DUNNING

UNITED STATES ATOMIC ENERGY COMMISSION

For sale by Superintendent of Documents, U. S. Government Printing Office, Washington, D. C

Price 40 cents

Introduction

On March 1, 1954, an experimental thermonuclear device was exploded at the U. S. Atomic Energy Commission's Eniwetok Proving Grounds in the Marshall Islands. Following the detonation, 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.

Although the calculated accumulated doses to these people were believed to be below levels that would produce serious injury or any mortality, the Commander of the Task Force requested the Department of Defense and the U. S. Atomic Energy Commission to organize a medical team to provide the best possible care of the exposed persons and to make a medical study of the exposures.

The medical surveys of the Marshallese exposed to the fallout from the March 1, 1954 nuclear test detonation at the Eniwetok Proving Ground, have been published under the editorship of Dr. Victor P. Bond,[12] Dr. Eugene P. Cronkite,[13] who headed the first two surveys, and Dr. Robert Conard,[14] who led the 2-year follow-up study. The present report brings together the radiological data developed by the Joint Task Force 7, Applied Fisheries Laboratory of the University of Washington, U. S. Naval Radiological Defense Laboratory, Health and Safety Laboratory, New York Operations Office of the Atomic Energy Commission, and the Office of Naval Research.

This report was undertaken by Dr. Gordon M. Dunning at the request of the Atomic Energy Commission. Dr. Dunning at the time of the fallout was a representative of the Division of Biology and Medicine, Atomic Energy Commission to Joint Task Force 7 and participated in the early surveys and in the evacuation of the natives of Rongelap and Utirik Atolls to Kwajalein.

It is hoped that this document will provide valuable information to those agencies and persons responsible for planning protection against radioactive fallout from whatever source. It not only gives a picture of the initial contamination, but in addition documents the radioactive decay as it has occurred on the Rongelap Atoll over a 2½-year period and thus suggests the developing patterns of the transfer of radioactive materials from the soil and water into the food chain.

CHARLES L. DUNHAM, M. D., *Director*
Division of Biology and Medicine
U. S. Atomic Energy Commission

Preface and Acknowledgments

Two to three days after the fallout on the Marshall Islands in March 1954, 82 people were evacuated from Rongelap and Ailiginae Atolls and 154 from Utirik Island. In June of 1954, the 154 personnel were returned to Utirik, and in the spring of 1957 the decision was made to return the Rongelapese to their home island. Since March 1954 periodic surveys have been made of these islands to investigate the degree of contamination.

Soils and biological collections were made on and around the Marshall Islands by the Applied Fisheries Laboratory (AFL) of the University of Washington on March 26, 1954, July 16, 1954, December 8 and 18, 1954, January 25–30, 1955, October 21–23, 1955, November 7, 1955, and July 23–24, 1956; by the Naval Radiological Defense Laboratory (NRDL) on February 1955 and February 1956. Analyses of the samples also were performed by AFL, NRDL and by the Health and Safety Laboratory (HASL) of the Atomic Energy Commission. Surveys were also made of residual activity in the Pacific Ocean by Health and Safety Laboratory of the AEC and Office of Naval Research in February–May 1955; by the Applied Fisheries Laboratory in June and September 1956. In addition, teams of medical experts from the United States examined and cared for the Marshallese following their exposure in March 1954, and returned to re-examine the Rongelapese at about six months, one year, and two years after exposure.

The purpose of this report is to abstract the highlights of the data from these investigations. In doing so there is the risk of unintentionally quoting the original reports out of context. It should be understood that the original authors are not responsible for any such violations and if there be any question it is recommended that reference be made to the basic documents (see references).

The following personnel participated in the field expeditions:

March 26, 1954 (*USS Nicholas, DDE 449*).

Applied Fisheries Laboratory: Dr. Lauren R. Donaldson, Director, Dr. Edward E. Held, Dr. Ralph F. Palumbo, Mr. Paul R. Olson, and Major Charles Barnes, USAF on assignment from the Air Force Veterinary Corps to the Applied Fisheries Laboratory.

In addition, Dr. Thomas Shipman, Dr. Thomas N. White,* P. R. Schivone, and W. W. Robbins accompanied the expedition to aid the natives in capturing some of their animals on Rongelap Island and to make radiation readings on some of the islands in the southern part of the atoll.

April 13, 1954 (*SA-16 Naval Aircraft*).

U. S. Naval Radiological Defense Laboratory and Naval Medical Research Institute: Dr. Stanton Cohn, Lt. R. S. Farr, P. E. Thompson HMC, J. C. Hendrie, HML, and J. Flannigan, NM1.

July 16, 1954. (*U. S. Navy Gruman Albatross, ASR-16, No. 902*).

Applied Fisheries Laboratory: Dr. Lauren R. Donaldson, Director, Dr. Frank G. Lowman, Dr. Arthur D. Welander and Lt. Commander Clarence F. Pautzke, USNR Aquatic biologist on active duty status for special training.

December 8, 1954 (*U. S. N. PBM No. 2471*).

Applied Fisheries Laboratory: Dr. Edward E. Held, Mr. Paul R. Olson. AEC Division of Biology and Medicine: Dr. Walter D. Claus, AEC Radiological Safety Officers, Mr. Robert Taylor and Mr. William Blakeman.

*Deceased.

December 18, 1954 (U. S. N. PBM No. 2471).

Applied Fisheries Laboratory, Dr. Lauren R. Donaldson, Director, Dr. Edward E. Held, Mr. Paul R. Olson, and Dr. Jared Davis, entomologist on loan to the Applied Fisheries Laboratory, from General Electric, Radiological Sciences, Aquatic Biology Group, Richland, Washington.

Mr. Robert Rinehart and Mr. Paul Zigman, NRDL, accompanied the expedition.

January 25–30, 1955 (U. S. Navy O. G. "Rio Grande").

U. S. Naval Radiological Defense Laboratory: Robert W. Rinehart, Evan C. Evans III, Joseph K. Gong, George M. Neuffer, Lt. (jg) USNR, and William G. Murray. Applied Fisheries Laboratory: Dr. Allyn H. Seymour and Dr. Frank G. Lowman.

October 21–23, 1955 (L. S. T. 664).

Applied Fisheries Laboratory, Dr. Allyn H. Seymour, Dr. Edward E. Held, Dr. Kelshaw Bonham and Dr. Frank G. Lowman.

November 7, 1955 (U. S. Navy PBM 612).

Applied Fisheries Laboratory, Dr. Allyn H. Seymour and Dr. Edward E. Held.

February 7–14, 1956.

U. S. Naval Radiological Defense Laboratory: Dr. Edward R. Thompkins, Evan C. Evans III, William T. Pflueger, Capt. USA, Joseph K. Gong, and Walter L. Milne. U. S. Geological Survey, Department of Interior: Dr. F. R. Fosberg.

July 23–24, 1956 (U. S. Navy Gruman Albatross).

Applied Fisheries Laboratory: Dr. Lauren R. Donaldson, Mr. Paul R. Olson and Dr. Arthur D. Welander.

The processing of the material and analyses of the data at the Applied Fisheries Laboratory were shared by the following staff members: Dr. Lauren R. Donaldson, Director, Allyn H. Seymour, Mary Ash Baird, Kelshaw Bonham, Grace C. Brewer, Simeon T. Cantril, Marion L. Chase, Edward E. Held, Neal O. Hines, Frank G. Lowman, Paul R. Olson, Ralph F. Palumbo, Dorothy South and Arthur D. Welander.

At the U. S. Naval Radiological Defense Laboratory: Mr. R. W. Rinehart, assisted by Mr. John A. Seiler and Mr. William H. Shipman were responsible for laboratory analysis of samples and evaluation of data in 1955, and were joined in this work in 1956 by Dr. Herbert V. Weiss. In addition to his field participation, Mr. Gong was responsible for preparation of samples and evaluation of data in 1955 and was joined in this work by Mr. Milne in 1956. Dr. Minoru Honma, Maurice J. Brau, HN, USN, and Phillip Simone, HM3, USN, assisted in the 1956 analytical determinations. Mr. William Murray performed the photographic services in 1955. During both years, Captain Albert R. Behnke (MC) USN, served as scientific advisor; Dr. Stanton H. Cohn as senior investigator for planning of the field trips and for analysis of biological data; Mr. Paul E. Zigman, as senior investigator for planning and analysis of chemical data. The divers that assisted in the 1956 survey were Lt. P. L. Schlegel, USNR, of Underwater Demolition Team 11, and Q. D. Dennison, QM1, USN, of Underwater Demolition Team 12, both of U. S. Naval Amphibian Base, Coronado, California.

The general concepts of Operation Troll were discussed at an ad hoc meeting in Washington, D. C., on January 12, 1955. The following were present: Dr. A. C. Vine, Woods Hole Oceanographic Institute, Dr. J. Isaacs, Scripps Institution of Oceanography, Dr. T. Folsom, Scripps Institution of Oceanography, Mr. F. Jennings, Scripps Institution of Oceanography, Dr. J. Smith, Office of Naval Research, Mr. J. Kane, Office of Naval Research and Mr. H. D. LeVine, Health and Safety Laboratory, AEC.

The detailed planning was worked out among Mr. J. Smith and Mr. J. Kane of the Office of Naval Research, Dr. Warren S. Wooster of Scripps Institution of Oceanography, Mr. Howard Brown and Dr. Willis R. Boss of the

Division of Biology and Medicine, AEC and Mr. Merril Eisenbud and Dr. John Harley of the Health and Safety Laboratory, New York Operations Office.

The senior personnel at sea were Dr. John Harley as Project Leader, Dr. Wooster as Oceanographer and Dr. Allyn H. Seymour of the Applied Fisheries Laboratory, University of Washington as marine biologist.

The chemical analyses at the Health and Safety Laboratory were performed by Edward Hardy, Gerald Hamada and William Collins under the direction of Dr. John Harley.

The initial team from the United States that examined and cared for the Marshallese who had been evacuated to Kwajalein were: Doctors E. P. Cronkite, R. A. Conard, N. R. Shulman, and R. S. Farr from the Naval Medical Research Institute, Dr. V. P. Bond and Lt. Commander L. J. Smith from the U. S. Naval Radiological Defense Laboratory, Dr. C. L. Dunham, AEC, and Dr. G. V. LeRoy, Consultant to AEC, and Lt. Col. L. E. Browning, M. C. from the Armed Forces Special Weapons Project. Before the arrival of the team, preliminary care and studies had been initiated by the station medical officer, Commander W. S. Hall. Doctors T. L. Shipman, Thomas White,* and Payne Harris of the Los Alamos Scientific Laboratory performed the urinalyses.

The six months medical survey was conducted by Drs. V. P. Bond, R. A. Conard, J. S. Robertson and E. A. Weden, Jr., and the twelve months medical survey was conducted by Drs. E. P. Cronkite, C. L. Dunham, David Griffin (USNRDL), S. D. McPherson (NMRI) and Kent T. Woodward (Field Command, AFSWP). The two year medical survey was performed by Drs. R. A. Conard, Bradford Cannon, C. E. Huggins (USNR), J. B. Richards (USNR), and Austin Lowery (USA) with the technical assistance of C. P. A. Strome, W. K. Border, J. W. Hamby, L. D. Snow, W. G. Clutter, and C. D. Severson (all USN).

Special appreciation is expressed to Violet M. McCarthy for the secretarial work in preparing this report.

*Deceased.

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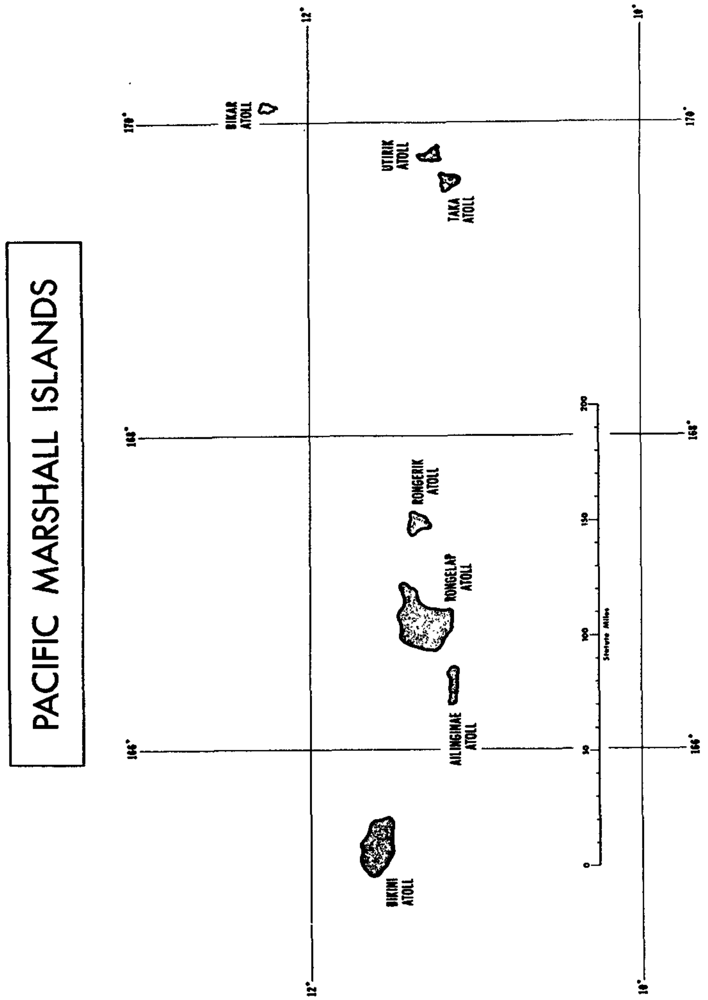


CHAPTER I

External Gamma Radiation

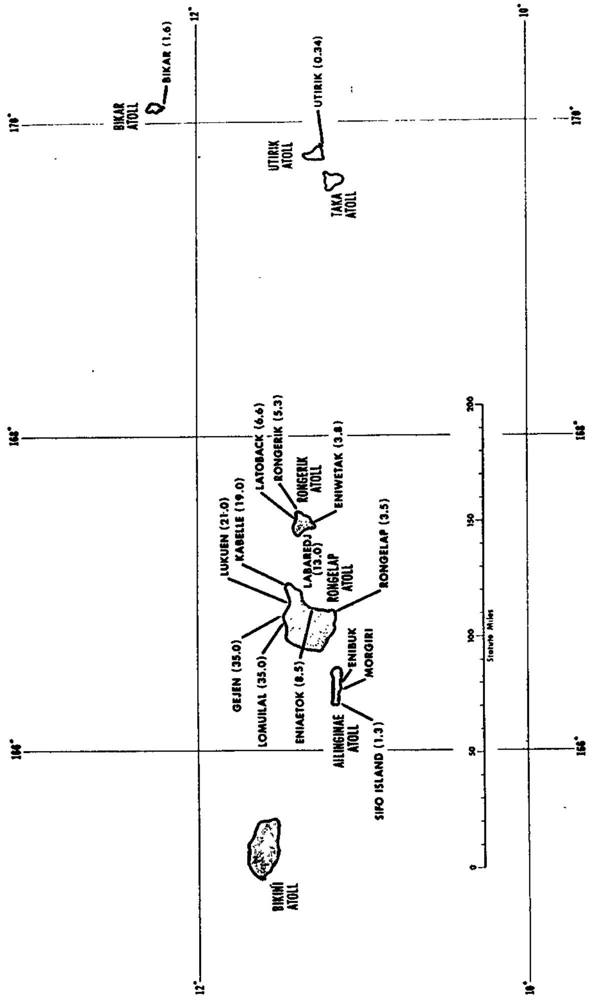
GAMMA DOSE RATES WERE taken periodically on several islands in the Pacific over a time ranging from about two days to more than two years. The attached map is an estimate of the gamma dose rates at three feet above the ground at D+1 (one day after the detonation on March 1, 1954). A very rough approximation of the degree of contamination may be made by dividing these readings by four to arrive at units of gamma megacuries per square mile. (The beta to gamma ratio varies with time but at one day may be near unity, so these values may also be thought of as beta activities.) However, the gamma dose rates do indicate the *relative* degrees of contamination on the islands, therefore are useful in this respect when evaluating the data in subsequent sections of this report.

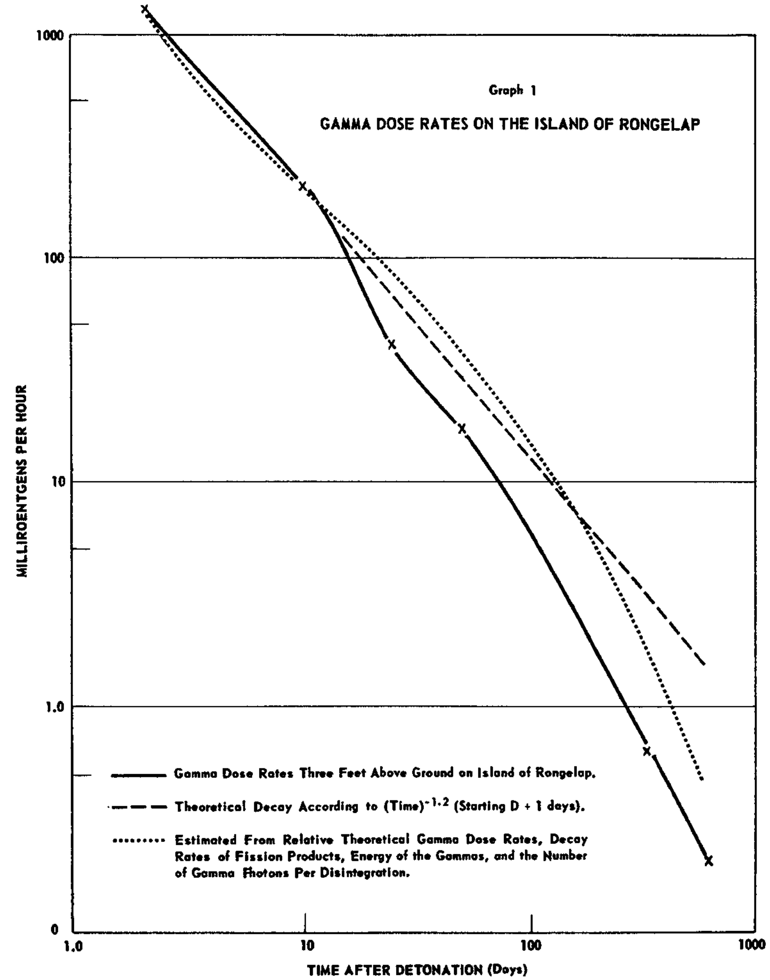
Graph 1 shows the decay with time of gamma dose rates on the Island of Rongelap. Similar decay curves were found on other islands in the Atoll and in nearby Atolls (Ailinginae and Rongerik). The decay of activity of mixed fission products is assumed to follow $(\text{time})^{-1.2}$ principle. This is intended to apply to disintegrations of atoms. However, in estimating the reduction of gamma dose rates above a plane with time there must be considered the changing numbers and energy spectra of gamma photons released per disintegration, and the effects of weathering. When computing the infinity radiation *doses* from fallout that occurs within a few hours after detonation, integration of the $(\text{time})^{-1.2}$ curve gives a fair approximation since most of this total dose is accumulated during the early periods when this curve lies near the theoretical gamma decay curve. However, in extrapolating by $(\text{time})^{-1.2}$ there may be a significant difference in estimating dose *rates* a year or more after detonation and in estimating *doses* that might occur at these later periods.

During the first two weeks after fallout there was no rainfall and the winds were light. About the end of the second week a tropical storm occurred. For these reasons, a straight line was drawn for the first two weeks followed by a break in the curve. The readings are not to be considered precise, due to the nature of such measurements, but the curves suggest that whatever was the reduction of gamma dose rates by weathering, it occurred principally with the first heavy rainfalls. Except for the last data point on Graph 1 for the Island of Rongelap, which may be somewhat high, the actual and theoretical decay curves correspond fairly well.

The theoretical curve of Graph 1 would flatten out with time due to the dominance of Cesium-137 with its 27 year half-life. The last survey of Rongelap Island in late July 1956 indicates a range of gamma dose rates at three feet above the ground of 0.2–0.5 milliroentgens per hour with an average of 0.4 mr/hr. These values are higher than suggested by Graph 1 and are due to the small additional fallout resulting from Operation Redwing (Spring and Summer 1956).

APPROXIMATE GAMMA DOSE RATES AT THREE FEET ABOVE THE GROUND ON D + 1 (One Day after Detonation)
(Roentgens Per Hour)





CHAPTER II

Gross Activity

A. Land Plants

Graphs 2 and 3 indicate the general levels of activity of edible plants (pandanus, papaya, breadfruit, arrowroot), and coconut meat and milk at Rongelap Atoll together with their decline of activity with time.[1,2]

Tables 1 and 2 show the analyses made by NRDL for their first survey in February 1955.[3] Table 3 is based on the February 1956 survey.[4]

Tables 4, 5 and 6 show the analyses by HASL.[5,6]

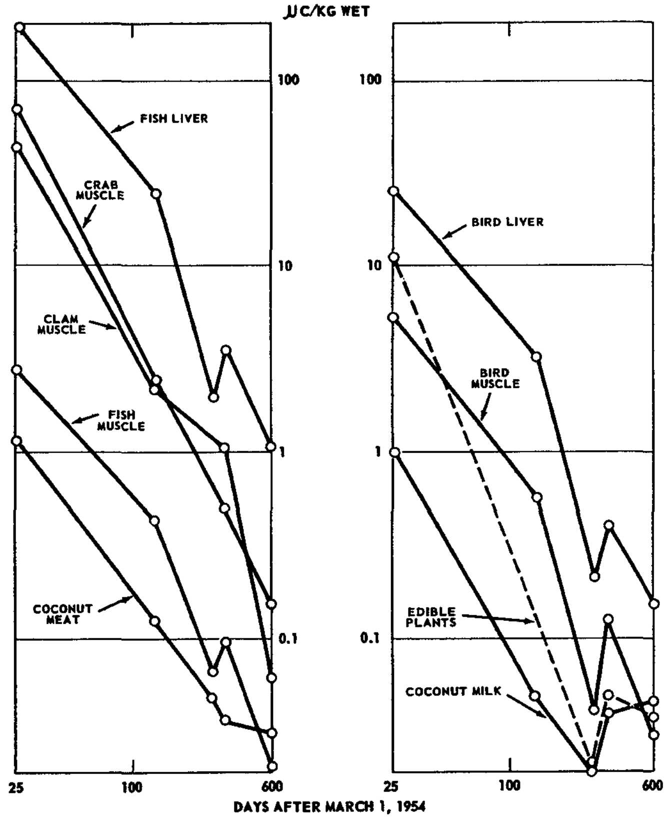
The high initial activity of the "edible plants" (Graph 2) was probably due to surface contamination caused by the direct fallout. The rise in activity after a year after the fallout occurred may be due to (a) sampling and counting variances, (b) the ability of some plants to concentrate Cs^{137} (see Section Radiochemical Analysis), (c) the increased availability of the radioactive fallout material to the plants, or (d) a combination of these factors. Initially the activity in the coconut milk and meat was less than other edible plants, but the rate of decline of activity has been less than for other edible land plants due principally to the higher percentage uptake of this longer-lived Cs^{137}.

Table 1—Summary of Gross Beta Activity in Miscellaneous Plant Samples*

Plant Material	Average Activity ($\mu c/g \times 10^6$) [a, b]											
	Island											
	Likiep	Utirik	Rongelap	Busch	Eniaetok	Labaredj	Kabelle	Lukuen	Gejen	Lomuilal	Bikar	Eniwetak
Grass	20	400	3000	420	2800	5300	1900	2100	68,000	5600	180	400
Coconut leaf		1100				750	1800	670				
Coconut frond stem								140				
Coconut shell							17		150			
Coconut husk	1.7	1.5	53				73		110		8.4	
Coconut sprout			28				110					
Sprouted coconut roots			72				740					
Scaevola leaf							120		100	290	6.7	60
Scaevola trunk section											23	
Arrowroot stem			19									
Arrowroot leaf			61									
Pumpkin	2.0		35									
Limes	2.0											
Taro	1.1											
Banana	4.6											
Vines									490			340

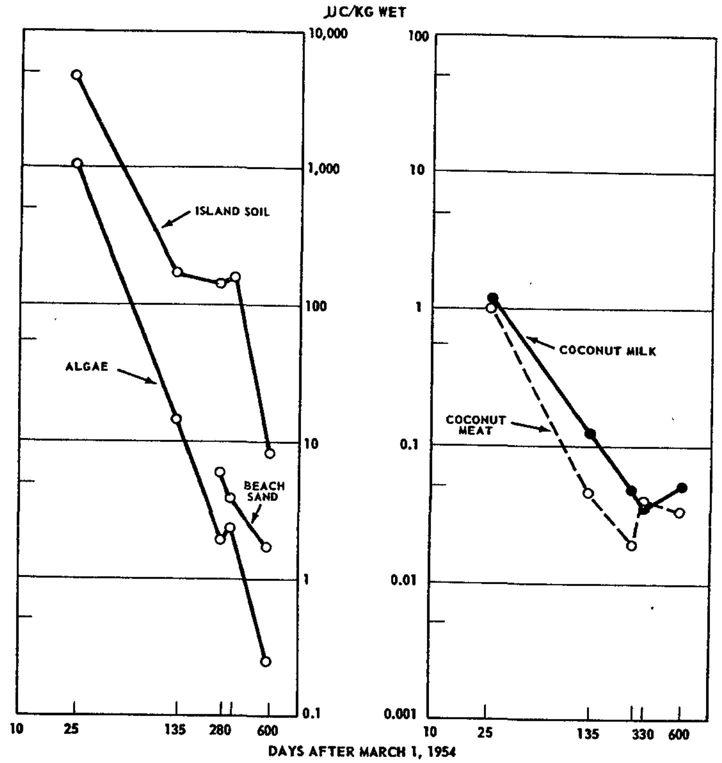
[a] Wet weight.
[b] As determined on basis U_3O_8 standards and empirical scattering and absorption corrections.
*Collections made about February 1, 1955. Data reported as of March 1, 1955.

Graph 2



RATE OF DECLINE OF RADIOACTIVITY IN FOOD ITEMS FROM COLLECTIONS AT RONGELAP ATOLL BETWEEN MARCH 26, 1954 AND OCTOBER 22-23, 1955. (AFL)

Graph 3



RATE OF DECLINE OF RADIOACTIVITY IN ALGAE AND SOILS AND COCONUT MEAT AND MILK AT RONGELAP ATOLL FROM MARCH 26, 1954 TO OCTOBER 23, 1955.

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Table 2—Summary of Gross Beta Activity in Major Plant Foods (NRDL)*

Source		Average Activity (μc/g x 10^6 or μc/cc x 10^6) [a] [b]					
Atoll	Island	Arrowroot	Breadfruit	Pandanus	Papaya	Coconut	
						Meat	Milk
Likiep	Likiep	4.0	9.1	5.7	3.6	2.5	3.0
Utirik	Utirik	16	3.4	5.0	9.0	2.3	2.6
Rongelap	Rongelap	15		28	27	9.8	9.6
Rongelap	Busch	68		13		8.0	11
Rongelap	Eniaetok	80		34		12	12
Rongelap	Labaredj	36				13	13
Rongelap	Kabelle	40		130		16	12
Rongelap	Lukuen					18	16
Rongelap	Gejen	130				72	25
Rongelap	Lomuilal	180				19	30
Bikar	Bikar					5.9	5.0
Rongerik	Eniwetak					7.8	9.4

[a] Wet weight.
[b] As determined on basis U_3O_8 standards and empirical scattering and absorption corrections.
*Collections made about February 1, 1955. Data reported as of March 1, 1955.

Table 3—Gross Beta Activity in Plant Samples [a] (NRDL)

Plant	Part	Plants [b] (c/m/kg x 10^{-6})						
		Gejen	Eniwetak	Eniaetok	Rongelap	Sifo	Utirik	Likiep
Portulaca	Whole plant	87.4	19.2	3.05	1.26		1.71	1.33
Arrowroot	Stem, leaves	11.0	4.5	0.32	0.25	0.21		0.03
	Tubers	2.32	0.57	0.69	0.55	0.08	0.14	0.03
Pandanus	Air root	2.87	0.17	1.05	0.32	0.96	0.08	0.02
	Leaves	2.64	1.02	5.26	0.38	0.15	0.21	0.03
	Green Keys	1.27	0.37	0.70	0.22	0.10	0.09	0.03
	Ripe Keys			0.53	0.17		0.07	0.02
Papaya	Ripe				0.12		0.11	
	Green				0.25		0.09	0.04
	Leaves, trunk				0.09		0.16	0.06
Ripe coconut	Milk	2.67			0.54	0.63	0.12	0.57
	Meat	1.90	0.36	1.97	0.24	0.17	0.08	0.06
	Shell	4.98	0.38	0.72	0.44	0.28	0.06	0.02
	Husk	1.83	0.65	1.57	1.31	0.77	0.21	0.09
Green coconut	Whole	3.1						
	Milk		0.29	0.11	0.05	0.13		0.05
	Meat		0.33	0.25		0.08	0.07	0.02
	Shell			0.80		0.37	0.06	0.09
	Husk			0.48	0.12	0.11	0.11	0.02
	Shell, husk		0.11					
Sprouting coconut	Milk		1.61	0.76	0.79	0.71	0.11	0.09
	Meat		0.38	0.40	0.12	0.30	0.07	0.06
	Shell		0.29	0.41	0.35	0.18	0.04	0.02
	Husk		0.73	1.57	0.88	0.68	0.26	0.07
Coconut	Leaves		15.4	0.86		0.84	04.7	1.66
	Frond		0.94	0.51		0.23	0.09	0.11
	Leaves, frond	1.48						
Banana	Fruit							0.06
	Bark							0.07
	Leaves							0.18
Taro	Leaves, stalks							0.06
	Tuber, roots with soil							0.19

[a] All counts were corrected for the counting efficiency of $Sr^{90}-Y^{90}$.
[b] Gross beta activity of plant samples was determined in April 1956 and that of soil and water in May 1956.

Table 4—HASL Analyses (AFL Surplus)

VEGETATION

HASL No.	Specimen No.	Organism	Tissue	Area Collected (Island)	Collection Date	Remarks	Total Activity* d/m/gram		Sr-90 d/m/gram		Percent Ca Based on Wet Weight	S. U.
							Wet	Dry	Wet	Dry		
3175	A 35-39	Papaya	Pulp	Rangelap	10-22-55	5 fruits—village area, skin and seeds removed: dried at 95° C.	58.2 ± 0.6	415 ± 4.3	0.43±0.02	3.07± 0.14	0.022	888 ±41
3172	A 40-42	do	Pulp and seed.	do	10-22-55	Halves from 3 fruits, village area: seeds removed: dried at 95° C.	105 ± 1.0	740 ± 7.0	1.23±0.06	8.64± 0.39	0.037	1511 ±74
3170	A 35-39	do	Skin	do	10-22-55	Peeled from 5 fruits, village area: dried at 95° C.	21.0 ± 0.5	146 ± 1.5	0.86±0.07	5.96± 0.48	0.070	559 ±45
3173	A 35-42	do	Seeds	do	10-22-55	8 fruits, village area: dried at 95° C.	63.9 ± 1.0	345 ± 5.4	0.32±0.04	1.75± 0.25	0.169	85.9±11
3177	A 62-64	*Morinda*	*Entire*	do	10-22-55	3 fruits, village area: dried at 95° C.	33.8 ± 1.9	278 ± 7.5	1.12±0.08	9.22± 0.67	0.065	783 ± 56
3171	A 67-71	Arrowroot	Corn	do	10-22-55	Peeled tubers, skin removed, village area: ashed at 550° C.	102 ± 1.1		3.61±0.32		0.030	5469 ±485
3168	A 143	Squash	Leaves and flowers.	do	10-22-55	Village area, plant in blossom but no fruit: dried at 95° C.	24 ± 1.0	307 ± 13	5.72±0.43	71.5 ± 4.27		
3213-3217	A 45-49	Pandanus	Entire	do	10-22-55	Part of 5 fruits from 5 trees, village area.	84.4 ± 0.6		2.57±0.07		0.136	859 ±23

ALGAE

3164	A 109			Rongelap	10-22-55	From cistern in village, species undefined: dried at 95° C.	9411 ±60	48440 ±425	9.73±9.35	70.0 ±67.3		
3166	A 110			do	10-22-55	From well in village (taken from sides below water level) species undefined: dried at 95° C.	683 ±13	2140 ± 72	6.90±2.14	37.7 ±11.7		

*Date of counting: February 1956.

Table 5—HASL Analyses (AFL Surplus)

COCONUTS

HASL No.	Specimen	Area Collected	Collection Date	Remarks (One Coconut From Each of Five (5) Trees)	d/m/gram—wet Total Activity*: Outer Husk	Inner Shell	Meat and Milk	d/m/gram—wet Sr-90: Outer Husk	Inner Shell	Meat and Milk	Percent Ca Based on Wet Weight: Outer Husk	Inner Shell	Meat and Milk
3198	A 30	Kabelle Is.	10-21-55	Various areas of the island	84.0± 3.3	15.8±0.7	54.5±2.3	1.2 ±0.34	0.60±0.19	0.06±0.33			
3199	A 31	do	10-21-55		56.6± 2.7	39.5±1.6	60.3±2.6	0.11±0.31	0.07±0.04	(−0.24)±0.18			
3200	A 32	do	10-21-55		66.3± 2.9	12 7±1.1	37.1±1.6	0.09±0.06	(−0.06)±0.08	0.03±0.14	0.038	0.058	0.013
3201	A 33	do	10-21-55		69.6± 3.1	20.4± .95	45.5±1.9	0.12±0.05	0.03±0.06	(−0.07)±0.14			
3202	A 34	do	10-21-55		127 ± 5.5	32.0±1.5	55.2±2.4	0.66±0.25	0.14±0.08	0.28±0.23			
3203	A 35	Labaredj Is.	10-21-55	Northern end of island	141 ± 6.0	20.9±0.9	59.2±2.5	1.3 ±0.14	0.28±0.11	(−0.35)±0.32			
3204	A 36	do	10-21-55		318 ±13	26.1±1.1	177 ±7.1	4.8 ±0.30	0.89±0.16	0.10±0.34			
3205	A 37	do	10-21-55		182 ± 7.6	31.1±1.3	61.3±2 6	1.3 ±0.18	0.17±0.07	0.10±0.18	0.062	0.019	0.011
3206	A 38	do	10-21-55		220 ± 9.2	41.2±1.7	63.1±2.7	1.0 ±0.29	0.19±0.12	0.56±0.22			
3207	A 39	do	10-21-55		143 ± 6.2	23.4±1.1	54.0±2.3	1.5 ±0.14	0.33±0.11	0.32±0.30			
3208	A 40	Rongelap Is.	10-22-55	Village area	254 ±11	46.3±1.9	81.2±3.3	3.5 ±0.24	0.51±0.13	0.22±0.20			
3209	A 41	do	10-22-55		49.4± 2.2	4.0±0.2	55.2±2.2	0.39±0.10	0.09±0.07	(−0.07)±0.10			
3210	A 42	do	10-22-55		87.4± 3.9	34.6±1.4	24.0±1.0	(−0.19)±0.20	0.21±0.09	0.44±0.21	0.053	0.078	0.007
3211	A 43	do	10-22-55		73.2± 3.3	9.5±0.5	33.3±1.5	0.70±0.21	0.31±0.13	0.57±0.42			
3212	A 44	do	10-22-55		84.3± 3.5	5.3±0.3	20.3±1.0	0.75±0.17	0.07±0.10	0.09±0.23			
COMMERCIAL COCONUTS													
3311		Puerto Rico	February 1956			1.2±0.2	5.1±1.0						
3312		do	do			8.0±0.2	5.3±1.0						
3313		do	do			1.9±0.2	5.8±1.0						

*Date of counting: February 1956.

Table 6—Results of Analyses Performed at HASL

LAND PLANTS

HASL No.	NRDL No.	Sampling Location	Organism	Tissue	Total Activity: C-Date*	d/m/gram	Sr^{90} d/m/gram	Cs^{137} d/m/gram	Ca grams/gram	S. U. •	Percent Sr^{90}	Percent Cs^{137}
3437	521	Rongelap	Coconut	Outer and inner shell.	4-17-56	26±0.7	0.22 ±0.01		0.00022	450± 21	0.85	
				Milk	4-17-56	43±1.7	0.11 ±0.10	19 ±2.7	0.00020	260±230	0.26	44
				Outer husk	4-17-56	71±1.7			0.00038			
3438	523	do	do	Inner shell	4-17-56	26±0.7	0.14 ±0.06		0.00013	480±210	0.52	
				Meat and milk	4-17-56	98±2.2	0.047±0.039		0.00001	2140±1800	0.048	
				Outer husk	4-17-56	66±1.7	0.70 ±0.04		0.00055	375± 21	1.1	
3439	525	do	do	Inner shell	4-17-56	35±0.7	0.081±0.071		0.00015	245±215	0.23	
				Meat and milk	4-17-56	87±2.1	0.080±0.043		0.00020	186± 98	0.094	
3513	752	Utirik	do	Entire	4-17-56	51±2.0	2.7 ±0.1		0.0096	104± 4.7	5.3	
3534	803	Likiep	do	do	4-17-56	10±0.7	0.046±0.02		0.00031	67± 29	0.45	
3441	535	Rongelap	Pandanus	do	4-14-56	42±1.9	0.26 ±0.11	16 ±3.7	0.00010	1180±500	0.62	38
3442	536	do	do	do	4-14-56	30±1.5	≤0.16		0.00010	≤730		
3447	558	do	Arrowroot	do	4-14-56	lost	lost					
3456	856	Gegen	do	do	4-14-56	300±4.1	3.6 ±0.15	250 ±5.4	0.0012	1370± 57	1.2	83
3476	580	Eniwetok	do	do	4-14-56	180±3.8	1.4 ±0.82	54 ±1.6	0.00060	1050±620	0.77	30
3492	726	Eniaetak	do	do	4-14-56	67±2.1	0.20 ±0.06	17 ±0.6	0.00060	155± 45	0.30	25
3505	674	Sifo	do	do	4-14-56	59±2.2	0.19 ±0.03	36 ±1.0	0.0026	32± 5.2	0.31	61
3519	756	Utirik	do	do	4-14-56	26±1.6	0.22 ±0.06	17 ±2.8	0.00003	3300±910	0.84	65
3541	807	Likiep	do	do	4-14-46	7.3±1.1	≤0.13	3.8±2.1	0.00070	≤85		52

*C-Date: Date of counting. • Sunshine Unit = 0.001 μc Sr^{90}/kg Ca.

B. Marine Organisms and Birds

Graph 2 indicates the general level of activity in fish at Rongelap Atoll and the decline of activity with time.[2]

Tables 7, 8, and 9 report the results of NRDL analyses for the February 1955 survey.[3] Tables 10, 11, and 12 are for the February 1956 survey.[4] Tables 13 and 14 show the analyses by HASL.[5, 6]

Table 7—Summary of Beta and Gamma Activity Concentration in Fish and Marine Invertebrates (NRDL)*

Location	Radioactivity Concentration (μc/kg)(a) — Large Fish (b): No. of Specimens	Activity β	Activity γ	Small Fish (c): No. of Specimens	Activity β	Activity γ	Crabs and Clams: No. of Specimens	Activity β	Activity γ	Snails: No. of Specimens	Activity β	Activity γ
Rongelap Atoll:												
North Lagoon	3	0.22	1.2	22	.49	1.58	4	1.54	1.25	2	19.5	5.6
South Lagoon	3	.054	0.33	7	.14	0.94	3	0.49	1.76	—(d)		
Rongerik Atoll:												
Eniwetak	2	0.23	0.26	2	.23	.21						
Utirik Atoll:												
Utirik				6	.14	.04						
Likiep Atoll:												
Likiep	1	0.02	0.01	3	.05	.01	1	0.12	0.35			
Bikar Atoll:												
Bikar							2	0.39	0.19			

(a) μc are in terms of Co^{60} equivalent. (b) >150 g. (c) <150 g. (d) No data taken.

*Collections made about February 1, 1955. Data reported as of March 1, 1955.

The data show a significant higher concentration of gross activity in the livers of fish and in the crustacean muscles.

Tables 9 and 12 show the gross activity in birds and fowls.[3, 4]

Table 8—Distribution of Gross Beta and Gamma Activity in Tissues of Large Fish [a] (NRDL)*

Island and Fish	Wet Weight (g)	Radioactivity (μc x 10⁴/Tissue) [(b)] Total β	Total γ	Skin β	Skin γ	Muscle β	Muscle γ	Bone β	Bone γ	Gills β	Gills γ	Viscera β	Viscera γ
Rongelap Atoll, North													
Gejen. flat Fish with Orange Spots [c]	597	196	714	25	24	18	96	120	310	7	16	26	268
North lagoon. 2 Pelargic	503	84	500	6	69	9	78	29	271	3	16	37	66
North lagoon. Snappers	391	53	550	4	68	9	94	35	313	3	17	8	60
Average	497	113	588	12	54	12	89	61	298	4	16	24	131
Percentage of total activity	------	------	------	10.6	9.2	10.6	15.1	54.0	50.7	3.5	2.7	21.0	22.3
Rongelap Atoll, South													
Southeast lagoon. Grouper	1,490	112	590	19	16	14	93	41	308	4	33	34	140
Southeast lagoon. Lutinius	2,170	69	513	25	69	19	119	18	111	6	51	1	163
Southeast lagoon. Red Snapper	1,980	106	339	12	36	14	104	59	122	8	27	13	50
Average	1,880	96	481	19	40	16	105	39	180	6	37	16	118
Percentage of total activity	------	------	------	19.8	8.3	16.7	21.9	40.7	37.5	6.3	7.7	16.7	24.6
Rongerik Atoll													
Eniwetak. Parrot	1,450	272	339	1	39	48	44	8	106	8	10	207	140
Eniwetak. Mullet	230	64	68	3	13	3	15	7	18	1	3	45	19
Average	840	168	204	5	26	26	30	8	62	5	7	126	80
Percentage of total activity	------	------	------	3.0	12.7	15.5	14.7	5.2	30.4	3.2	3.4	82.0	39.2

[a] >150 g. [b] μc are in terms of Co^{60} equivalent. [c] Name unknown.
*Collections made about February 1, 1955. Data reported as of March 1, 1955.

Table 9—Summary of the Gross Beta and Gamma Activity in Birds and Fowl *

Island and Specimen	No. of Specimens	Wet Weight (g)	Activity (μc x 10⁴/tissue) [a] β	Activity γ
Rongelap Atoll				
Gejen—*Terns*	2	163	------	------
Gut	------	------	46	115
Tibia	------	------	10	10
Carcass	------	------	197	290
			253	415
Kabelle—*Terns*	2	184	------	------
Gut	------	------	13	9
Tibia	------	------	23	[b] NDA
Muscle	------	------	22	6
Carcass	------	------	242	133
			300	148
Larbaredj—*Terns*	2	146	------	------
Gut	------	------	114	37
Tibia	------	------	29	4
			143	41
Rongelap—*Rooster*	1	1,140	------	------
Skeleton	------	268	6,300	8,270
Muscle	------	434	260	120
Viscera	------	64	166	51
Liver	------	144	29	6
Rongelap—*Rooster*—Continued				
Heart	------	15	8	2
Skin	------	157	16	18
Lung	------	------	2	2
			7,281	8,479
Rongerik Atoll				
Eniwetak—*Terns*	2	([c])	------	------
Gut	------	------	10	9
Tibia	------	------	6	NDA
Muscle	------	------	33	14
Carcass	------	------	126	294
			175	317
Bikar Atoll				
Bikar—*Terns*	2	126	------	------
Gut	------	------	9	8
Tibia	------	------	6	1
Muscle	------	------	40	14
Carcass	------	------	14	14
			69	32

[a] μc are in terms of Co^{60} equivalent.
[b] No detectable activity.
[c] *No data taken.*
*Collections made about February 1, 1955. Data reported as of March 1, 1955.

Table 10—Distribution of Gross Beta and Gamma Activity in Tissues of Fish (NRDL) *

Island and Fish	Wet Weight (g)	Radioactivity (d/m/tissue x 10^{-4}) [a] Total β	Total γ	Skin β	Skin γ	Head β	Head γ	Muscle β	Muscle γ	Bone β	Bone γ	Gill β	Gill γ	Viscera β	Viscera γ
Rongelap Atoll, South:															
Rongelap—Goat	218	8.8	15.5	0.2	2.4	0.45	3.3	1.1	2.1	1.5	2.7	0.6	2.2	4.9	2.8
Rongelap—Grouper	452	5.2	5.7	0.4	0.3	0.8	0.7	0.4	0.5	1.4	2.6	0.3	0.3	1.9	1.4
Average		7.0	10.6	0.3	1.3	0.63	2.0	0.8	1.3	1.5	2.7	0.5	1.3	3.4	2.1
Percent of total activity		100	100	4.2	12.1	8.8	18.7	11.2	12.1	21.0	25.2	7.0	12.1	47.7	19.6
Rongelap Atoll, North:															
Gejen—Snapper	1,154	26.3	87.0	1.0	11.8	6.6	24.7	5.4	16.8	5.5	15.7	1.7	2.1	6.1	15.9
Kabelle—Snapper	735	12.3	18.5	1.0	11.2	4.5	1.9	1.0	0.7	2.4	4.4	0.5	1.1	2.9	6.3
Kabelle—Parrot	1,957	24.8	71.3	1.1	8.9	8.5	20.9	2.4	6.6	7.0	23.4	0.8	2.7	5.0	8.8
Average		21.1	58.9	1.0	10.6	6.5	15.8	2.9	8.0	5.0	14.5	1.0	2.0	4.7	10.3
Percent of total activity		100	100	4.8	17.3	30.8	25.9	13.7	13.1	23.7	23.7	4.8	3.3	22.3	16.9
Ailinginae Atoll:															
Sifo—Snapper	640	3.2	38.9	0.3	5.9	0.7	9.9	0.6	6.2	0.5	10.6	0.1	2.7	0.9	3.6
Percent of total activity		100	100	9.7	15.2	22.5	25.4	19.3	15.9	16.1	27.2	3.2	7.0	29.0	9.4
Rongerik Atoll:															
Eniwetak—Squirrel	387	0.41	2.0	0.02	0.35	0.23	0.55	0.04	0.27	0.06	0.39	0.02	0.08	0.04	0.4
Percent of total activity		100	100	4.9	17.3	55	27.2	9.8	13.4	14.6	19.3	4.9	4.0	9.8	18.8
Utirik Atoll:															
Utirik—Parrot	425	0.66	0.87	0	0.24	0	0.09	0.15	0.22	0.13	0.13	0	0.04	0.38	0.2
Percent of total activity		100	100	0	27.6	0	10.3	22.7	25.3	19.7	15.0	0	4.6	57.5	17.2
Likiep Atoll:															
Likiep—Snapper	453	1.1	2.2	0	0	0	0.02	0.1	0.2	0	0	0	0	1	2
Percent of total activity		100	100	0	0	0	9	9	9	0	0	0	0	91	90

[a] As determined on basis of U_3O_8 standards and empirical scattering and absorption corrections.
*Collections made February 1956. Data reported as of April–May 1956.

Table 11—Summary of Beta and Gamma Activity in Fish and Marine Invertebrates (NRDL) *

Island	Fish: No. of Samples	Fish: Activity [a] (d/m/kg×10^{-4}) β	γ	Crabs: No. of Samples	Crabs: Activity [a] (d/m/kg×10^{-4}) β	γ	Clams: No. of Samples	Clams: Activity [a] (d/m/kg×10^{-4}) β	γ	Snails: No. of Samples	Snails: Activity [a] (d/m/kg×10^{-4}) β	γ
Rongelap Atoll:												
North:												
Gejen	8	24.5	78.8	2	28	87	------	------	------	4	648	513
Kabelle	10	14.9	55.4	------	------	------	------	------	------	1	17.7	43.9
Central: Eniaetok	5	19.3	45.1	1	4.5	14.1	1	4.5	8.8	------	------	------
South: Rongelap	5	17.7	32	6	25.4	24.5	2	23	56	2	31	51
Rongerik Atoll:												
Eniwetak	8	2.2	7.8	1	2.8	18.3	------	------	------	------	------	------
Ailinginae Atoll:												
Sifo	6	4.5	22.7	3	21.9	14.5	1	6.4	15.0	------	------	------
Utirik Atoll:												
Utirik	8	1.6	2.1	------	------	------	------	------	------	3	0.006	2.8
Likiep Atoll:												
Likiep	8	2.6	1.3	------	------	------	------	------	------	------	------	------

[a] As determined on basis of U_3O_8 standards and empirical scattering and absorption corrections.
*Collections made February 1956. Data reported as of April–May 1956.

Table 12—Summary of Gross Beta and Gamma Activity in Birds and Eggs *

Island	Sample	No. of Samples	Average Weight (g)	Radioactivity [a] Beta (d/m/sample×10^{-4})	Beta (d/m/kg×10^{-4})	Gamma (d/m/sample×10^{-4})	Gamma (d/m/kg×10^{-4})
Rongelap Atoll:							
Rongelap	Tern:						
	Egg shell	1	6	NDA	0	0.62	10.3
	Egg, soft tissue	1	33	0.26	7.9	0.11	3.3
Gejen	Tern	1	92	0.93	10.1	0.32	3.5
	Viscera	1	101	0.38	3.8	0.025	0.25
	Muscle	1	141	NDA	0	0.019	0.14
	Tibia	1	------	NDA	0	NDA	0
Kabelle	Tern	1	145	1.1	7.8	1.7	12
	Muscle	1	16.9	0.1	5.9	0.13	7.7
	Tibia	1	0.9	0.07	79	0.027	30
	Egg shell	2	5.3	NDA	0	0.13	26
	Egg, soft tissue	2	22.8	0.15	6.7	0.3	1.3
Ailinginae Atoll:							
Sifo	Tern	7	116	0.38	3.3	1.7	14.7
	Muscle	7	11.7	0.057	4.9	0.43	36.7
	Viscera	7	------	0.08	—	0.14	—
	Tibia	7	0.31	NDA	0	NDA	0
	Egg shell	1	6	NDA	0	0.06	10
	Egg, soft tissue	1	33	0.26	7.9	0.11	3.3
Rongerik Atoll:							
Eniwetak	Tern	2	92	1.9	21.0	0.9	9.8
	Muscle	2	19.7	0.04	2.3	0.03	1.9
	Tibia	2	.23	NDA	0	NDA	0
	Viscera	2	------	0.05	—	0.09	—

[a] As determined on basis of U_3O_8 standards and empirical scattering and absorption corrections.
*Counted in April–May 1956.

Table 13—HASL Analyses (AFL Surplus)

FISH

HASL No.	Specimen No.	Organism	Tissue	Area Collected	Collection Date	Remarks	d/m/gram Total Activity* Wet	d/m/gram Total Activity* Dry	d/m/gram Sr-90 Wet	d/m/gram Sr-90 Dry	% Ca Based on Wet Weight
3176	A 165	Dog-tooth tuna.	Bone	Kabelle-Labaredj	10-21-55	Caught half-way between Kabelle and Labaredj Islands in Rongelap Lagoon. Total weight: 44 lbs. Bone includes some connective tissue. Not possible to remove all tissue.	31±35	86±95	0.17 ±.07	0.48±0.20	11.8
3179	A 165	Do	Muscle	do	10-21-55	Dried at 95° C.—shared with U of W: NYOO samples placed into 5 bags.	24.4±1.0	111±4.5	(−0.01)±0.04	(−0.05)±0.18	0.0017
3167	A 165	Do	Liver	do	10-21-55	Dried at 95° C.—shared with U of W	186±2.5	1483±20	0.104±0.41	0.83±3.3	0.0048
3174	A 64	Bonito	Muscle	Labaredj Island	10-21-55	1 fish dried at 95° C	56.3±1.0	269±4.8	0.019±0.11	0.089±0.53	0.043
3165	A 64	do	Bone	do	10-21-55	Backbone boiled to remove meat. Wet weight given is that after boiling.	227±78	269±87	(−0.28)±0.90	(−0.33)±1.06	18.0
3169	A 112-116	Goatfish	Muscle	Rongelap Island	10-22-55	Part sample of 5 fish: dried at 95° C	21.1±1.8	89.6±7.7	0.082±0.12	0.35±0.51	----------

PLANKTON

HASL No.	Specimen No.	Organism	Tissue	Area Collected	Collection Date	Remarks	d/m/gram Total Activity* Wet	d/m/gram Total Activity* Dry	d/m/gram Sr-90 Wet	d/m/gram Sr-90 Dry	% Ca Based on Wet Weight
3178	A 2-5	----------	----------	Kabelle-Rongelap	10-21, 22-55	A 2-5, pooled after removing samples for U. of W.—AFL—Sample A 2 and A 3 off Kabelle Island, 10-21-55; and A 4 and A 5 off Rongelap Island, 10-24-55. ~20 gms wet weight in pooled sample, of which~80% is from samples A 4 and A 5.	43.1±1.0	663±17	0.19±0.89	2.97±13.7	----------

*Date of counting: February 1956.

Table 14—Results of Analyses Performed at HASL

MARINE ORGANISMS

HASL No.	NRDL No.	Sampling Location	Organism	Tissue	C-Date Total Activity*	Total Activity d/m/gram	Sr^{90} d/m/gram	Cs^{137} d/m/gram	Ca grams/gram	S. U.	%Sr^{90}
3336	1519	Rongelap	Surgeon	Entire	4-9-56	52±6.4	≤0.10	----------	----------	----------	----------
3337	1512	do	Damsel	do	4-9-56	37±6.0	----------	----------	----------	----------	----------
3350	1541	Kabelle	Butterfly	do	4-9-56	Lost	Lost	----------	----------	----------	----------
3351	1542	do	Damsel	do	4-9-56	125±8.0	2.8±0.55	----------	0.031	41±8.1	2.3
3354	1622	Gegen	Surgeon	do	4-9-56	235±8.9	----------	----------	----------	----------	----------
3369	1555	Sifo	Butterfly	do	4-9-56	95±5.7	≤0.81	----------	.024	≤15	----------
3374	1564	Eniwetak	Damsel	do	4-9-56	20±6.2	≤0.15	----------	.033	≤2.1	----------
3376	1559	do	Surgeon	do	4-9-56	34±6.9	----------	----------	.033	----------	----------
3379	1606	Likiep	Butterfly	do	4-9-56	51±6.2	----------	----------	.023	----------	----------
3380	1615	do	Damsel	do	4-9-56	11±6.5	0.37±0.23	----------	.037	4.5±2.8	3.4
3383	1593	Utirik	Surgeon	do	4-9-56	22±5.4	----------	----------	.015	----------	----------
3384	1574	do	Damsel	do	4-9-56	14±11	----------	----------	.039	----------	----------
3385	1577	do	do	do	4-9-56	22±6.7	----------	----------	.038	----------	----------
3387	1572	do	Surgeon	do	4-9-56	18±6.0	----------	----------	.022	----------	----------
3346	1522	Rongelap	Coral	----------	4-10-56	35±17	----------	----------	----------	----------	----------
3357	1635	Gejen	do	----------	4-10-56	310±22	≤0.62	----------	.31	≤0.91	----------
3363	1534	Eniaetok	do	----------	4-10-56	205±20	3.1±0.42	----------	.35	4.1±0.55	1.5
3381	1617	Likiep	do	----------	4-10-56	≤15	≤0.45	----------	.30	≤0.68	----------
3393	1601	Utirik	do	----------	4-10-56	≤18	≤0.27	----------	.26	≤0.47	----------
3394	1589	do	do	----------	4-10-56	21±15	0.48±0.14	----------	.24	0.91±0.27	2.3
3326	1636	Gejen	Spider Snail	Entire	4-23-56	520±10	4.4±0.39	13±0.48	.018	110±9.8	.85
3327	1637	do	do	do	4-23-56	2180±29	1.3±0.34	4.0±0.48	.0072	82±21	.061
3328	1638	do	Scorpion Snail	do	4-23-56	23310±290	1.1±0.44	3.4±1.5	.0085	57±24	.0046
3329	1639	do	do	do	4-23-56	9800±120	1.5±0.58	7.1±1.1	.0125	55±21	.015

*C-Date: Date of counting.

C. Soils

Graph 3 shows the general levels of activity in the soils of Kabelle and Labaredj Islands of Rongelap Atolls, as reported by AFL.[2]

Tables 15, 16 and 17 report the activity in different soils at different depths for the February 1955 survey,[3] and Table 18 for the February 1956 survey [4] by NRDL.

Tables 19 and 20 show the analyses by HASL.[5]

The data clearly indicate the major portion of the activity is to be found in the top three inches of the soil. As suggested in chapter III, Ce^{144}–Pr^{144} and Ru^{106}–Rh^{106} make up much of the fixed contamination in the soils at periods of one year and more after the fallout occurred.

*Table 15—Beta Activity in Core Samples of Soil (NRDL)**

Island	No. of Cores	Beta Activity (β-/min/g) — 1-in. increment of soil coring: 1st	2d	3d	4th	5th	6th	7th	8th	9th
Likiep	1	140	40	40	NDA (a)	NDA	----------	----------	----------	----------
Utirik	3	1,250	480	240	130	100	160	60	25	----------
Rongelap	4	6,600	2,100	570	420	230	160	200	150	50
Busch	1	10,800	7,100	7,200	6,400	6,800	----------	----------	----------	----------
Eniaetok	1	57,000	24,000	4,300	18,000	26,000	12,000	11,000	----------	----------
Labaredj	1	42,000	33,000	29,000	23,000	19,000	----------	----------	----------	----------
Kabelle	3	43,000	30,000	10,000	3,600	2,000	2,300	180	----------	----------
Lomuilal	3	53,000	48,000	26,000	20,000	14,000	1,000	----------	----------	----------
Gejen	1	37,000	37,000	8,000	4,000	4,400	3,400	----------	----------	----------
Lukuen	2	35,000	40,000	13,000	10,500	10,000	10,000	4,700	----------	----------
Bikar	3	4,000	740	250	170	120	100	27	----------	----------
Eniwetak	2	16,000	7,500	3,000	2,000	1,800	1,100	160	100	----------

(a) No detectable activity.
*Collections made about February 1, 1955. Data reported as of March 1, 1955.

*Table 16—Summary of Beta Activity in Gross Samples of Soil (NRDL)**

Island	Number of Samples	Beta Activity (β-/min/g), Depth of Soil: 0 to 1 in.	1 to 5 in.
Likiep	1	90	----------
Utirik	4	960	550
Rongelap	5	8,900	800
Eniaetok	2	48,000	640
Labaredj	3	85,000	1,300
Kabelle	6	96,000	3,100
Gejen	1	348,000	12,400
Bikar	1	8,400	90
Eniwetak	1	12,000	240

*Collections made about February 1, 1955. Data reported as of March 1, 1955.

*Table 17—Beta Activity in Soil Samples Taken From Exposed Soil Profiles (NRDL)**

Depth (in.)	Beta Activity (β-/min/g), Island: Rongelap	Labaredj	Kabelle	Kabelle	Kabelle
0 to 1	12,400	130,000	72,000	93,000	97,000
3	1,500	380	6,800	2,900	440
6	110	950	1,700	400	130
9	140	770	130	2,300	240
12	NDA(a)	160	40	580	140
18	70	120	70	70	90
24	----------	40	100	70	NDA
30	----------	----------	----------	NDA	----------
36	----------	----------	----------	60	----------
40	----------	----------	----------	40	----------

a No detectable activity.
*Collections made about February 1, 1955. Data reported as of March 1, 1955.

Table 18—Gross Beta Activity in Water and Soil Samples a (NRDL)

	Gejen	Eniwetak	Eniaetok	Rongelap	Sifo	Utirik	Likiep
Source	Water b (c/m/liter x 10^{-8})						
Cistern	----------	----------	----------	0.008	----------	NDA (a)	----------
Well	----------	----------	NDA	----------	----------	0.1, 0.03, NDA	NDA
Ocean	NDA	NDA	0.06	0.06	0 09	NDA	0.08
Lagoon	NDA	NDA	NDA	NDA	0.08	0.09	NDA
Depth (in.)	Soil b (c/m/kg x 10^{-8})						
0–1	3470	34.8	6.43	7.00	4.97	4.43	NDA
12	----------	----------	----------	0.70	----------	----------	----------
18	0.80	----------	NDA	----------	----------	----------	NDA
24	----------	NDA	----------	----------	0.04	0.51	----------
33	1.33	----------	----------	NDA	----------	----------	----------
36	----------	----------	----------	----------	----------	----------	NDA
44–45	----------	----------	0.07	----------	----------	----------	----------
48	----------	NDA	----------	----------	NDA	----------	----------
55–56	----------	----------	----------	----------	----------	0.70	----------

All counts were corrected for the counting efficiency of Sr^{90}–Y^{90}.
Gross beta activity of plant samples was determined in April 1956 and that of soil and water in May 1956. Collection date: February 1956.
NDA indicates no detectable activity.

Table 19—HASL Analyses (AFL Surplus)

SOIL

HASL No.	Spec. No.	Collection Date	Area Collected (Island)	Description	Depth	Beckman MX-5 Reading: Surface	Beckman MX-5 Reading: 3" below	Beckman MX-5 Reading: 6" below	Total Activity* d/m/gram: Wet	Total Activity* d/m/gram: Dry	Sr-90 d/m/gram: Wet	Sr-90 d/m/gram: Dry
3182	A 1	10-21-55	Kabelle	Open area—200 yards from lagoon near midisland.	0-3"	3.5/12	....	0.2/0.9	15000±225	16300±244	506±4.7	548±5.1
3183	A 2	10-21-55	do	Open area—200 yards from lagoon near midisland.	3-6"	3.5/12	....	0.2/0.9	617± 90	658± 96	22.7±2.6	24.2±2.8
3184	A 3	10-21-55	do	Grass area—20 feet from A 1 and A 2	0-3"	2/8	....	0.2/0.5	6620±152	7950±182	200±3.3	240±4.0
3185	A 4	10-21-55	do	Grass area—20 feet from A 1 and A 2	3-6"	2/8	....	0.2/0.5	302±104	329±113	4.7±0.67	5.1±0.73
3186	A 5	10-21-55	Labaredj	Open area—100 yards from lagoon (high tide mark in SW part of island).	0-3"	2/8	....	0.08/0.5	5470±147	5990±161	188±3.4	206±3.7
3187	A 6	10-21-55	do	Open area—100 yards from lagoon (high tide mark in SW part of island).	3-6"	2/8	....	0.08/0.5	623± 88	678± 97	6.7±0.99	7.3±1.1
3188	A 7	10-21-55	do	Under a tree 15 feet from A 5 and A 6	0-3"	0.6/7.0	0.3/1.0	0.07/0.5	7480±129	9490±164	263±4.5	334±5.7
3189	A 8	10-21-55	do	Under a tree 15 feet from A 5 and A 6	3-6"	0.6/7.0	0.3/1.0	0.07/0.5	356± 70	395± 78	4.9±0.47	5.4±0.52
3190	A 9	10-21-55	Rongelap	Grass near well (10 feet W of well)	0-3"	0.3/0.9	0.05/0.3	0.05/0.2	3000± 74	4230±104	187±2.6	264±3.7
3191	A 10	10-22-55	do	Grass near well (10 feet W of well)	3-6"	0.3/0.9	0.05/0.3	0.05/0.2	406± 54	543± 72	11.8±0.68	15.8±0.91
3192	A 11	10-22-55	do	Papaya cluster (near schoolhouse) rocky soil.	0-3"	0.3/1.0	0.1/0.5	0.1/0.4	5700± 69	12300±149	212±3.3	457±7.1
3193	A 12	10-22-55	do	Papaya cluster (near schoolhouse) rocky soil.	3-6"	0.3/1.0	0.1/0.5	0.1/0.4	1040± 75	1410±101	32.3±1.0	43.6±1.4

*Date of counting: February 1956.

See table 34 for estimates of *available* calcium and of Sunshine Units.

Table 20—Results of Analyses Performed at HASL

SOIL

HASL No.	NRDL No.	Sampling Location	C-Date* Total Activity	Total Activity d/m/gram	Sr^{90} d/m/gram	Cs^{137} d/m/gram	% Sr^{90}	% Cs^{137}
3482	605	Enlaetok	4-21-56	65±45	≤0.42	....	....	....
3483	608	do	4-21-56	≤41	1.6±0.42	....	....	....
3481	600	do	4-14-56	290±40	20±0.8	....	6.9	....
3549	819	Likiep	4-21-56	≤53	≤0.47	....	....	....
3548	814	do	4-21-56	≤65	1.2±0.71	....	....	....
3494	734	Eniwetak	4-21-56	≤61	≤0.68	....	....	....
3493	728	do	4-14-56	3000 ±93	80±1.4	....	2.7	....
3463	847	Gegen	4-21-56	120±69	1.0±0.48	....	0.84	....
3462	842	do	4-14-56	69400±470	1640±2.4	1535±60	2.4	2.2
3530	768	Utirik	4-21-56	≤73	3.4±0.72	....	....	....
3529	762	do	4-14-56	1600±92	49±1.3	....	3.1	....
3507	682	Sifo	4-21-56	≤57	≤0.55	....	....	....
3506	676	do	4-14-56	620±79	28±1.0	....	4.5	....

*C-Date: Date of counting.

See table 34 for estimates of *available* calcium and of Sunshine Units.

D. Water

Table 21 suggests a relatively high ratio of activity associated with the filtrate. However, it is probable that much of the insoluble material had settled out, therefore, the values do not represent all of the radioactive material that fell on these surfaces. In fact, data from other fallouts suggest a value of about 10–20% solubility.

Tables 18,[4] 21,[2] and 22 [2] show additional data on gross activity found in water sources. Table 23 gives the analyses by HASL.[6]

Table 21—Radioactivity of Water Samples, July 1954–October 1955 (AFL)

(Values expressed in d/m/liter±0.95 counting error)

Date and Island	Lagoon Water: Untreated	Lagoon Water: Treated	Island Water: Unfiltered	Island Water: Filtered: Filtrate	Island Water: Filtered: Residue
Rongelap Atoll:					
7/16/54, Kabelle	3800±3200	....	....	....	....
12/18/54, Rongelap	....	....	3000±190*	1800±180#	....
1/26-30/55, Enlaetok	....	....	17000±2200##	....	....
Kabelle	3300±2700	....	48000±3200**	....	....
Labaredj	6800±3000	....	25000±2200##	....	....
Lomuilal	5600±3000	....	....	....	....
Rongelap	5600±3000	....	4200±1800*	....	....
10/21-22/55, Kabelle	3500±1600	410±150	....	....	....
Labaredj	600±1500	450±160	....	....	....
Rongelap	1900±1600	60±120	540±120 5300±140 1300±86	310±190 4300±200 850±140	75±17# 1200±34* 75±19***
Ailinginae Atoll:					
10/23/55, Enibuk	1600±1400	80±130	1400±91	820±140	820±56##

*From cistern near schoolhouse; #from well back of schoolhouse; **ground water; ##standing water from can, drum, etc.; ***from cistern with collapsed roof. Date of analysis: November 18-20, 1955.

Table 22—Summary of Gross Beta Activity in Water (NRDL)*

Island	Beta Activity (β-/min/liter)							
	Sources of Water							
	Ocean		Cistern		Well	Barrell	Tree Bole	Exposed Soil Profile
	Lagoon Side	Ocean Side	Top	Bottom				
Likiep	NDA [a]	NDA	12	----------	NDA	----------	----------	----------
Utirik	50	NDA	290	1,350	28	----------	----------	----------
Rongelap	80	330	6,300	16,000	430	44,000	----------	----------
Busch	36	NDA	----------	----------	----------	----------	14,000	----------
Eniaetok	460	260	23,000	----------	----------	----------	----------	----------
Labaredj	7,700	56	----------	----------	----------	----------	8,100	----------
Kabelle	2,300	60	----------	----------	----------	----------	----------	15,000
Lomuilal	380	170	----------	----------	----------	----------	----------	----------
Bikar	37	28	----------	----------	----------	----------	----------	----------
Eniwetak	100	170	----------	----------	----------	----------	----------	----------

[a] No detectable activity.

*Collections made about February 1, 1955. Data reported as of March 1, 1955.

Table 23—Results of Analyses Performed at HASL

WATER

HASL Number	NRDL Number	Sampling Location	Type	C-Date* Total Activity	d/m/l Total Activity		Sr^{90} d/m/l	Cs^{137} d/m/l	% Sr^{90}	% Cs^{137}
3457	543	Rongelap	Well or cistern	5-8-56	2500±32	1530±32	590±21	310±20	24	12
3480	599	Eniaetok	Lens	5-8-56		560±23	--------	130±12	--------	--------
3526	785	Utirik	Well	5-8-56	37±15	$\leq$20	--------	44±5.2	--------	--------
3527	787	do	do	5-8-56	34±15	$\leq$19	--------	35±16	--------	--------
3528	788	do	Cistern	5-8-56		43±20	--------	49±18	--------	--------
3520	757	do	Well	5-8-56		28±20	--------	27±4.6	--------	--------
3547	830	Likiep	do	5-8-56	18±16	$\leq$20	--------	34±13	--------	--------
3458	1003	Rongelap	Lagoon	5-11-56		$\leq$26	--------	35±5.4	--------	--------
3459	1036	Gejen	do	5-11-56		$\leq$21	--------	--------	--------	--------
3478	1007	Eniaetok	do	5-11-56		$\leq$20	--------	22±16	--------	--------
3497	1028	Eniwetak	do	5-11-56		$\leq$19	--------	32±5.4	--------	--------
3509	1023	Sifo	do	5-11-56		$\leq$20	--------	24±10	--------	--------
3525	1030	Utirik	do	5-11-56		$\leq$19	--------	--------	--------	--------
3546	1032	Likiep	do	5-11-56		$\leq$20	--------	31±10	--------	--------
3460	1002	Rongelap	Ocean	5-11-56		49±18	--------	34±2.2	--------	--------
3461	1034	Gejen	do	5-11-56		$\leq$18	--------	--------	--------	--------
3479	1008	Eniaetok	do	5-11-56		$\leq$23	--------	39±2.2	--------	--------
3496	1027	Eniwetak	do	5-11-56		25±19	--------	--------	--------	--------
3510	1024	Sifo	do	5-11-56		$\leq$19	--------	--------	--------	--------
3524	1029	Utirik	do	5-11-56		$\leq$21	--------	41±2.2	--------	--------
3545	1031	Likiep	do	5-11-56		45±19	--------	43±3.0	--------	--------

*C-Date: Date of counting.

CHAPTER III

Radiochemical Analyses

Tables 24 and 25 show the radiochemical analyses made by AFL for the 1954–55 surveys,[2] and Tables 26 and 27 for the July 1956 survey.[7] In two pools of 15 and 19 fish muscle samples collected in late July 1956 and analyzed by AFL no radiostrontium was found.

Tables 28 and 29 show the radiochemical analyses made by NRDL for the February 1955 survey,[3] and Tables 30, 31, 32, and 33 for the February 1956 survey.[4] Table 34 shows additional analysis of soils from the February 1956 survey including data on exchangeable calcium.

Tables 4, 5, 6, 13, 14, 19, 20, 23, and 35 show analyses by HASL.

In terms of a potential biological hazard the strontium–90 activity is of most interest. At one year post detonation NRDL reports: ". . . In muscle and viscera samples of the animals from Rongelap, Utirik, and Rongerik, Sr^{89} contributes approximately 0.5 percent of the total beta activity. Sr^{90} is present in an approximately 1:1 ratio with Sr^{89}. Since the Hunter and Ballou calculations indicate that Sr^{89} and Sr^{90} each contribute about 2 percent of the total beta activity at one year after fission, there does not appear to be any fractionation of radiostrontium into the soft tissues. As expected, most of the internally deposited radioactivity was found in the skeleton.

"Tissues of a few marine specimen were analyzed for Cs^{137} (37-year half-life)* since this nuclide was present in high concentrations in water and coconut milk from this area. The tissues of the rooster and of the coconut crab contain significant amounts of Cs^{137}. A very high fraction of Cs^{137} activity was noted in the muscle of the rooster (40 percent of the total beta).* Further radioanalyses of marine specimens indicated that the rare earth group constituted a few percent of the total beta activity. Ru^{106}-Rh^{106} and Zr^{95}-Nb^{95} contributed the largest percentage of the total beta activity."

The AFL reports:

". . . The Sr^{90} values for food plants, except coconuts, collected in October 1955 approximate the theoretical proportion of mixed fission products activity[12] at 1.7 years, 4 percent. Coconuts contained 0.1 percent Sr^{90} with appropriate correction for time of collection. . . .

". . . *In contrast to the strictly marine* forms, the coconut crab, which feeds principally on land plants, had Sr^{90} levels of 3 percent in the muscle and 12 percent in the hepatopancreas or liver, where calcium salts are stored. The radioisotopes in salts leached from the carapace were found to consist entirely of Sr^{90}-Y^{90}. . . .

". . . Radionuclides of Sr, Cs, Ce and their daughters did not account for the total activity in most (fish) samples analyzed. Complete fission product analyses of samples collected at Eniwetok and Bikini Atolls indicate that non-fission-product radionuclides may account *for more than half of the total activity in some* fish. Zn^{65} contributes one-fourth or more of the total activity in shark muscle as determined by radiochemical analysis and confirmed by following the decay." (Zn^{65} is not a fission product.)

The two-year survey by NRDL continues to indicate the high percentage of Zn^{65} in fish.

*Newest estimates indicate 27.7-year half-life.

*See Section IV.

Unlike localization in the liver of mammals, Zn^{65} was found distributed fairly uniformly among the tissues. The Co^{60} found in clams accounted for the major portion of the activity. (The ability of clams to concentrate Co^{60} selectively was verified by laboratory experiments.)

Table 24—Radiostrontium, Radiocesium and Radiocerium-Praseodymium in Biological Samples, December 1954–January 1955 (AFL)

Island	Organism	Percentage of Total Activity: Sr^{89}	Sr^{90}	Cs^{137}	Ce^{144} Pr^{144}
		*June-July 1955**		*Sept., Oct. 1955**	*July, Aug. 1955**
Rongelap Atoll:					
Gejen	31 coconut milk	<0.1	<0.1	81.	0.0
Kabelle	37 *Caulerpa*	-----	-----	0.0	71.
	30 coconut milk	-----	-----	72.	0.0
	38 *Halimeda*	-----	-----	0.0	28.
	39 coconut crab muscle.	0.86	4.8	67.	1.0
	41 mullet muscle	0.0	0.0	0.0	1.5
Labaredj	29 coconut milk	<0.5	<0.5	76.	0.0
	42 tern bone	0.0	0.0	0.0	28.
	43 tern bone	0.0	0.0	0.0	26.
Mellu	40 dogtooth tuna muscle.	0.0	0.0	4.8	0.6
Rongelap	27 coconut meat	0.0	0.0	26.	<0.4
	28 coconut milk	0.0	0.0	78.	<0.2
	32 pandanus fruit	>0.1	1.3	110.	0.7
	34 papaya meat	>0.1	2.5	68.	3.7
	33 squash meat	>0.1	1.5	51.	1.0

*Dates of analysis.

Table 25—Sr^{90} in Biological and Lagoon Bottom Samples from Rongelap Atoll, October 1955 (AFL)

Island	Sample	Total Activity d/m/g*	Sr^{90}, Percent of Total Activity
Rongelap	Coconut meat	110	0
	Pandanus fruit	180	2.1
	Morinda fruit	47	4.6
Labaredj	Arrowroot corm	40	3.2
Kabelle	Coconut crab muscle	440	2.9
	Coconut crab liver	1,200	12.
	Coconut crab salts of carapace	-----	50.0
	Coconut crab cuticle of carapace	-----	29.0
Labaredj	Giant clam mantle and muscle	1,700	0
	Giant clam kidney	5,200	0
Do	Bonito muscle	150	0
	Bonito liver	1,700	0
	Bonito bone	390	<0.6
Kabelle	Grouper muscle	31	0
	Grouper liver	5,500	0
	Goatfish muscle	42	0
Labaredj	Tern muscle	61	0
Kabelle	Lagoon bottom, depth of water 6′, fraction containing particles >0.074 mm diameter. Top inch	40,000	0.73
	7th inch	25,000	0.71

*Wet weight basis except lagoon bottom which is on a dry weight basis.

Table 26—Radiostrontium in Plants Collected at Rongelap Atoll July 23–24, 1956

Counted September 4, 1956 (AFL)

Plant	Tissue	Island	Total β activity d/m/g wet	Sr^{90} d/m/g wet	Calcium g/g wet	"Sunshine Units"	Sr^{89}:Sr^{90}
Breadfruit	Pulp	Rongelap	42.0	0.82±0.03	0.000628	591±70	1.77±0.10
Morinda	Pulp and seed	do	80.4	3.1±0.1	0.00136	694±0	3.68±0.22
Pandanus	Seed	do	79.7	2.2±0.6	0.00450	150±44	0.76±0.96
Arrowroot	Pulp and skin	do	108	2.5±0.6	0.00333	294±39	1.48±0.05
Coconut	Milk	do	262	0	-----	-----	-----
Do	Meat	do	64.6	0	-----	-----	-----
Do	Milk	Kabelle	36.9	0	-----	-----	-----
Do	Meat	do	148	0	-----	-----	-----

Table 27—Radiostrontium in Land Hermit Crabs (*Cenobita sp.*) Collected at Rongelap Atoll July 23–24, 1956 (AFL)

Radioactivity as of Counting Date, September 10, 1956

Specimen Number	Tissue	Island	Total β activity d/m/g wet	Sr^{90} d/m/g wet	Calcium g/g wet	"Sunshine Units"	Sr^{89}:Sr^{90}
I-49	Liver	Kabelle	243	42±2	0.00304	6250±231	1.6 ±0.3
Do	Muscle	do	434	62±22	0.00320	8890±3110	0.0
Do	Skeleton	do	5,410	2400±9	0.206	5310±19	0.24±0.02
I-50	Liver	do	633	47±14	0.00718	3110±946	3.6 ±1.6
Do	Muscle	do	273	24±6	0.00223	4910±1170	2.4 ±0.75
Do	Skeleton	do	4,100	1310±3	0.202	2960±7	0.58±0.16
I-51	Muscle	do	444	90±6	0.00919	5120±382	0.71±0.05
Do	Skeleton	do	5,600	2130±130	0.189	4440±158	0.32±0.04
I-52	do	Rongelap	3,900	1310±5	0.177	3360±14	0.48±0.14

Table 28—Radiochemical Composition of Residual Contamination (NRDL)*

Material	Percentage of Total Activity Observed [a] — Radionuclides: Sr^{89}	Sr^{90}	Rare Earths	Zr^{95} [b]	Ru^{106} [b]	Cs^{137}
Arrowroot	1.3	5.9	3.0	0.5	7.8	80
Breadfruit	[c] NDA	6.3	50	19	NDA	24
Coconut frond	1.2	5.0	80	4.2	6.7	1.6
Coconut meat	NDA	NDA	1.2	NDA	NDA	95
Coconut milk	NDA	NDA	0.9	NDA	NDA	96
Grass	1.3	4.6	74	6.4	4.8	8.4
Pandanus	0.5	2.4	1.2	0.2	0.6	95
Papaya	1.6	7.3	37	31	12	11
Coral	3.2	14	67	10	4.5	1.1
Soil	0.8	2.2	73	0.1	23.3	1.1
Lagoon bottom	1.1	5.0	82	0.2	13	NDA
Cistern water	2.9	8.6	41	24	20	13
Ground water	0.8	2.5	49	20	16	9.2
Lagoon water	0.9	4.0	76	9.7	7.0	0.8

[a] Values as of 15 July 1955 (16 mos after the nuclear detonation). [b] Nb^{95} and Rh^{106} may be calculated from the reported parent values. [c] No detectable activity.

*Collections made about Febraury 1, 1955.

Table 29—Radiochemical Analysis of Fish and Chicken (NRDL)*

Island	Fish	Weight (g)	Tissue	Total Beta Activity (d/m x 10^{-3})	Percentage of Total Beta Activity: Sr^{89}	Sr^{90}	Rare Earths	Cs^{137}	Ru^{106}-Rh^{106}	Zr^{95}
Rongelap Atoll										
Rongelap Lagoon	Pelargic, Snapper	503	Viscera	82	1.2	1.0	3.2	0.07		
			Gill	3	0.4	0.3	3.2			
			Muscel	20	0.2	0.2	(a)			
	Flat fish	597	Muscle	40	0.6	0.5	5.6			
			Viscera	585	0 1	0.1	18		14.2	61
	Coconut crab	1008	Muscle	175	0.2	0.2	1.3			
			Viscera	225	0.7	0.6	1.9	2.1		
Gejen	Spider snail	26	Total body	1204	0.1	0.1	7.8			
	do	11	do	432	0.1	[b] NDA	1.9		5.3	65
	Red eye crab	30	do	29	1.1	0.8	1.6	1.0		
Labaredj	Killer clam	230	do	60	0.2	0.2	2.5			
Rongelap	Rooster	1140	Muscle	11			2	40		
			Viscera	23	0.6	0.5	14			
			Liver	7	2.0	1.6	4			
			Skin	12	1.3	1.0	51			
			Tibia	101	0.2	0.2	1.4	1.0		
Utirik Atoll										
Utirik	Eel	24	Total body	1	1.1	0.9	11			
	Butterfly fish	185	do	7						
Rongerik Atoll										
Eniwetak	Mullet	230	Muscle	7	0.8		8.2			
			Viscera	100	0.2	0.2	89	0.04		

[a] No data taken. [b] No detectable activity.
*Collections made about February 1, 1955. Data reported as of April 1955.

Table 30—Radiochemical Analysis of Biological Specimens from Rongelap Atoll (NRDL)

Island, Sample No., and Sample	Tissue	Wet Weight (g)	Ca (mg)	Beta Activity (d/m/sample x 10^{-4})	Gamma Activity (d/m/sample x 10^{-4})	Nuclide	Nuclide Activity (d/m/sample x 10^{-3})	Percent of Total Activity	Sunshine Units [a]
Rongelap Island:									
						R.E.[b]	NDA [a]	0	
1502C, Goat fish	Bone	29	860	1.5	217	Sr^{90}	11±1.7	7.3	587±90
						Zn^{65}	240	89	
						R.E.	0.68	0.14	
	Viscera	10	37.5	4.9	2.8	Sr^{90}	NDA	0	0
						Zn^{65}	250	89.3	
						R.E.	2.5	12.5	
	Skin	28	337	0.2	2.4	Sr^{90}	0.34±0.26	1.7	45±84
						Zn^{65}	230	95.8	
						R.E.	NDA	0	
	Muscle	87	111	1.1	2.1	Sr^{90}	0.46±0.76	0.4	189±313
						Zn^{65}	190	90.6	
						R.E.	NDA	0	
1509, Killer clam	Soft tissue	1800	743	20	33	Sr^{90}	2.4±0.69	0.12	146±42
						Co^{60}	2090	63.4	
						R.E.	77	2.5	
1513, Killer clam	do	882	1565	31	83	Sr^{90}	83.8±0.90	2.7	2436±31
						Co^{60}	7370	89	
1520A, Langousta lobster	do	79	330	1.3	2.1	R.E.	26	20	0
						Sr^{90}	NDA	0	
1520C, Red eye crab	do	57	2343	0.75	3.8	R.E.	37	49	3±1
						Sr^{90}	0.13±0.07	0.2	
1520D, Red spotted crab	do	73	2900	0.75	0.43	R.E.	15	20	20±3
						Sr^{90}	1.28±0.18	1.7	
1520B, Coconut crab	do	114		3.5	3.1	Cs^{137}	26	7.4	0
						R.E.	0.58	16.5	
Kabelle Island:									
						R.E.	4.1	4.2	
1538, Snapper fish	Muscle	281	85	0.95	0.69	Sr^{90}	NDA	0	0
						Zn^{65}	58	84.2	
						R.E.	2.4	2.4	
	Skin	89	987	1	4.1	Sr^{90}	0.53±0.76	0.5	24±34
						Zn^{65}	380	92.7	
						R.E.	19	7.9	
	Bone	141	1842	2.4	4.4	Sr^{90}	3.0±0.36	1.2	73±8
						Zn^{65}	440	100	
						R.E.	120	44	
	Viscera		2413	2.7	6.3	Sr^{90}	7.85±0.94	2.9	147±18
						Zn^{65}	530	84.2	
						R.E.	NDA	0	
1540, Grouper fish	Whole	176	1630	0.75	6	Sr^{90}	0.79±0.17	1.0	22±4
						Zn^{65}	580	97	
						R.E.	5	0.7	
1544, Parrot fish	Bone	449	1905	7.0	23.4	Sr^{90}	13.7±1.0	2	326±22
						Zn^{65}	1870	79.6	
						R.E.	3.9	4.7	
	Gill	56	428	0.83	2.7	Sr^{90}	0.55±0.44	0.7	58±46
						Zn^{65}	180	66.8	
						R.E.	3.7	0.4	
	Head	280	7920	8.5	20.9	Sr^{90}	0.97±0.52	0.1	6±3
						Zn^{65}	1670	80	
						R.E.	NDA	0	
	Viscera	258	11450	5	8.8	Sr^{90}	2.5±1.38	0.3	10±5
						Zn^{65}	820	93	
						R.E.	59	12,3	
737, Helmet snail	Soft tissue	271	224	4.8	11.9	Sr^{90}	1.36±0.34	0,3	276±69
						Zn^{65}	1090	91,6	

Table 30—Radiochemical Analysis of Biological Specimens from Rongelap Atoll (NRDL)—Con.

Island, Sample No., and Sample	Tissue	Wet Weight (g)	Ca (mg)	Beta Activity (d/m/sample $\times 10^{-4}$)	Gamma Activity (d/m/sample $\times 10^{-4}$)	Nuclide [b]	Nuclide Activity (d/m/sample $\times 10^{-3}$)	Percent of Total Activity	Sunshine Units [a]
Gejen Island:									
1621, Snapper fish	Head	219	3250	6.6	24.7	R.E.	NDA	0	23±33
						Sr^{90}	1.65±2.4	0.2	
	Skin	73	1315	1.0	11.8	R.E.	NDA	0	24±16
						Sr^{90}	0.68±0.48	0.7	
	Bone	173	3270	5.5	15.7	R.E.	NDA	0	21±6
						Sr^{90}	1.5±0.44	0.3	
						Zn^{65}	1540	98	
	Muscle	511	190	5.4	16.8	R.E.	3.5	0.7	53±88
						Sr^{90}	0.22±0.35	0.04	
						Zn^{65}	1600	95	
	Viscera	87		6.1	15.9	R.E.	11	1.8	0
						Sr^{90}	1.2±0.29	0.2	
						Zn^{65}	1480	93	
	Gill	28	403	1.7	2.1	R.E.	NDA	0	0
						Zn^{65}	210	100	
1630, Grouper fish	Whole	169	2190	1.8	77.9	R.E.	13.3	7.4	35±18
						Sr^{90}	1.7±0.92	0.1	
						Zn^{65}	6230	80	
1629, Sand crab	Soft tissue	46	1090	1.3	2.3	R.E.	0.8	0.6	196±25
						Sr^{90}	4.72±0.59	2.0	
1637, Spider snail	do	90	713	18.7	18	Ru^{106}	360	19.2	336±30
						R.E.	1210	65	
						Sr^{90}	5.28±0.47	0.3	
1638, Spider snail	do	56	175	102	68	R.E.	11900	116	502±331
						Sr^{90}	1.95±0.60	0.02	

[a] Sunshine Unit=0.001 μc Sr^{90}/kg Ca. [b] R.E.=Rare Earth Group. [c] NDA=No Detectable Activity.
Date of collection: February 1956. Date of counting: April–May 1956.

Table 31—Average Relative Composition of Nuclides in Plants, Soil, and Water (NRDL)

Source	Part	No. of Samples Averaged	Relative Composition (percent): Cs^{137}	Total Rare Earths	Sr^{90}	Ru^{106}
Plants						
Portulaca	Whole	1	48.9	39.2	11.8	
Papaya	Fruit	1	79.8	17.8	2.5	
Coconut	Husk	3	98.2	1.1	0.7	
	Meat	2	98.9	0.05	1.0	
	Shell	2	99.5	0.4	0.1	
	Milk	1	99.6	0.2	0.2	
	Leaves	2	8.3	86.5	0.4	5.1
Pandanus	Keys	2	92.6	2.2	5.5	
	Leaves	2	72.7	13.3	5.1	8.9
	Air root	2	88.9	10.3	0.8	
Arrow root	Tuber	1	75.4	16.8	1.0	6.8
	Leaves	1	11.7	83.9	3.0	1.4
Soil						
Depth, 0–1 in		2	0.34	83.8	5.6	10.0
Water						
Cistern		2		64.4	35.6	
Well		2		100	0	
Lagoon		2		94.5	5.5	
Ocean		2		100	0	

Date of collection: February 1956. Date of counting: April–May 1956.

Table 32—Sunshine Units of Plant Samples

Sample	Island	Sample Weight (g)	Calcium Content (mg)	Sr^{90} (d/m/sample)	Sunshine Units (2.2 d/m Sr^{90}/g Ca)
Portulaca	Eniaetok	223	178	10000±100	2.58 x 10^4±250
	Gejen	23	398	5380±106	6140±120
Papaya	Rongelap	240	338	240±33	322±44
Coconut husk	Rongelap	200	162	340±28	950±76
	Eniaetok	23	58	150±24	1200±190
	Gejen	360	47	420±24	4060±240
Coconut meat	Rongelap	450	28	110±60	1801±960
	Eniaetok	160	40	18±29	200±320
	Gejen	190	20	28±23	635±520
Coconut shell	Eniaetok	90	16	25±18	706±500
	do	120	8	NDA	0
	Gejen	85	23	NDA	0
Coconut milk	Gejen	140	20	41±21	955±500
Coconut leaves	Eniwetak	35	69	197±37	1300±250
	Utirik	36	163	NDA	0
Coconut, whole	Gejen	170	19.5	157±22	3600±520
Arrowroot tuber	Eniaetok	305	1140	250±26	103±10
	Sifo	280	383	73±16	86±19
	Gejen	103	114	196±35	780±140
Arrowroot leaves and stalks	Gejen	15	385	290±44	340±50
Pandanus keys	Eniaetok	180	86	1060±50	5600±280
	do	215	134	420±44	1400±150
Pandanus leaves	do	10	65	460±41	3200±300
	Gejen	32	43	NDA	0
Pandanus air root	Eniaetok	46	23	20±33	390±650
	Gejen	30	14	105±27	3360±840

Date of collection: February 1956. Date of counting: April–May 1956.

Table 33—Sunshine Units of Water Samples

Sample	Island	Calcium in Liter (mg)	Sr^{90} (d/m/liter)	Sunshine Units (2.2 d/m Sr^{90}/g Ca)
Cistern	Rongelap	48	1180±10	1.1×10^4±230
	Utirik	61	20±14	147±104
Well	do	88	39±10	201± 54
	do	80	NDA	0
	Eniaetok	2300	NDA	0
Ocean	Rongelap	352	NDA	0
	Utirik	408	NDA	0
	Eniwetak	402	NDA	0
Lagoon	Rongelap	456	190±68	188± 68
	Eniwetak	137	NDA	0
	Utirik	441	204±150	208±150

NDA indicates no detectable activity.
Date of collection: February 1956. Date of counting: April–May 1956.

Table 34—Sunshine Units of Marshall Island Soils (NRDL)

Island	Soil Type	Sr^{90} d/m/g Soil	Exchangeable Calcium mg/g Soil	Sunshine Units
Utirik	Small sand-like particles.	3±1.5	1.9	660±330
Gejen	Large coral particles.	1886±20	1.4	6.2×10^5±6.3×10^3
Likiep	Loamy	11±2	11.3	430±60
Eniwetok	Small sand-like particles and loam.	62±2	4.6	6.1×10^3±180
Rongelap	Loamy	234±4	12.7	8.4×10^3±150
Sifo	Small sand-like particles.	25±3	.8	1.3×10^4±1.7×10^3
Eniaetok	do	400±11	.9	1.9×10^5±5.4×10^3

Table 35—UWAFL Post Redwing Marshall Island Survey Samples

HASL Number	UWAFL Number	Organism	Tissue	Sampling Location Island	Collection Date	No. Spec.	Lab.	Total Activity (β)		Sr^{90} d/m/g—wet	Ca gms/g—wet	S. U.
								C-Date	d/m/g—wet			
Invertebrates:												
4042	I-9	Holothurai atra	Gonad	Rongelap	7-23-56		I, Inc.	10-10-56	46	2.7 ±0.14	0.00566	210 ±11
4043	I-10	do	Gut and content	do	7-23-56		I, Inc.	10-10-56	31	1.2 ±0.03	0.155	3.4 ±0.08
4044	I-11	do	Integument	do	7-23-56		I, Inc.	10-10-56	10	0.27 ±0.007	>0.00101	±150
4045	I-12	Tridaena gigas	Mantle	Kabelle	7-24-56		I, Inc.	10-10-56	2.6	0.030±0.016	>0.00239	≥6
4046	I-13	do	Muscle	do	7-24-56		I, Inc.	10-10-56	1.5	±0.046	0.00400	>5.3
4047	I-49a	Cenobita	do	do	7-24-56		NSE		310	16 ±0.58	0.0016	4600 ±300
4048	I-49b	do	Skeleton	do	7-24-56		NSE		2700	1550 ±59	0.189	3940 ±170
4049	I-49c	do	Liver	do	7-24-56		NSE		700	34 ±1.6	0.0034	4600 ±300
4050	I-50a	do	Skeleton	do	7-24-56		NSE		1660	910 ±31	0.188	2190 ±80
4051	I-50b	do	Liver	do	7-24-56		NSE		790	25 ±1.0	0.0046	2620 ±130
4052	I-50c	do	Muscle	do	7-24-56		NSE		250	9.5 ±0.45	0.0015	2860 ±170
4053	I-52	do	Skeleton	Rongelap	7-23-56		NSE		1960	750 ±35	0.156	2200 ±120
4054	I-51	do	do	Kabelle	7-24-56		NSE		2780	1450 ±50	0.182	3600 ±150
Fish:												
4035	F-266a	Reef fish	Muscle	Rongelap	7-23-56	19	NSE		12	0.036±0.003	0.000808	20 ±1.9
4036	F-266b	do	Bone	do	7-23-56	19	NSE		31	1.9 ±0.082	0.0711	12 ±0.5
4037	F-266c	do	Liver	do	7-23-56	19	NSE		230	0.058±0.029	0.000990	27 ±13
4038	F-314a	do	Muscle	Kabelle	7-24-56	15	I, Inc.	10-10-56	2.9	0.027±0.004	0.00125	9.8 ±1.6
4039	F-314b	do	do	do	7-24-56	15	I, Inc.	10-10-56	0.39	0.401±0.007	0.00104	4.4 ±1.4
4040	F-314c	do	Bone	do	7-21-56	15	I, Inc.	10-10-56	0.66	0.106±0.014	0.0744	0.65±0.09
4041	F-314d	do	Liver	do	7-24-56	15	I, Inc.	10-10-56	7.2	0.061±0.041	>0.00485	≥6
Land Plants:												
4024	RO-1	Breadfruit	Meat	Rongelap	7-23-56		NSE		31	0.26 ±0.008	0.000447	260 ±10
4025	RO-2	Papaye	Seeds	do	7-23-56		I, Inc.	10-11-56	0.86	0.38 ±0.01	>0.00208	≥86
4026	RO-2	do	do	do	7-23-56		NSE		28	0.38 ±0.002	0.00237	74 ±4
4027	RO-6	Coconut	Meat	do	7-23-56		I, Inc.	10-10-56	0.36	0.033±0.003	>0.000376	≥41
4028	RO-7	do	Milk	do	7-23-56		NSE		66 (d/m/ml)	0.034±0.004 (/ml)	0.000277 (gms/ml)	58 ±7
4034	RO-8	Morinda	Pulp and seeds	do	7-23-56		NSE		46	1.4 ±0.048	0.000659	1000 ±50
4029	RO-12	Arrowroot	Corn	do	7-23-56		I, Inc.	10-10-56	0.16	0.27 ±0.004	0.000642	190 ±3
4030	RO-16	Pandanus	Fruit	do	7-23-56		NSE		63	1.2 ±0.041	0.00106	530 ±20
4031	RO-20	Coconut	Meat	Kabelle	7-24-56		I, Inc.	10-10-56	0.56	0.15 ±0.003	>0.000250	≥272
4032	RO-21	do	Milk	do	7-24-56		NSE		145	1.9 ±0.076	0.000474	1720 ±110
4033	RO-22	Papaya	Fruit	Rongelap	7-23-56		I, Inc.	10-10-56	0.40	0.37 ±0.006	0.000636	265 ±4

HASL Number	Type	Island Location	S-Date	Area	Lab	Total Activity (β)		Sr^{90} d/m/l
						C-Date	d/m/l	
Water:								
3814	Cistern	Rongelap	7-27-56	Village	I, Inc.	8-7-56	31,000 (after filtering twice)	150±4
3815	Well	Rongelap	7-23-56	Village	I, Inc.	8-7-56	22,000 (after filtering twice)	80±3

HASL Number	UWAFL Number	Sampling Location	Collection Date	Depth (inch)	Area	Lab	Total Activity (β)		Sr^{90} d/m/gm—wet	Sr^{90} d/m/ft^2	Sr^{89}* / Sr^{90}
							C-Date	d/m/gm—wet			
Soil:											
3802	No sample numbers assigned.	Kabelle	7-24-56	0-2	(First set)	HASL	8-4-56	1980±80	150 ±3.7	5.5 ×10^5	0.07
						I, Inc.	8-29-56	1820	155 ±4.1	5.7 ×10^5	
3803		do	7-24-56	2-4	do	HASL	8-4-56	406±45			
						I, Inc.	8-29-56	471	40 ±0 41	1.3 ×10^5	
3804		do	7-24-56	4-6	do	HASL	8-4-56	≤40			
						I, Inc.	8-29-56	106	1.5 ±0.07	0.064×10^5	
3807		do	7-24-56	0-2	(Second set)	HASL	8-4-50	6210±110	250 ±4.9	9.3 ×10^5	0.16
						I, Inc.	8-30-56	5940	265 ±1.2	9.8 ×10^5	
3806		do	7-24-56	2-4	do	HASL	8-4-56	3300±102	58 ±2.9	2.2 ×10^5	0.07
						I, Inc.	8-30-56	1735	96 ±1.7	3.6 ×10^5	
3805		do	7-24-56	4-6	do	HASL	8-4-56	1160±62	54 ±2.8	1.8 ×10^5	0.08
						I, Inc.	8-30-56	651	30 ±0.57	1.0 ×10^5	
3808		Rongelap	7-23-56	0-2	100′ fr. lagoon village area.	HASL	8-4-56	266±52			
						I, Inc.	8-30-56	152	10 ±0.40	0.46 ×10^5	
3809		do	7-23-56	2-4	do	HASL	8-4-56	≤39			
						I, Inc.	8-30-56	79.2	4.5 ±0.1	0.21 ×10^5	
3810		do	7-23-56	4-6	do	HASL	8-4-56	≤45			
						I, Inc.	8-30-56	54.9	1.4 ±0.06	0.064×10^5	
3813		do	7-23-56	0-2	Mid island	HASL	8-4-56	1220±53	68 ±2.8	2.3 ×10^5	0.06
						I, Inc.	8-30-56	663	31 ±0.21	1.0 ×10^5	
3812		do	7-23-56	2-4	do	HASL	8-4-56	134±51			
						I, Inc.	8-30-56	106	4.0 ±0.2	0.16 ×10^5	
3811		do	7-23-56	4-6	do	HASL	8-4-56	≤37			
						I, Inc.	8-30-56	54.9	0.98±0.03	0.040×10^5	
3818		Parry	7-25-56	Surface	Shore	HASL	8-4-56	17900±203	7.6 ±2.0	------	8.7
3819		do	7-25-56	Sub-surface	do	HASL	8-4-56	103±39			

*As of September 20, 1956.

I, Inc.—Isotopes, Incorporated, Westwood, N. J. N.SE.—Nuclear Science and Engineering, Pittsburgh, Pa.

Date of counting: September-October 1956.

See Table 34 for estimates of *available* calcium and of sunshine units for soils.

CHAPTER IV

Internal Contamination of Animals

At the time of the fallout on Rongelap Island there were a variety of animals present. These were left to live on the island, and representative numbers were collected on the 8th, 25th, 33rd, and 51st–53rd days and then sacrificed. Tables 36, 37, and 38 show the relevant data concerning external doses to the animals while living on the island, and an analysis of their internal contamination.[8]

Over 90 percent of the activity in the body of animals was in the skeleton. At 82 days past detonation, 62 percent of the skeletal beta activity of the pigs was due to Sr^{89}, 7 percent Ba^{140}, and 10 percent rare earth group. However, it was reported that ". . . *In the 6 months period post detonation* neither significant gross changes nor pathological changes which could be definitely ascribed to radiation were detected in any of the animals." [8]

Table 39 shows the activity of a rooster and rats collected 2 years post detonation.[4] The gross activity in this rooster was 40 percent of that of a rooster from the same locality at 1 year post detonation.

Since these animals represented interesting cases of living continuously in a heavily contaminated environment, a strontium-90 analysis was made later of some rats and a rooster collected at the 2-year period. (Table 40).[9] Additional analysis was made by AFL of a single rat bone specimen (Table 40). These *data are extensive but do indicate the relatively* low body burden of strontium-90.

Table 36—Mortality and External Radiation Dose of Animals From the Living Areas of Rongelap and Utirik

External Dose (**Day of Collection) Animals	Series A			Series B			Series C			Series D			Total		
	280r (day 8)			330r (day 25)			340r (day 33)			360r (day 51-53)					
	Total Received	Dead	Sac'd	Total Received	Dead	Sac'd	Total Received	Dead	Sac'd	Total Received	Dead	Sac'd	Total Received	Dead	Sac'd
Hens	6	1 Day 23	1 Day 23	----	----	----	20	2 Day 42 Day 43	2 Day 44	11	5 Day: 67 #36, 74 #39, 92 #35, 99 #7, 130 #24	----	37	8	3
Roosters	1	----	----	----	----	----	2	1 Day 49	----	1	----	----	4	1	----
Chicks	----	----	----	----	----	----	9	9	----	----	----	----	9	9	----
Ducks	----	----	----	----	----	----	4	----	1 Day 56	----	----	----	4	----	1
Pigs	1	----	1 Day 45	7	----	4 Day: 38 Sow, 57 #6, 82 #24, 82 #25	----	----	----	3*	----	----	11	----	5
Cat	1	----	----	----	----	----	----	----	----	----	----	----	1	----	----
													66	18	9

*Animals from Utirik; all others from Rongelap (Group IV area animals rec'd 32 r external dose). **Day Post Detonation

Table 37—Radiochemical Analysis of Tissues and Urine of Pigs From Rongelap on 82nd Day Post-Detonation

BETA ACTIVITY—D/M/TOTAL SAMPLE

Sample	Gross Activity (x 10^{-3})	Sr^{89} (x 10^{-3})	Ba^{140} (x 10^{-3})	Total Rare Earth (x 10^{-3})
Pig #24 (25.8 kgm):				
Skeleton (total)	8890	5660	660	1010
Liver	31	0.40	0.33	6.4
Colon and contents	12	5.0	2.4	3.2
Lung (alveolar)	1.5	0.22	0.20	0.8
Stomach	1.2	0.22	1.1	1.3
Intestine (small)	2.3	0.62	0.50	0.51
Kidney	3.3	0.21	0.42	0.74
Remaining tissues	690	----	----	----
Total	9630	5667	665	1020
Urine sample, 24 hr	13	8.7	1.2	1.6
Pig #25 (22.7 kgm):				
Skeleton (total)	8600	5100	530	690
Liver	27	0.53	0.20	5.5
Colon and contents	16	5.0	3.2	4.9
Lung (alveolar)	1.1	0.26	0.23	0.33
Stomach	2.0	0.29	0.13	0.30
Intestine (small)	2.6	0.83	0.88	0.88
Kidney	3.1	0.14	0.19	0.52
Remaining tissues	220	----	----	----
Total	8870	5107	534	702
Urine sample, 24 hrs	6.2	4.4	0.40	0.54

SUMMARY

Gross Beta Activity	Skeleton	Total Body	Urine (24 Hrs.)
SR^{89}	62.0	58.0	69.0
Ba^{140}	6.8	6.5	7.9
Rare Earth	9.7	9.0	10.5
	78.5	73.5	87.4

All values corrected for decay.

Table 38—Beta and Gamma Activity of Chickens From Rongelap ($\mu c \times 10^4$)

	Hen #1		Hen #2		Hen #39		Hen #36		Hen #35		Hen #7		Hen #24	
Day of death**	Day 23		Day 23		Day 74		Day 97		Day 121		Day 138		Day 159	
Day analyzed**	Day 24		Day 24		Day 79		Day 107		Day 122		Day 140		Day 159	
Tissue	Beta	Gamma	Beta	Gamma	Beta	Gamma	Beta	Gamma	Beta	Gamma	Beta	Gamma	Beta	Gamma
Tibia	7600	3850	8180	4610	133	695		253	215.5	59	41.3	31.3	33 2	8.1
Skeleton	11030	55800	11900	66900	1930	8600		*3670	3120	*850	600	*454	437	*117.5
Liver	119	21	352	271	12	72		34	32	33	17.7	13.5	10.7	1.8
Gizzard					4.1	17		7.0	8.5	7.6	10.3	7.9	3.6	0.6
Gizzard (content)					0.93	—		—	1.4	—	7.5	1.2	0	0.8
Crop					0.43	5.0		2.0	7.9	—	12.2	9.3	4.5	0
Intestine (L) and contents					0.63	10.0		3.0	6.3	—	14.0	10.7	8.9	0.29
Intestine (S) and contents					1.6	4.0		3.0		—	8.4	6.4		
Pancreas					0.16	—		—	—	—	—	—	0.75	0
Spleen					—	—		1.0	—	—	—	—	0.26	—
Kidney	198	46			1.17	9.0		9.0	14.2	10.0	14.9	12.4	0.79	0.23
Lungs (Alveoli)	17	28	0	26	0.57	4.0		2.0	1.4	4.5	5.6	4.3	16.8	0.83
Trachea					0.24	2.0		1.0	10.7	3.7	0.9	0.2	—	—
Turbinates					3.87	19		22	15.8	7.6	—	—	—	—

*Calculated using ratio of gamma activity skeleton/tibia. **Day post detonation.

Table 39—Summary of Gross Beta and Gamma Activity in Rongelap Island Animals (NRDL)*

Sample	No. of Samples	Average Weight (g)	Radioactivity[a] Beta (d/m/sample ×10⁻⁴)	Beta (d/m/kg ×10⁻⁴)	Gamma (d/m/sample ×10⁻⁴)	Gamma (d/m/kg ×10⁻⁴)
Rooster	1	2,250				
Skeleton		560	52	93	101	181
Muscle		1,050	5.1	4.9	6.9	6.6
Gastrointestinal tract		185	0.8	4.3	1.6	8.7
Liver		192	2.4	12.5	9.4	49.0
Respiratory tract		32	0.2	8.7	0.4	17.4
Total activity			60.5		119.3	
Rats	4	62.9				
Skeleton		4.1	0.73	179	0.15	35.5
Head		5.4	0.15	36	0.1	18
Muscle		39	0.03	7.5	0.04	10.2
Gastrointestinal tract		10	0.32	32.0	0.27	27
Liver		3.6	0.08	21.7	0.06	15.6
Respiratory tract		0.5	0.03	62.0	0.02	36.0
Total activity			1.34		0.64	

[a] As determined on basis of U_3O_8 standards and empirical scattering and absorption correction.
*Date of collection: February 1956. Date of counting: Apr–May 1956.

Table 40—Analysis of Rats and a Rooster Collected on Island of Rongelap

February 1956 [a]

Specimen	Wet Weight	d/m Sr^{90}/sample	Ca/sample (gm)	S. U.
Rat:				
1515 Carcass [b]	44.7	642±23	0.533	545±19
1516C Carcass	62.5	315±62	0.315	453±90
1517C Carcass	32.3	367±21	0.353	470±27
Rooster:				
1510 Femur	[c] 26.0	1,210±39	5.19	105±3
1510 Tibia	41.0	5,702±119	9.50	272±5

July 1956 [d]

Specimen	Sr^{90}	Calcium	S. U.
Rat:			
Bone	245±5 d/m/g/wet	171±9 mg/g wet	644

[a] NRDL. [b] Does not include head, femurs, tibiae and viscera. [c] Dry weight of 2 femur halves. [d] AFL.

CHAPTER V

Residual Activity in Pacific Ocean

During February–May 1955, a survey was made by the Health and Safety Laboratory of the U. S. Atomic Energy Commission and the Office of Naval Research (Operation Troll) of the Pacific Ocean extending from the Marshall Islands westward across the Pacific, northward to Japan, then east to SanFrancisco.

The chart, on page 40 represents data on activity found in sea water and plankton. Table 41 shows some representative data on activity versus depth of water sample.[10] Tables 42 and 43 show representative data for marine life.[10]

Below is a summary of some of their conclusions:

1. Sea water and plankton samples show the existence of wide-spread low-level activity in the Pacific Ocean. Water activity ranged from 0–570 d/min/liter and plankton from 3–140 d/min/g wet weight.

2. There is some concentration of the activity in the main current streams, such as the North Equatorial Current. The highest activity was off the coast of Luzon, averaging 190 d/min/liter down to 600 m (April 1, 1955).

3. Analyses of fish indicate no activity approaching the maximum permissible level for foods. The highest activity in tuna fish was 3.5 d/min/g ash, less than 1 percent of the permissible level.*

4. Measurements of plankton activity offer a sensitive indication of activity in the ocean.

On June 11–21, 1956 another survey of radioactivity in the sea was conducted near Bikini and Eniwetok Atolls by the AFL. Since this survey was conducted during the Spring 1956 test series of detonations, temporarily relatively higher activities might be expected. Table 44 summarizes some of the data.[11]

*Based on 1/10 m.p.c. of that for atomic energy workers.

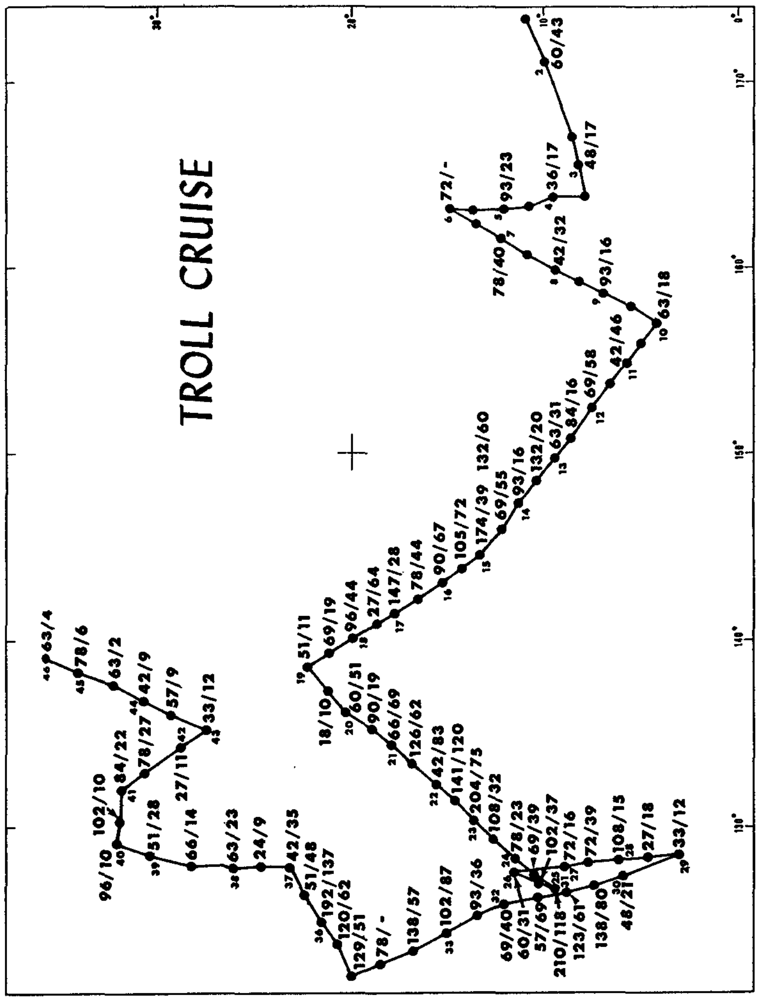

Table 41—Water Samples at Stations

Stations	Sample No.	Depth, m	d/min/Liter	Stations	Sample No.	Depth, m	d/min/Liter
1	3	0	24	5	66	0	51
	4	8	—		67	9	210
	5	24	60		68	26	120
	6	43	—		69	52	45
	7	64	42		70	73	160
	8	88	—		71	98	96
	9	128	96		72	142	36
	10	169	—		73	190	(−320)
	11	250	30		74	280	110
	12	340	—		75	369	87
	13	437	90		76	468	72
	14	552	—		77	579	110
2	18	0	3	6	81	Doubtful cast	66
	19	9	—		82	—	72
	20	25	6		83	—	78
	21	44	—		84	—	(−66)
	22	63	120		85	—	48
	23	85	—		86	—	72
	24	119	110		87	—	96
	25	155	—		88	—	(−9)
	26	222	9		89	—	57
	27	296	—		90	—	60
	28	370	120		91	—	84
	29	468	—		92	—	72
3	34	0	60	7	96	0	66
	35	9	—		97	9	0
	36	28	60		98	27	100
	37	55	—		99	54	120
	38	79	42		100	76	3
	39	110	—		101	108	(−140)
	40	164	(−15)		102	154	6
	41	Pretripped	—		103	205	42
	42	325	57		104	202	27
	43	426	—		105	293	130
	44	534	84		106	404	260
	45	646	—		107	519	0
4	49	0	36	8	112	0	66
	50	9	66		113	9	140
	51	25	87		114	27	9
	52	51	18		115	54	96
	53	71	24		116	77	30
	54	98	160		117	109	(−9)
	55	136	27		118	153	21
	56	164	0		119	197	100
	57	279	0		120	281	18
	58	373	45		121	357	100
	59	478	36		122	449	99
	60	590	100		123	552	99

Table 42—Radioactivity by Tissues of Yellowfin Tuna and Shark from the "TROLL" and Other Areas. Values in Disintegrations per Minute per Gram Wet Weight

Area	Date	No. of Fish	Skin	Light Muscle	Dark Muscle	Bone Rib-Vert.	Liver	G. I. Tract	Gonad	Gill
Yellowfin Tuna:										
Off Morotai	4-1-55		0	19, 16	10, 10	4, 24	0, 4	5	17	10.
Do	4-1-55		3	4, 9	12, 8	0, 0	13, 16	9	7	6.
Do	4-1-55		2	10, 21	8, 8	9, 22	10, 22	0	6	13.
Average		3	2	13	9	10	11	5	10	10.
Eniwetok	2-12-55	1	785	70	608	286	2820	272	90	
Ponape	12-16-54	6		79		101	742			
						(Cartilage)			(Kidney)	
Shark:										
Station 4	3-14-55		20	22	15		19		8	Carcharhinus.
Station 9 A	3-18-55		11	10	11	0	13		9	menisorrah.
Station 9 A	3-18-55		15	32	19	4	28			
Station 10	3-18-55		0	18	19	0	40		9	
Station 151	3-24-55		171	13	30	9	4		52	
Station 29	4-1-55		44	11	26	8	56		39	
Average		6	44	18	20	4	27		23	
Bikini	12-6-54			142			671			
Rongelap	1-29-55	1	687	125		191	2670	490		Carcharhinus melanopterus.
Eniwetok	12-1-54	1	1320	173		728	18900	583		

Table 43—Observed Values of the Radioactivity of Tissues of Reef Fishes by Area and Species from the "TROLL" Collections. Values in Disintegrations per Minute per Gram Wet Weight

	Squirrel	*Damsel*	*Grouper*	*Surgeon*			
Truk:							
Skin	48, 16, 45, 29, 38	26	48	29, 0, 10, 35, 0			
Muscle	12, 14, 15, 12, 11	4	9	16, 12, 14, 10, 7			
Bone	10, 32, 39, 42, 0	25	55	27, 56, 36, 0			
Liver	70, 58, 58, 52, 53	30	323	35, 5, 72, 15, 307			
G. I. tract	33, 28, 31, 10, 18	49	10	78, 47, 47, 57, 65			
				Blenny	*Wrasse*	*Siganid*	*Snapper*
Guam:							
Skin	10, 18, 24	71	44		21, 37	13,22	23
Muscle	14, 12, 12	17	20		17, 19	17, 11	17
Bone	28, 45, 13	40	44		66, 43	5, 33	14
Liver	126, 27, 51	408	310		116,68	86, 51	19
G. I. tract	105, 82	2344	64		74, 633	387, 289	340
Entire		194, 160, 144, 184, 207.		115, 337, 728, 321			
					Brotulid		
Parece Vela:							
Skin	4, 5		13, 13, 0, 14, 13				
Muscle	8, 13		15, 15, 9, 12, 14				
Bone	7, 9		38, 30, 17, 0, 172				
Liver	12, 0		36, 65, 98, 138, 81				
G. I. tract	6, 88		10, 12, 9, 79, 132				
Entire		85		335	20, 18		
		Butterfly Fish	*"Catfish"*		*Cardinal*		
Okinawa:							
Skin	17, 0	6			13, 17, 15, 0, 5		
Muscle	13, 9	13	14, 15		21, 5, 12, 6, 10		
Bone	0, 0	0	10, 14		32, 0, 12, 18, 30		
Liver	12, 0	19			0, 0, 0, 19, 31		
G. I. tract	10, 15	20	8, 21		82, 25, 44, 12, 7		
Entire				18, 0, 12			

Table 44—Average Value of Gross Fission Products for All Stations for Plankton, Residue From Water, and Filtered Water (Less K^{40}) as of Date of Collection (June 12–21), 1956. (AFL)

Depth in meters, 0–200. Plankton d/m/g (wet) 71000.

	Residue from Water		Filtered Water		Total d/m/l
	d/m/l	Percent of Total	d/m/l	Percent of Total	
0	5900	58	4200	42	10000
25	280	4	6500	96	6800
50	1800	19	7800	81	9600
75	1300	19	5500	81	6800
100	1000	26	2900	74	3900

CHAPTER VI

Return of Rongelapese

One of the major consequences of the heavy fallout on some of the Marshall Islands in March 1954 was the evacuation of their inhabitants. The 154 personnel from Utirik were returned to their island in June 1954. However, the contamination of the Rongelap Atoll was appreciably greater than at Utirik, therefore it was not advisable to return the Rongelapese at that time. Since then the contamination has decreased, as shown by the data from the foregoing surveys, to a level where return was permissible. The discussion below summarizes the factors that led to this decision.*

A. *Medical Status of Rongelapese*

Relevant to the considerations for the return of the Rongelapese to their home island was the body insult they previously suffered from radiation following the fallout of March 1, 1954 and their present body burden of radioactive isotopes. Below are summaries of the findings over a two-year period.

Of the Rongelapese exposed, 64 received about 175 roentgens, and 18 people about 69 roentgens whole body external gamma radiation. The clinical findings showed, ". . . The more seriously irradiated individuals had initial symptoms of anorexia, vomiting and diarrhea which subsided without treatment within 2 days. The same individuals slowly developed granulocytopenia and thrombocytopenia unassociated with secondary complications. The only other manifestations of radiation exposure observed were skin lesions and epilation, . . . The incidence of infectious and noninfectious disease in the more severely exposed groups was no greater than that in the least exposed group. . . ."[8]

*The Rongelapese were returned to their home island on June 29, 1957

The skin damage observed was as follows:

45 individuals—superficial lesions
13 individuals—deep lesions
6 *individuals—no lesions*
35 individuals—some degree of epilation

As the Marshallese continued to live on the contaminated islands for the two days before evacuation some radioactive materials were taken internally by inhalation and ingestion. Table 45 shows the results of urinalysis of Group I (the 64 Marshallese exposed to 175 roentgens) and Table 46 the estimated body burden.[8] The major findings on internal contamination were as follows:

". . . The total amount of radioactive material in the G. I. tract at one day post detonation was estimated to be 3 mc in people from Rongelap. This activity was contributed chiefly by isotopes of short radiological and biological half-life and limited solubility, and thus the levels of activity in the tissues of the body were relatively low. The concentration of radioisotopes at 6 months post detonation was barely detectable in the urine of most of the exposed individuals.

"The estimated dose to the thyroid from I^{131} and other short-lived iodine isotopes was 100 to 150 rep for the Rongelapese. Iodine is probably the most hazardous internal radioemitter at early times after exposure. The dose to the thyroid, although greater than tolerance, was low compared to the partially or totally ablating doses of I^{131} used in the treatment of hyperthyroidism or carcinoma." [8]

At one day post detonation, the concentration of Sr^{89} was calculated to be near the maximum permissible level for this nuclide. At later times following exposure, this longer-lived fission product presents the greatest potential internal hazard.

Table 45—Gross Beta Activity in Urine of Group I on 46th Day Post Detonation

Case No.	Total Volume 24 hrs (ml)	Beta Activity d/m/24 hrs	Case No.	Total Volume 24 hrs (ml)	Beta Activity d/m/24 hrs
Age < 5 yrs			*Age > 16 yrs*		
2	120	712	4	455	634
3	150	894	7	810	1700
5	155	313	9	355	201
23	40	223	10	980	549
33	260	0	11	450	1583
54	80	385	13	340	1677
69	455	301	14	780	2460
			18	455	1670
Mean	165	404	22	47	77
			30	960	438
			34	750	570
			37	480	792
			40	550	1450
			46	330	495
			49	425	0
			52	780	0
			55	320	1060
			56	700	3220
			57	650	1095
Age 6–15 yrs			58	750	2170
20	265	1900	60	810	580
24	550	0	62	980	1985
26	650	1032	63	635	2260
35	255	0	66	855	1715
36	190	236	68	300	2010
39	280	1100	71	290	1450
47	650	1705	73	230	0
67	450	674	78	965	52
72	110	507	79	465	2038
75	440	0	80	540	1353
76	930	1180	82	670	2140
Mean	439	758	Mean	581	1208

Values corrected for decay.

"Analysis of the internal contamination indicates that the dose to the tissue of the body was near, but, with exception of the dose to the *thyroid, did not exceed the maximum permissible* dose levels. The activity fixed in the body decreased rapidly as a function of time. The contribution of the effects of internal contamination to the total radiation response observed appears to be small on the basis of the estimated body burden of the radio-elements. In view of the short half-life of the most abundant fission products in the situation, the possibility that chronic irradiation effects will occur is quite small. . . ."[8]

These data suggest a low relative hazard from internally deposited radioisotopes since the values for maximum permissible concentrations are based on the concept that these levels will be maintained indefinitely.

The report stated, "—The total white count increases during the first *2 or more* days and then decreases below normal levels. —The count becomes stabilized during the 7th or 8th week at low levels, and minimum counts probably occur at this time. A definite trend upward is apparent in the 9th or 10th week; however complete recovery may require several months or more.

"The neutrophile count parallels the total white blood cell count. Complete return to *normal values does not occur for several months* or more. The initial rise in total white count is due to a neutrophilic leukocytosis.

"The drop in lymphocytes is early and profound. Little or no evidence of recovery may be apparent several months after exposure, and return to normal levels may not occur for months or years.

"The platelet count, unlike the fluctuating *total leukocyte count, falls in a regular fashion* and reaches a low on the 30th day. Some recovery is evident early; however, as with the other elements, recovery may not be complete several months after exposure. . . ."[8]

At one year later the Marshallese were reexamined with the following conclusions:

"—In general, the Marshallese have recovered satisfactorily from the radiation injury received during March 1954. Visible residual effects are limited to a few areas of depigmen*tation and two small, distinct scars from radi*ation burns, one of which will possibly require plastic repair.

"Neutrophil values have returned to the normal range of the control population. All

Table 46—Mean Body Burden of the Rongelap Group

Radioisotope	Activity at 82 Days μc (USNRDL)	Activity at 1 Day* μc (USNRDL)	Activity at 1 Day* μc (LASL)
Sr^{89}	0.19	1.6	2.2
Ba^{140}	0.021	2.7	0.34
Rare Earth Group	0.03	1.2	------
I^{131} (in thyroid)	0	6.4	11.2
Ru^{106}	------	------	0.013
Ca^{45}	0	0	0.019
Fissile material	0	0	0.016 (ugm)

*Extrapolated from 82d day.

other members of the leukocyte population and the platelets remain below the levels for the control population; however, levels are higher than at 6 months and, presumably, will soon be in the normal range."[13]

At two years the examination showed that, "In general, the people of both exposed and control groups appear to be in good health and nutritional status."[14]

A 77-year old man showed a history of paresis of the lower extremities. The symptoms suggested that, "These findings can best be explained on the basis of a cerebrovascular accident."[14] An 11-year old boy was hospitalized with acute rheumatic fever and cardiac decompensation. "The diagnosis of rheumatic heart disease with mitral stenosis and insufficiency was substantiated and at the time of the examination, the boy was fully active without evidence of decompensation."[14] A 46-year old man died on May 13, 1956, of heart failure. It was concluded that, "With the exception of the residual of skin lesions, none of the clinical findings in the exposed group could be attributed to the effects of irradiation."[13]

In regard to skin lesions it was reported, "Some residual lesions are present in the Rongelap people. . . . The majority of all show improvement. Almost all of the early superficial lesions are completely healed at this time without any apparent residual changes. . . . There appears to be no evidence of any change which would suggest malignancy."[14]

Urinalysis was made about two years after the March 1954 *detonation, for people living* on Utirik and Likiep Islands, for the Rongelapese living on Majuro Island and for personnel at HASL (Table 47).[6,14] It is recognized that these are limited data, but the values for the HASL group show the general world-wide distribution of the fallout debris, and indicates that the Sr^{90} activities found in the Pacific group are probably more the result of living in

Table 47—NRDL Marshall Island Resurvey—1956 Results of Analyses of Human Urine Performed at HASL

HASL No.	NRDL No.	Sampling Location	Collection Date	Name	Age	Total Volume Received (ml)	C-Date Total Activity	Total Activity d/m/l *	Total Activity d/m/l **	Sr^{90} d/m/l	Cs^{137} d/m/l
3399	6	Utirik	2-11-56	A	4	190	3-25-56	4800±240			
3400	1	do	2-11-56	B	2	250	3-25-56	3600±280			
3401	4	do	2-11-56	C	12	570	3-25-56	3360±320			
3402	9	do	2-11-56	D	27	440	3-25-56	3320±300			
3403	10	do	2-11-56	E	22	135	3-25-56	7600±240		3.4±0.3	720±15
3404	7	do	2-11-56	F	5	180	3-25-56	4400±280			
3405	2	do	2-11-56	G	16	285	3-25-56	8200±360	170±100		
3406	3	do	2-11-56	H	6	310	3-25-56	2200±320			
3407	8	do	2-11-56	I	16	340	3-25-56	3480±240			
3408	11	do	2-11-56	POOLED		620	3-25-56	7600±320	≤100	6.8±1.4	2540±63
3409	4	Likiep	2-11-56	J		260	3-25-56	4400±320			
3410	1	do	2-11-56	K	3	360	3-25-56	4400±320			
3411	8	do	2-11-56	L	8	160	3-25-56	4800±320			
3412	9	do	2-11-56	M	1	225	3-25-56	4000±240			
3413	5	do	2-11-56	N	26	235	3-25-56	4800±320		5.3±0.3	1487±23
3414	3	do	2-11-56	O	13	410	3-25-56	9800±360	600±100		
3415	2	do	2-11-56	P	35	600	3-25-56	2920±280	≤100		
3416	7	do	2-11-56	Q	45	190	3-25-56	8800±320			
3417	10	do	2-11-56	POOLED		990	3-25-56	9200±360	≤100	4.7±0.7	2862±45
3418	9	Majuro***	2-29-56	R	24	980	3-25-56	2600±240			
3419	40	do	2-29-56	S	31	990	3-25-56	2400±240			
3420	36	do	2-29-56	T	8	1,000	3-25-56	1160±200		2.4±0.2	33±8
3421	26	do	2-29-56	U	13	930	3-25-56	2200±240			
3422	76	do	2-29-56	V	11	990	3-25-56	1360±280			
		Control	3-26-56	Pooled sample collected at HASL.		1,000		4250±250	≤100	1.6±0.4	29±8
		do	June 1956	do		5,000				1.4±0.2	
		do	June 1956	do		5,000				1.9±0.2	
		do	June 1956	do		5,000				1.0±0.2	
		do	June 1956	do		2,000					30±8

*Direct plating. **Carbonate precipitation. ***Rongelap natives.

an environment of continual intake and excretion rather than the results of body elimination of previously deposited Sr^{90}.

B. *Medical Surveillance*

When the Rongelapese were returned to their home island, it was planned to inaugurate a program of continuing medical inspections. The Rongelapese would be examined once a month by a Marshallese practitioner and complete medical examination performed once a year by an American physician. Arrangements would be made for urine collections and analyses every three months for the first year and afterward on a yearly basis unless the findings indicate the necessity for more frequent analyses. A radio would be provided on Rongelap for communication with the Trust Territories Office on Ebeye (Kwajalein Atoll) where a plane would be available at all times for any emergency. A fully equipped dispensary would be provided on Rongelap and an experienced health aide (a Marshallese) would be present at all times. Before their return, the Marshallese would be given a complete medical examination, and immunized against smallpox, typhoid and tetanus.

C. *Environmental Contamination*

The degree of contamination on the home islands of the Rongelapese was considered according to the external gamma dose rate and the amount of strontium-90.

1. External Gamma Dose Rates on Rongelap Atoll

The external gamma dose rates at three feet above the ground on the Island of Rongelap are shown in Graph I. It would be expected that this curve would flatten out with time due to the dominance of the cesium-137 with its half-life of 27 years. The latest survey of the Rongelap Island at the end of July 1956 showed a range of values from 0.2–0.5 milliroentgen per hour, with an average of 0.4 mr/hr. However, the graph suggests an anticipated dose rate at the July 1956 survey of about 0.1 mr/hr. The higher value found is undoubtedly due to the small additional fallout that occurred during Operation Redwing. Since this was relatively fresh radioactive material, the decay should be more rapid so that the dose rates on Rongelap Island at the time of repatriation should be less than 30 milliroentgens/week.

The maximum permissible external gamma exposure to adult workers recommended by the National (U. S.) Committee on Radiation Protection is 0.3 rems/week with an added restriction that the maximum permissible accumulated dose in rems, at any age is equal to five times the number of years beyond age 18, provided no annual increment exceeds 15 rem. (This applies to all critical organs except the skin, for which the value is double.) The maximum permissible exposure for the population as a whole from all sources of radiation, including medical and other man-made sources, and background shall not exceed 14 million rem per million of population over the period from conception up to age 30, and one-third that amount in each decade thereafter.

It is difficult to extrapolate precisely far into the future, but the data suggest that the gamma doses on Rongelap Island would not greatly exceed (if at all) 0.5 roentgens for the first year of reoccupancy, with lesser doses in subsequent years, plus some additional whole body dose from internally deposited cesium-137.* The gamma dose rates on other island of Rongelap Atoll have not been followed as closely as on Rongelap but the data suggest the *relative* dose rates now are the same as measured in the first part of March 1954; i. e., the highest activity on any island is about a factor of 12 higher than Rongelap. The Rongelapese go on fishing expeditions to other islands, including those showing both higher and lower activity. However, these Rongelapese spend an appreciable part of their time in boats over water where the external gamma activity is near background values. Thus, the yearly average for these probably would not differ greatly from those on Rongelap Island.

2. Strontium-90

a. Food Supply

The basic data on the normal food supply of the Rongelapese are contained in Table 48. There are wide variances in the data so that estimated average values are used. This is not an unreasonable approach since it would be expected that the food actually consumed would be about as variable as the individual samples collected for analysis. As will be seen below, these estimates could be in error by a factor of several without changing the conclusion.

The isotope of principal concern in the food chain is strontium-90. For an adult worker the maintained maximum permissible body burden is 1,000 Sunshine Units (1,000 micromicrocuries of Sr^{90} per gram of calcium). Values for maximum permissible exposures to the general population are 1/10 that for adult workers, or 100 Sunshine Units, maintained level in the body. The National (U. S.) Academy of Sciences report stated, ". . . There seems no reason to hesitate to allow a universal human strontium—burden of 1/10 of the permissible . . ." for adult workers. This corresponds to the 100 Sunshine Units.

*Gamma dose rates at three feet above the ground on the Island of Rongelap in June 1957 were as follows:
Highest reading 0.13 mr/hr
Lowest reading 0.01 mr/hr
Average reading 0.03 mr/hr

Table 48 indicates that the average concentration of strontium–90 in the total food supply might be less than 360 Sunshine Units. (The data on land crabs shown in Table 48 are from the Island of Kabelle which is more heavily contaminated than the Island of Rongelap).*

Table 48—Estimates of Contamination of the Normal Food Supply of Rongelapese

	A	B	C	D	E	F
	Daily Intake Pounds/Day/Person	Calcium Content (gms Ca/gm wet weight)	Daily Intake of Ca (gms)	Fraction of Total Ca Intake	Strontium-90 Content (S. U.)[a]	Contribution To Sr^{90} Intake (S. U.) (Column D X E)
Fish	1.22	0.001	0.56	0.645	12	7.73
Pandanus	0.36	0.001	0.16	0.184	[b] 500	[b] 92.0
Clams	0.1	0.004	0.018	0.021	5	0.11
Arrowroot	0.09	[d] 0.0006	0.025	0.029	250	7.26
Wild birds (muscle)	0.09	0.0001	0.004	0.0046	300	[b] [c] 1.38
Land crabs	[e] 0.03	0.004	0.055	0.063	[b] [c] (4000)	(252.0)
Coconut meat and milk	0.02	0.0004	0.004	0.0046	40	0.02
Bread fruit	0.01	0.0006	0.003	0.0034	260	0.88
Imported:						
Rice						
Flour						
Canned beef						
Milk	0.1	~0.0001	~0.045	~0.046	Few	Small
Sardines						
Shoyu						
Coffee						
Tea						

[a] Average values.

[b] These data are from island of Kabelle (no date from island of Rongelap for July 1956 survey). General contamination of island of Rongelap is about one-fifth that of Kabelle. Lagoon water around these islands do not show as great a difference in activity.

[c] These are land crabs from island of Kabelle. The strontium-90 concentration is higher than from earlier surveys, which is contrary to the plant activity as well as to the soil, and marine life data. (It has been estimated that about one-third of the intake of crab meat is from ocean crabs which have very little strontium-90 content.)

[d] Estimated.

[e] An unknown part of this intake may be sea crabs (which contain considerably less Sr^{90}) but is assumed here to be all land crabs.

However, if crabs were eliminated from the diet, the intake might average about 107 Sunshine Units. Further, elimination or restriction of the consumption of pandanus would reduce the strontium–90 intake to well under 100 Sunshine Units.

b. *Estimated Future Body Burden of Strontium–90*

Three principal factors are operative in estimating the future body burden of strontium–90 of the Rongelapese:

(1) Although precise values have not been established, there may be a discriminatory factor of several between Sr/Ca ratio in the food supply and that found in the bones.[15]

(2) If the Rongelapese were returned to their home island, their diet would be supplemented by imported (relatively uncontaminated) foods, especially rice. Also, the cisterns would be cleaned out and refilled with fresh water as well as having new cisterns built.

(3) Despite the wide variances in the data, analysis of the results from all of the surveys on the Pacific Islands shows a general decline of Sr^{90} with time in the food chain (except the land crabs).

*There is some doubt concerning the correct strontium-90 activity in the land crabs, since the values are higher than for previous surveys which is contrary to all other data. Additional surveys should clarify this point. In any event the land crabs tested are from the island of Kabelle. (There were no collections of land crabs made on Rongelap Island during the last survey.) The general contamination on Rongelap is about one-fifth that of Kabelle. The difference in strontium-90 content may not be as great as this, but since these are land crabs it would be expected those on Rongelap Island to be lower than on Kabelle Island.

Although there is obviously a certain degree of uncertainty, the above data and estimates indicate that if land crabs are eliminated from their diet, the estimated future body burden of the Rongelapese would be substantially less than 100 $\mu\mu c$ of Sr^{90} per gram of calcium. Limiting the intake of pandanus would further reduce the estimated Sr^{90} intake. By means of the continuing medical examinations described below it would be possible to note any tendency of untoward accumulation of strontium–90 with time, and appropriate action could be taken before excessive levels were reached.

c. *Radiological Resurveys*

Plans are currently being developed for a continuing and long-range program for radiological resurveys on and around the Marshall Islands. The principal objective will be to monitor the environmental contamination especially for strontium–90.

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U. S. GOVERNMENT PRINTING OFFICE: 1957