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B

Date:

To:

From: SIDNEY MARKS

Does the 20 mrem
natural background
exposure include the
25 mrem from internal
radiation, i.e., potassium-
40, etc.?

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WHOLE BODY COUNTING RESULTS FROM 1974 TO 1979 FOR BIKINI ISLAND

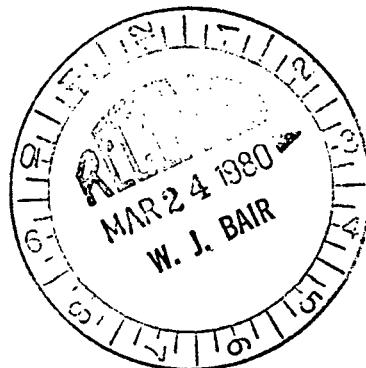
RESIDENTS

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ABSTRACT

Three body burden measurements of the Bikini Island population were conducted from 1974 to 1978 at Bikini Island. During this time, the mean ¹³⁷Cs body burden of the adult Bikini population increased by a factor of 20. This dramatic elevation of the body burden appears to be solely attributable to increased availability of locally grown food products, specifically coconuts and coconut plant products. In January 1979, forty-five percent of the individuals that were whole body counted in April 1978 were recounted approximately one hundred and forty-five days after the Bikini Island population departed from Bikini Atoll. These results show that the adult population mean ¹³⁷Cs body burden decreased by a factor of 2.9 between the April 1978 and January 1979 in vivo measurements.



Historical Development

Bikini Atoll was one area used by the U.S. government to test nuclear weapons from 1946 to 1958. Prior to commencement of the testing program, all Bikini Atoll inhabitants were moved first to Rongerik Atoll and then finally to Kili Island. On March 1, 1954 a thermonuclear device, code named Bravo, was detonated at Bikini Atoll.

The radioactive cloud from this test moved eastward depositing fallout on several of the Northern Marshall Island Atolls: Bikini Atoll (all Marshallese inhabitants had been moved), Rongelap with 64 people, Ailingnae with 18 people, Rongerik with 28 people, and Utirik with 157 people. The Japanese fishing boat Fukurju - Maru (Lucky Dragon) with 23 fisherman aboard was also contaminated (CO 75).

The exposure of individuals to radioactive fallout 6 to 24 hours post detonation of "Bravo" resulted in external total body gamma dose equivalents ranging from 20 to 200 rem (CO 75). This incident initiated the involvement of R. A. Conard et al. who for the past 24 years has been responsible for the ongoing medical surveillance of the inhabitants living on the contaminated atolls, those Marshallese who were initially exposed to the fallout and have moved, and to a control Marshallese population.

The medical history acquired by R. A. Conard included total body burden measurements of radioactive material inhaled or ingested by the Marshallese. This work was performed by S. Cohn et al. (CO 63, CO 75).

In recent years (1974 to present), the medical services provided by R. A. Conard and the Brookhaven Medical Team were expanded to include sick call and body burden measurements of the returning Bikini population. Body burden measurements were made in 1974 (CO 75) and in 1977 (CO 77). In August 1977, the responsibility for providing body burden measurements was transferred from the Medical Division to the Safety and Environmental Protection Division at Brookhaven National Laboratory. The 1978 and 1979 body burden measurements of the Bikini population were conducted by the latter organization.

PREFACE

Although Bikini Atoll has not been officially turned over to the Bikinians, a significant number of Marshallese reside there; and the population has risen steadily since rehabilitation efforts began in 1969-70. The population, numbering about 138 persons in April 1978, consisted of caretakers and agriculturists employed by the Trust Territory, and other Bikini families who found their way back to their atoll via Trust Territory trade ships.

At the time this report was written the Bikini residents had been moved to Kili Island in the southern Marshalls and to Ejit Island, Majuro Atoll, (September 1978).

INTRODUCTION

The Brookhaven National Laboratory Radiological Surveillance Program in the Marshall Islands includes the quantitative assessment of internally deposited radioactive material in the Marshallese. In, this report, the results of four whole body counting measurements on the Bikini population that were conducted in 1974, 1977, 1978 and 1979 are presented. Because the body burden measurements were performed by two different organizations, the current experimental design included a cross check mechanism to ensure that previous and current results are directly comparable. The approach to the problem was multidirectional. First, key detection components were duplicated. Second, the systems were calibrated in the same manner (CO 63). Third, the operational procedures and counting geometries were basically similar, and duplicate counts were made on Brookhaven personnel with known body burdens to ensure total system comparability.

EXPERIMENTAL DESIGN

A. Instrumentation

The detector chosen for field use by both Brookhaven organizations is a 28 cm diameter, 10 cm thick, sodium iodide thallium activated scintillation crystal NaI(Tl). It is optically coupled to seven, 7.6 cm diameter low background magnetically shielded, photomultiplier tubes. In the current system the signal output from each photomultiplier tube is connected in parallel through a summing box with the combined output routed to a preamplifier/amplifier and

then to a microprocessor-based computer/pulse height analyzer (PHA). The PHA data is stored on a magnetic discette, and the results may be analyzed either in the field or at BNL using a matrix reduction, minimization of the sum of squares technique (TS 76).

B. Calibration

Analysis of NaI(Tl) spectra by the matrix reduction technique requires that the computer library contain individual standards for each radionuclide that is expected in the field measurements and that the field measurements and standards be the same geometry.

To accomplish this, a review of the previous whole body counting data (CO 75, CO 77) indicated the need to calibrate for ⁴⁰K, ⁶⁰Co and ¹³⁷Cs. The current system was calibrated using an Anderson REMCAL phantom (CO 63). Each radionuclide was introduced into the phantom's organs in an amount equivalent to the fraction of the total body concentration as defined by the ICRP in Publication 2 (ICRP 59). To verify the activity in the phantom prior to use as a standard, an aliquot of the phantom solution was counted on a lithium drifted germanium detector which was calibrated with NBS standard sources.

The phantom was then counted in a shadow shield whole body counter (WBC) (PA65). The whole body counting system consists of a stationary crystal and stationary bed. The counter detects radioactive material located principally in the thorax, so positioning of the phantom and the in vivo counting subjects must be as similar as possible. To facilitate reproducible counting geometries, each subject and the standard phantom was positioned such that the central

axis of the crystal intersected the central axis of the body about 25 cm below the sternal notch. The distance between the surface of the bed and the bottom of the detector is 32.4 cm. The total system efficiencies for ^{40}K , ^{60}Co and ^{137}Cs are listed in Table 1 as are typical minimum detection limits for these nuclides.

C. Quality Control

The quality control (QC) program consisted of a cross comparison of the radionuclide quantities estimated to be in the phantom volume versus NBS calibration standards. Agreement between these two activity concentrations is within $\pm 5\%$ for all radionuclides. Other quality control mechanisms employed were repetitive counting of secondary point source standards, multiple counts of Brookhaven personnel and the recounting of certain non-Bikini and Bikini residents.

Two point sources were used in the QC program. A ^{137}Cs source, which has been used by the BNL medical surveys in previous years, was used to monitor potential changes in system resolution and efficiency as function of time. A second source, a $^{137}\text{Cs} + ^{60}\text{Co}$ point source, was used for zero and gain determination.

Table 2 lists the results of Brookhaven personnel counted in the field and at the Brookhaven Medical Department Whole Body Counter by S. Cohn. The results of this comparison of WBC data support our thesis that the field counting system produces results that are consistent with prior studies and that are accurate measurements of radionuclide body burdens in people. From the 2 sigma counting error on all data and the lack of the field systems's sensitivity to detect

less than 37 Becquerels (1 nCi) ^{137}Cs , we can conclude that the detection efficiency of the field system is less than that of the whole body counter at the BNL Medical Department. However, once the activity of an individual significantly exceeds the minimum sensitivity of the field system, the agreement between the results from the two systems is within the 2 sigma counting statistic error. This is seen from the body potassium measurements.

Finally, two Marshallese subjects were counted for quality control purposes. The first person was a recount to determine the expected variability from counting an individual more than once. The replicate count was within 2% of the initial count. The second Marshallese subject counted was from Rongelap Atoll. This individual's ^{137}Cs result (11 kBq or 291 nCi) compared well with his previous ^{137}Cs result in April 1977 (14 kBq or 371 nCi) (CO 77). The difference of 22% is close to that which would be predicted from the 12% yearly decrease in the Rongelap population.

RESULTS

Tables 3 and 4 present a list of adult individuals who were counted in 1974 (CO 75), 1977 (CO 77), 1978 and 1979. There is a general increase in the body burdens of adult males from 1974 to 1977 by a factor of 13.3, and from 1977 to 1978 by a factor of 1.8. The general increase for adult females from 1977 to 1978 was slightly higher than that for males over the same period. In most cases, the 1979 data are significantly lower than the 1978 data with an average reduction in the ^{137}Cs body burden by a factor of 2.9.

Tables 5 and 6 summarize the ^{137}Cs body burden data collected in 1978 and 1979 for children. It must be noted that data reported here are uncorrected for height and weight differences between subjects and the phantom. This will have a minimal effect on adult data (10-15% possible error) (MI 76). Body burdens of the children reported in Tables 5, 6 and 7 have been corrected for geometric differences between adult standard man and the average Marshallese child.

Table 7 summarizes the ^{137}Cs data that is presently available. It presents the mean (\bar{x}), standard deviation from the mean (σ), and range of values reported for the sampled population. The data are segregated by sex and age.

Table 8 compares the observed reduction in ^{137}Cs body burdens from April 1978 to January 1979 with the reduction in ^{137}Cs body burden that was expected as a result of relocating the Bikini Population in late August 1978. Values for the biological removal rate constants were obtained from NCRP Report 52 (NCRP 77) and ICRP Publication 10A (ICRP 71).

RESULTS AND DISCUSSIONS

The whole body counting data indicate that previous estimates of the type of food and amount of various components in the Bikini diet did not adequately describe the dietary patterns that existed between 1974 and 1978. As certain local food crops, coconuts, became available in 1976, they were incorporated into the diet in the form of jekaru (the water sap of the coconut tree), jekomai (a syrup concentrate made from jekaru) and waini (drinking coconuts). The maturation time of the coconut tree is 5-7 years. Consequently, one would expect to observe a steady increase in the ^{137}Cs body burden through 1978 at which time an equilibrium body burden would be reached. Comparison of the observed reduction in the ^{137}Cs body burden from April 25, 1978 to January 24, 1979 with the expected reduction in the body burdens from September 1, 1978 to January 24, 1979 yields almost identical results for the adult male and adult female groups as shown in Table 8. This implies that the Bikini population was at equilibrium and that the body burdens on September 1, 1978 were not significantly different than those measured in April 1978. The child data do not agree with the expected value; however, the difference is not beyond the range of half-times listed in NCRP Report 52 (NCRP 77). Although NCRP Report 52 lists a mean half-time for children ages 5 through 15, it does not specify the age distribution of the sample. Most of the Bikini children (9) were in the 5-10 year category; hence, one would expect the observed reduction factor for this group to be somewhat higher than the expected value.

Although the data indicates that the ^{137}Cs body burdens did not increase between April and September 1978, it is noted that the body burdens would not have increased when new dietary items like pandanus and breadfruit became available for daily consumption.

Furthermore, while the population may have been at equilibrium with their April-September dietary uptake, individuals within the population may not have been in equilibrium. This is apparent in the adult male ^{137}Cs body burden data where two individuals showed no decline in activity between the April 1978 and January 1979 whole body count. In one case, the individual was present on Bikini for only 5 months prior to the April 1978 count. This places the individual at approximately 60% of his equilibrium body burden value. In the second case, there seems to be no clear explanation for the lack of any reduction in the body burden. Several possible explanations include

1. the individual may have lived away from Bikini prior to the April count; hence, equilibrium was not established at the time of counting, or
2. the individual changed his diet pattern between April and September.

These deviations from the norm do not alter the conclusion that equilibrium or near equilibrium had been reached for the population as a whole for ^{137}Cs . Indeed, they illustrate variations about a mean value.

Finally, the data clearly illustrates that at least 19% of the Bikini residents would have received a dose equivalent in excess of 5m Sv (0.5 rem) due to the ingestion of ^{137}Cs had the April 1978 activity ingestion rate of ^{137}Cs continued. This dose equivalent level does not include the dose equivalent from external radiation or other internally deposited radioactive material. Removal of the Bikini population from Bikini Atoll eliminated the ^{137}Cs source term from the diet and limited the dose equivalent received by this population.

ACKNOWLEDGEMENT

We would like to express our sincere appreciation to Stanton H. Cohn, Ph.D., Brookhaven National Laboratory, Medical Department, for his advice and assistance during the initial setup, preliminary operations and transfer of responsibility for bioassay services to our division.

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Table 1.

Summary of System Efficiency and MDLS for Field WBC System

Nuclide	Energy	Efficiency	MDL	Time
¹³⁷ Cs	662 KeV	8.7×10^{-3}	37 Bq (1 nCi)	900 sec
⁶⁰ Co	1173 & 1334 KeV	6.7×10^{-3}	37 Bq (1 nCi)	900 sec
⁴⁰ K	1460 KeV	7.0×10^{-3}	222 Bq (6 nCi)	900 sec

Table 2

Bikini 1978 QC Data of Non-Bikinians

<u>I.D.#</u>	<u>Date</u>	<u>Location</u>	<u>Potassium grams</u>	<u>¹³⁷Cs. nCi</u>	<u>Bq</u>
1	3/14/78	Bldg. 535-S&EP	141 ± 10%	MDL(1)	MDL(1)
1	4/25/78	Bikini-S&EP	122 ± 10%	MDL	MDL
1	5/23/78	Bldg. 490-Medical (3)	113 ± NA(2)	2.00 ± NA	74.0 ± NA
2	3/14/78	Bldg. 535-S&EP	151 ± 10%	MDL	MDL
2	4/23/78	Bikini-S&EP	152 ± 14%	MDL	MDL
2	5/18/78	Bldg. 490-Medical (3)	151 ± NA	2.1 ± NA	78 ± NA
3	3/14/78	Bldg. 535-S&EP	131 ± 12%	2.0 ± 50%	74.0 ± 50%
3	3/14/78	Bldg. 490-Medical (3)	118 ± NA	4.9 ± NA	181 ± NA
4	2/16/78	Bldg. 490-Medical (3)	150 ± NA	3.0 ± NA	111.0 ± NA
4	4/24/78	Bikini-S&EP	122 ± 10%	MDL	MDL
5	10/77	Enewetak-Medical (3)	111 ± NA	1.9 ± NA	70 ± NA
5	10/77	Bldg. 490-Medical (3)	111 ± NA	1.1 ± NA	41 ± NA
5	4/25/78	Bikini-S&EP	106 ± 10%	MDL	MDL
6	4/77	Rongelap-Medical (3)	105 ± NA	371 ± NA	14000 ± NA
6	4/24/78	Bikini-S&EP	112 ± 11%	291 ± 5%	11000 ± 5%

1. MDL for ¹³⁷Cs = $\frac{3(\text{cts})^{1/2}}{900 \times 370 \times 8.6 \times 10^{-3}} = 0.7 \text{ nCi or } 26 \text{ Bq, S\&EP Field System}$

2. NA - Results reported without counting error

3. Data obtained from personal communications with S. Cohn (CO 77)

Table 3

Bikini WBC Results 1974 and 1979, Adult Male Population

Medical ID	Weight in Kilo-grams	Age	Years on Bikini	1974 ¹		1977 ²		1978				1979							
				Potas- sium grams	¹³⁷ Cs μCi	Potas- sium grams	¹³⁷ Cs kBq	Potas- sium grams	⁶⁰ Co nCi	⁶⁰ Co Bq	¹³⁷ Cs μCi	¹³⁷ Cs kBq	Potas- sium grams	⁶⁰ Co nCi	⁶⁰ Co Bq	¹³⁷ Cs μCi	¹³⁷ Cs kBq		
80	61	69	0.75	-	-	-	-	97.6	1.42	53	1.14	42	-	-	-	-	-	-	
6006	63	37	0.75	-	-	-	-	141	2.39	88	1.47	54	-	-	-	-	-	-	
863	67	27	4	-	-	146	0.729	27	156	4.93	180	2.34	87	179	2.5	93	1.1	41	
6070	85	28	10	170	0.093	3.4	167	1.51	56	152	8.17	300	3.92	150	137	3.0	111	1.6	59
6004	95	28	0.25	-	-	-	-	167	1.88	70	1.33	49	-	-	-	-	-	-	-
6033	79	27	6	148	0.095	3.5	136	1.52	56	132	8.65	320	3.84	140	-	-	-	-	-
6018	89	34	6	198	0.22	8.2	-	-	-	180	14.3	530	5.88	220	-	-	-	-	-
6069	61	32	8	-	-	-	-	-	-	132	4.01	150	1.17	43	-	-	-	-	-
6068	79	56	6	165	0.051	1.9	144	0.778	29	141	6.17	230	3.07	110	-	-	-	-	-
6067	74	56	7	-	-	-	-	-	-	151	5.91	220	2.99	110	137	2.4	89	1.0	37
6066	94	32	3	-	-	-	-	-	-	168	2.04	75	0.820	30	171	1.2	44	0.48	18
6017	80	49	8	-	-	-	-	-	-	153	13.9	510	5.72	210	-	-	-	-	-
6019	60	48	5	-	-	-	119	0.791	29	107	3.95	150	1.03	38	135	2.9	107	0.39	14
6001	85	66	7	143	0.078	2.9	-	-	-	126	3.33	120	1.73	64	132	1.9	70	0.77	28
6073	85	24	7	-	-	-	132	0.775	29	127	4.19	160	2.18	80	-	-	-	-	-
6005	70	58	1.5	-	-	-	-	-	-	133	3.40	130	2.08	77	-	-	-	-	-
6008	55	32	4	-	-	-	153	1.99	74	125	5.00	190	1.94	72	148	3.2	118	1.3	48
6086	78	46	8	170	0.17	6.2	149	2.14	79	151	7.92	290	3.51	130	179	2.8	104	0.86	32
6071	78	32	0.75	-	-	-	-	-	-	136	2.26	84	1.72	64	136	1.2	44	0.93	34
6076	69	39	3	-	-	-	-	-	-	163	6.64	250	3.44	130	171	2.9	107	2.4	89
6072	55	20	0.67	-	-	-	-	-	-	128	2.96	110	1.75	65	-	-	-	-	-
813	58	23	4	-	-	-	143	0.995	37	138	3.65	140	1.69	62	154	1.8	67	0.61	23
6118	55	22	6	126	0.77	2.9	-	-	-	108	1.92	71	0.631	23	144	1.6	59	0.75	28
6126	55	35	2	-	-	-	149	2.21	82	137	7.79	290	3.30	120	-	-	-	-	-
6003	77	22	8	168	0.076	2.8	161	0.923	34	139	5.60	210	2.44	90	-	-	-	-	-
6117	80	22	6	-	-	-	169	1.15	43	148	6.09	230	2.68	99	172	2.9	107	0.90	33
6128	52	31	7	-	-	-	149	1.29	48	119	4.79	180	1.85	69	155	2.7	100	0.92	34
6125	64	35	9	159	0.10	3.8	150	1.54	57	144	5.65	210	2.52	93	-	-	-	-	-
6007	82	35	0.58	-	-	-	-	-	-	127	2.58	95	1.49	55	144	0.67	25	0.32	12
6130	69	29	0.42	-	-	-	-	-	-	143	2.20	81	1.46	54	156	1.5	56	1.5	56
6119	54	17	7	-	-	-	138	0.641	24	124	4.58	170	2.13	79	-	-	-	-	-

Table 3 (cont'd)

Medical ID	Weight in Kilo-grams	Age	Years on Bikini	1974 ¹			1977 ²			1978			1979						
				Potas-sium grams	¹³⁷ Cs μ Ci	¹³⁷ Cs kBq	Potas-sium grams	¹³⁷ Cs μ Ci	¹³⁷ Cs kBq	Potas-sium grams	⁶⁰ Co nCi	⁶⁰ Co Bq	¹³⁷ Cs μ Ci	¹³⁷ Cs kBq	Potas-sium grams	⁶⁰ Co nCi	⁶⁰ Co Bq	¹³⁷ Cs μ Ci	¹³⁷ Cs kBq
864	90	51	7	163	0.29	11	133	3.23	120	136	5.99	220	3.05	110	-	-	-	-	-
966	75	56	7	-	-	-	162	2.22	82	174	14.8	550	5.71	210	-	-	-	-	-
6135	81	35	1	-	-	-	-	-	-	142	3.30	120	2.12	78	-	-	-	-	-
6096	66	48	3	-	-	-	145	1.93	64	146	4.32	160	1.91	71	146	2.5	93	1.3	48
6002	66	65	2	-	-	-	130	1.04	38	116	2.21	82	1.26	46	-	-	-	-	-
\bar{x}	72	38		161	0.13	4.6	146	1.43	53	139	5.25	190	2.42	90	153	2.2	81	1.0	37
σ	12	14		19	0.077	2.9	13.0	0.687	25	18.6	3.39	130	1.32	49	16	0.77	28	0.51	19
Range	52-95	17-69		126	0.051	1.9	119	0.641	24	97.6	1.42	53	0.631	23	132	0.67	25	0.32	12
				198	0.29	11	169	3.23	120	180	14.8	550	5.88	220	179	3.2	118	2.4	89

1 ∞ 75

2 ∞ 77

Table 4

Bikini Female Adult WBC Results 1974 through 1979

Med- ical ID	Weight in Kilo- grams	Years on Bikini	Age	1974 ¹		1977 ²		1978				1979							
				Potas- sium grams	¹³⁷ Cs μCi	Potas- sium grams	¹³⁷ Cs kBq	Potas- sium grams	⁶⁰ Co nCi	⁶⁰ Co Bq	¹³⁷ Cs μCi	¹³⁷ Cs kBq	Potas- sium grams	⁶⁰ Co nCi	⁶⁰ Co Bq	¹³⁷ Cs μCi	¹³⁷ Cs kBq		
6045	83	0.75	28	-	-	-	-	95	1.79	66	1.15	43	-	-	-	-	-		
6112	90	1	35	-	-	-	-	96	2.18	81	1.76	65	94	1.6	59	0.98	36		
6114	54	0.75	32	-	-	-	-	79	1.40	52	0.818	30	102	0.32	12	0.12	4.4		
6111	84	0.5	32	-	-	-	-	100	2.11	78	1.31	49	107	1.2	44	0.53	20.		
6122	73	10	70	94	0.033	1.2	-	86	3.20	120	1.34	49	93	1.9	70.	0.31	11		
6123	77	4	50	-	-	-	107	1.53	57	99	3.81	140	52	126	2.5	93	0.62	23	
6059	45	1	19	-	-	-	-	80	1.33	49	0.861	32	-	-	-	-	-		
6063	49	4	24	-	-	-	89.6	0.799	30	81	3.16	120	56	-	-	-	-		
6032	63	3	32	-	-	-	96.4	1.88	70	100	5.49	200	110	94	1.7	63	0.77	28	
6124	53	0.58	54	-	-	-	-	71	1.27	47	0.957	35	-	-	-	-	-		
6108	86	4	24	94	0.029	1.1	98.0	0.706	26	93	2.48	92	0.729	27	114	1.6	59	0.53	20
6058	66	5	18	106	0.077	2.9	88.8	0.690	26	92	4.63	170	77	-	-	-	-		
6113	54	4	25	-	-	-	91.7	0.534	20	91	2.33	86	38	107	1.1	41	0.30	11	
6065	52	4	19	-	-	-	101	0.734	27	93	2.39	88	39	96	1.3	48	0.36	13	
6097	53	4	19	86	0.036	1.3	88.9	0.468	17	90	2.15	80	47	95	1.0	37	0.31	11	
6109	50	4	15	-	-	-	110	0.621	23	88	1.49	55	15	106	0.53	20	0.060	2.2	
6046	85	1.75	43	-	-	-	94.3	0.833	31	100	3.81	140	78	-	-	-	-		
6098	60	3	16	-	-	-	91.4	0.706	26	93	2.38	88	33	66	1.2	44	0.47	17	
6060	55	2	22	-	-	-	-	81	2.00	77	1.39	51	105	0.84	31	0.18	6.7		
6036	56	0.34	27	-	-	-	-	73	1.54	57	1.53	57	-	-	-	-	-		
6110	77	8	32	111	0.11	4.0	-	-	-	94	3.98	150	56	-	-	-	-		
525	78	0.75	37	-	-	-	-	106	2.96	110	2.36	87	-	-	-	-	-		
6064	60	7	30	-	-	-	-	83	2.55	94	0.907	34	74	1.6	59	0.42	16		
6061	65	6	32	-	-	-	-	81	3.62	130	2.22	82	-	-	-	-	-		
6051	50	5	19	-	-	-	95.9	0.545	20	88	2.25	83	53	-	-	-	-		
934	74	6	43	-	-	-	98.8	2.23	83	110	10.8	400	200	-	-	-	-		
6062	54	4	21	-	-	-	96.8	0.840	31	79	2.53	94	53	-	-	-	-		
6035	77	6	20	-	-	-	113	0.573	21	100	4.94	180	100	100	2.3	85	0.65	24	
6115	56	7	43	95	0.058	2.2	85.9	1.15	43	80	4.16	150	84	84	1.8	67	0.48	18	
6034	76	7	46	102	0.12	4.3	93.7	0.995	37	92	6.92	260	140	-	-	-	-		
865	54	7	45	59	0.018	0.67	89.4	0.558	21	78	1.70	63	49	-	-	-	-		
6050	62	2	22	-	-	-	-	81	3.42	130	1.40	50	-	-	-	-	-		
\bar{x}	65		31	93	0.059	2.2	96.1	0.911	34	89	3.15	120	62	98	1.4	52	0.44	16	
σ	13		13	16	0.037	1.4	7.6	0.492	18	9.9	1.92	71	37	15	0.59	22	0.24	8.9	
Range		45-90	16-70	59	0.018	0.67	85.9	0.468	17	71	1.27	47	15	66	0.32	12	0.060	2.2	
				100	0.12	4.3	113	2.23	83	110	10.8	400	200	126	2.5	93	0.98	36	

1 CO 75

2 CO 77

Table 5

Bikini 1978 and 1979 WBC Results of Children AGES 5 - 10

Medical ID	Weight kilograms	Years on Bikini	AGE	Potassium Grams	1978 ⁶⁰ Co		1979 ¹³⁷ Cs		Potassium grams	nCi	1979 ⁶⁰ Co		1979 ¹³⁷ Cs	
					nCi	Bq	μCi	kBq			Bq	μCi	kBq	
Males														
6009	20	4	6	35.6	0.98	36	1.26	47	-	-	-	-	-	-
6049	23	2	8	46.9	2.7	99	1.71	63	-	-	-	-	-	-
6042	23	0.25	7	43.1	1.0	38	1.07	39	-	-	-	-	-	-
6014	20	1.34	5	41.1	1.7	64	1.50	56	-	-	-	-	-	-
6012	24	7	7	40.5	1.7	63	1.27	47	-	-	-	-	-	-
6023	28	4	8	51.6	1.7	63	1.28	47	43	0.91	34	0.16	5.9	-
6016	27	7	10	53.2	2.5	93	1.43	53	-	-	-	-	-	-
6013	18	2	5	32.6	1.3	50	1.00	37	-	-	-	-	-	-
\bar{x}	23		7	43.1	1.7	63	1.31	49						
σ	3.5		2	7.3	0.62	23	0.229	8.5						
Range	18-28		5-10	32.6-53.2	0.98-2.7	36-99	1.00-1.71	37-63						
Females														
6094	34	6	10	51.0	2.3	86	2.02	75	-	-	-	-	-	-
6092	29	6	8	52.1	2.8	100	2.25	83	-	-	-	-	-	-
6080	34	0.58	7	50.3	0.35	13	0.543	20	-	-	-	-	-	-
6010	29	7	8	55.6	1.8	67	1.41	52	50	0.49	18	0.17	6.3	-
6038	21	2	6	41.7	1.3	47	1.00	37	-	-	-	-	-	-
6105	22	3	5	30.7	1.2	43	0.967	36	65	-	-	0.053	2.0	-
6103	-	3	9	47.9	1.4	53	1.40	52	-	-	-	-	-	-
6028	25	5	7	52.0	1.4	51	1.26	47	-	-	-	-	-	-
6030	34	3	10	54.1	3.0	110	2.38	88	34	0.35	13	0.26	9.6	-
6027	22	3	6	35.6	5.6	210	1.16	43	58	0.42	16	0.042	1.6	-
6044	18	5	6	35.1	6.4	240	1.15	43	-	-	-	-	-	-
6025	21	3	5	43.6	0.97	36	1.03	38	45	0.59	22	0.13	4.8	-
6081	26	0.67	9	49.3	0.57	21	1.02	38	-	-	-	-	-	-
6106	22	3	6	32.3	0.48	18	0.622	23	37	-	-	0.077	2.9	-
\bar{x}	26		7	45.1	2.1	78	1.30	48	48	0.46	17	0.12	4.4	-
σ	5.6		2	8.51	1.8	68	0.558	21	12	0.10	3.7	0.080	3.0	-
Range	18-34		5-10	32.3-55.6	0.35-6.4	13-240	0.543-2.38	20-88	34	0.35	13	0.042	1.6	-
								65		0.59	22	0.26	9.6	-

Table 6

Bikini 1978 and 1979 WBC Results of Children AGES 11 - 15

Medical ID	Weight kilograms	Years on Bikini	AGE	Potassium Grams	1978				1979				
					⁶⁰ Co nCi	Bq	¹³⁷ Cs μ Ci	kBq	Potassium grams	⁶⁰ Co nCi	Bq	¹³⁷ Cs μ Ci	kBq
Males													
6132	33	2	12	58.0	3.45	130	1.85	68	-	-	-	-	-
6131	38	6	14	69.0	3.40	130	1.69	63	108	2.1	78	0.76	28
6011	40	6	11	53.2	1.34	50	0.830	31	59	1.0	37	0.055	2.0
6127	32	7	13	53.3	2.17	80	0.732	27	95	2.0	74	0.21	7.8
6133	27	7	11	52.8	3.42	130	2.09	78	-	-	-	-	-
6015	29	1.42	11	56.5	1.18	44	1.28	47	37	0.5	19	0.071	2.6
\bar{x}	33		12.0	57.2	2.50	92	1.41	52	75	1.4	52	0.27	10
σ	5.0		1.3	6.2	1.07	40	0.557	21	33	0.78	29	0.33	12
Range	27-40		11-14	52.8-69	1.18-3.45	44-130	0.732-2.09	27-78	37	0.5	19	0.055	2.0
									108	2.1	78	0.76	28
Females													
6129	48	4	13	69.0	1.32	49	.744	28	73	1.2	44	0.27	10
6048	40	0.25	13	70.4	2.61	96	2.05	76	-	-	-	-	-
6091	43	6	13	68.6	2.20	82	1.17	43	103	1.4	52	0.15	5.6
\bar{x}	44		13	69.4	2.05	76	1.32	49	88	1.3	48	0.21	7.8
σ	4.0		-	0.9	0.66	24	0.665	25	21	0.14	5.2	0.080	3.1
Range	40-48		13-13	68.6-70.4	1.32-2.61	49-96	.744-2.05	28-76	73	1.2	44	0.15	5.6
									103	1.4	52	0.27	10

Table 7

Summary of ^{137}Cs Body Burdens for Bikini Inhabitants, 1974 to 1979

Population	Number Counted 1974(5)	Range of ^{137}Cs Results 1974(5)	Mean ^{137}Cs Result 1974(5)	Number Counted 1977(5)	Range of ^{137}Cs Results 1977(5)	Mean ^{137}Cs Result 1977(5)	Number Counted 1978	Range of ^{137}Cs Results 1978	Mean ^{137}Cs Result 1978	Number Counted 1979	Range of ^{137}Cs Results 1979	Mean ^{137}Cs Result 1979
Adult Male	18	1.6 kBq (0.043 μCi) to 15 kBq (0.40 μCi)	4.7 kBq (0.13 μCi) \pm 3.4 kBq (0.0093 μCi)	22	21 kBq (0.57 μCi) to 120 kBq (3.2 μCi)	48 kBq (1.3 μCi) \pm 27 kBq (0.73 μCi)	36 ⁽¹⁾	23 kBq (0.63 μCi) to 220 kBq (5.9 μCi)	90 kBq (2.4 μCi) \pm 49 kBq (1.3 μCi)	17	12 kBq (0.32 μCi) to 89 kBq (2.4 μCi)	37 kBq (1.0 μCi) \pm 19 kBq (0.51 μCi)
Adult Female	13	0.67 kBq (0.018 μCi) to 9.3 kBq (0.25 μCi)	2.7 kBq (0.073 μCi) \pm 2.3 kBq (0.063 μCi)	20	20 kBq (0.53 μCi) to 83 kBq (2.2 μCi)	34 kBq (0.93 μCi) \pm 17 kBq (0.47 μCi)	32	15 kBq (0.41 μCi) to 200 kBq (5.5 μCi)	62 kBq (1.7 μCi) \pm 37 kBq (1.0 μCi)	16	2.2 kBq (0.060 μCi) to 36 kBq (0.98 μCi)	16 kBq (0.44 μCi) \pm 8.9 kBq (0.24 μCi)
Male Children 11-15 yrs	0	ND	ND	3	24 kBq (0.65 μCi) to 39 kBq (1.0 μCi)	30 kBq (0.82 μCi) \pm 7.6 kBq (0.21 μCi)	6 ⁽²⁾	27 kBq (0.73 μCi) to 77 kBq (2.1 μCi)	53 kBq (1.4 μCi) \pm 21 kBq (0.56 μCi)	4	2.0 kBq (0.055 μCi) to 28 kBq (0.76 μCi)	10 kBq (0.27 μCi) \pm 12 kBq (0.33 μCi)
Female Children 11-15 yrs	0	ND	ND	3	20 kBq (0.56 μCi) to 35 kBq (0.94 μCi)	25 kBq (0.68 μCi) \pm 8.5 kBq (0.23 μCi)	3	28 kBq (0.74 μCi) to 76 kBq (2.1 μCi)	46 kBq (1.3 μCi) \pm 25 kBq (0.66 μCi)	2	5.6 kBq (0.15 μCi) to 10 kBq (0.27 μCi)	7.8 kBq (0.21 μCi) \pm 3.1 kBq (0.080 μCi)
Male Children 5-10 yrs	0	ND	ND	0	ND	ND	8 ⁽³⁾	37 kBq (1.0 μCi) to 64 kBq (1.7 μCi)	50 kBq (1.3 μCi) \pm 7.6 kBq (0.21 μCi)	1	5.9 kBq (0.16 μCi)	5.9 kBq (0.16 μCi)
Female Children 5-10 yrs	0	ND	ND	0	ND	ND	14	20 kBq (54 μCi) to 92 kBq (2.4 μCi)	47 kBq (1.3 μCi) \pm 21 kBq (0.56 μCi)	6	1.6 kBq (0.042 μCi) to 9.6 kBq (0.26 μCi)	4.4 kBq (0.12 μCi) \pm 3.0 kBq (0.080 μCi)

Table 7 (Cont'd)

Population	Number Counted 1974(5)	Range of ¹³⁷ Cs Results 1974(5)	Mean ¹³⁷ Cs Result 1974(5)	Number Counted 1977(5)	Range of ¹³⁷ Cs Results 1977(5)	Mean ¹³⁷ Cs Result 1977(5)	Number Counted 1978	Range of ¹³⁷ Cs Results 1978	Mean ¹³⁷ Cs Result 1978	Number Counted 1979	Range of ¹³⁷ Cs Results 1979	Mean ¹³⁷ Cs Result 1979
All Adults	21	0.67 kBq (0.018 μCi) to 15 kBq (0.40 μCi)	3.9 kBq (0.11 μCi) ± 3.1 kBq (0.085 μCi)	42	20 kBq (0.53 μCi) to 120 kBq (3.2 μCi)	42 kBq (1.1 μCi) ± 24 kBq (0.64 μCi)	68	15 kBq (0.41 μCi) to 220 kBq (5.9 μCi)	77 kBq (2.1 μCi) ± 46 kBq (1.2 μCi)	33	2.2 kBq (0.060 μCi) to 89 kBq (2.4 μCi)	27 kBq (0.73 μCi) ± 18 kBq (0.49 μCi)
All Children	0	ND	ND	6	20 kBq (0.56 μCi) to 39 kBq (1.0 μCi)	28 kBq (0.75 μCi) ± 7.8 kBq (0.21 μCi)	31	20 kBq (0.54 μCi) to 92 kBq (2.3 μCi)	50 kBq (1.4 μCi) ± 18 kBq (0.49 μCi)	13	1.6 kBq (0.042 μCi) to 28 kBq (0.76 μCi)	8.3 kBq (0.22 μCi) ± 7.8 kBq (0.21 μCi)
Total Average	21	0.67 kBq (0.018 μCi) to 15 kBq (0.40 μCi)	3.9 kBq (0.11 μCi) ± 3.1 kBq (0.085 μCi)	48	20 kBq (0.53 μCi) to 120 kBq (3.2 μCi)	40 kBq (1.1 μCi) ± 22 kBq (0.61 μCi)	99	15 kBq (0.41 μCi) to 220 kBq (5.9 μCi)	68 kBq (1.8 μCi) ± 38 kBq (1.0 μCi)	46	1.6 kBq (0.042 μCi) to 89 kBq (2.4 μCi)	22 kBq (0.59 μCi) ± 18 kBq (0.49 μCi)

ND - No Data available for the specific column.

- (1) One adult, counted at Bikini, was a visitor from Rongelap Atoll. He remained on ship with our staff while at Bikini and returned at Ebeye with us. His body count was not used in this table.
- (2) One male child in this age group was counted twice to determine what effect showering prior to the body count had on the final result. Only one result was used for this individual since both results were similar.
- (3) A six month old child's data has not been included in this table and category due to the difference in geometry between a baby and our calibration phantom.
- (4) The 1978 mean value for all individual count includes the 5-10 year age group while the 1977 mean value has no representation in this sample section and the 1974 mean value has no child representation.
- (5) The 1974 (CO 75) and 1977 ¹³⁷Cs body burden data were obtained from S. Cohn, Brookhaven National Laboratory, Medical Department.

Table 8

Comparison of Observed
Versus Expected Reduction Factors

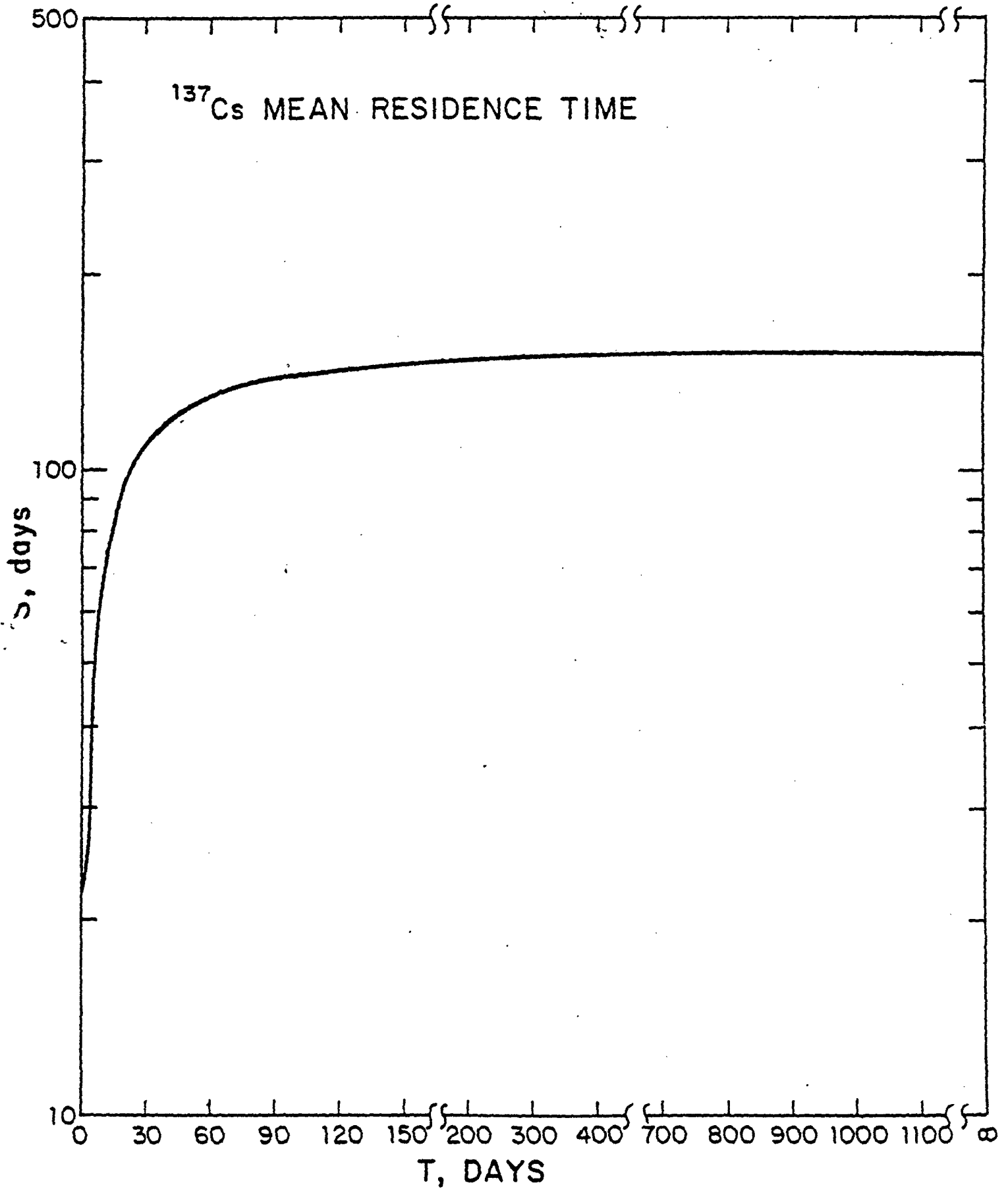
<u>Description</u>	<u># of Persons</u>	<u>Mean Reduction Factor</u>
Expected Reduction Factor for Adult Males ⁽¹⁾	NA	2.4
Observed Reduction Factor for Adult Bikini Males	17	2.3
Expected Reduction Factor for Adult Females ⁽²⁾	NA	3.5
Observed Reduction Factor for Adult Bikini Females	16	3.8
Expected Reduction Factor for Children Ages 5-14 ⁽²⁾	NA	5.9
Observed Reduction Factor for Children Ages 5-14	12	12.

NA = Data Not Available

(1) Effective half time obtained from ICRP Publication 10A (ICRP 71).

(2) Effective half time obtained from NCRP Report 52 (NCRP 77).

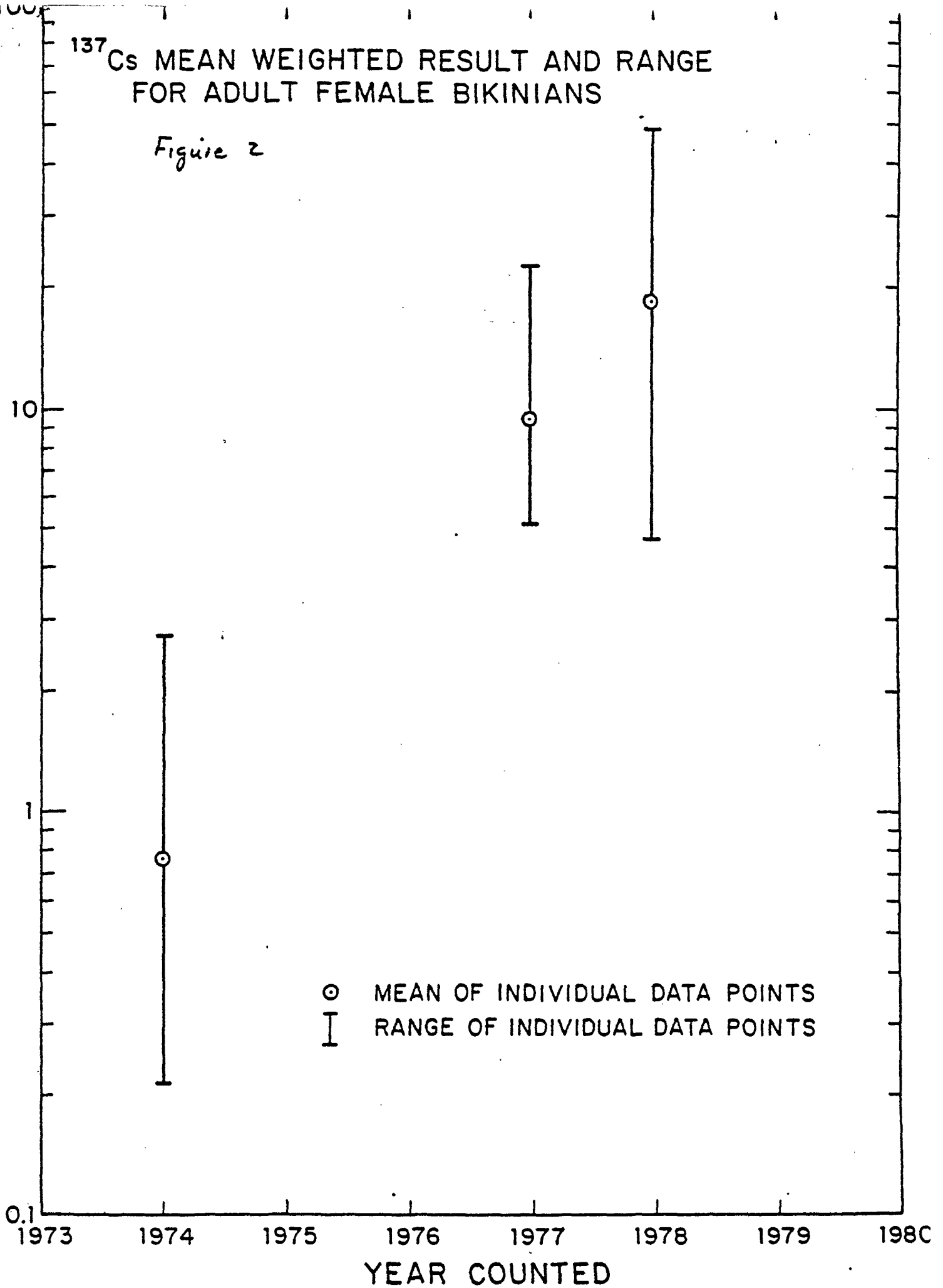
Figure 3



¹³⁷Cs MEAN WEIGHTED RESULT AND RANGE
FOR ADULT FEMALE BIKINIANS

Figure 2

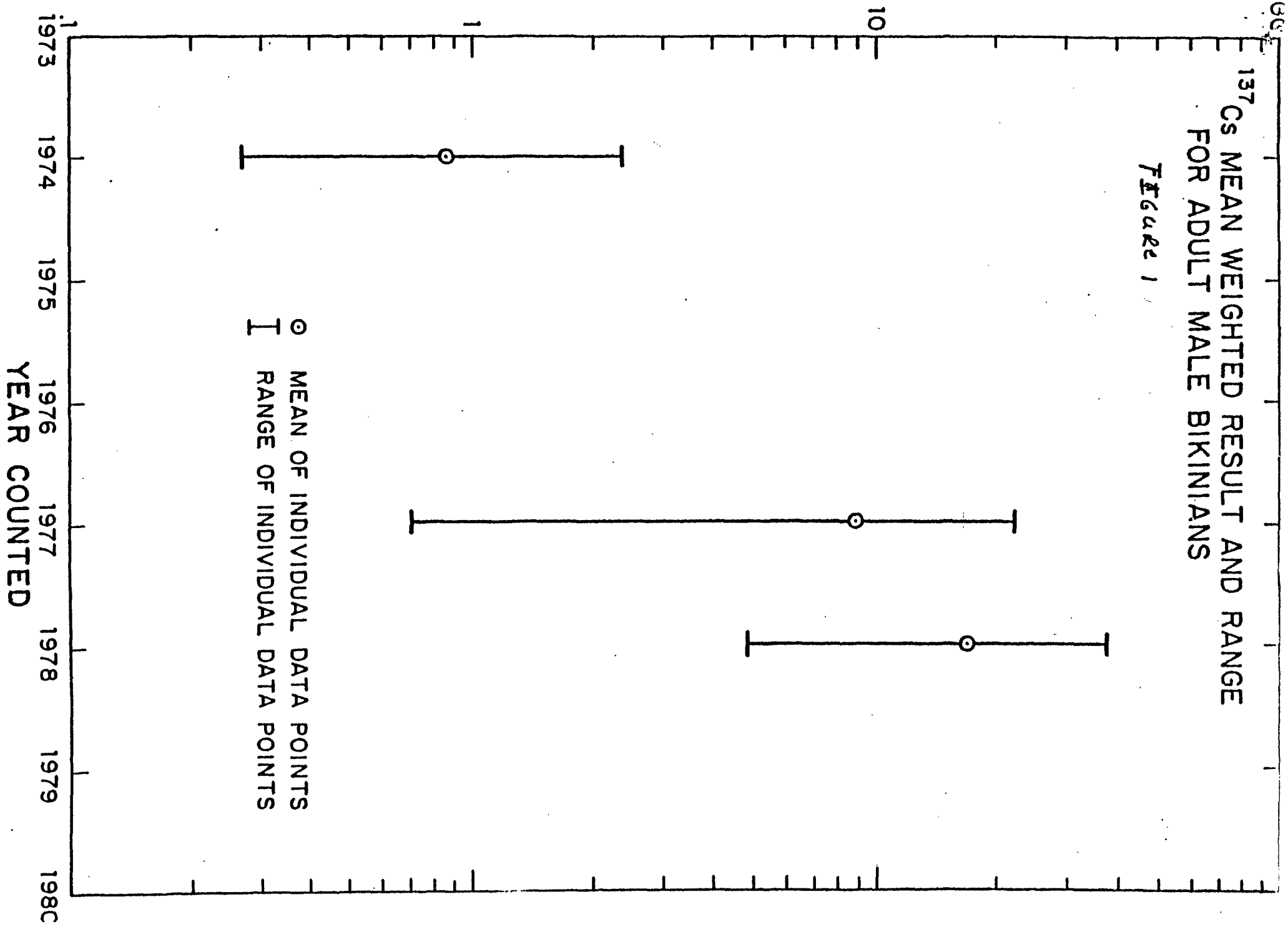
¹³⁷Cs WEIGHTED RESULT, nCi ¹³⁷Cs/g POTASSIUM



^{137}Cs WEIGHTED RESULT., nCi $^{137}\text{Cs}/\text{g}$ POTASSIUM

^{137}Cs MEAN WEIGHTED RESULT AND RANGE FOR ADULT MALE BIKINIANS

Figure 1



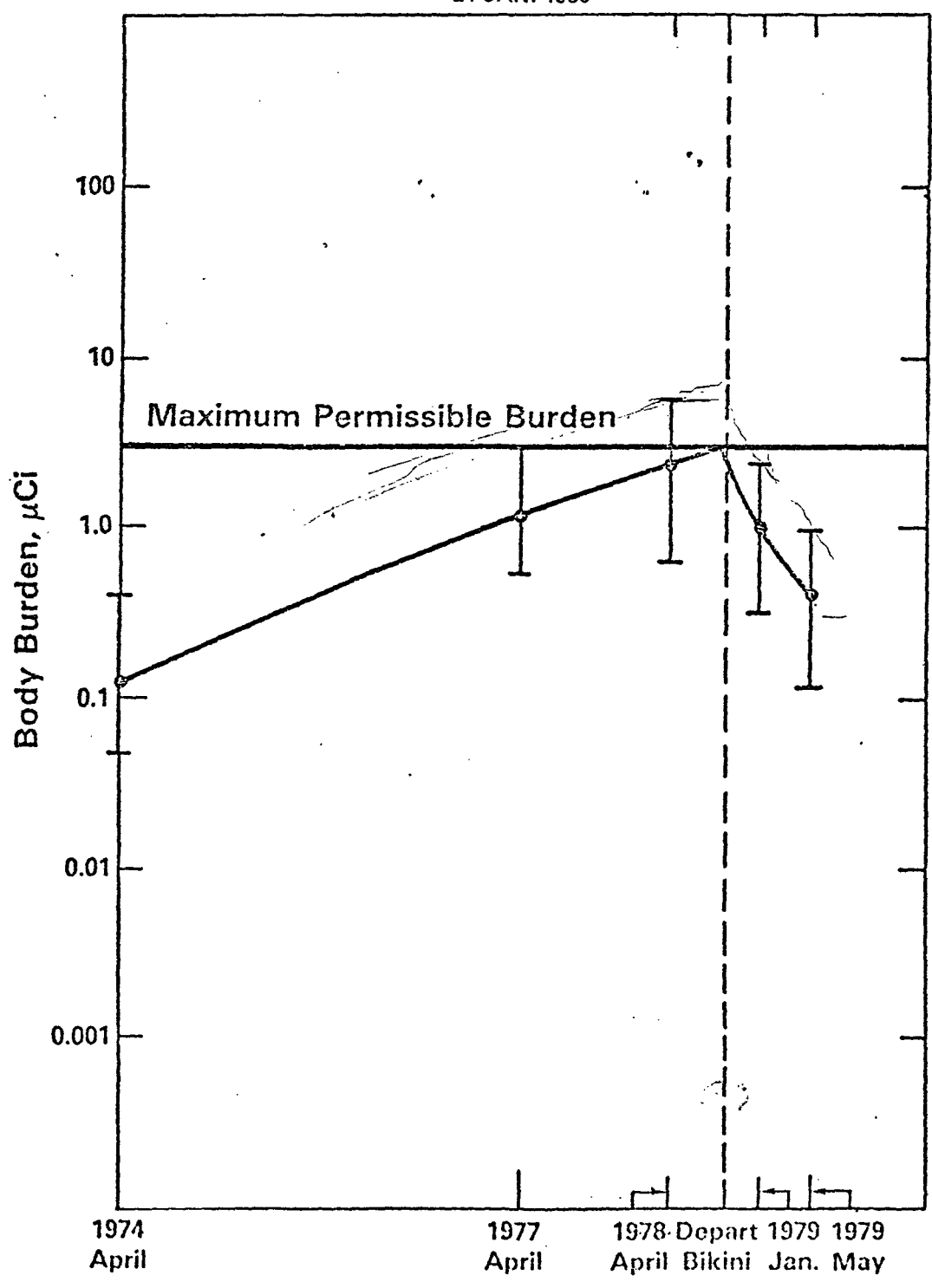
B

137

¹³⁷Cs Body Burden History for Adult Bikini Males

Mean and Range vs. Time

24 JAN. 1980

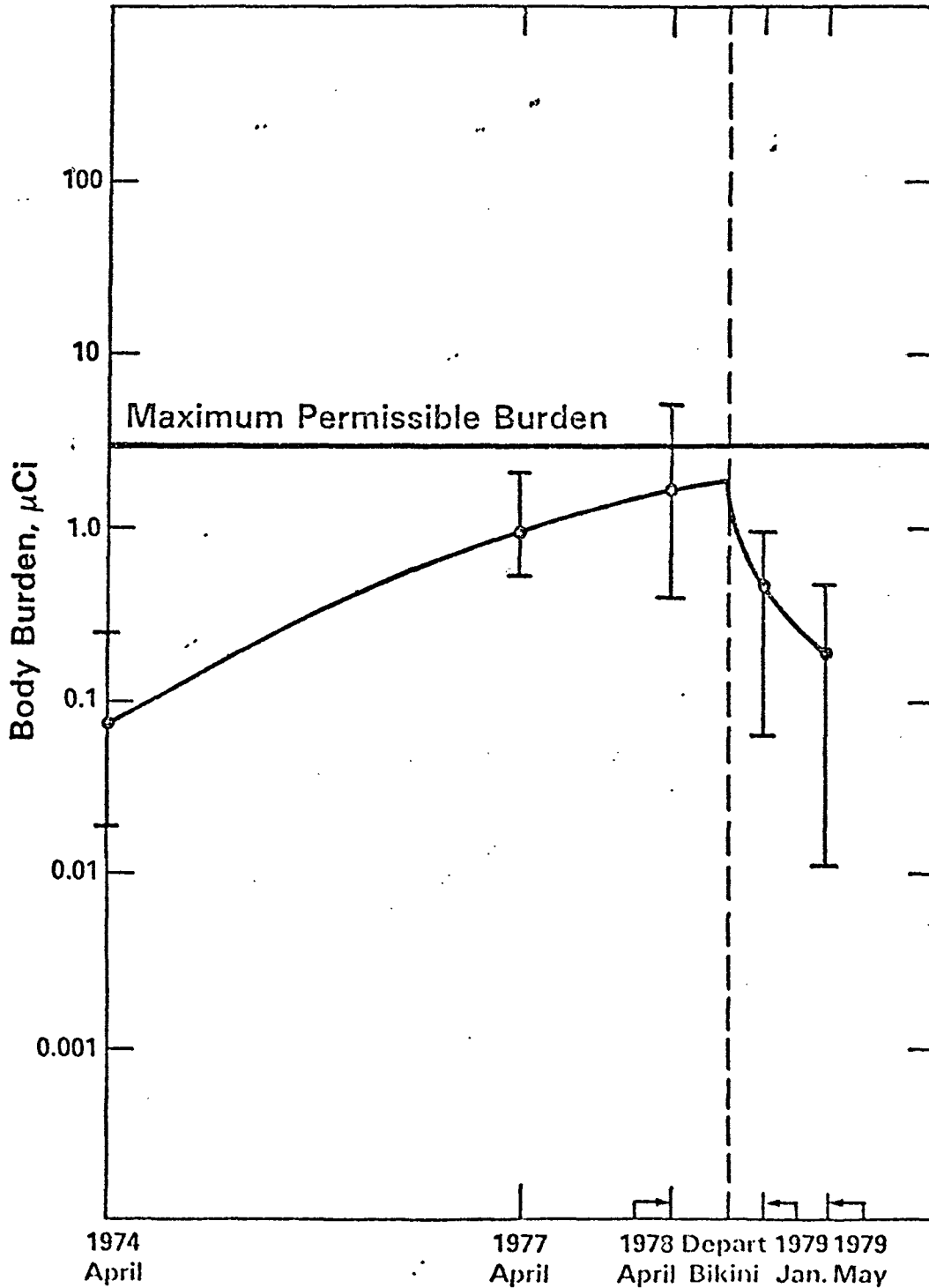


137

¹³⁷Cs Body Burden History for Adult Bikini Females

Mean and Range vs. Time

24 JAN. 1980

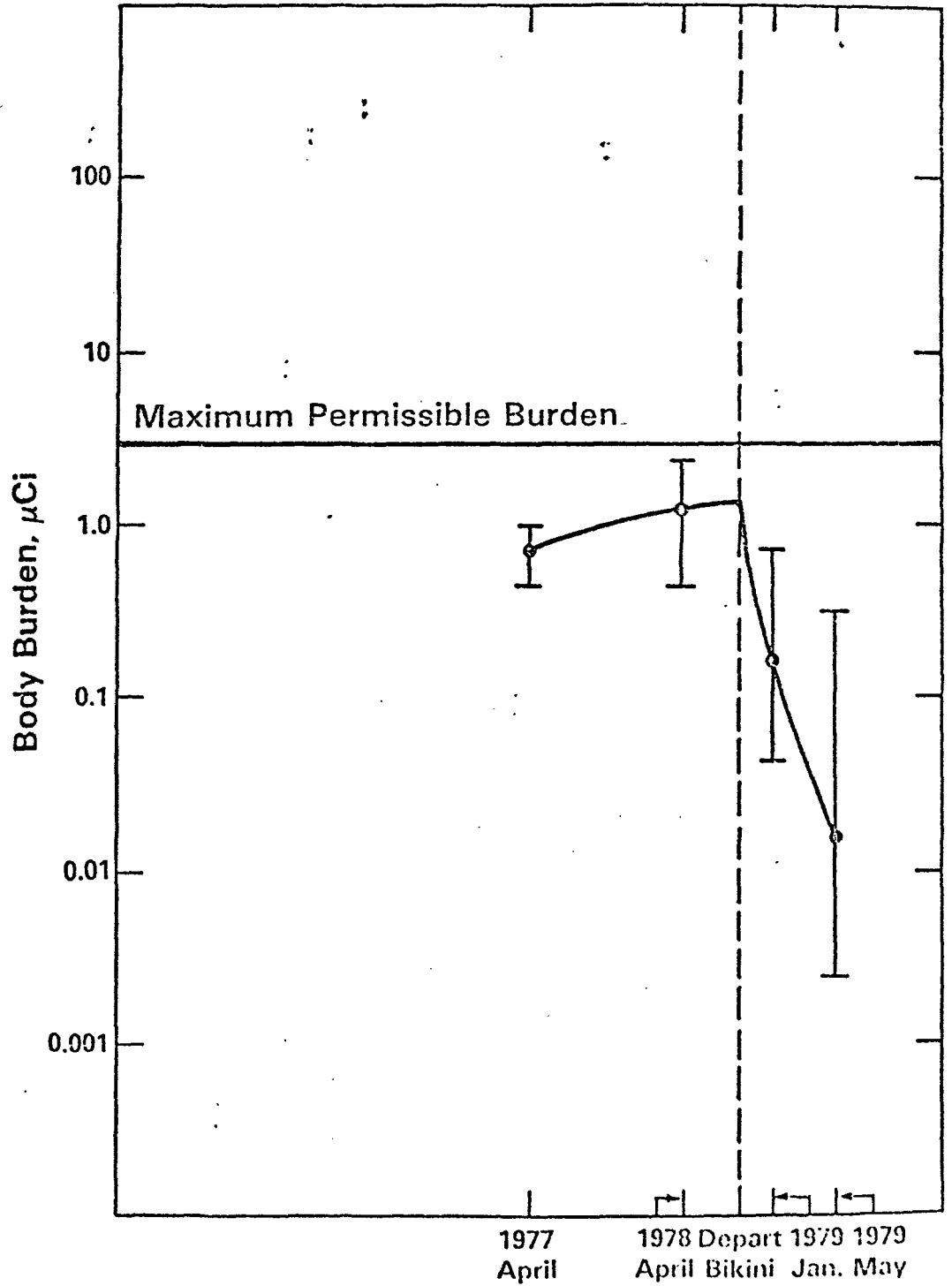


137

Cs Body Burden History for Bikini Youths

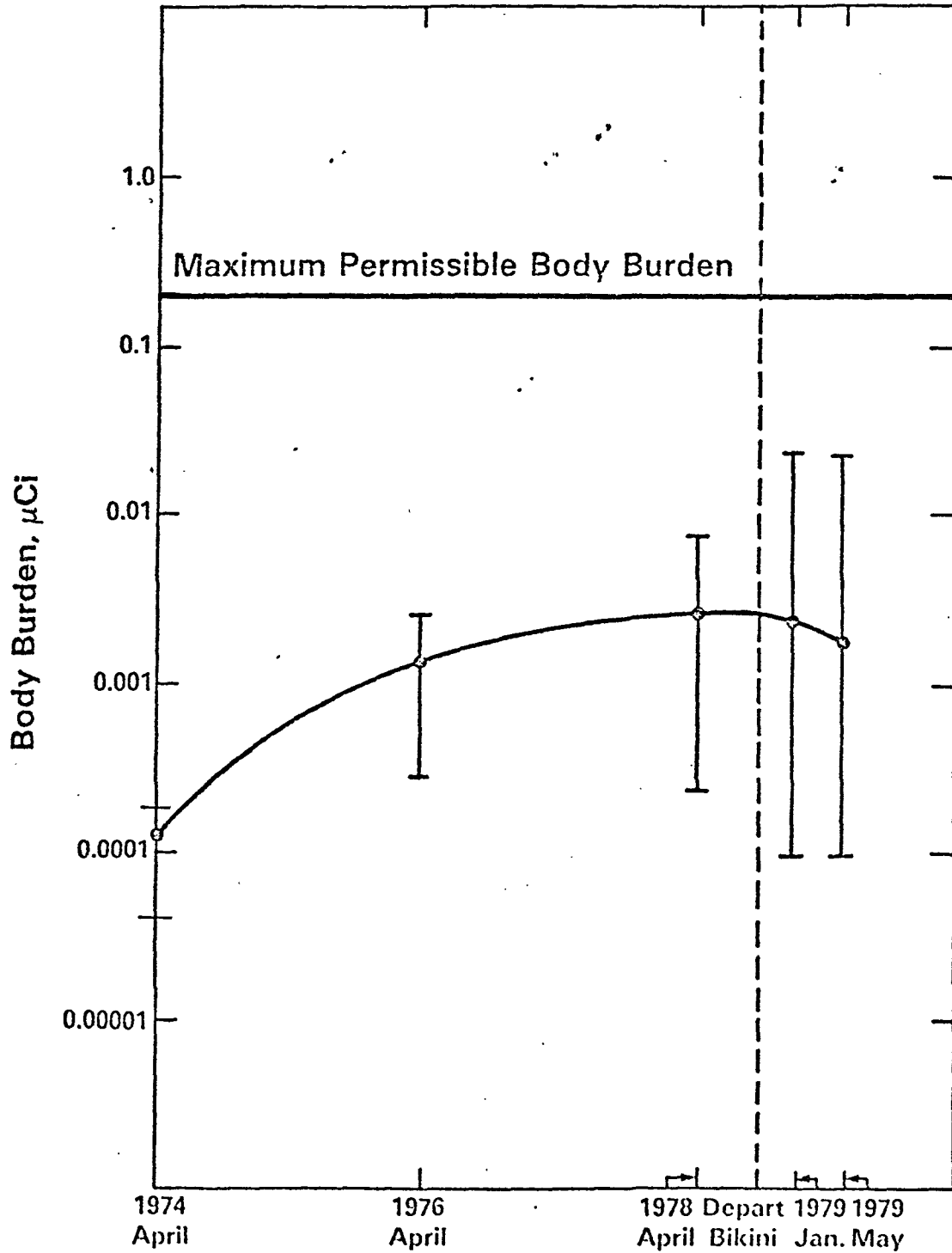
Mean and Range vs. Time

24 JAN. 1980



⁹⁰ ⁹⁰
**SR-Y Body Burden History for
Adult Bikini Males**
Mean and Range vs Time

24 JAN. 1980

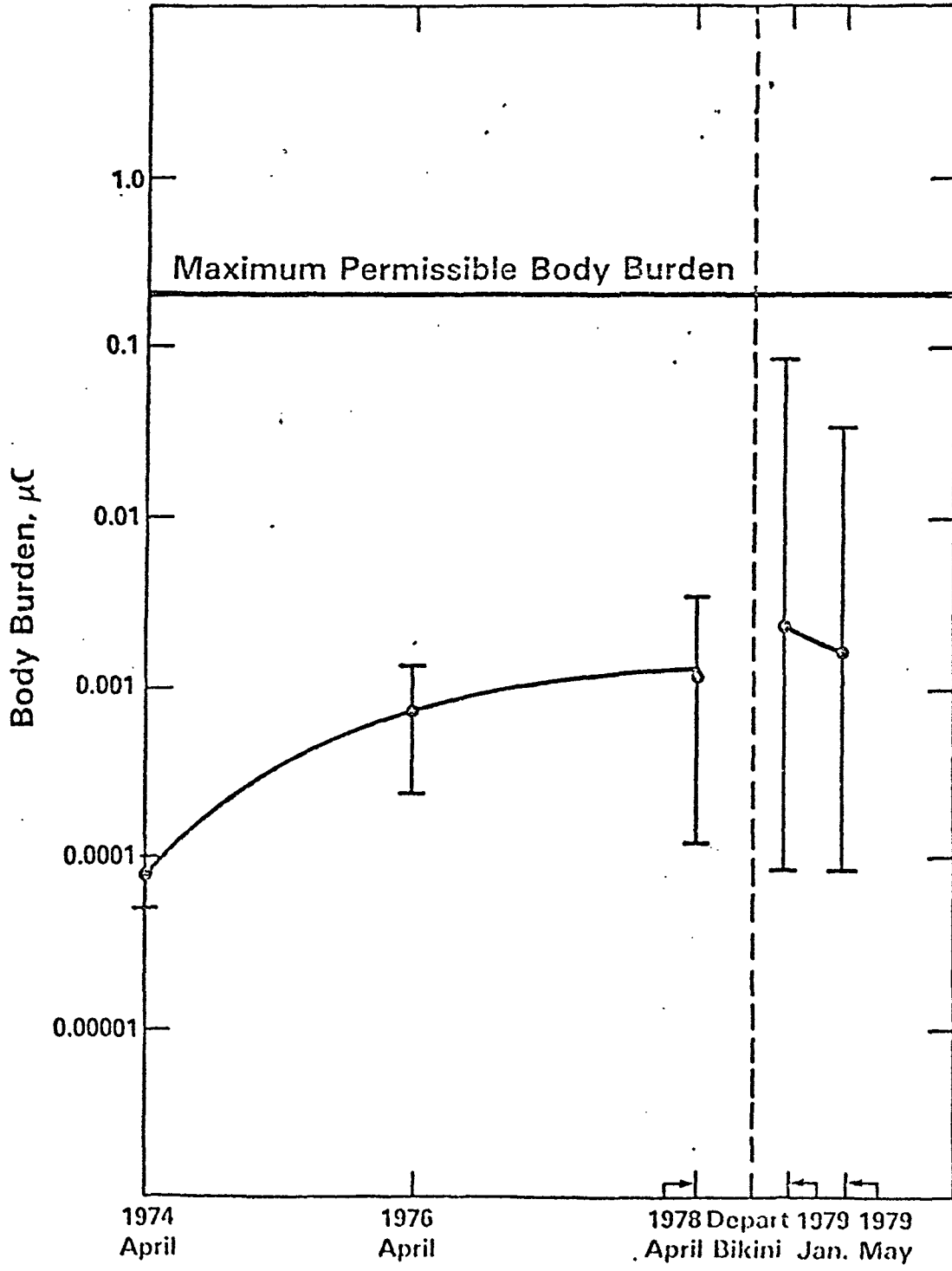


JJ 90

SR-Y Body Burden History for Adult Bikini Females

Mean and Range vs Time

24 JAN. 1980



90 90

SR-Y Body Burden History for Bikini Youth

Mean and Range vs Time

24 JAN. 1980

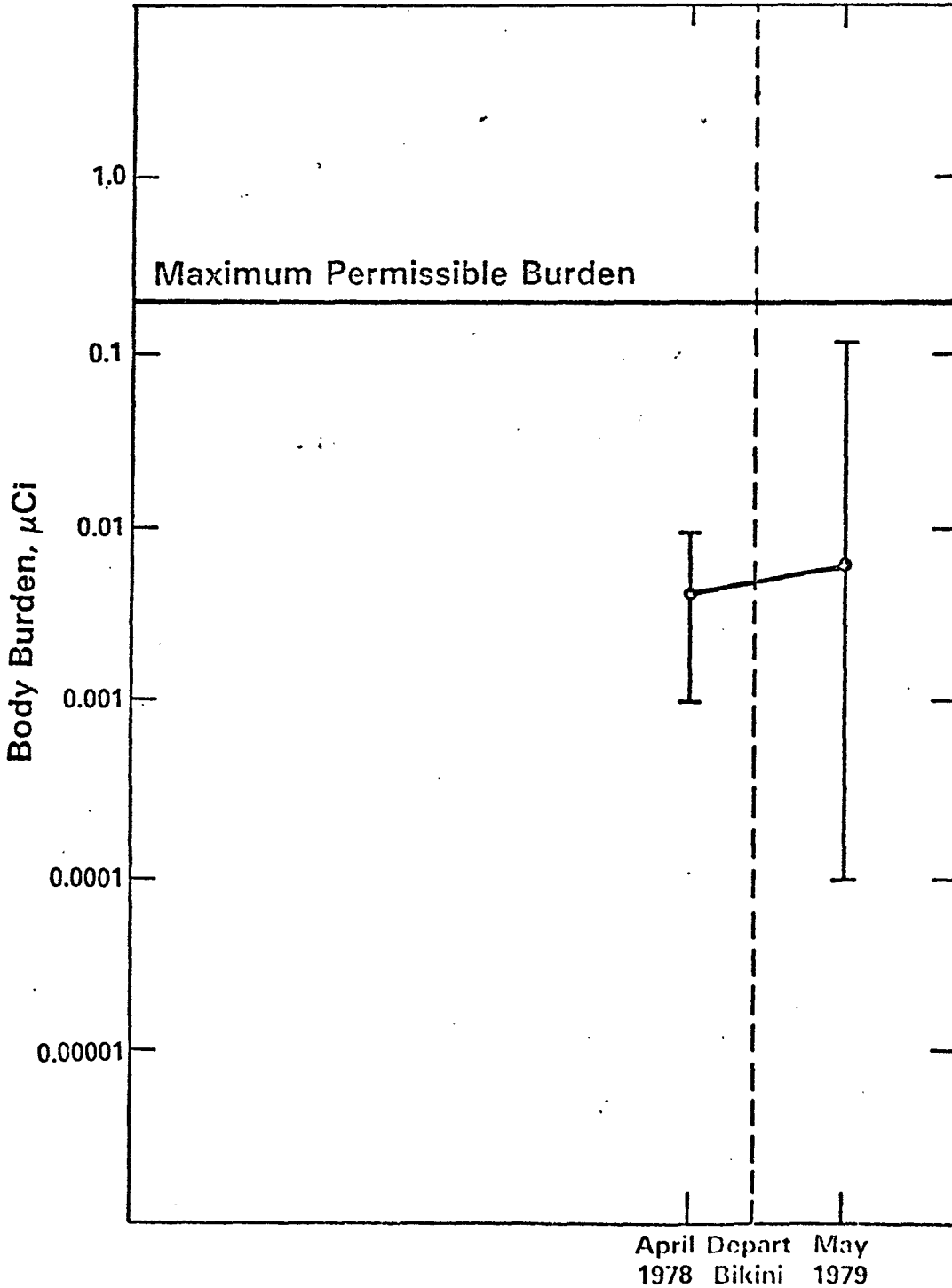
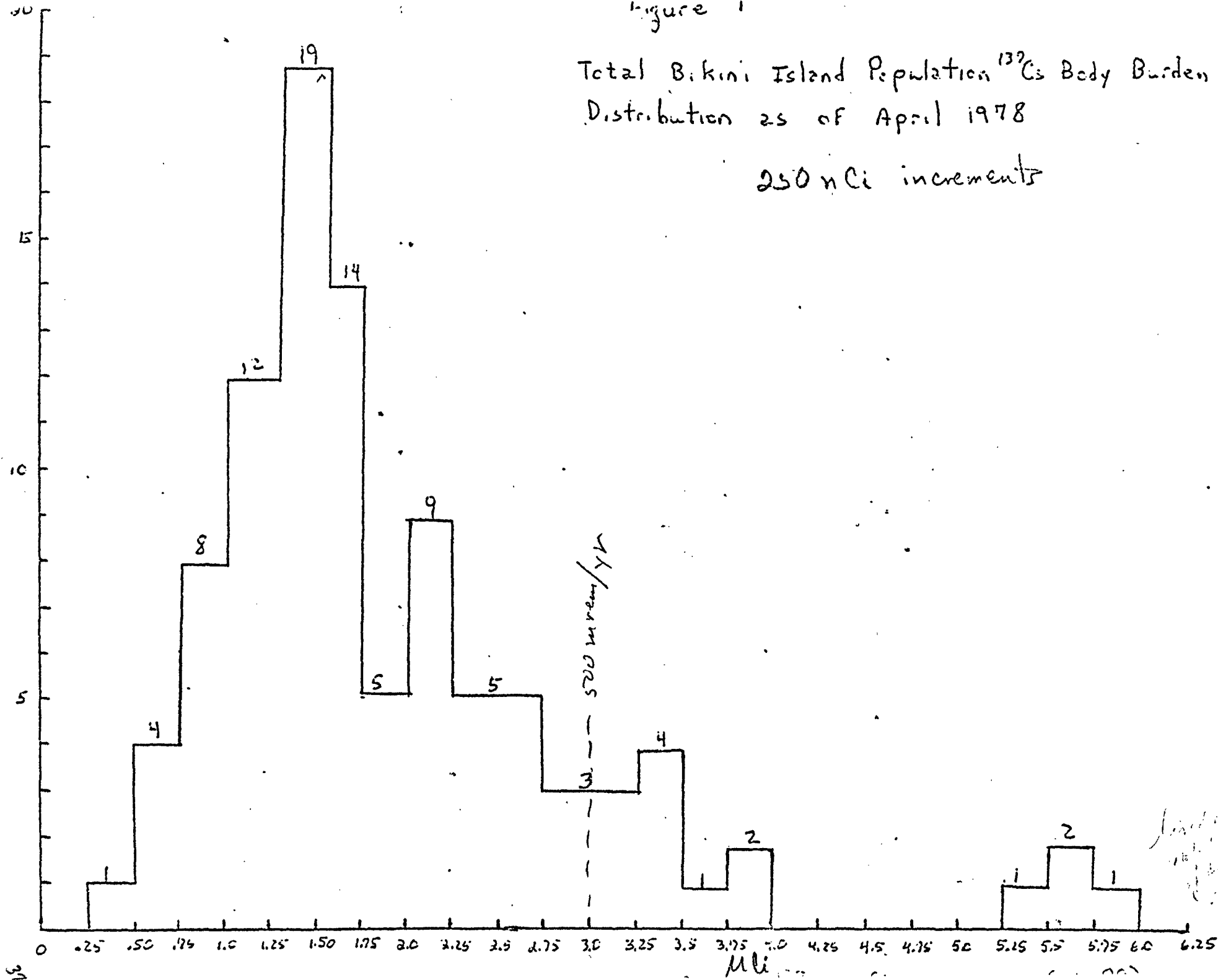


Figure 1

Total Bikini Island Population ¹³⁷Cs Body Burden
Distribution as of April 1978

250 nCi increments

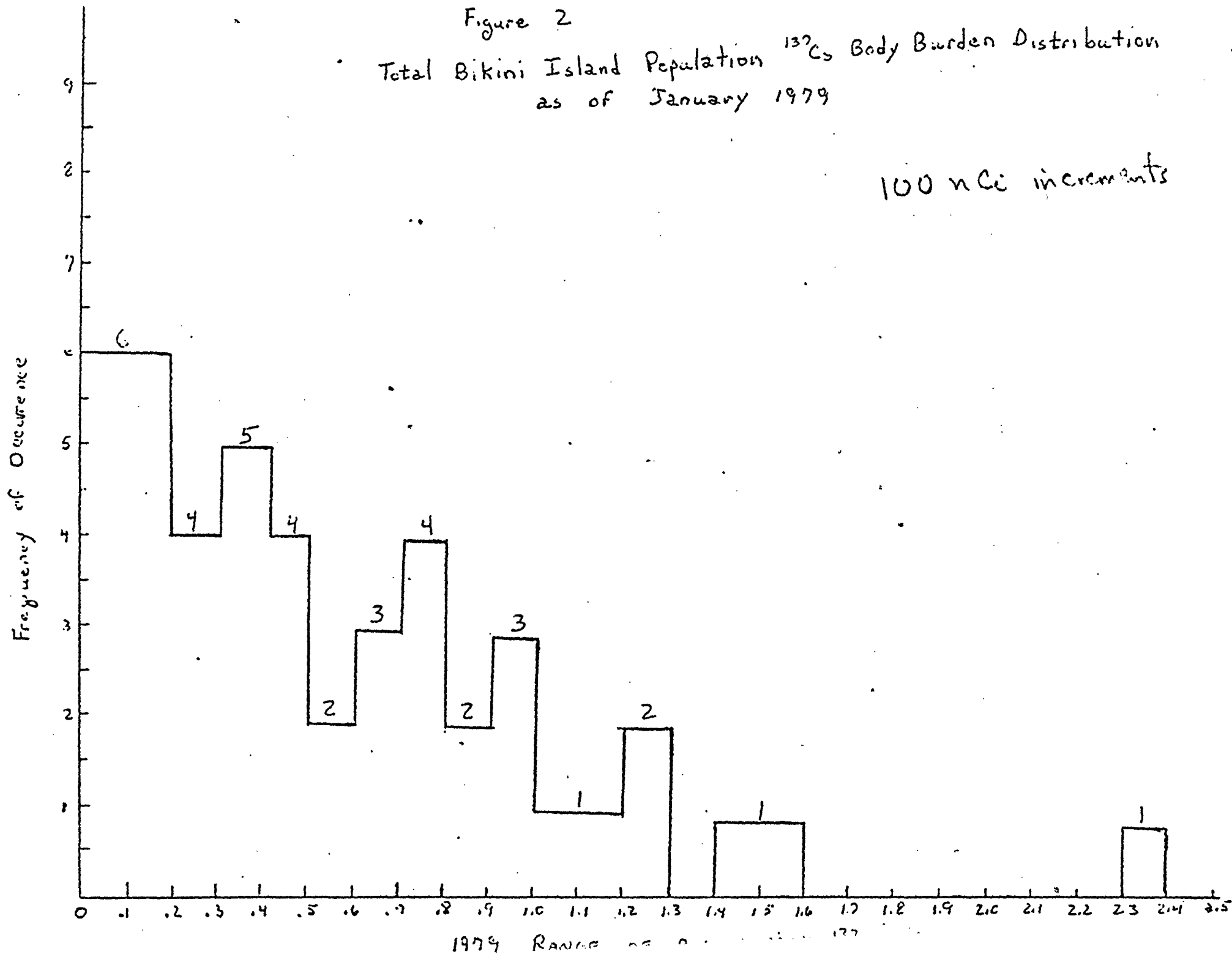


Handwritten notes:
Total population
1000

Figure 2

Total Bikini Island Population ^{137}Cs Body Burden Distribution
as of January 1979

100 nCi increments



B

Bikini Households (1975)

<u>Age</u>	<u>Male</u>	<u>Female</u>	<u>Total</u>
0-4	65	69	134
5-9	57	70	127
10-14	42	55	97
15-19	43	52	95
20-24	36	35	71
25-29	34	29	63
30-34	21	23	44
35-39	17	19	36
40-44	7	9	16
45-49	11	8	19
50-54	9	6	15
Over 55	24	20	44
Unknown	<u>16</u>	<u>8</u>	<u>24</u>
	382	403	785

Cancer Incidence (Persons who returned to Bikini)

Based on 140 Bikini residents actually returned

Assume 70 male & 70 female (no dose to children born to this group)

Average male bone marrow dose 72.36/50 1.45 rem
 Average female bone marrow dose 56.7/49 1.15

$1.45 \times 70 = 101.50$ person rem

$1.15 \times 70 = 80.29$ person rem

181.79 person rem

Total person rem = 182

BEIR I relative 458/11⁶ × 182 = 0.0834 ≈ .08

absolute 87/10⁶ × 182 = 0.0158 ≈ .02

0.0158 → 0.02
 0.0834 → 0.08

BEIR III

		Conf.			
Rel.	L-Q	182 × 10 ⁻⁶	× 182 person rem	.033124	= .033
	L-L	430 "		.078260	.08
Ab.	L-Q	67 "		.012194	.012
	L-L	158 "		.028756	.03

Birth Defects (Persons who returned to Bikini)

Assumptions -

1. No children will be conceived by those above 40 years old
2. To the population of 140 who were removed from Bikini in 1978, 300 children will be born after August 1978
3. All children born will be offspring of parents both of whom returned to Bikini

Normal incidence of birth defects:

$$10.7\% \text{ of } 300 = 32 \approx 30$$

rate of increase of birth defects: 0.2% per rem

Parental dose: average male dose (<40 yrs old) = 1.36 rem

average female dose (<40 yrs old) = 1.08 rem

$$\text{Total parental dose} = \frac{2.44 \text{ rem}}{2} = 1.22$$

$$1.22 \text{ rem} \times 0.2\%/\text{rem} = 0.244\% \text{ increase}$$

$$30 \text{ natural incidence} \times 0.00244 \text{ increase} = 0.0732 \approx \textcircled{0.07}$$

$$\text{Total Birth Defects} = 15 + 0.07$$

SEIR III

$$1.22 \text{ rem} \times 0.01\%/\text{rem} = 0.000122$$

$$30 \times 0.000122/\text{rem} = 0.0037$$

$\textcircled{0.004}$

143 people

99 Pediatric Residents

Resident

8

Based on Bone Marrow Dose

Cancer Deaths

Total Person Rem = 128.56

~~Resident~~
for 140 people

BEIR I

Relative 1972 $310/10^6$ man rem 0.0403 Cancer deaths

$458/10^6$ man rem

0.0595

Updated 568

0.0738

Absolute 1972 95

0.0124

87

0.0113

Updated 115

0.015

BEIR III

Relative 182 0.0237

Absolute 67 0.0087

Birth Defects

Assume ~100 children
born to this pop. of 99
Eleven (11) can be expected
to have birth defects
from maternal cancer

~~Resident~~
for 140 people

Total whole body dose

124.790 rem

Ave (n = 99) = 1.26 $1.26_{rem} \times 0.2\%/rem = 0.2521\%$ increase

based on 0.2%/rem $11 \times 0.0025 = 0.0275$ increased birth defects.

based on 0.01%/rem $1.26_{rem} \times 0.01\%/rem = 0.0126\%$ increase

$11 \times 0.000126 = 0.0014$ increased birth defects

I. Assumptions

~~A number of assumptions were made in the~~
estimates of ^{cancer & birth defect} risks for the Bikini population were based on a number of assumptions. Some of these assumptions required for consultation with ~~scientists~~ other scientists, including members of the BEIR committee.

1. Risk coefficients from BEIR-I were used because BEIR-III had not been accepted by any U.S. Government agency. We elected to use the ~~BEIR-I~~ values as given in BEIR-I rather than the revised values based on an increase in age of the population shown in Table V-4 of BEIR-III.
2. The relative between risk both the relative risk coefficient & the absolute risk coefficient were used to give a range of estimates. The Absolute risk coefficient gives a lower value, is less variable with the population, & is not dependent upon the environmental cancer incidence, which is not known for

the Baku population. The relative risk coefficient give a high value, but since it is based on the spontaneous cancer incidences, which is unknown for the Baku population, it is probably less reliable than the estimate ~~that~~ calculated from the absolute risk coefficients.

3. For estimating ^{increased} cancer incidences, the bone marrow dose was used because it was slightly higher than the whole body dose. This ^{probably} introduces a small element of conservatism.

4. For estimating birth defects with BEIR-I or BEIR-II is very clear about what is meant by parental dose, thus it is not clear whether ~~the~~ birth defects should be based on the dose to one parent or ~~to~~ both parents, ~~the~~

In the latter case, the ~~the~~ 30-yr whole body

We assumed the BEIR-I risk of 0.2% was based on both parents being dose would be doubled, ^{immediately}, also because we believe

the risk coefficient from BEIR-I ^{is} ~~is~~ ^{already} conservative

based on comparison with BEIR-II. we elected to use the

20 year whole body dose ^{provided as} D_0 - not doubled.

5. For ²¹⁴³ persons who returned to Baker & were covered in August 1978, it was assumed that no children will be conceived by persons above age 40, that 300 children will be born after August 1978, and that all children born will be offspring of parents, both of whom returned to Baker. The parental dose was obtained as follows:

Average dose to males ≤ 40 years old = 1.36 rem

Average dose to females ≤ 40 years old = 1.08 rem

Total parental dose = 2.44 rem

parental dose used in calculations = 1.72 rem

6. The average dose values ^{for persons who lived in Baker} were calculated from ^{individual} ~~data~~ ^{data} ~~for 50 males & 40 females~~ ^{for 50 males & 40 females}. These values are tabulated in the Appendix.

7. The ^{spontaneous} ~~parent~~ incidence of birth defects was taken to be 10.7% of all live births ~~from~~ ^{from} LUR-III.

8, The ~~original~~ ^{original} incidence of cancer death
was assumed to be 15%. The value
~~which is known~~ ^{is less than the approximate}
20%. ~~The~~ given for the U.S. population was
used because ~~of~~ the ^{people's} ~~living~~ ^{living} ^{and} ^{will}
probably be exposed to much lower levels of
environmental carcinogens than people living in the
U.S. & because ^{of limited medical services & prevalence}
~~of other risks such as drowning, poisoning, etc.~~
~~the risk of cancer is probably smaller~~
~~of ^{other} ~~risks~~ ~~such~~ ~~as~~ ~~drowning~~, ~~poisoning~~, ~~etc.~~~~
death are probably higher in the ~~British~~ ^{British} population
than in the U.S. population. ~~Therefore,~~ ~~the~~ ~~value~~ ~~of~~
We also recognized the average life span was
less than in the U.S. population, which might
tend to reduce the number of ~~cancers~~
cancers that ^{would} occur in the elderly.

9. The largest dose a person might receive in
a year was estimated to be 3 times the
average dose. Data in the Appendix for individuals
show that the highest individual dose is more than
three times the average but less than three times.

II Population Estimate

To estimate the number of births, deaths & the magnitude of the ^{Bikini} population after 30 years, information was used from the final draft of the Marshall Islands 5-year Health Plan prepared by the Trust Territory Department of Health Services Office of Health Planning & ^{the} Resources Department.

The document is undated, but the presence of data from 1975 indicates that it must have been prepared in the period of 1977 to 1979 when we received it. It was noted that there are apparent inconsistencies among several of the different tables. For example, Table III-1 gives data for the Marshall Islands for the period 1955-1975 and Table III-5 gives data for the infant mortality rate for 1976. In Table III-1, the infant death rate per 1000 births for 1970 through 1975 is given as 28.3, 33.6, 25.4, 46.4, 21.1 and 37.0. However, Table III-5 indicates the infant mortality rate to be only 17.04. We ~~have~~ used the data of Table III-1 in the following estimates; because it is more complete and it provides a self-consistent set of data. However, in view of the discrepancies, the results can only be considered as approximations. ~~In my view~~ ^{probably} this makes little real difference in view of the uncertainties in the risk estimating coefficients. ^{that were based on} There is also a bias built into the data because of the inclusion of Ebye and Majaro in the overall Marshall Island rates. This arises from the different death rates (particularly infants) at these two locations. ^{In many respects the population of Ebye & Majaro are quite dissimilar from the Bikini population because they have the advantages of a more advanced}

^{because they are probably} For the estimates we ~~used~~ ^{as being} the last 5 or 5 year average of the data ^{the administration of a more advanced} ~~was~~ ^{the following were} obtained:

1. Rate of increase of the population ^{has been about} 3.8%/yr.
2. Infant death rate ^{is about} 3.2% per birth.
3. Overall death rate ~~is~~ 0.54% per year.
4. Birth rate ~~is~~ 4.2% per year.

A population of 550 was assumed ~~to be~~ ^{for} the one that ~~may~~ ^{might} move back to ~~the~~ ^{Return at} island. Values for other initial populations ~~may be~~ ^{can} obtained by ratios of the results.

The total population at the end of 30 years is given by the compounding equation:

$$P_{30} = 550 (1+0.038)^{30} = 1684$$

The number of births in 30 years are given by:

$$B = 0.042 \times 550 \int_0^{30} (1.038)^x dx$$

where x is the time between 0 and 30. This gives

$$B = \frac{0.042 \times 550}{\ln 1.038} [1.038^{30} - 1] = 1277$$

Similarly, the number of deaths in the 30 year period would be:

$$\text{Deaths} = 0.0054 \times 550 \int_0^{30} (1.038)^x dx$$

$$\text{Deaths} = \frac{0.0054 \times 550}{\ln 1.038} [1.038^{30} - 1] = 164$$

One other ~~item~~ ^{datum} needed is the reduction in 30 year dose to those born after the return because of the decrease in radiation levels and the smaller amount of time in the 30 year period that is spent on the island. For this, the total population dose for those born after returning assuming an initial dose rate of 1 rad/year is given by:

$$P = 550 D_1 \int_0^{30} e^{-\lambda x} (1.038^x) dx$$

λ is the half-life of decrease of the radiation dose, taken here as 30 years.

Because This integral cannot be solved analytically. An approximate solution was obtained by calculating this function for each of 30 years and summing. This gave 8949 rads for the total population including the original 550. The total dose received by the original 550, assuming that all live for the 30 years, is

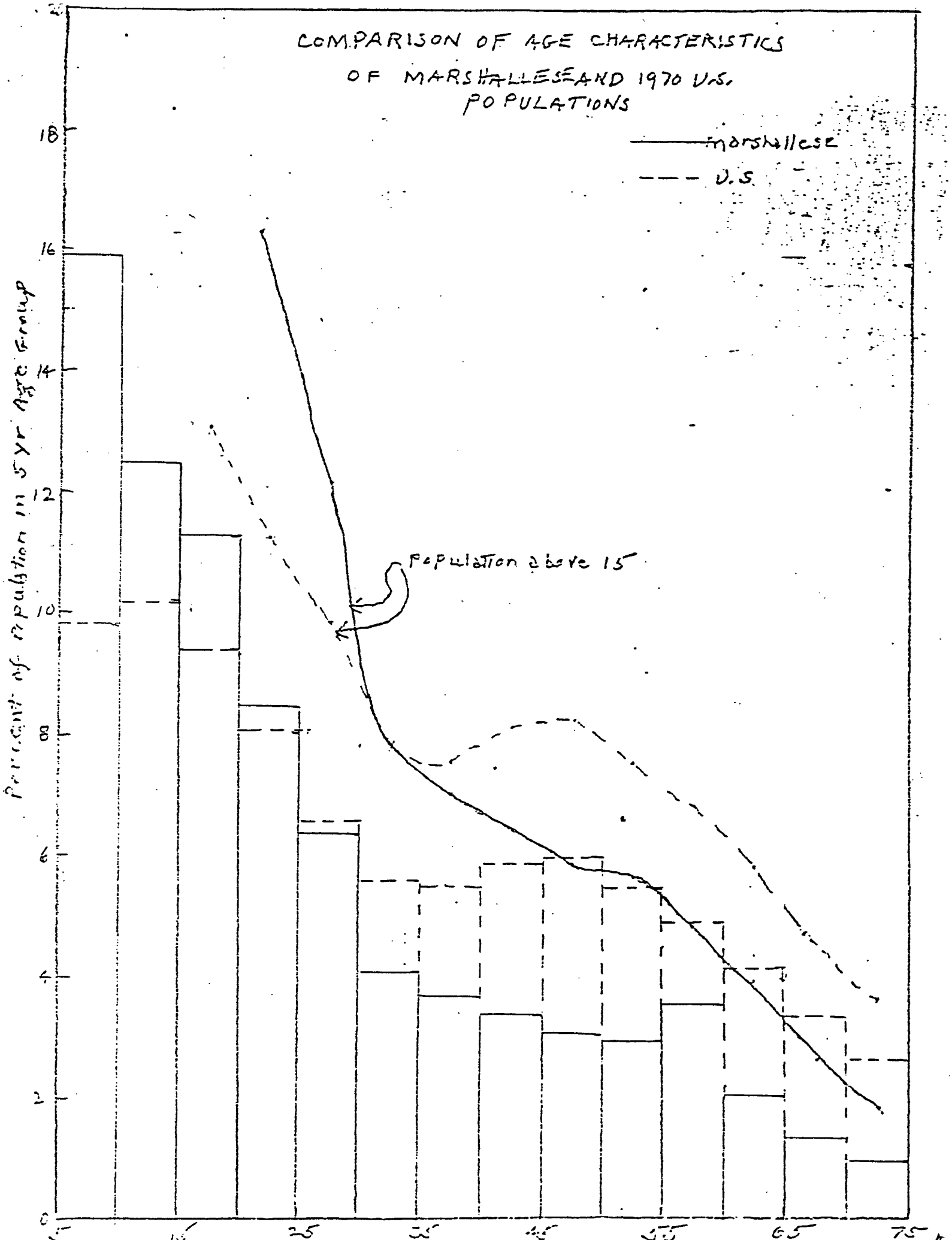
$$P' = \frac{550}{\lambda} (1 - e^{-\lambda t}) = 11,902 \text{ rads}$$

For those born after the return, the population would be the difference between the total population in 30 years, the number of deaths and the original 550 people or 1134. Thus, the per capita dose for this group is $8949/1134 = 7.9$ rads. For the original 550, the per capita dose is $11,902/550 = 22$ rads. The ratio of these two to give an estimate of the fraction of the full 30 year dose received by the children is 0.36.

The assumption of no deaths in the original 550 returning was made for simplicity and the lack of good death rate data.

We ~~I also took a brief look at~~ *Compared* the age characteristics of the Marshallese from Table IV-3 and the U.S. population in 1970. This comparison is given in the attached curve. ~~As you can see~~ The slopes are similar above age 35 but the magnitudes are distorted by the high birth rate in the Marshall Islands. However, in terms of the relative risk the similar slopes ~~mean to me~~ *mean to me* that if the ~~two~~ *same* natural cancer rates ~~are similar~~ *in the two populations*, the relative risk for people above 35 in both populations would be similar because most of the cancer occurs at ages ~~about~~ *now* about 40 and above. However, the magnitude of the relative risk in the U.S. used for the Marshallese will be high by a factor of somewhere around 2-3 because of the distortion caused by the very high proportion of young people who have a relatively low natural cancer incidence.

COMPARISON OF AGE CHARACTERISTICS
OF MARSHALLESE AND 1970 U.S.
POPULATIONS



~~Population Calculations~~

Using the preceding calculations for a population of 550, calculations were made for other population sizes

For a population of 550 (from preceding):

$$\begin{aligned} \text{Deaths in 30 years} &= 164 \approx 160 \\ \text{Births in 30 years} &= 1277 \approx 1300 \end{aligned}$$

For a population 140 (the number that returned to Bikini):

$$\text{Deaths in 30 years } \frac{164}{550} = \frac{x}{140}, x = \underline{41.7} \approx 40$$

$$\text{Births in 30 years } \frac{1277}{550} = \frac{x}{140}, x = \underline{325.} \approx 300$$

For a population of 235:

$$\text{Deaths in 30 years, } \frac{164}{550} = \frac{x}{235}, x = 70.07 \approx 70$$

$$\text{Births in 30 years, } \frac{1277}{550} = \frac{x}{235}, x = 545.62 \approx 550$$

For A Population of 350

$$\text{Deaths in 30 years, } \frac{164}{550} = \frac{x}{350}, x = 104.36 \approx 100$$

$$\text{Births in 30 years, } \frac{1277}{550} = \frac{x}{350}, x = 812.63 \approx 800$$

The U.S. Government had accepted the risk coefficients in BEIR. Thus we were constrained to use risk coefficients from BEIR. While not included in the printed book, risk estimates for BEIR-III were calculated for comparison purposes. The following give the origin of the risk coefficients used.

A. BEIR-I

I. Cancer (Tables 3-3 and 3-4)

	Cancer Deaths/year in U.S. from 0.1 rem/year (pop=197,863,000)		Derived Cancer Deaths/10 ⁶ person rem	
	Absolute	Relative	Absolute	Relative
Leukemia	576	738	26	37
Other Cancers				
30 year elevated risk	1,210	2,436	61	123
lifetime elevated risk	1,485	8,340	75	421
Range	1,726-2,001	3,174-9,078	87-101	160-458

From the above the minimum estimate of cancer risk would be given by a risk coefficient of 87/10⁶ person rem and the maximum by 458/10⁶ person rem. Thus, these two risk coefficients even used to define a range of estimated cancer deaths.

2. Genetic Effects (from Page 1+2 BEIR-I)

a. Based on specific defects

5 rem / 30 year reproductive generation would cause

in the first generation 100-1800 cases of dominant diseases and defects per year (3.6 million births/year) =

or 5 times this amount at equilibrium. The

1800 cases represent an increase of 0.25% incidence

per year first generation & 0.25% at equilibrium
there would be

In addition a few chromosomal defects and recessive diseases and a few congenital defects due to single gene defects and chromosome aberrations

The Total incidence ^{at equilibrium} is 100 to 27,000/year. Then at equilibrium ~~0.75%~~ ^{0.15%} at equilibrium the maximum would be 0.75% or 0.15% (in the first generation).

These are equivalent to 0.15% per rem at equilibrium and 0.03% from in the first generation.

b. Based on overall ill health.

Overall ill health: 5% - 50% of ill health is proportional to mutation rate

Using 20% and doubling dose of 20 rem, 5 rem per generation → 5% increase in ill health. would eventually lead to a

Thus ~~the rate of overall ill health~~ the rate of overall ill health is 1%/rem at equilibrium or 0.2% from in first generation.

For estimating ~~the~~ the potential ~~genetic~~ genetic
 derived health defects in the Bunker population
 it was decided to use a risk coefficient
 of 0.2% per
 rem in first generation, ~~the~~
~~multiplier~~
~~recognizing that it was probably very conservative,~~

**B. BEIR-III
 No. Cancer (Table V-4)**

Lifetime Risk of Cancer Death
 (deaths/10⁶/rad)

Model	Single exposure to 10 rad		Continuous Exposure to 1 rad/yr	
	Absolute	Relative	Absolute	Relative
L-Q, $\overline{LQ-L}$	77	226	67	182
L-L, $\overline{L-L}$	167	501	158	430
Q-L, $\overline{Q-L}$	10	28	----	----

**B. Birth Defects--pages 166-169
 (mean parental age = 30 years)**

1 rem per generation (1 rem parental exposure) per 10⁶ live
 offspring → 5 to 75 birth defects, this is 0.0005
 --0.0075%--First generation

Since the

Spontaneous rate is 10.7% (in the U.S. population), thus 1 rem will increase the rate
 from 10.7% to 10.7005--10.7075%

In terms of percent increase of the spontaneous rate the 1 rem per generation since
 $\frac{0.0005}{10.7} = 0.000047 = 0.0047\%$ and

$\frac{0.0075}{10.7} = 0.0007 = 0.07\%$

IV Calculations of Risk

Table 1 gives the relative risk values provided by Dr. Robins for use in developing estimates of increased health risks in the Eastern Province.

A. Risks For 14 different living conditions.

1. ~~Cancer Risks~~ Cancer Risks Table 3 shows the calculations for the estimates of increased cancer risks for 14 different living conditions. The ~~range of relative risk values~~ data ~~was provided by Dr. Robins, from~~ ~~Interviews~~.

2. Birth defect risks

Table 3 gives the calculations for the estimates of Birth defects. The ~~range of relative risk values~~ were ~~provided by Dr. Robins~~.

B. Risk estimates based on BEIR-III

1. Table 4 gives risk estimates based on BEIR-III risk Coefficients. These were calculated for comparative purposes only & were not used in the Robins book. The highest ~~relative risk~~ estimates, ~~from~~ ^{for cancer risk result} from using the linear relative risk model and are about the same as those given in Table 2 for the relative risk model. The lowest estimates result from the linear - quadratic

ESTIMATED RADIATION DOSES TO RESIDENTS OF
ENEU AND/OR BIKINI ISLANDS ASSUMING VARIOUS LIVING PATTERNS**

Residence Island	Years on/ Years off	Time on Eneu (%)	Time on Bikini (%)	Imported Food (50% of Diet)	Maximum Annual Dose (Millirem)* to Bone Marrow	30 Year Dose (Millirem)**	
						Whole Body	Bone Marrow
4 Bikini	Permanent	0	100	No	6200	44,000	47,000
3 Bikini	Permanent	0	100	Yes	3300	24,000	25,000
2 Eneu	Permanent	100	0	No	780	5,400	6,000
1 Eneu	Permanent	100	0	Yes	390	2,800	3,000
6 Eneu	Permanent	90	10	No	830	5,900	6,500
5 Eneu	Permanent	90	10	Yes	440	3,200	3,400
8 Eneu	1/1	100	0	No	540	2,800	3,100
7 Eneu	1/1	100	0	Yes	280	1,400	1,500
10 Eneu	1/1	90	10	No	590	3,000	3,300
9 Eneu	1/1	90	10	Yes	330	1,600	1,700
12 Eneu	1/2	100	0	No	540	1,900	2,100
11 Eneu	1/2	100	0	Yes	280	960	1,030
14 Eneu	1/2	90	10	No	590	2,000	2,200
13 Eneu	1/2	90	10	Yes	330	1,100	1,200
16 Eneu	1/3	100	0	No	540	1,500	1,700
15 Eneu	1/3	100	0	Yes	280	760	810
Eneu	1/3	90	10	No	590	1,600	1,800
Eneu	1/3	90	10	Yes	330	860	920

* Doses are rounded off.

** ~~Federal Radiation Council exposure limit is 500 millirem per year to the maximum exposed individual~~
(numerical value given is three times the average)

*** Federal Radiation Council exposure limit is an average of 5,000 millirem to a population.
These values are best estimates based upon the most complete information available. Furthermore, these are average values based upon averaged parameters (e.g., soil concentration of radionuclides, food concentrations of radionuclides, diet); any specific individual might receive radiation exposure higher or lower than these values depending upon islands visited, amount of various foods consumed, etc. (No claim is made as to

182

1009

75

Risk Estimates based on BEIR-III

	Total Person rem	Cancer Risk				6 Num of Birth Defects	7 30-yr Whole body dose (rem)	8 Birth Defects (5-75/10 ⁶ /rem)	9 Spontaneous Number	10 % Increase **
		Relative		Absolute						
		L-Q* 182*	L-L 430	L-Q 67	L-L 158					
1	3054	.556	1.31	.205	.483	1300	2.8	139	0.19	
2	6108	1.11	2.63	.409	.965	1300	5.4	139	0.38	
3	25450	4.63	10.94	1.71	4.02	1300	24.0	139	1.68	
4	47846	8.71	20.57	3.21	7.56	1300	44.0	139	3.1	
5	3461	.63	1.49	.23	.547	1300	3.2	139	0.22	
6	6617	1.20	2.85	.44	1.05	1300	5.9	139	0.41	
7	957	.174	.41	.064	.15	550	1.4	85.6	0.098	
8	1978	.36	.851	.133	.313	550	2.8	85.6	0.196	
9	1085	.197	.467	.073	.17	550	1.6	85.6	0.112	
10	2105	.383	.905	.141	.33	550	3.0	85.6	0.21	
11	446	.081	.192	.0298	.0705	550	.96	58.85	0.068	
12	910	.166	.39	.061	.144	550	1.9	58.85	0.13	
13	520	.095	.224	.035	.082	550	1.1	58.85	0.074	
14	953	.173	.41	.064	.151	550	2.0	58.85	0.14	

*Risk coefficient
eg 182 x 10⁶ man rem

eg 2.8 rem x 5 x 139
10.6

** eg 2.8 rem x 5 x 1300 birth
104

Based on highest value from column 8

1009

absolute risk model and are slightly less than those ~~values~~ for the absolute model in Table 2. Thus, as far as ~~the~~ estimates of cancer risk are concerned, those obtained using ^{risk coefficients from} BEIR I ~~are~~ are in the same general range as those obtained using ^{risk coefficients from} BEIR-III.

Risk estimates for birth defects obtained using the risk factor from BEIR-I give values about 3 times those obtained using the ~~values~~ ^{value} of the range of risk ~~coefficients~~ ^{factors} given in BEIR-III. If BEIR-II ~~values~~ risk factors for birth defects ~~are~~ ~~more~~ ~~reasonable~~ ~~than~~ represent a ~~more~~ ~~enlightened~~ ~~assessment~~ ~~of~~ ~~the~~ ~~potential~~ ~~consequences~~ ~~of~~ ~~radiation~~ ~~exposure~~ ~~than~~ ~~the~~ ~~factor~~ ~~taken~~ ~~from~~ ~~BEIR-I~~ for overall health defects, then the estimates ~~obtained~~ given in the previous book ~~are~~ ~~more~~ ~~likely~~ ~~to~~ ~~be~~ ~~more~~ ~~accurate~~ ~~by~~ ~~a~~ ~~factor~~ ~~of~~ ~~3.~~

Appendix
~~Bokim~~ ~~Kristant~~

Estimates of radiation doses received by person who resided at Bokim for about 10 years until August, 1978

A. Bone Marrow Doses - Calculation of average dose (rad/cm³)

Males		Females	
1600	710	260	280
1600	510	1000	770
300	2100	1700	1100
1300	1800	810	480
1200	680	1400	2200
1300	500	700	1200
1600	1100	1500	1300
890	350	1700	900
2400	2700	1600	870
1300	1600	900	1400
1500	210	1200	1100
1900	2100	2100	760
900	1400	1500	1500
2100	1900	410	300
310	1600	400	1900
1500	1900	1300	620
370	1600	340	670
1300	3000 (highly unlikely)	1500	56,200 <i>mean</i>
2300	72,360 <i>mean</i>	1200	
1900		2400	
1600	n = 50	320	n = 49
480		1400	
1800		1600	
2000	72,360	1900	56,200
2500		2300	
2300		1100	
1900		1900	
590		1400	
1500	Average dose to all people	740	Total Person <i>mean</i>
2600	72.36 <i>mean</i>	2200	50 Males 72,360
2600	56.20 <i>mean</i>	430	49 Females 56,200
1600	128.56	1500	728.56
	99		

1.3rem *mean*

B. Whole Body Loss
Males

WRITE
COLUMN

	1	2	3	4
	Identification Number	Age	Total Whole Body dose (mrem)	
1	6001	66	1400	X
2	6127	13	1500	
3	6130	29	300	
4	6076	39	1300	
5	813	23	1200	
6	6019	48	1100	X
7	6132	12	1500	
8	6066	32	830	
9	6070	28	2200	
10	6118	22	1200	
11	6117	22	1400	
12	6128	31	1800	
13	6015	11	870	
14	6033	27	2000	
15	6087	35	300	
16	6008	32	1400	
17	6071	32	350	
18	863	27	1200	
19	6086	46	2100	X
20	6067	32	1700	
21	6073	24	1400	
22	6072	20	460	
23	6119	17	1700	
24	864	51	1900	X
25	966	56	3200	X highest value
26	6009	6	2200	
27	6049	8	1900	
28	6042	7	580	
29	6014	5	1500	
30	6012	7	2400	
31	6016	10	2400	
32	6013	5	1600	
33	6005	38	700	
34	6135	35	500	
35	6125	35	2100	
36	6067	56	1700	X
37	6002	65	670	X
38	6006	37	490	
39	6096	48	1100	X
40	80	69	330	X
	6017	49	2300	X

6058	56	1500
6004	28	200
6018	34	1900
6126	35	1400
6003	22	1700
6023	8	1500
6131	14	1800
6011	11	1400
6133	11	2800

Total for 39 units 53,230 $\frac{53,230}{39} = 1364.87$ per unit
 age 40
 Total for 211 units 70,530 $\frac{70,530}{211} = 1410.6$ per unit
 age 50

age 40 $\frac{11}{50}$

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Females

COLUMN WRITE

	1	2	3	4
	Identical #	Age	Total whole body dose	
1	6111	32	250	
2	6097	19	950	
3	6115	43	1600	X
4	6109	15	760	
5	6091	13	1300	
6	6046	43	600	X
7	6061	32	1400	
8	6122	70	1600	X
9	6030	10	1600	
10	6129	13	850	
11	6027	6	1200	
12	6010	8	2000	
13	6105	5	1500	
14	6059	19	400	
15	6124	54	390	X
16	6058	18	1200	
17	6036	27	340	
18	6110	32	1400	
19	6051	19	1200	
20	6092	8	2400	highest value
21	6080	7	310	
22	6038	6	1400	
23	6103	9	1600	
24	6028	7	1800	
25	6044	6	2200	
26	6062	21	1100	
27	6034	46	1800	X
28	865	45	1300	X
29	6050	22	710	
30	6094	10	2100	
31	6112	35	420	
32	6035	20	1400	
33	6045	28	220	
34	6108	24	730	
35	6063	24	1100	
36	525	37	470	
37	934	43	2100	X
38	6106	6	1100	
39	6025	5	1300	
40	6113	25	880	
	6060	22	790	

6032	32	1400
6123	50	1000
6098	16	720
6065	19	910
6114	32	290
6064	30	1300
6081	9	610
6048	13	660

total for 41 under
age 40

44320

average = 1080.98

total for all 49 females

54710

average = 1116.53

avg 40, $\frac{8}{49}$

Total Males & females
54.7
70.5
125.2

1
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B

BASES FOR CALCULATION OF RISK ESTIMATES USED IN
"THE MEANING OF RADIATION AT BIKINI ATOLL"

1.1. Assumptions (CNS) — ~~ESTER~~

Estimates of cancer and birth defects risks for the Bikini populations were based on a number of assumptions. Some of these assumptions resulted from consultation with other scientists including members of the BEIR committees.

~~1.1~~

~~1.1.1~~ 1. Risk coefficients from BEIR-I were used because BEIR-III had not been accepted by any U.S. government agency. We elected to use the values as given in BEIR-I rather than the revised values based on increased age of the population shown in Table V-4 of BEIR-III.

~~1.1.2~~ 2. For estimates of cancer risk both the relative risk coefficient and the absolute risk coefficient were used to give a range of estimated risk. The absolute risk coefficient gives a lower value, is less variable with the population and is not dependent upon the spontaneous cancer incidence, which is not known for the Bikini population. The relative risk coefficient gives a high value, but since it is based on the spontaneous cancer incidences, which is unknown for the Bikini population, it is probably less reliable than the estimates calculated from the absolute risk coefficients.

3. For estimating increased cancer incidences, the bone marrow dose was used because it was slightly higher than the whole body dose. This probably introduced a small element of conservatism.

4. For estimating birth defects neither BEIR-I or BEIR-III is very clear about what is meant by parental dose, thus it is not clear whether birth defects should be based on the dose to one parent or both parents. In the latter case, the 30-year whole body dose would be doubled. We assumed the BEIR-I risk of 0.2% rem was based on both parents being irradiated. Also because we believed the risk coefficient from BEIR-I was already conservative based on comparisons with BEIR-III, we elected to use the 30-year whole body dose as provided us--not doubled.

5. For the 140 persons who returned to Bikini and were removed in August 1978, it was assumed that no children will be conceived by persons above age 40, that 300 children will be born after August 1978, and that all children born will be offspring of parents, both of whom returned to Bikini. The parental dose was obtained as follows:

Average dose to males < 40 years old	=	1.36 rem	—
Average dose to females < 40 years old	=	1.08 rem	—
Total parental dose	=	2.44 rem	
Parental dose used in calculations	=	1.22 rem	

6. The average dose values for persons who lived on Bikini were calculated from individual dose data (whole body and bone marrow) for 50 males and 49 females. These values are tabulated in the Appendix.

7. The spontaneous incidence of birth defects was taken to be 10.7% of all live births from BEIR-III.

8. The normal incidence of cancer deaths was assumed to be 15%. A value less than the approximately 20% given for the U.S. population

was used because the Bikini people have been and will probably be exposed to much lower limits of environmental carcinogens than people living in the U.S. and because of limited medical services and prevalence of other risks such as drowning, poisoning, etc. Other causes of death are probably higher in the Bikini population than in the U.S. population. We also suspected the average life span was less than in the U.S. population, which might tend to reduce the number of cancers that would occur in the elderly.

9. The largest dose a person might receive in a year was estimated to be three times the average dose. Data in the appendix for individuals show that the highest individual dose is more than twice the average but less than three times.

II. Population Estimate (CAPS) — CENTER

To estimate the number of births, deaths and the magnitude of the Bikini population after 30 years, information was used from the final draft of the Marshall Islands five year health plan prepared by the Trust Territories' Department of Health Services' Office of Health Planning and the Resources Department. The document is undated, but the presence of data from 1976 indicates that it must have been prepared in the period of 1977 to 1979 when we received it. It was noted that there are apparent inconsistencies among several of the different tables. For example, Table III-1 gives data for the Marshall Islands for the period 1955-1975 and Table III-5 gives data for the infant mortality rate for 1976. In Table III-1, the infant death rate per 1000 births for 1970 through 1975 is given as 28.3, 33.6, 25.4, 46.4, 21.1 and 37.0. However, Table III-5 indicates the infant mortality rate to be only 17.04. We used the data of Table III-1 in the

following estimates; because it is more complete and it provides a self-consistent set of data. However, in view of the discrepancies, the results can only be considered as approximations. This probably makes little real difference in view of the uncertainties in the risk coefficients that were used. There is also a bias built into the data because of the inclusion of Ebye and Majaro in the overall Marshall Island rates. This arises from the different death rates (particularly infants) at these two locations. In many respects the population of Ebye and Majaro are quite dissimilar from the Bikini population because they have the advantages and disadvantages of a more technical environment.

For the estimates the last 5 or 6 year average of the data were used because they are probably the most representative of current conditions. From this, the following were obtained:

1. Rate of increase of the population has been about 3.8%/year.
2. Infant death rate is about 3.2% per birth.
3. Overall death rate is 0.54% per year.
4. Birth rate is 4.2% per year.

A population of 550 was assumed for the one that might move back to Bikini Atoll. Values for other initial populations were obtained by ratios of the results.

The total population at the end of 30 years is given by the compounding equation:

$$P_{30} = 550 (1 + 0.038)^{30} = 1684$$

The number of births in 30 years are given by:

$$B = 0.042 \times 550 \int_0^{30} (1.038)^x dx$$

where x is the time between 0 and 30. This gives

$$B = \frac{0.042 \times 550}{\ln 1.038} [1.038^{30} - 1] = 1277$$

Similarly, the number of deaths in the 30 year period would be:

$$\text{Deaths} = 0.0054 \times 550 \int_0^{30} (1.038)^x dx$$

$$\text{Deaths} = \frac{0.0054 \times 550}{\ln 1.038} [1.038^{30} - 1] = 164$$

One other datum needed is the reduction in 30 year dose to those born after the return because of the decrease in radiation levels and the smaller amount of time in the 30 year period that is spent on the island. For this, the total population dose for those born after returning assuming an initial dose rate of 1 rad/year is given by:

$$P = 550 D_1 \int_0^{30} e^{-\lambda x} (1.038)^x dx$$

λ is the half-life of decrease of the radiation dose, taken here as 30 years.

Because this integral cannot be solved analytical, an approximate solution was obtained by calculating this function for each of 30 years and summing. This gave 8949 rads for the total population including the original 550. The total dose received by the original 550, assuming that

all live for the 30 years, is

$$P' = \frac{550}{\lambda} (1 - e^{-\lambda t}) = 11,902 \text{ rads}$$

For those born after the return, the population would be the difference between the total population in 30 years, the number of deaths and the original 550 people or 1134. Thus, the per capita dose for this group is $8949/1134 = 7.9$ rads. For the original 550, the per capita dose is $11,902/550 = 22$ rads. The ratio of these two to give an estimate of the fraction of the full 30 year dose received by the children is 0.36.

The assumption of no deaths in the original 550 returning was made for simplicity and the lack of good death rate data.

We also compared the age characteristics of the Marshallese from Table IV-3 and the U.S. population in 1970. This comparison is given in the attached curve. The slopes are similar above age 35 but the magnitudes are distorted by the high birth rate in the Marshall Islands. However, in terms of the relative risk the similar slopes suggest that if the natural cancer rates in the two populations are similar, the relative risk for people above 35 in both populations would be similar because most of the cancer occurs at ages from about 40 and above. However, the magnitude of the relative risk in the U.S. used for the Marshallese will be high by a factor of somewhere around 2-3 because of the distortion caused by the very high proportion of young people who have a relatively low natural cancer incidence.

Using the preceding calculations for a population of 550, calculations were made for other population sizes. For a population of 550 (from preceding):

Deaths in 30 years = 164 ~ 160

Births in 30 years = 1277 ~ 1300

For a population of 140 (the number that returned to Bikini):

$$\text{Deaths in 30 years, } \frac{164}{550} = \frac{x}{140}, x = \frac{41.7}{\cancel{1.111}} \sim 40$$

$$\text{Births in 30 years, } \frac{1277}{550} = \frac{x}{140}, x = \frac{325.}{\cancel{1.111}} \sim 300$$

For a population of 235:

$$\text{Deaths in 30 years, } \frac{164}{550} = \frac{x}{235}, x = 70.07 \sim 70$$

$$\text{Births in 30 years, } \frac{1277}{550} = \frac{x}{235}, x = 545.62 \sim 550$$

For a population of 350:

$$\text{Deaths in 30 years, } \frac{164}{550} = \frac{x}{350}, x = 104.36 \sim 100$$

$$\text{Births in 30 years, } \frac{1277}{550} = \frac{x}{350}, x = 812.63 \sim 800$$

III. Risk Coefficients ——— CENTRAL & CAPS

At the time the Bikini book was prepared no agency in the U.S. government had accepted the risk coefficients in BEIR-III. Thus we were constrained to use risk coefficients from BEIR-I. While not included in the printed book, risk estimates based on BEIR-III were calculated for comparison purposes. The following gives the origin of the risk coefficients used.

A. BEIR-I

1. Cancer (Tables 3-3 and 3-4)

Cancer deaths/year in U.S. from 0.1 rem/year (pop = 197,863,000)	<u>Derived</u> Cancer deaths/10 ⁶ person rem rem
--	--

	<u>Absolute</u>	<u>Relative</u>	<u>Absolute</u>	<u>Relative</u>
Leukemia	516	738	26	37
Other Cancers				
30 year elevated risk	1210	2436	61	123
lifetime elevated risk	1485	8340	75	421
Range	1726-2001	3174-9078	87-101	160-458

From the above the minimum estimate of cancer risk would be given by a risk coefficient of 87/10⁶ person rem and the maximum by 458/10⁶ person rem. Thus, these two risk coefficients were used to define a range of estimated cancer deaths.

2. Genetic Effects (from Page 1 & 2 BEIR-I)

- a.
 - Based on specific defects
- File* 5 rem/30 year reproductive generation would cause in the first generation 100-1800 cases of dominant diseases and defects per year (3.6 million births/year) or 5 times this amount at equilibrium. The 1800 cases represent an increase of 0.05% incidences per year first generation and 0.25% at equilibrium.

In addition there would be a few chromosomal defects and recessive diseases and a few congenial defects due to a single gene defects and chromosome aberrations.

~~The total incidence at equilibrium is 1100 to 27,000/year.~~

- The total incidence at equilibrium is 1100 to 27,000/year. These at equilibrium, the maximum would be 0.75% or 0.15% in the first generation.
- These are equivalent to 0.15% per rem at equilibrium and 0.03%/rem in the first generation.

b. Based on Overall Ill Health

Overall ill health: 5% - 50% of ill health is proportional to the mutation rate using 20% and doubling dose of 20 rem, 5 rem per generation would eventually lead to a 5% increase in ill health.

Thus the rate of overall ill health is 1%/rem at equilibrium or 0.2%/rem in first generation.

For estimating the potential genetic derived health defects in the Bikini population it was decided to use a risk coefficient of 0.2% per rem in the first generation recognizing that it was probably very conservative.

B. BEIR-III

I. Cancer (Table V-4)

Lifetime Risk of Cancer Death

(deaths/10⁶/rad)

Model	Single exposure to 10 rad		Continuous Exposure to 1 rad/yr	
	Absolute	Relative	Absolute	Relative
L-Q, L-Q-L	77	226	67	182
L-L, L-L	167	501	158	430
Q-L, Q-L	10	28	---	---

2. Birth Defects--pages 166-169 *

(mean parental age = 30 years)

- 1 rem per generation (1 rem parental exposure) per 10⁶ live offspring
5 to 75 birth defects, this is 0.0005--0.0075%--First
generation.

- Since the spontaneous rate is given as 10.7%, in the U.S. population,
1 rem will increase the rate from 10.7% to 10.7005--10.7075%.

- In terms of the spontaneous rate 1 rem per generation gives $\frac{0.0005}{10.7} =$
0.000047 = 0.0047% increase and $\frac{0.0075}{10.7} = 0.0007 = 0.07\%$ increase.

IV. CALCULATIONS OF RISK

Table 1 gives the radiation dose values provided by Dr. Robison for use
in developing estimates of increased health risks in the Bikini population.

A. RISKS FOR 14 DIFFERENT LIVING CONDITIONS

1. Cancer Risks

Table 3 shows the calculations for estimates of increased cancer risk
for 14 different living conditions.

2. Birth Defects Risks

Table 3 gives the calculations for the estimates of birth defects.

B. RISK ESTIMATES BASED ON BEIR-III

Table 4 gives risk estimates based on BEIR-III risk coefficients. These were calculated for comparison purposes only and was not used in the Bikini book. The highest estimates for cancer risk result from using the linear relative risk model and are about the same as those given in ~~Table 2 for the relative risk model. The lowest estimates result from the linear-quadratic~~

Table 2 for the relative risk model. The lowest estimates result from the linear-quadratic absolute risk model and are slightly less than those for the absolute model in Table 2. Thus, as far as estimates of cancer risk are concerned, those obtained using risk coefficients from BEIR-I are in the same general range as those obtained using risk coefficients from BEIR-III.

Risk estimates for birth defects obtained using the risk factor from BEIR-I gives values about three times those obtained using the upper value of the range of risk factors given in BEIR-III. If BEIR-III risk factors for birth defects represent a more enlightened assessment of this potential consequence of radiation exposure than the factor taken from BEIR-I for overall health defects, then the estimates given in the Bikini book may be conservative by a factor of three.

Emcee - 10%

30 year doc - 3000, million

pop - 550

Total Manum = 1,650,000 manum = 1650 person per

Risk Coefficients	Relation	Absolute
BEIR - I	$\sqrt{310/10^6}$ person per	95/10 ⁶ person per
BEIR - I (from BEIR III)	568	115
BEIR - III	182	67

Cancer Death

BEIR I	$\frac{310 \times 1650}{10^6} = \frac{511,500}{10^6} = 0.5115$	$\frac{95 \times 1650}{10^6} = \frac{156,750}{10^6} = 0.15675$
	$\frac{160 \times 1650}{10^6} = \frac{264,000}{10^6} = 0.264$	5.16
	$\frac{458 \times 1650}{10^6} = \frac{755,700}{10^6} = 0.7557$	

i. Based on 15%
 Cancer incidence
 3 rem - 30yo) $83 \times 0.004 \times 3 = 0.996$

ii. Based on 10%
 cancer incidence $55 \times 0.004 \times 3 = 0.66$

BEIR I (from BEIR III)	$\frac{568 \times 1650}{10^6} = 0.9372$	$\frac{115 \times 1650}{10^6} = 0.18975$
BEIR III	$\frac{182 \times 1650}{10^6} = 0.3003$	$\frac{67 \times 1650}{10^6} = 0.11055$

Rokone foto

B

(document on the ...)

June 1982

Summary - ...

...
...
... mean ...

Rokone

24 - white ...
 27 - ...
 extra ...

2 per 550
 ~ 4 per 1000
 3.6 per 1000
 22 per 550
 48 per 1000

550 extra ... based on 1300 live ...
 4.8
 1018

+ 550
 1850
 * 1695
 2/1550
 2/1000
 22/1000
 13

1.2
 11.9
 13
 1 to 2
 1.96
 2.0

...

7/1350 = 5/1000
 12/1350 = 9.2/1000

Table:

Weight	47	48
Time	244	250

Page 20

Table 10

200,000 ... ?
 200 - 200,000 ...

$$22 - 40 \times .09 + 8 \times .46 = 1.98 + 3.68 = 5.66$$

$$200 \times 300 = 60,000$$

25	x	.09	=	2.25	
200	x	.46	=	92.00	2 - 22

200		94.25
22		8.8

✓Ruben Zackhras, Acting President and Minister of Transportation and
Communications

Be...

✓Kinja Andrike, Secretary, Education

✓Jerry Bennett, Department of Education

✓Carmen Bigler, Secretary, Internal Affairs

✓Alfred Capelle, College of Micronesia Extension Services
Director and Staff, Marshallese Community Action Agency

✓William Graham, Chief of Curriculum Development

✓Dr. Isaacs, Medical Doctor, Health Services

Tony Johns, Clerk of the Cabinet

✓Phillip Kabua, Acting Chief Secretary

✓Marie Maddison, Chairwoman, Public Service Commission

✓Enid McKay, Secretary of Social Services

✓Henry Samuel, Minister of Health Services

In Honolulu, Hawaii, the following people were visited and/or consulted and contributed information that was used to formulate the plan:

✓ Sister Edna L. Demanche, retired, University of Hawaii, formerly teacher in
the Marshall Islands

✓ Jim Harpstrite, University of Hawaii, Energy Project, teacher training for
Micronesia teachers

Robert C. Kiste, Professor of Anthropology, University of Hawaii, anthropolo-
gist with extensive field experience and published work on Marshall Islands

Billiet Edmond and Louise E. Wohl, Pacific Area Language Materials Development
Center, University of Hawaii

Marje Terpstra, University of Hawaii, former instructor in teacher training
at the College of Micronesia at Ponape.

In the United States, during special work on Marshall Island information book-
lets, the following people were consulted:

Alice Buck, Kwajalein, Marshall Islands

Long-time Marshall Islands resident and Marshallese translator

Meleron Jelke, Ebeye, Marshall Islands, Marshallese businessman and translator.

Bill--

Here are the people that were listed in Carl Unruh's trip report. I don't know if they are officials in the Marshallese Government, so please put a check by the ones you want to thank. Carl's list did not have any of the people from the first list I compiled.

✓ Ruben Zackhras	Acting President (Minister of Transportation and Communication)
✓ Phillip Kabua	Acting Chief Secretary
✓ Kinja Andrike	Secretary of Education
✓ Dr. Issacs	Doctor
✓ Henry Samuel	Minister of Health
✓ Bill Graham	Chief of Curriculum Development
Jerry Bennett	CLT
Enid McKay	Social Services
Alfred Capelle	Director of the College of the Marshallese Islands (College of Micronesia Extension Services)
Marie Maddison	Chairwoman, Public Service Commission The Marshallese Community Action Agency (Director, Acting Director and 10 staff)
Sister Edna L. Demanche	Retired
Jim Harpstripe	University of Hawaii, Energy Project
Robert C. Kiste	Professor of Anthropology, University of Hawaii
Billiet Edmond	Pacific Language Materials Development Center
Louise E. Wohl	Pacific Language Materials Development Center.
Linda	

8/13/80

Bill:

Bruce's secretary called this morning and gave me names of people you should discuss with Alice:

Tom Kijiner - Minister of Education

young

Kinje Andrike - Secretary of Education

Mel's relative

William Graham - Chief, Programs and Development, Department of Education

Dr. Ezra ^RBiklon - Secretary of Health

^mCaren Bigler - Director of Public Affairs

*Gene Bennett - Curriculum/Learning/Training Center
(U.S.)*

*John Andrike
Headmaster of ...
Eastern ...
Headmaster
Some ...*

as minutes of Transp. + Committee

Need to get
Roster of
govt people
from Carl

Zackhouse	Dexter Elms
Wabua	
Andaka	Joyce Wall
Devoce	Robert Ditson
Samuel	
Bredan	Abn - Cannon Reylee
Bennett	
McCoy	
Capelle	
Meddison	

Dear

On behalf of Mr Carl Unruh & Dr Ray Baalman
and myself I want to thank you for ~~the~~
~~your~~ meeting with me the week of
September 30. ~~It was very helpful to have your~~
~~views on how~~ ~~information~~ about
radiation ~~might~~ ~~be~~ ~~communicated~~ to the
people of the Marshall Islands. ~~We~~ ~~are~~ ~~expected~~ to
have a plan to accomplish this ~~purpose~~ prepared for ^{consideration}
United States
by the Department of Energy & the Department of Interior within
the next few weeks.

Thank you again for your help. It was a pleasure
meeting you, and we look forward to seeing you again.

List of People who helped (in any way) on the Bikini Book (31)

Bill -
please
check list of
names

- PA Anderson
- RW Baalman (Ray)
- VE Bannick
- DC Borg (Dr. Donald)
- A Buck (Alice, Mrs. Elden)
- MA Carlile
- ✓ G Casarett (George)
- J Conway (John)
- P Dunaway (Dr. Paul)
- RO Gilbert
- ~~NA Greenhouse~~
- ✓ JW Healy (Jack)
- ✓ RC Kiste
- HE Kreuger (Hank)
- RO McClellan
- T McCraw (Tommy)
- S Marks (Sid)
- RP Marshall (Bob)
- ✓ ~~J Naidu (Jan)~~
- NT Nero (Norv)
- JF Park
- HS Pratt
- ✓ R Ray (Roger)
- ~~WL Robison (Bill)~~
- ✓ ~~AH Seymour (Allynn)~~
- JA Smith
- ~~WL Templeton (Bill)~~
- ~~RC Thompson (Roy)~~
- ✓ ~~CM Unruh (Carl)~~
- ~~B Wachholz (Bruce)~~
- JM Weisgall

1. Review of old material
2. Review art work
3. Rev of new material - Jack, B, + A
4. Write new mat if necessary -

Pat	Alice	Ray	BGM
x	x		x
	F	-	

Need for Books

Level of cost on Islands

# of Books	1	W + W0
	2	
	3	14 W0
	4	
	5	
	6	
	7	
	8	
	9	
	10	

50% imported
55% split across islands

- 1. 100% on Ennea W + WO imported food
550 people all local food from Ennea
- 2. 90% on Ennea 10% Pitkin W + WO imported
all local from Ennea
- 3. 50% - 50% W + WO
local food 50-50

4. 100% on Pitkin W + WO
all local from Pitkin

5. 350 people - 100% Ennea
Katala 1 year on Ennea & 1 year Katala
W with & WO imported
local food from Ennea

6. Same - 1 year on & 2 off

7. 350 people - 90% Ennea 10% Pitkin
Katala 1 year on Ennea 1 year Pitkin & 1 year off-island
W with & WO imported food
local food all from Ennea

8. 233 people 100% on Ennea
1 year on & 2 years off
with & WO imported food

9. 235 people 1009, even ~~1000~~
1 on + 1 off W & W O local food
local food for even

10. 235 people 909, even 127 on 127 off
1 W & W O local food
local food for

14 total

When do we get doves?

potatoes -
all by June 17 - ?

Cooperating soil water -

Dr. Cone,

Providence - 1977

S + 15 3, or 8. B

June 10

- Determine what paragraphs are ~~fixed~~ in final form
- ~~What-paragraphs require a small amount of work (Alice will start on these)~~
Determine what paragraphs require a small amount of work (Alice ~~will start on these~~)-
Ray, meleran and keorong will sta on those)
- Bruce, Bill and Jack will start on new material.

Procedure for ~~Alice, Ray, Me~~ translation work on paragraphs requiring small amount of work:

~~will be handled in the same manner as before~~

- Ray will give the translated material to Martha.
- Martha will type the material, draw a line through the retyped material and put the draft with the new version in the File (Date, time, paragraph number on all material)
- Martha will give out retyped version (when? without interrupting the material being worked on at the moment? Should we have a time of updating notebooks for everyone at the same time and should I keep all retyped material until then?)

Legends for allrest

PROCEDURES FOR SECRETARY

folders

- Pick up material from out~~XXXXX~~ of translators and scientists
- Type material from translators and distribute
- Type material from scientists and distribute
- When a paragraph has been retyped draw a line through the previous draft
- Insert retyped paragraphs into file
- Mark on chart when

PROCEDURES FOR TRANSLATORS

- Mark all translated copy with notation signifying who should receive copies before giving to Martha for typing (put in MARTHA folder)
- Be sure paragraph numbers are on all paragraphs
- All work to be translated will be put in your TRANSLATORS folder.
- All final copy will be put in your TRANSLATORS folder.
- Put your initials on all pages received by you and put them in your notebook behind the proper number. The latest version always goes on the top.
- When you have completed translating a paragraph, mark it on your chart.
- When a paragraph has been finalized, mark it with a gold star.

PROCEDURES FOR WORK ON BIKINI BOOK

Each person will receive a looseleaf notebook for storing material with numbers up to 62

& under numbers each will have page in place

XXXXXXXXXX

XXXXXXXXXX

A

Ray Baalman

Bill Bair

XXXXXXXXXX

Alice Buck

Jack Healy

Meleran Jelke

Keorong Sam

Martha Stifter

14

1. When you are given a new piece of material please initial and put in your looseleaf notebook under appropriate number.

*who gets to keep
at the end to ~~me~~ ^{copy}
~~Keep them~~
Copy?*

PROCEDURES FOR SCIENTISTS

- Mark all copy with notation signifying who should receive copies before giving to Martha for typing (put in MARTHA folder)
- Be sure paragraph numbers are on all paragraphs
- All ~~final~~ copy will be put in your SCIENTISTS folder.
- Put your initials on all pages received by you and put them in your notebook behind the proper number. The latest version always goes on the top.
- When you reach a final version of a paragraph, mark it final and initial it.
- When you have completed a paragraph, mark it on your chart.
- When a paragraph has been finalized, mark it with a gold star.

<p>Jonan radiation eo elaptata bwelen juon armij emaroñ boke iumin juon yio</p> <p>The largest amount of radiation one person might receive during 1 year</p>	millirem	millirem
<p>Jonan radiation eo iolap (average) bwelen juon armij emaroñ boke iumin 30 yio:</p> <p>ilo aoleben enbwinnin (whole body)</p> <p>ilo nonnonmej iloan dri (bone marrow)</p> <p>Average amount of radiation a person might receive during 30 years</p>	millirem millirem	millirem millirem
<p>Jonan löñlok in cancer ko bwelen remaroñ walok ilo yio kein 30 iman</p> <p>The number of cancer that might occur within the next 30 years</p>	%	%

Melelen, bwe elane enaj wor 83 armij remij ilo yio kein 30 iman jen jabrewot cancer ijellokin cancer ko rej walok jen radiation eo ej walok jen atomic bomb, emaroñ bar kobatok ro rej mij jen cancer ko rej walok jen radiation eo ej walok jen atomic bomb.

This means that if there would be 83 people die within the next 30 years from any cancer other than that caused by radiation left from atomic bombs, there might be an additional who die from cancer that is caused by radiation left from atomic bombs.

Melelen, bwe elane enaj wor 83 armij remij ilo yio kein 30 iman jen jabrewot cancer ijellokin cancer ko rej walok jen radiation eo ej walok jen atomic bomb, emaroñ bar kobatok ro rej mij jen cancer ko rej walok jen radiation eo ej walok jen atomic bomb.

This means that if there would be 83 people die within the next 30 years from any cancer other than that caused by radiation left from atomic bombs, there might be an additional who die from cancer that is caused by radiation left from atomic bombs.

<p>Jonan löñlok in ajiri ro bwelen remaroñ lotaktok kin naninmij in utamwe ilo yio kein 30 iman</p> <p>The number of children born with health defects within the next 30 years</p>	%	%
--	---	---

Melelen, bwe elane enaj wor 550 ajiri ro rej lotaktok kin naninmij in utamwe walok jen jabrewot un ko ijellokin radiation eo ej walok jen atomic bomb ilo yio kein 30 iman, emaroñ bar kobatok ajiri rej lotaktok kin naninmij in utamwe walok jen radiation eo ej walok jen atomic bomb.

This means that if there were 550 children born with health defects occurring from any cause other than radiation left from atomic bombs, within the next 30 years, there might be an additional children born with defects caused by radiation left from atomic bombs.

Melelen, bwe elane enaj wor 550 ajiri ro rej lotaktok kin naninmij in utamwe walok jen jabrewot un ko ijellokin radiation eo ej walok jen atomic bomb ilo yio kein 30 iman, emaroñ bar kobatok ajiri rej lotaktok kin naninmij in utamwe walok jen radiation eo ej walok jen atomic bomb.

This means that if there were 550 children born with health defects occurring from any cause other than radiation left from atomic bombs, within the next 30 years, there might be an additional children born with defects caused by radiation left from atomic bombs.

80-a

(1)

80

92

Jonan radiation eo elaptata bwelen juon armij emaron boke iumin juon yio	millirem	.....	millirem
The largest amount of radiation one person might receive during 1 year			
Jonan radiation eo iolap (average) bwelen juon armij emaron boke iumin 30 yio: ilo aoleben enbwinnin (whole body)	millirem	.....	millirem
ilo nonnonmej iloan dri (bone marrow)	millirem	.....	millirem
Average amount of radiation a person might receive during 30 years			
Jonan lonlok in cancer ko bwelen remaron walok ilo yio kein 30 iman . . . . .	%	.....	%
The increase of cancer that might occur within the next 30 years			

Melelen, bwe elane enaj wor 83 armij remij ilo yio ken 30 iman jen jabrewot cancer ijellokin cancer ko rej walok jen radiation eo ej walok jen atomic bomb, emaron bar kobatok ro rej mij jen cancer ko rej walok jen radiation eo ej walok jen atomic bomb.

This means that if there would be 83 people die within the next 30 years from any cancer other than that caused by radiation left from atomic bombs, there might be an additional who die from cancer that is caused by radiation left from atomic bombs.

Melelen, bwe elane enaj wor 83 armij remij ilo yio kein 30 iman jen jabrewot cancer ijellokin cancer ko rej walok jen radiation eo ej walok jen atomic bomb, emaron bar kobatok ro rej mij jen cancer ko rej walok jen radiation eo ej walok jen atomic bomb.

This means that if there would be 83 people die within the next 30 years from any cancer other than that caused by radiation left from atomic bombs, there might be an additional who die from cancer that is caused by radiation left from atomic bombs.

Jonan lonlok in ajiri ro bwelen remaron lotaktok kin naninmij in utamwe ilo yio kein 30 iman . . . . .	%	.....	%
The percent of children born with health defects within the next 30 years			

Melelen, bwe elane enaj wor 550 ajiri ro rej lotaktok kin naninmij in utamwe walok jen jabrewot un ko ijellokin radiation eo ej walok jen atomic bomb ilo yio kein 30 iman, emaron bar kobatok ajiri rej lotaktok kin naninmij in utamwe walok jen radiation eo ej walok jen atomic bomb.

This means that if there were 550 children born with health defects occurring from any cause other than radiation left from atomic bombs, within the next 30 years, there might be an additional children born with defects caused by radiation left from atomic bombs.

Melelen, bwe elane enaj wor 550 ajiri ro rej lotaktok kin naninmij in utamwe walok jen jabrewot un ko ijellokin radiation eo ej walok jen atomic bomb ilo yio kein 30 iman, emaron bar kobatok ajiri rej lotaktok kin naninmij in utamwe walok jen radiation eo ej walok jen atomic bomb.

This means that if there were 550 children born with health defects occurring from any cause other than radiation left from atomic bombs, within the next 30 years, there might be an additional children born with defects caused by radiation left from atomic bombs.

80-a

(2)

2

23

Jonan radiation eo elaptata bwelen juon armij emaron boke iumin juon yio The largest amount of radiation one person might receive during 1 year	millirem	.....	millirem
Jonan radiation eo iolap (average) bwelen juon armij emaron boke iumin 30 yio: ilo aoleben enbwinnin (whole body)	millirem	.....	millirem
ilo nonnonmej iloa dri (bone marrow)	millirem	.....	millirem
Average amount of radiation a person might receive during 30 years			
Jonan lonlok in cancer ko bwelen remaron walok ilo yio kein 30 iman The average of cancer that might occur within the next 30 years	%	.....	%

Melelen, bwe elane enaj wor 83 armij remij ilo yio kein 30 iman jen jabrewot cancer ijellokin cancer ko rej walok jen radiation eo ej walok jen atomic bomb, emaron bar kobatok ro rej mij jen cancer ko rej walok jen radiation eo ej walok jen atomic bomb.

This means that if there would be 83 people die within the next 30 years from any cancer other than that caused by radiation left from atomic bombs, there might be an additional who die from cancer that is caused by radiation left from atomic bombs.

Melelen, bwe elane enaj wor 83 armij remij ilo yio kein 30 iman jen jabrewot cancer ijellokin cancer ko rej walok jen radiation eo ej walok jen atomic bomb, emaron bar kobatok ro rej mij jen cancer ko rej walok jen radiation eo ej walok jen atomic bomb.

This means that if there would be 83 people die within the next 30 years from any cancer other than that caused by radiation left from atomic bombs, there might be an additional who die from cancer that is caused by radiation left from atomic bombs.

Jonan lonlok in ajiri ro bwelen remaron lotaktok kin naninmij in utamwe ilo yio kein 30 iman The proportion of children born with health defects when the next 30 years	%	%
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Melelen, bwe elane enaj wor 550 ajiri ro rej lotaktok kin naninmij in utamwe walok jen jabrewot un ko ijellokin radiation eo ej walok jen atomic bomb ilo yio kein 30 iman, emaron bar kobatok ajiri rej lotaktok kin naninmij in utamwe walok jen radiation eo ej walok jen atomic bomb.

This means that if there were 550 children born with health defects occurring from any cause other than radiation left from atomic bombs, within the next 30 years, there might be an additional children born with defects caused by radiation left from atomic bombs.

Melelen, bwe elane enaj wor 550 ajiri ro rej lotaktok kin naninmij in utamwe walok jen jabrewot un ko ijellokin radiation eo ej walok jen atomic bomb ilo yio kein 30 iman, emaron bar kobatok ajiri rej lotaktok kin naninmij in utamwe walok jen radiation eo ej walok jen atomic bomb.

This means that if there were 550 children born with health defects occurring from any cause other than radiation left from atomic bombs, within the next 30 years, there might be an additional children born with defects caused by radiation left from atomic bombs.

80-b

3

nb

Jonan radiation eo elaptata bwelen juon armij emaron boke iumin juon yio	millirem	.....	millirem
<small>The largest amount of radiation one person might receive during 1 year.</small>			

Jonan radiation eo iolap (average) bwelen juon armij emaron boke iumin 30 yio: ilo aoleben enbwinnin (whole body)	millirem	.....	millirem
ilo nonnonmej iloon dri (bone marrow)	millirem	.....	millirem
<small>Average amount of radiation a person might receive during 30 year.</small>			

Jonan loñlok in cancer ko bwelen remaron walok ilo yio kein 30 iman . . . . .	%	.....	%
<small>The percentage of cancer that might occur within the next 30 years.</small>			

Melelen, bwe elane enaj wor **53** armij remij ilo yio kein 30 iman jen jabrewot cancer ijellokin cancer ko rej walok jen radiation eo ej walok jen atomic bomb, emaron bar kobatok ro rej mij jen cancer ko rej walok jen radiation eo ej walok jen atomic bomb.

This means that if there would be 53 people die within the next 30 years from any cancer other than that caused by radiation left from atomic bombs, there might be an additional who die from cancer that is caused by radiation left from atomic bombs.

Melelen, bwe elane enaj wor **53** armij remij ilo yio kein 30 iman jen jabrewot cancer ijellokin cancer ko rej walok jen radiation eo ej walok jen atomic bomb, emaron bar kobatok ro rej mij jen cancer ko rej walok jen radiation eo ej walok jen atomic bomb.

This means that if there would be 53 people die within the next 30 years from any cancer other than that caused by radiation left from atomic bombs, there might be an additional who die from cancer that is caused by radiation left from atomic bombs.

Jonan loñlok in ajiri ro bwelen remaron lotaktok kin naninmij in utamwe ilo yio kein 30 iman . . . . .	%	.....	%
<small>The percentage of children born with health defects within the next 30 years.</small>			

Melelen, bwe elane enaj wor **350** ajiri ro rej lotaktok kin naninmij in utamwe walok jen jabrewot un ko ijellokin radiation eo ej walok jen atomic bomb ilo yio kein 30 iman, emaron bar kobatok ajiri rej lotaktok kin naninmij in utamwe walok jen radiation eo ej walok jen atomic bomb.

This means that if there were 350 children born with health defects occurring from any cause other than radiation left from atomic bombs, within the next 30 years, there might be an additional children born with defects caused by radiation left from atomic bombs.

Melelen, bwe elane enaj wor **350** ajiri ro rej lotaktok kin naninmij in utamwe walok jen jabrewot un ko ijellokin radiation eo ej walok jen atomic bomb ilo yio kein 30 iman, emaron bar kobatok ajiri rej lotaktok kin naninmij in utamwe walok jen radiation eo ej walok jen atomic bomb.

This means that if there were 350 children born with health defects occurring from any cause other than radiation left from atomic bombs, within the next 30 years, there might be an additional children born with defects caused by radiation left from atomic bombs.

80-c
(1)

Jonan radiation eo elaptata bwelen juon armij emaroñ boke iumin juon yio The largest amount of radiation one person might receive during 1 year	millirem	millirem
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Jonan radiation eo iolap (average) bwelen juon armij emaroñ boke iumin 30 yio: ilo aoleben enbwinnin (whole body)	millirem	millirem
ilo nonnonmej iloañ dri (bone marrow)	millirem	.....	millirem
Average amount of radiation a person might receive during 30 year			

Jonan lōñlok in cancer ko bwelen remaroñ walok ilo yio kein 30 iman .....	%	.....	%
The number of people who might die within the next 30 year			

Melelen, bwe elane enaj wor 53 armij remij ilo yio kein 30 iman jen jabrewot cancer ijellokin cancer ko rej walok jen radiation eo ej walok jen atomic bomb, emaroñ bar kobatok ro rej mij jen cancer ko rej walok jen radiation eo ej walok jen atomic bomb.

This means that if there would be 53 people die within the next 30 year from any cancer other than that caused by radiation left from atomic bombs, there might be an additional who die from cancer that is caused by radiation left from atomic bombs.

Melelen, bwe elane enaj wor 53 armij remij ilo yio kein 30 iman jen jabrewot cancer ijellokin cancer ko rej walok jen radiation eo ej walok jen atomic bomb, emaroñ bar kobatok ro rej mij jen cancer ko rej walok jen radiation eo ej walok jen atomic bomb.

This means that if there would be 53 people die within the next 30 years from any cancer other than that caused by radiation left from atomic bombs, there might be an additional who die from cancer that is caused by radiation left from atomic bombs.

Jonan lōñlok in ajiri ro bwelen remaroñ lotaktok kin naninmij in utamwe ilo yio kein 30 iman .....	%	.....	%
The number of children who will be born with defects			

Melelen, bwe elane enaj wor 350 ajiri ro rej lotaktok kin naninmij in utamwe walok jen jabrewot un ko ijellokin radiation eo ej walok jen atomic bomb ilo yio kein 30 iman, emaroñ bar kobatok ajiri rej lotaktok kin naninmij in utamwe walok jen radiation eo ej walok jen atomic bomb.

This means that if there were 350 children born with health defects occurring from any cause other than radiation left from atomic bombs, within the next 30 years, there might be an additional children born with defects caused by radiation left from atomic bombs.

Melelen, bwe elane enaj wor 350 ajiri ro rej lotaktok kin naninmij in utamwe walok jen jabrewot un ko ijellokin radiation eo ej walok jen atomic bomb ilo yio kein 30 iman, emaroñ bar kobatok ajiri rej lotaktok kin naninmij in utamwe walok jen radiation eo ej walok jen atomic bomb.

This means that if there were 350 children born with health defects occurring from any cause other than radiation left from atomic bombs, within the next 30 years, there might be an additional children born with defects caused by radiation left from atomic bombs.

50-c
(2)

51

Jonan radiation eo elaptata bwelen juon armij emaron boke iumin juon yio	millirem	.....	millirem
<small>The average amount of radiation one person might receive during 1 year.</small>			

Jonan radiation eo iolap (average) bwelen juon armij emaron boke iumin 30 yio: ilo aoleben enbwinnin (whole body)	millirem	.....	millirem
ilo nonnonmej iloa dri (bone marrow)	millirem	.....	millirem
<small>Average amount of radiation one might receive during 30 years.</small>			

Jonan lonlok in cancer ko bwelen remaron walok ilo yio kein 30 iman .....	%	.....	%
<small>The percentage of people who die within 30 years from cancer that is caused by radiation left from atomic bombs.</small>			

Melelen, bwe elane enaj wor 35 armij remij ilo yio kein 30 iman jen jabrewot cancer ijellokin cancer ko rej walok jen radiation eo ej walok jen atomic bomb, emaron bar kobatok ro rej mij jen cancer ko rej walok jen radiation eo ej walok jen atomic bomb.

This means that if there were 35 people die within the next 30 years from any cancer other than that caused by radiation left from atomic bombs, there might be an additional who die from cancer that is caused by radiation left from atomic bombs.

Melelen, bwe elane enaj wor 35 armij remij ilo yio kein 30 iman jen jabrewot cancer ijellokin cancer ko rej walok jen radiation eo ej walok jen atomic bomb, emaron bar kobatok ro rej mij jen cancer ko rej walok jen radiation eo ej walok jen atomic bomb.

This means that if there would be 35 people die within the next 30 years from any cancer other than that caused by radiation left from atomic bombs, there might be an additional who die from cancer that is caused by radiation left from atomic bombs.

Jonan lonlok in ajiri ro bwelen remaron lotaktok kin naninmij in utamwe ilo yio kein 30 iman .....	%	.....	%
<small>The percentage of children born with health defects within the next 30 years.</small>			

Melelen, bwe elane enaj wor 235 ajiri ro rej lotaktok kin naninmij in utamwe walok jen jabrewot un ko ijellokin radiation eo ej walok jen atomic bomb ilo yio kein 30 iman, emaron bar kobatok ajiri rej lotaktok kin naninmij in utamwe walok jen radiation eo ej walok jen atomic bomb.

This means that if there were 235 children born with health defects occurring from any cause other than radiation left from atomic bombs within the next 30 years, there might be an additional children born with defects caused by radiation left from atomic bombs.

Melelen, bwe elane enaj wor 235 ajiri ro rej lotaktok kin naninmij in utamwe walok jen jabrewot un ko ijellokin radiation eo ej walok jen atomic bomb ilo yio kein 30 iman, emaron bar kobatok ajiri rej lotaktok kin naninmij in utamwe walok jen radiation eo ej walok jen atomic bomb.

This means that if there were 235 children born with health defects occurring from any cause other than radiation left from atomic bombs within the next 30 years, there might be an additional children born with defects caused by radiation left from atomic bombs.

80 - c
(3)

c

bb

<p>Jonan <i>radiation</i> eo elaptata bwelen juon armij emaron̄ boke iumin juon yio</p> <p>The biggest amount of radiation one person might receive during 1 year</p>	millirem	millirem
<p>Jonan <i>radiation</i> eo iolap (average) bwelen juon armij emaron̄ boke iumin 30 yio: ilo aoleben enbwinnin (whole body)</p> <p>ilo nonnonmej iloan dri (bone marrow)</p> <p>Average amount of radiation one person might receive during 30 years</p>	millirem	millirem
<p>Jonan lōñlok in <i>cancer</i> ko bwelen remaron̄ walok ilo yio kein 30 iman</p> <p>The amount of radiation left from atomic bombs during 30 years</p>	%	%
<p>Melelen, bwe elane enaj wor 35 armij remij ilo yio kein 30 iman jen jabrewot <i>cancer</i> ijellokin <i>cancer</i> ko rej walok jen <i>radiation</i> eo ej walok jen <i>atomic bomb</i>, emaron̄ bar kobatok ro rej mij jen <i>cancer</i> ko rej walok jen <i>radiation</i> eo ej walok jen <i>atomic bomb</i>.</p> <p>This means that if there would be 35 people die within the next 30 years from any cancer other than that caused by radiation left from atomic bombs, there might be an additional who die from cancer that is caused by radiation left from atomic bombs.</p>		<p>Melelen, bwe elane enaj wor 35 armij remij ilo yio kein 30 iman jen jabrewot <i>cancer</i> ijellokin <i>cancer</i> ko rej walok jen <i>radiation</i> eo ej walok jen <i>atomic bomb</i>, emaron̄ bar kobatok ro rej mij jen <i>cancer</i> ko rej walok jen <i>radiation</i> eo ej walok jen <i>atomic bomb</i>.</p> <p>This means that if there would be 35 people die within the next 30 years from any cancer other than that caused by radiation left from atomic bombs, there might be an additional who die from cancer that is caused by radiation left from atomic bombs.</p>
<p>Jonan lōñlok in ajiri ro bwelen remaron̄ lotaktok kin naninmij in utamwe ilo yio kein 30 iman</p> <p>The amount of radiation left from atomic bombs during the next 30 years</p>	%	%
<p>Melelen, bwe elane enaj wor 235 ajiri ro rej lotaktok kin naninmij in utamwe walok jen jabrewot un ko ijellokin <i>radiation</i> eo ej walok jen <i>atomic bomb</i> ilo yio kein 30 iman, emaron̄ bar kobatok ajiri rej lotaktok kin naninmij in utamwe walok jen <i>radiation</i> eo ej walok jen <i>atomic bomb</i>.</p> <p>This means that if there were 235 children born with health defects occurring from any cause other than radiation left from atomic bombs within the next 30 years, there might be an additional children born with defects caused by radiation left from atomic bombs.</p>		<p>Melelen, bwe elane enaj wor 235 ajiri ro rej lotaktok kin naninmij in utamwe walok jen jabrewot un ko ijellokin <i>radiation</i> eo ej walok jen <i>atomic bomb</i> ilo yio kein 30 iman, emaron̄ bar kobatok ajiri rej lotaktok kin naninmij in utamwe walok jen <i>radiation</i> eo ej walok jen <i>atomic bomb</i>.</p> <p>This means that if there were 235 children born with health defects occurring from any cause other than radiation left from atomic bombs within the next 30 years, there might be an additional children born with defects caused by radiation left from atomic bombs.</p>

80-D

7

Jonan radiation eo elaptata bwelen juon armij emaron boke iumin juon yio	millirem	millirem
<i>The biggest amount of radiation one person might receive during 1 year</i>		

Jonan radiation eo iolap (average) bwelen juon armij emaron boke iumin 30 yio: ilo aoleben enbwinnin (whole body)	millirem	millirem
ilo nonnonmej ilon dri (bone marrow)	millirem	millirem
<i>Average amount of radiation per person received during 30 years</i>		

Jonan lonlok in cancer ko bwelen remaron walok ilo yio kein 30 iman	%	%
<i>The amount of radiation that would cause 1 death in 1000 people during 30 years</i>		

Melelen, bwe elane enaj wor **35** armij remij ilo yio kein 30 iman jen jabrewot cancer ijellokin cancer ko rej walok jen radiation eo ej walok jen atomic bomb, emaron bar kobatok ro rej mij jen cancer ko rej walok jen radiation eo ej walok jen atomic bomb.

This means that if there would be 35 people die within the next 30 years from any cancer other than that caused by radiation left from atomic bombs, there might be an additional 35 who die from cancer that is caused by radiation left from atomic bombs.

Melelen, bwe elane enaj wor **35** armij remij ilo yio kein 30 iman jen jabrewot cancer ijellokin cancer ko rej walok jen radiation eo ej walok jen atomic bomb, emaron bar kobatok ro rej mij jen cancer ko rej walok jen radiation eo ej walok jen atomic bomb.

This means that if there would be 35 people die within the next 30 years from any cancer other than that caused by radiation left from atomic bombs, there might be an additional 35 who die from cancer that is caused by radiation left from atomic bombs.

Jonan lonlok in ajiri ro bwelen remaron lotaktok kin naninmij in utamwe ilo yio kein 30 iman	%	%
<i>The percentage of children born with health defects within the next 30 years</i>		

Melelen, bwe elane enaj wor **235** ajiri ro rej lotaktok kin naninmij in utamwe walok jen jabrewot un ko ijellokin radiation eo ej walok jen atomic bomb ilo yio kein 30 iman, emaron bar kobatok ajiri rej lotaktok kin naninmij in utamwe walok jen radiation eo ej walok jen atomic bomb.

This means that if there were 235 children born with health defects occurring from any cause other than radiation left from atomic bombs, within the next 30 years, there might be an additional 235 children born with defects caused by radiation left from atomic bombs.

Melelen, bwe elane enaj wor **235** ajiri ro rej lotaktok kin naninmij in utamwe walok jen jabrewot un ko ijellokin radiation eo ej walok jen atomic bomb ilo yio kein 30 iman, emaron bar kobatok ajiri rej lotaktok kin naninmij in utamwe walok jen radiation eo ej walok jen atomic bomb.

This means that if there were 235 children born with health defects occurring from any cause other than radiation left from atomic bombs, within the next 30 years, there might be an additional 235 children born with defects caused by radiation left from atomic bombs.

<p>Jonan radiation eo elaptata bwelen juon armij emaroñ boke iumin juon yio</p> <p>The largest amount of radiation one person might receive during 1 year</p>	<p>millirem</p>	<p>millirem</p>
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<p>Jonan radiation eo iolap (average) bwelen juon armij emaroñ boke iumin 30 yio:</p> <p>ilo aoleben enbwinnin (whole body)</p> <p>ilo nonnonmej illoan dri (bone marrow)</p> <p>Average amount of radiation a person might receive during 30 year</p>	<p>millirem</p> <p>millirem</p>	<p>millirem</p> <p>millirem</p>
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<p>Jonan lōñlok in cancer ko bwelen remaroñ walok ilo yio kein 30 iman</p> <p>The increase in cancer that might occur within the next 30 year</p>	<p>%</p>	<p>%</p>
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Melelen, bwe elane enaj wor **53** armij remij ilo yio kein 30 iman jen jabrewot cancer ijellokin cancer ko rej walok jen radiation eo ej walok jen atomic bomb, emaroñ bar kobatok ro rej mij jen cancer ko rej walok jen radiation eo ej walok jen atomic bomb.

This means that if there would be **53** people die within the next 30 years from any cancer other than that caused by radiation left from atomic bombs, there might be an additional who die from cancer that is caused by radiation left from atomic bombs.

Melelen, bwe elane enaj wor **53** armij remij ilo yio kein 30 iman jen jabrewot cancer ijellokin cancer ko rej walok jen radiation eo ej walok jen atomic bomb, emaroñ bar kobatok ro rej mij jen cancer ko rej walok jen radiation eo ej walok jen atomic bomb.

This means that if there would be **53** people die within the next 30 years from any cancer other than that caused by radiation left from atomic bombs, there might be an additional who die from cancer that is caused by radiation left from atomic bombs.

<p>Jonan lōñlok in ajiri ro bwelen remaroñ lotaktok kin naninmij in utamwe ilo yio kein 30 iman</p> <p>The percentage of children born with health defects within the next 30 year</p>	<p>%</p>	<p>%</p>
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Melelen, bwe elane enaj wor **350** ajiri ro rej lotaktok kin naninmij in utamwe walok jen jabrewot un ko ijellokin radiation eo ej walok jen atomic bomb ilo yio kein 30 iman, emaroñ bar kobatok ajiri rej lotaktok kin naninmij in utamwe walok jen radiation eo ej walok jen atomic bomb.

This means that if there were **350** children born with health defects occurring from any cause other than radiation left from atomic bombs within the next 30 years, there might be an additional children born with defects caused by radiation left from atomic bombs.

Melelen, bwe elane enaj wor **350** ajiri ro rej lotaktok kin naninmij in utamwe walok jen jabrewot un ko ijellokin radiation eo ej walok jen atomic bomb ilo yio kein 30 iman, emaroñ bar kobatok ajiri rej lotaktok kin naninmij in utamwe walok jen radiation eo ej walok jen atomic bomb.

This means that if there were **350** children born with health defects occurring from any cause other than radiation left from atomic bombs within the next 30 years, there might be an additional children born with defects caused by radiation left from atomic bombs.

Jonan radiation eo elaptata bwelen juon armij emaroñ boke iumin juon yio The largest amount of radiation one person might receive during 1 year	millirem	millirem
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Jonan radiation eo iolap (average) bwelen juon armij emaroñ boke iumin 30 yio: ilo aoleben enbwinnin (whole body)	millirem	millirem
ilo nonnonmej iloan dri (bone marrow)	millirem	millirem
Average amount of radiation one person might receive during 30 years		

Jonan lönlok in cancer ko bwelen remaroñ walok ilo yio kein 30 iman The most likely cancer that might occur within the next 30 years	%	%
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Melelen, bwe elane enaj wor 35 armij remij ilo yio kein 30 iman jen jabrewot cancer ijellokin cancer ko rej walok jen radiation eo ej walok jen atomic bomb, emaroñ bar kobatok ro rej mij jen cancer ko rej walok jen radiation eo ej walok jen atomic bomb.

This means that if there would be 35 people die within the next 30 years from any cancer other than that caused by radiation left from atomic bombs, there might be an additional who die from cancer that is caused by radiation left from atomic bombs.

Melelen, bwe elane enaj wor 35 armij remij ilo yio kein 30 iman jen jabrewot cancer ijellokin cancer ko rej walok jen radiation eo ej walok jen atomic bomb, emaroñ bar kobatok ro rej mij jen cancer ko rej walok jen radiation eo ej walok jen atomic bomb.

This means that if there would be 35 people die within the next 30 years from any cancer other than that caused by radiation left from atomic bombs, there might be an additional who die from cancer that is caused by radiation left from atomic bombs.

Jonan lönlok in ajiri ro bwelen remaroñ lotaktok kin naninmij in utamwe ilo yio kein 30 iman The greatest number of children born with health defects within the next 30 years	%	%
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Melelen, bwe elane enaj wor 235 ajiri ro rej lotaktok kin naninmij in utamwe walok jen jabrewot un ko ijellokin radiation eo ej walok jen atomic bomb ilo yio kein 30 iman, emaroñ bar kobatok ajiri rej lotaktok kin naninmij in utamwe walok jen radiation eo ej walok jen atomic bomb.

This means that if there were 235 children born with health defects occurring from any cause other than radiation left from atomic bombs within the next 30 years, there might be an additional children born with defects caused by radiation left from atomic bombs.

Melelen, bwe elane enaj wor 235 ajiri ro rej lotaktok kin naninmij in utamwe walok jen jabrewot un ko ijellokin radiation eo ej walok jen atomic bomb ilo yio kein 30 iman, emaroñ bar kobatok ajiri rej lotaktok kin naninmij in utamwe walok jen radiation eo ej walok jen atomic bomb.

This means that if there were 235 children born with health defects occurring from any cause other than radiation left from atomic bombs within the next 30 years, there might be an additional children born with defects caused by radiation left from atomic bombs.

<p>Jonan radiation eo elaptata bwelen juon armij emaroñ boke iumin juon yio</p> <p>The largest amount of radiation one person might receive during 1 year</p>	millirem	millirem
<p>Jonan radiation eo iolap (average) bwelen juon armij emaroñ boke iumin 30 yio: ilo aoleben enbwinnin (whole body)</p> <p>ilo nonnonmej iloa dri (bone marrow)</p> <p>Average amount of radiation a person might receive during 30 years</p>	millirem millirem	millirem millirem
<p>Jonan löñlok in cancer ko bwelen remaroñ walok ilo yio kein 30 iman</p> <p>The percentage of cancer that might occur within the next 30 years</p>	%	%

Melelen, bwe elane enaj wor **83** armij remij ilo yio kein 30 iman jen jabrewot cancer ijellokin cancer ko rej walok jen radiation eo ej walok jen atomic bomb, emaroñ bar kobatok . . . ro rej mij jen cancer ko rej walok jen radiation eo ej walok jen atomic bomb.

This means that if there would be **83** people die within the next 30 years from any cancer other than that caused by radiation left from atomic bombs, there might be an additional . . . who die from cancer that is caused by radiation left from atomic bombs.

Melelen, bwe elane enaj wor **83** armij remij ilo yio kein 30 iman jen jabrewot cancer ijellokin cancer ko rej walok jen radiation eo ej walok jen atomic bomb, emaroñ bar kobatok . . . ro rej mij jen cancer ko rej walok jen radiation eo ej walok jen atomic bomb.

This means that if there would be **83** people die within the next 30 years from any cancer other than that caused by radiation left from atomic bombs, there might be an additional . . . who die from cancer that is caused by radiation left from atomic bombs.

<p>Jonan löñlok in ajiri ro bwelen remaroñ lotaktok kin naninmij in utamwe ilo yio kein 30 iman</p> <p>The percentage of children born with health defects within the next 30 years</p>	%	%
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Melelen, bwe elane enaj wor **550** ajiri ro rej lotaktok kin naninmij in utamwe walok jen jabrewot un ko ijellokin radiation eo ej walok jen atomic bomb ilo yio kein 30 iman, emaroñ bar kobatok . . . ajiri rej lotaktok kin naninmij in utamwe walok jen radiation eo ej walok jen atomic bomb.

This means that if there were **550** children born with health defects occurring from any cause other than radiation left from atomic bombs, within the next 30 years, there might be an additional . . . children born with defects caused by radiation left from atomic bombs.

Melelen, bwe elane enaj wor **550** ajiri ro rej lotaktok kin naninmij in utamwe walok jen jabrewot un ko ijellokin radiation eo ej walok jen atomic bomb ilo yio kein 30 iman, emaroñ bar kobatok . . . ajiri rej lotaktok kin naninmij in utamwe walok jen radiation eo ej walok jen atomic bomb.

This means that if there were **550** children born with health defects occurring from any cause other than radiation left from atomic bombs, within the next 30 years, there might be an additional . . . children born with defects caused by radiation left from atomic bombs.

Jonan <i>radiation</i> eo elaptata bwelen juon armij emaroñ boke iumin juon yio The largest amount of radiation one person might receive during 1 year	millirem	millirem
---	----------	----------

Jonan <i>radiation</i> eo iolap (average) bwelen juon armij emaroñ boke iumin 30 yio: ilo aoleben enbwinnin (whole body)	millirem	millirem
ilo nonnonmej iloan dri (bone marrow)	millirem	millirem
Average amount of radiation a person might receive during 30 years		

Jonan lōñlok in cancer ko bwelen remaroñ walok ilo yio kein 30 iman The amount of cancer that might occur within the next 30 years	%	%
---	---	---

Melelen, bwe elane enaj wor **53** armij remij ilo yio ken 30 iman jen jabrewot cancer ijellokin cancer ko rej walok jen radiation eo ej walok jen atomic bomb, emaroñ bar kobatok ro rej mij jen cancer ko rej walok jen radiation eo ej walok jen atomic bomb.

This means that if there would be **53** people die within the next 30 years from any cancer other than that caused by radiation left from atomic bombs, there might be an additional who die from cancer that is caused by radiation left from atomic bombs.

Melelen, bwe elane enaj wor **53** armij remij ilo yio kein 30 iman jen jabrewot cancer ijellokin cancer ko rej walok jen radiation eo ej walok jen atomic bomb, emaroñ bar kobatok ro rej mij jen cancer ko rej walok jen radiation eo ej walok jen atomic bomb.

This means that if there would be **53** people die within the next 30 years from any cancer other than that caused by radiation left from atomic bombs, there might be an additional who die from cancer that is caused by radiation left from atomic bombs.

Jonan lōñlok in ajiri ro bwelen remaroñ lotaktok kin naninmij in utamwe ilo yio kein 30 iman The probability of children born with health defects within the next 30 years	%	%
---	---	---

Melelen, bwe elane enaj wor **350** ajiri ro rej lotaktok kin naninmij in utamwe walok jen jabrewot un ko ijellokin radiation eo ej walok jen atomic bomb ilo yio kein 30 iman, emaroñ bar kobatok ajiri rej lotaktok kin naninmij in utamwe walok jen radiation eo ej walok jen atomic bomb.

This means that if there were **350** children born with health defects occurring from any cause other than radiation left from atomic bombs, within the next 30 years, there might be an additional children born with defects caused by radiation left from atomic bombs.

Melelen, bwe elane enaj wor **350** ajiri ro rej lotaktok kin naninmij in utamwe walok jen jabrewot un ko ijellokin radiation eo ej walok jen atomic bomb ilo yio kein 30 iman, emaroñ bar kobatok ajiri rej lotaktok kin naninmij in utamwe walok jen radiation eo ej walok jen atomic bomb.

This means that if there were **350** children born with health defects occurring from any cause other than radiation left from atomic bombs, within the next 30 years, there might be an additional children born with defects caused by radiation left from atomic bombs.

Jonan radiation eo elaptata bwelen juon armij emaroñ boke iumin juon yio	millirem	.....	millirem
The largest amount of radiation one person might receive during 1 year			

Jonan radiation eo lolap (average) bwelen juon armij emaroñ boke iumin 30 yio: ilo aoleben enbwinnin (whole body)	millirem	.....	millirem
ilo nonnonmej iloan dri (bone marrow)	millirem	.....	millirem
Average amount of radiation a person might receive during 30 year			

Jonan lönlok in cancer ko bwelen remaroñ walok ilo yio kein 30 iman .....	%	.....	%
The percentage of cancer that might occur within the next 30 years			

Melelen, bwe elane enaj wor armij remij ilo yio kein 30 iman jen jabrewot cancer ijellokin cancer ko rej walok jen radiation eo ej walok jen atomic bomb, emaroñ bar kobatok ro rej mij jen cancer ko rej walok jen radiation eo ej walok jen atomic bomb.

This means that if there would be people die within the next 30 years from any cancer other than that caused by radiation left from atomic bombs, there might be an additional who die from cancer that is caused by radiation left from atomic bombs.

Melelen, bwe elane enaj wor armij remij ilo yio kein 30 iman jen jabrewot cancer ijellokin cancer ko rej walok jen radiation eo ej walok jen atomic bomb, emaroñ bar kobatok ro rej mij jen cancer ko rej walok jen radiation eo ej walok jen atomic bomb.

This means that if there would be people die within the next 30 years from any cancer other than that caused by radiation left from atomic bombs, there might be an additional who die from cancer that is caused by radiation left from atomic bombs.

Jonan lönlok in ajiri ro bwelen remaroñ lotaktok kin naninmij in utamwe ilo yio kein 30 iman .....	%	.....	%
The percentage of children born with health defects within the next 30 years			

Melelen, bwe elane enaj wor ajiri ro rej lotaktok kin naninmij in utamwe walok jen jabrewot un ko ijellokin radiation eo ej walok jen atomic bomb ilo yio kein 30 iman, emaroñ bar kobatok ajiri rej lotaktok kin naninmij in utamwe walok jen radiation eo ej walok jen atomic bomb.

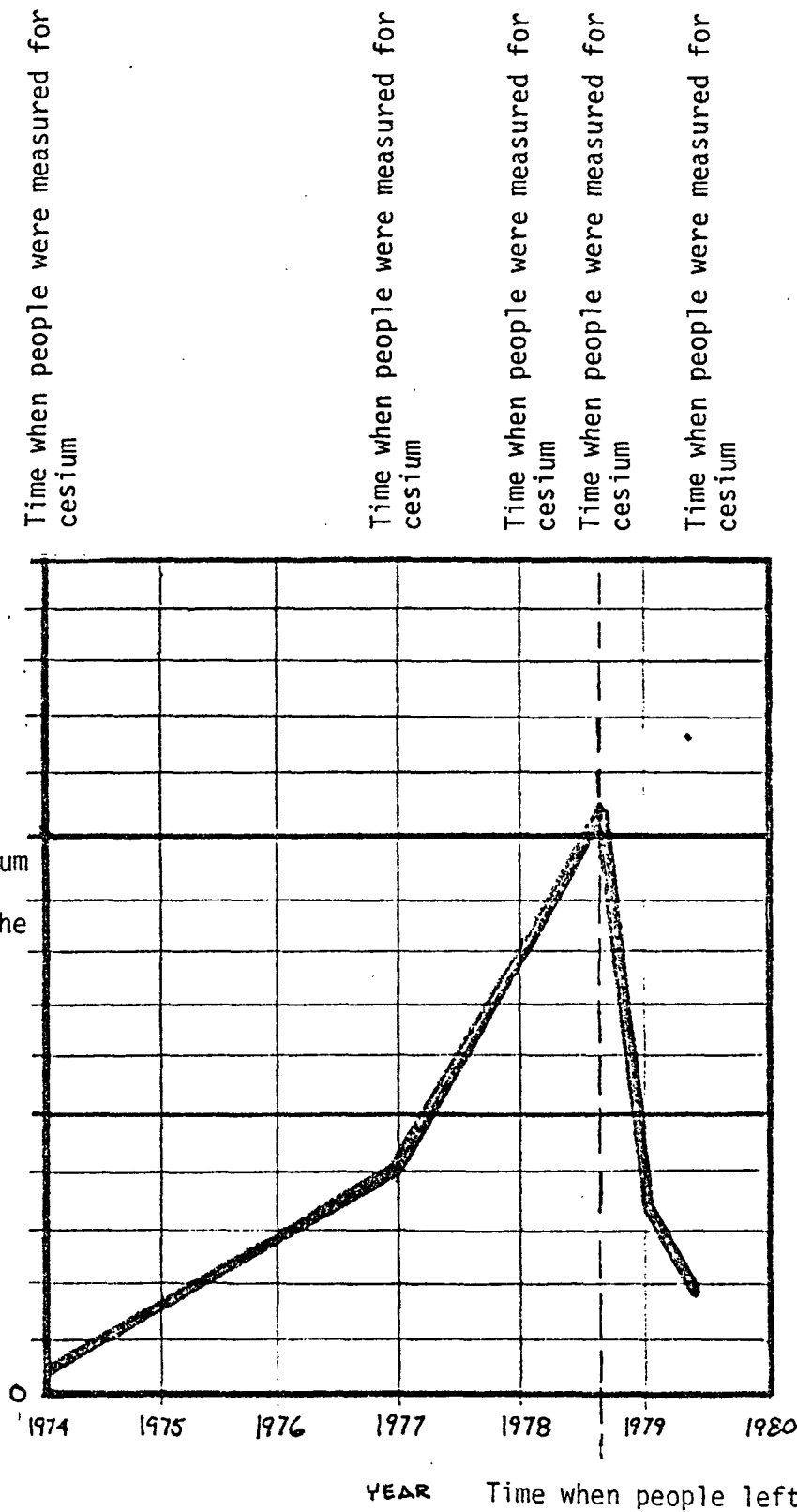
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Melelen, bwe elane enaj wor ajiri ro rej lotaktok kin naninmij in utamwe walok jen jabrewot un ko ijellokin radiation eo ej walok jen atomic bomb ilo yio kein 30 iman, emaroñ bar kobatok ajiri rej lotaktok kin naninmij in utamwe walok jen radiation eo ej walok jen atomic bomb.

This means that if there were children born with health defects occurring from any cause other than radiation left from atomic bombs, within the next 30 years, there might be an additional children born with defects caused by radiation left from atomic bombs.

The amount of radioactive atoms of cesium that will produce radiation equal to the radiation standard

One-half of the radiation standard



for discussion in 1978

- ¶ 4 - sentence 3 in Review 2
 spelling of island names
 Islands VS island
 - ¶ 119 - ?
 Set vs cost
 - 26 a - island translation need
 - 32 - why change last sentence
 - 12 - Need to compare books of text
 - 42 - WATO ?
 - 5 - Army on all in last line
- (To do 9 in sub to the 1st line of text (1978)
 A on

(Need - further line on titles - year of text
 Birds ¶ 9 - Do Make

Barans

¶ 33 - more to
 review

Page 8 - The islands

Surface notes game, Henry Koon
 71 20 - ... and ...
 106

Dennis Prager

Off of Science & Technology Policy

Fed. Coordinating Council for
Science Engineering & Technology

Statutory Office

Old Executive Office Bldg

17th & Penn Ave N.W.

Wash

20520

tell

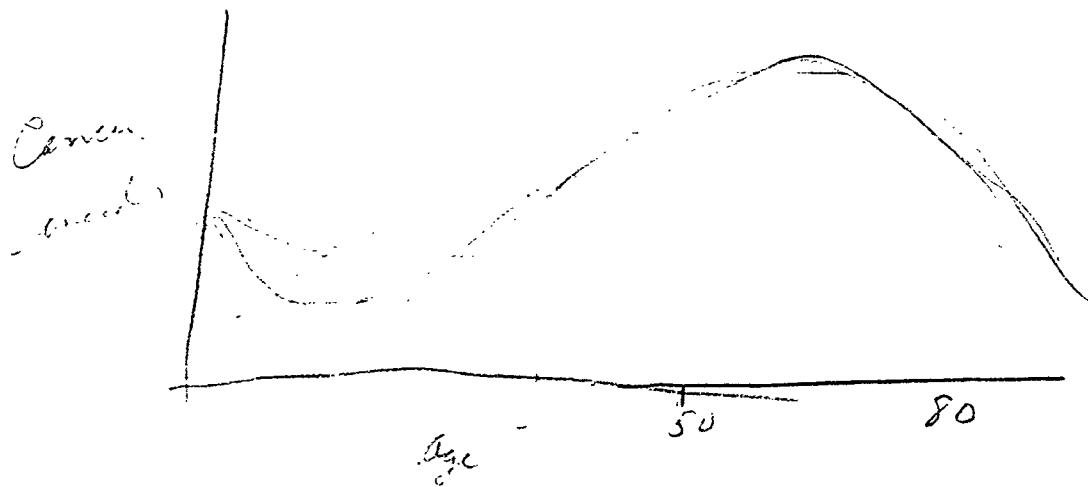
456 - 6272

Wick Carter

629 - 3205

The way Radiation affects the body
 How Radiation can affect people's body

1st year



Title - The Meaning of
 Radiation at Bikini Atoll

1/12

~~The~~ Meaning of
 Radiation at Bikini Atoll

glossary -

perhaps we should have stressed ~~the~~ radionuclides
as toxic substances - a ^{special} kind of poison

~~Radionuclides - become less poisonous with~~

Some ~~of~~ poisons lose their power to harm people
- bacteria etc die
- chemicals

Radioactive Poisons

Some last for years
- uranium

Some last for 1000 years - radium

Some radionuclides last almost for ever

Some last for 10000 years, etc.

Two groups -
to clean up

to plant
ade. with American + cats fish
some coconuts + some pandanus
which they ate
Some trees were not cut down

After American left - where did food come from?

George _____ a Japanese Hawaiian - was still there
Food was brought from Kwajalein

First group was to return to Rukin - and make
Rukin a permanent reservation of US
could avoid problems that arose to the American
Rukin, located good request
No other choice - to go back to Rukin
But they didn't understand about Rukin

Want to know about radiation in all of the atolls
Birds & fish - are they stable
(I think we had birds & animals of various kinds)
Is there a plan to continue studies of other islands?

We will have info on radioactive waste but not well respect
to health of fish

P. - most important info will be radiation - some of Rukin
What is less important info?

Cells from - Thurs.

Sat,

Tues

What do Bikinis feel is most important

People need to know how much local food can be eaten
How about birds & fish that go to different islands.

Can the book indicate where bombs were tested?

Amount of radiation at said spots where test were

Will we indicate what the dose levels mean in terms of
health?

E 51

HENCHI ZILOS

MOSES LEWIS

ICHIRO (?) MARK

Alpha rad. - not go through skin.

(^{include} Actual data on food?)

~~show fractions of dose from different foods~~
Info - radionuclides in water, fish

21 -

max of chems -
dysent in lungs, etc
absorption into blood

Probability

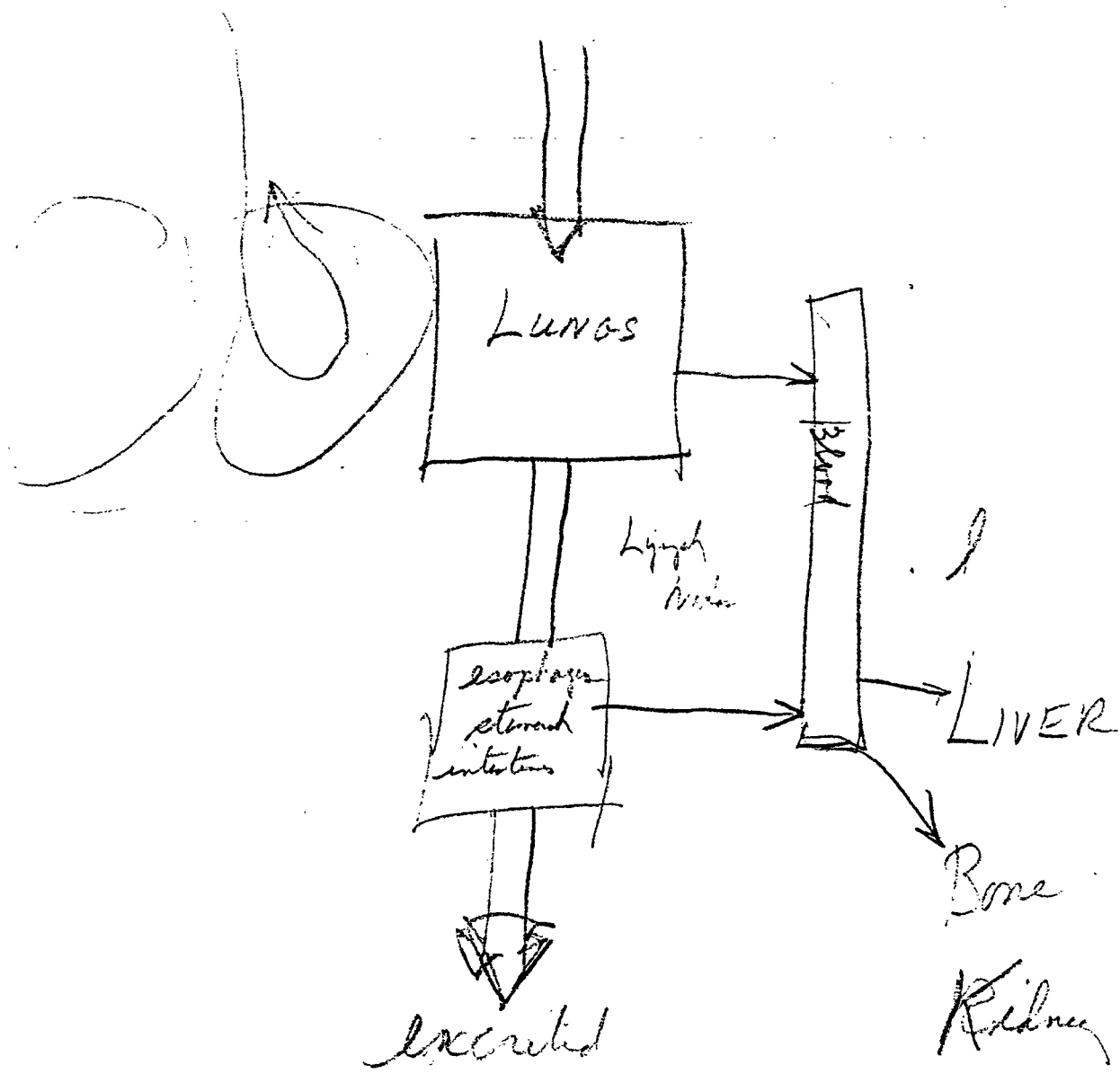
26

13
or half life
Chart

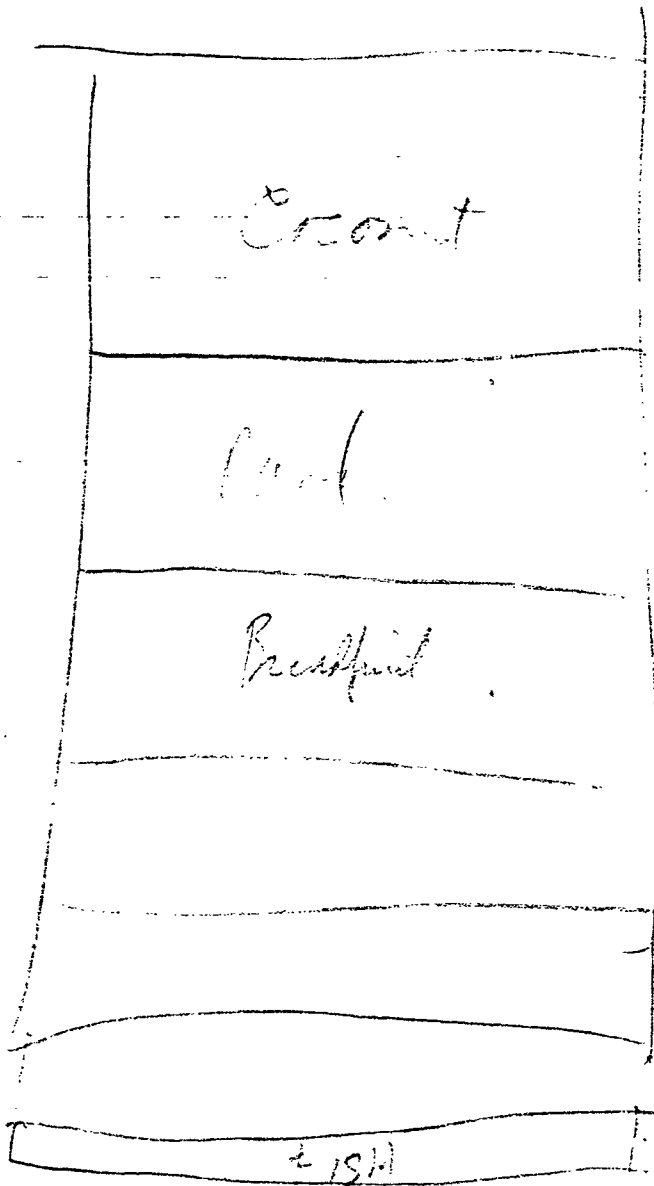
Bone marrow

.7 - Cs
.07 S
4 Est
1.77

6
~~64%~~
30
100



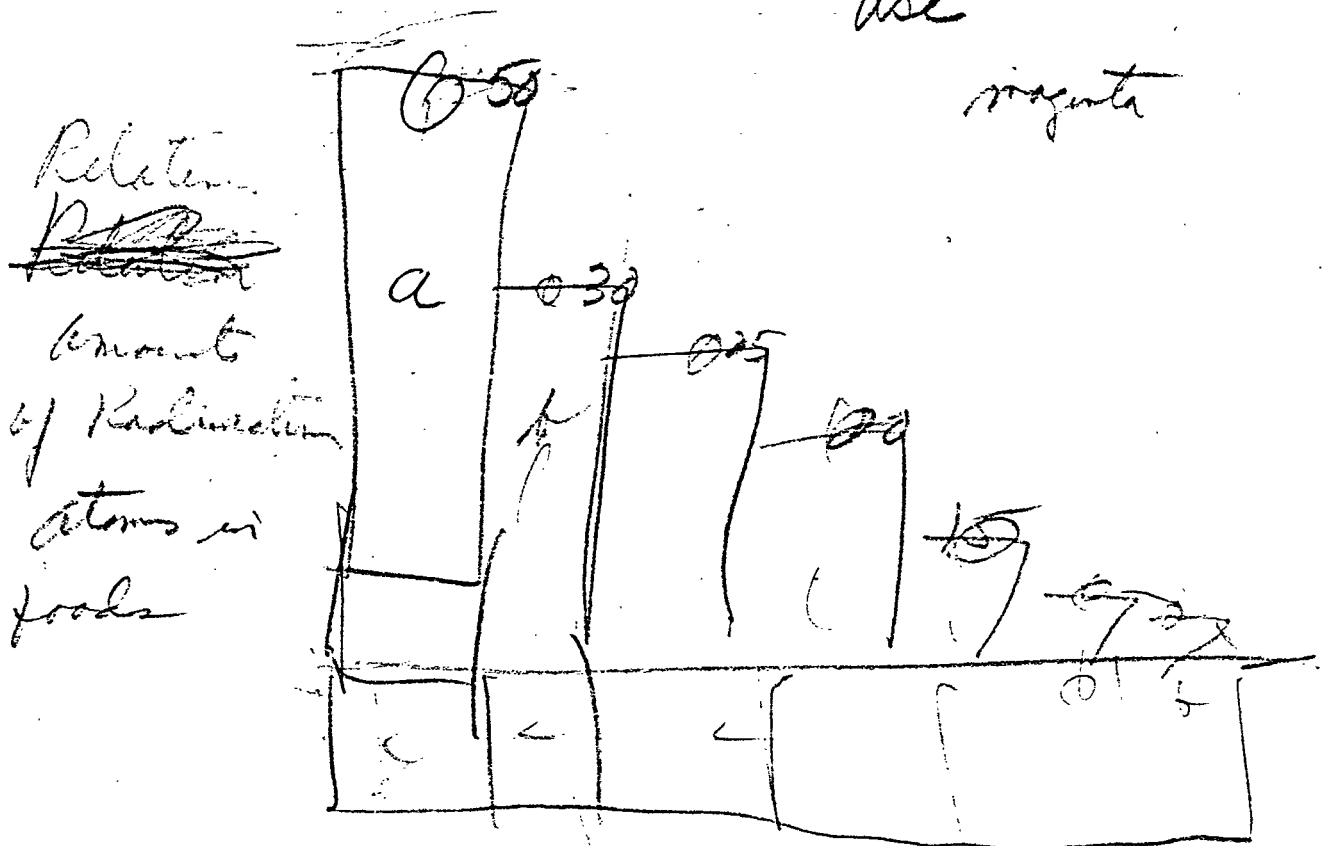
Coconut
Pandanus
Breadfruit
Arrowroot
Fish
Pumpkin
Banana
Papaya
Sweet



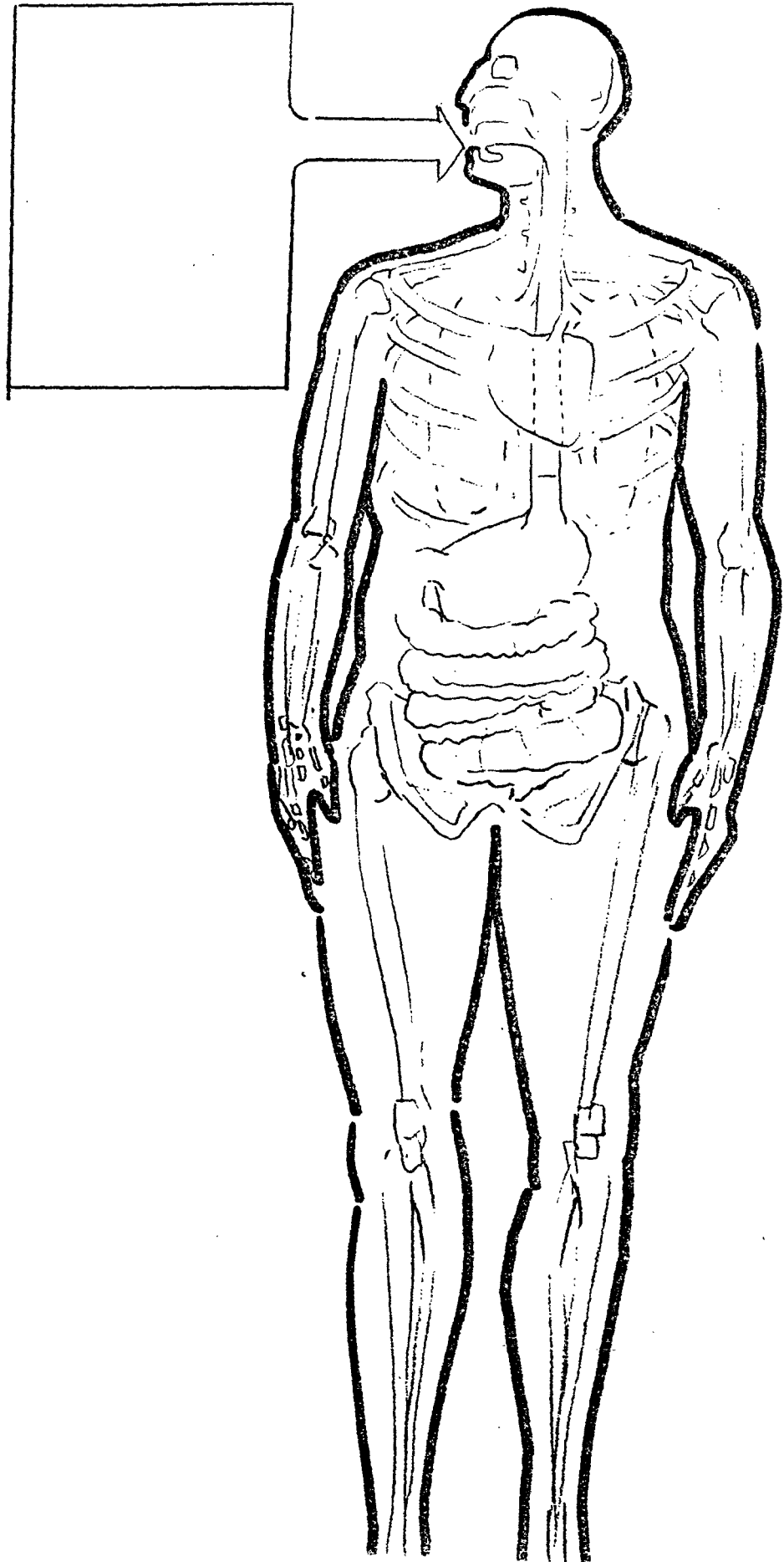
New Chart - page 10

Call Release -

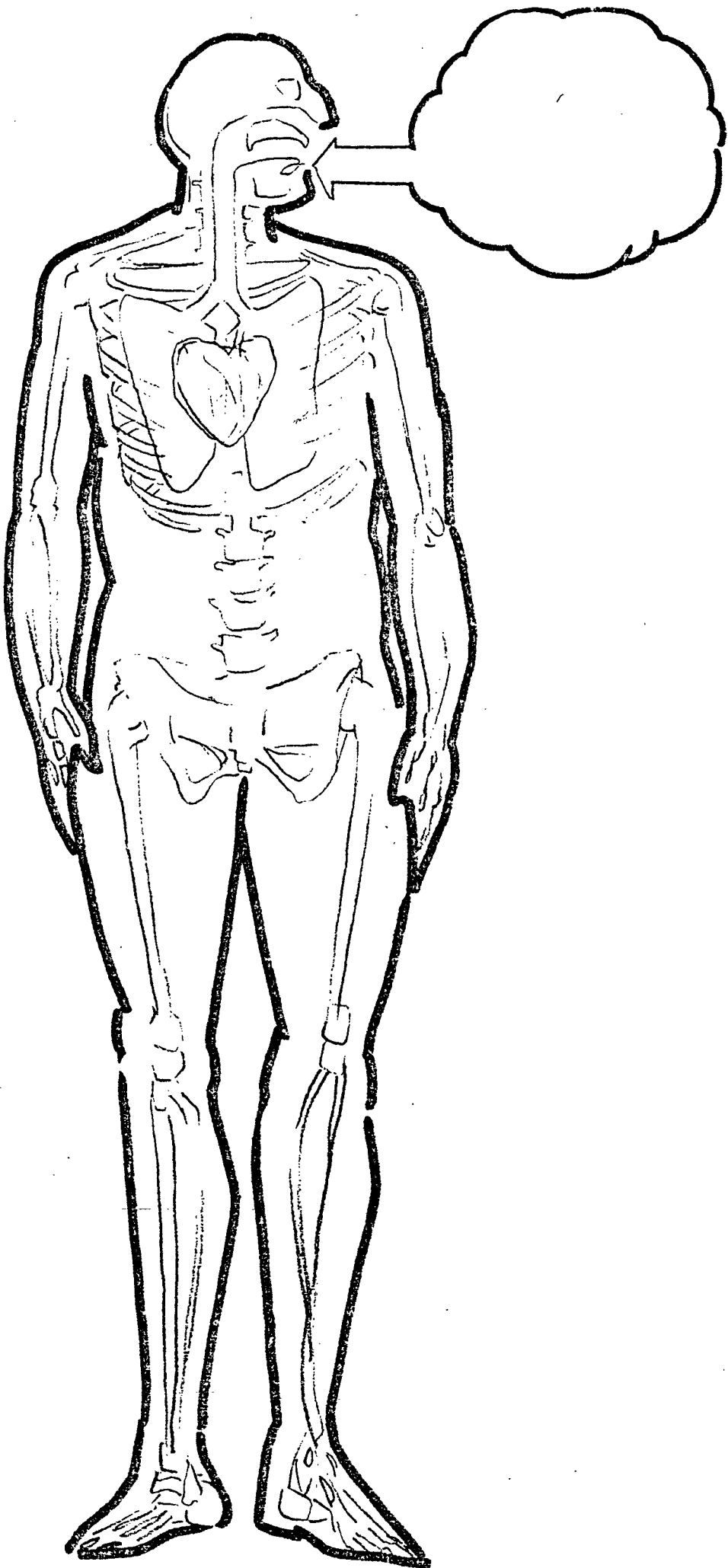
Relation of Energy Use

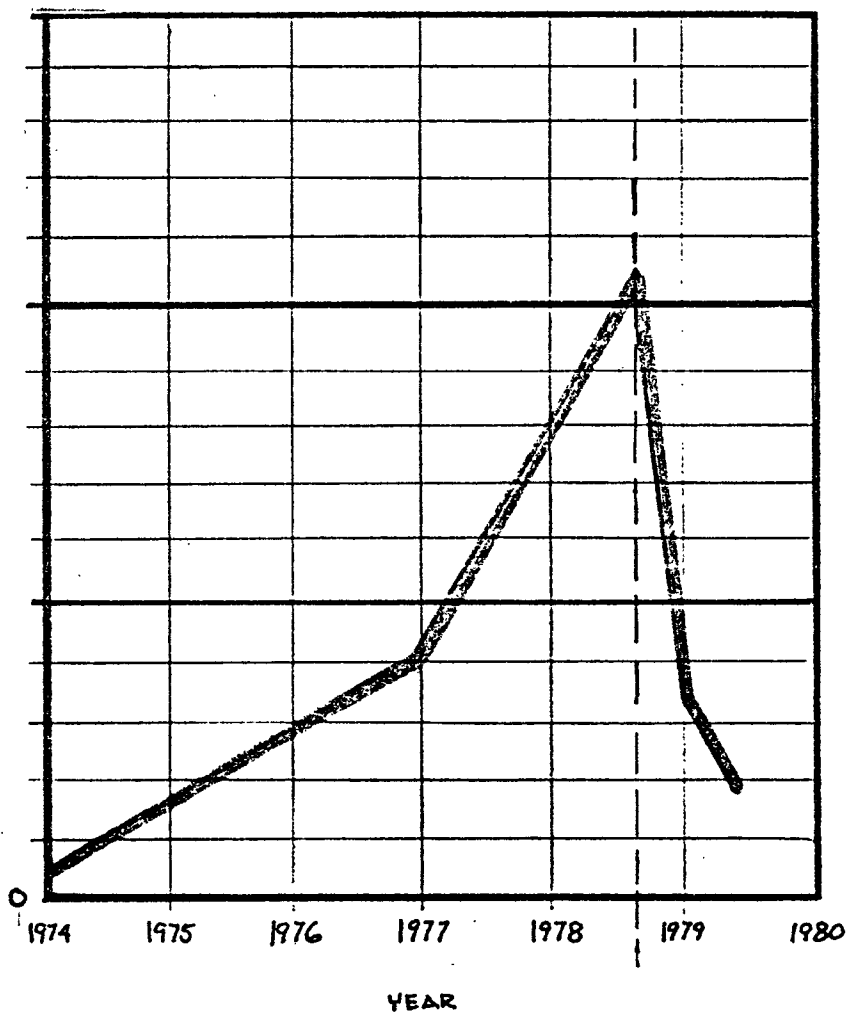


- fish
- bird fruit
- pancakes
- bars, corn
- coconuts
- Coconut cake
- papaya
- banana
- squash
- fruit



B





B

From Ray Baalman Via Telephone, 4/8/80

1. Why is Bikini hotter than Enewetak (They did not explain)
2. We don't know exactly what land is missing though we mention it in the book. Not sure exactly where that is. The people wanted to know about it.
3. We didn't know whether or not coconuts were present on Bikini at the time of the cleanup and if there were why weren't they used to make measurements?
4. We didn't know if we should discuss the 13-Atoll Survey in this book or not. Maybe it is not a good idea. But if we are, we don't know what they found out from it.
5. Have not dealt with the table that needs to be in that will show how much time needs to elapse before they can go back.

What we did was--we went through the Enewetak Book and updated it and changed it quite a bit here and there so Bill will want to pay attention to that. And also, we tried to address all of the questions which Tommy McCraw gave us.

We should receive by telefax about 10 pages and maybe more than that.

We tried to do a new thing in the back for the risk estimates. We decided to try some tables. It would be used to replace all the maps in the back.

Martha - make a copy for Ray before it is sent off with bill and one for the file.

Have Bill Call Jack if not too tied up

4-10 Ray
 Bill
 Martha
 Jack

LOS ALAMOS SCIENTIFIC LABORATORY
 FACSIMILE TRANSMISSION HEADER

Dr. D. L. Brown (MS)
 3.15D 5/15/80

FROM	
J. W. Healy	
ORGANIZATION: H-DO	MAIL STOP: 400
PO BOX 1663, LOS ALAMOS, NEW MEXICO 87545	
LASL FAX NO.	CONFIRMATION NO.
FTS.....843-6937	FTS.....843-5113
COM'L..505-667-6937	COM'L..505-667-5113

NOTE: FAX is intended for the transmission of urgent, unclassified, data that cannot be sent via teletype. Division or Department level approval is required if document exceeds five pages. To avoid delay, sender must fill in Header form completely. For additional instructions, refer to LASL Manual of Office Procedures, Sec. 1, A.

TO	AT	FAX NO.	CONFIRM. N
W. J. Bair	Battelle Pacific Northwest Lab. Richland, Washington	8-444-6540	444-731

I certify that this is an unclassified document and transmission is essential:
David J. Ford April 10 '80
 (Approva) Signature (Date)

HANDLING INSTRUCTIONS TO RECEIVING TELECOPIER:
 (Do not start message text on this sheet)

9645

APR 10 9 49 AM '80

APR 11 12 52 AM '80

BIKINI ATOLL TODAY

INTRODUCTION

In 1946, the Bikini people agreed to leave their home atoll to permit the U.S. to test atomic bombs. In 1968 President Johnson announced the people could return following cleanup of debris left from the tests. Before the people returned the U.S. planted thousands of food-bearing trees and built 40 concrete houses for the people. In 1978 the U.S. government asked the people to leave. This book explains the reason for this request (action) and the present information on the condition of the atoll.

The U. S. Government has prepared this booklet to assist the Bikini people in understanding the effect of the atom bomb testing on their atoll and what that means to the people.

The Marshallese text is a dynamic equivalent translation of an original English draft, and the English text is a modified literal translation of the Marshallese text.

TINY THINGS THAT ARE RADIOACTIVE

Everything on earth is formed from many many tiny things that we cannot see. (These are called atoms.) Some of these things are set apart (distinct) and are alike in a certain way because they change and become other kinds of tiny things that do not change. We say that these tiny things (atoms) that are set apart are radioactive because they do change.

As each tiny thing (atom) changes it produces a kind of energy which we cannot see and which is called "radiation." When they have completely changed, this energy is gone from them. (Further explanation of radiation appears on page 4.)

Of the things that are radioactive some have always been a part of the world. These are God-made and they will not go away. They are in soil, in water, in food-bearing plants and other plants, in animals, and in our bodies.

There are also radioactive things that came from the atomic bombs. Some of these changed quickly - during just a few minutes or days. But the others change slowly and are still present on the islands in the Bikini Atoll. The names of some of the important radioactive things are cobalt, cesium, strontium, plutonium, and americium. One-half of the cobalt will disappear after 5 years. Of the part that remains, one-half will disappear after another 5 years and this process will continue indefinitely. One-half of the cesium and one-half of the strontium will disappear after 30 years. Of the part that remains, one-half will disappear after another 30 years. This process will again continue indefinitely. Plutonium and americium will not change over hundreds and hundreds of years.

ENERGY CALLED RADIATION

The energy from radioactive materials is similar to heat of fire and light of the sun in that it travels from where it is formed to other places; however, we cannot see it, hear it, taste it, smell it, or feel it.

There are three kinds of radiation that come from the earth:

1. alpha radiation - the place it reaches from where it is made is short, perhaps 3 inches surrounding it in air, and a paper can stop it (its movement).
2. beta radiation - the place it reaches from where it is made is farther, perhaps 4 yards surrounding it in air, and things thicker than paper, such as plywood, are needed to stop it.
3. gamma radiation - the place it reaches from where it is formed is very much farther, perhaps 300 yards surrounding it in air, and only those things that are thick and dense, such as cement, huge rocks, and metal, can stop it.

Alpha radiation cannot pass into the skin of people. Beta radiation can pass through the skin and reach about one inch into the body. However, things that are radioactive may enter the body with food and air and can reach the blood, bones, lungs and other parts of the body. When these things that are radioactive change they produce alpha and beta radiation that can reach the internal organs.

When gamma radiation hits people it goes through their bodies, but some of the energy of this radiation remains in their bodies.

Just like in other places around the world, alpha, beta, and gamma radiation have occurred on Bikini Atoll from radioactive things that have been a part of the world since the beginning. There are also kinds of radiation that come from the sky that pass through people's bodies.

At Bikini Atoll some alpha radiation also comes from plutonium and americium. Beta radiation also comes from strontium, cesium, and cobalt.

Bikini

to Why Bikini cannot be cleaned up like Eniwetok

Wiseball

1. What happened in Bikini re fallout
plume of fallout pattern

2. How different from Eniwetok

3.

4. What went wrong - re decision to move people
on + off etc

5. What is risk to people who have been there

6. What would exposure be on 24hr rotation?
(Radium dating)

7. Info on small islands - south end of atoll

8.

Bruce to get

Pop. - for Eniwetok

Sex & age

+ 120 children < 5

for Bikini

Gamma radiation also comes from cesium and cobalt, and a little comes from americium. At Bikini Atoll, the amounts of plutonium and americium are far less than on the Eniwetok Atoll.

TINY PARTICLES AND ASHES OF ATOM BOMBS [FALLOUT]

When an atomic bomb explodes, it takes up materials, such as rock, soil, water, and so forth, which join with the things that are radioactive from the bomb. They rise rapidly into the air, and later fall back down to the earth. The tiny particles and ash of the bombs fell in the lagoon, in the ocean, on the islands, and the winds blew some to places that are far away.

There were 23 atomic bombs tested at Bikini Atoll. Only a few of the atom bomb tests at Bikini occurred on the islands. Most took place in or over the water with some on the reef between the islands. In two atom bomb tests small pieces of the islands of Nam and Enirik were destroyed. In addition, there are 11 U.S. ships sunk in the lagoon at Bikini as a result of an atom bomb test involving ships. The map on page 7 shows the islands where the U.S. government tested these bombs, the portions of the islands that were destroyed, and the location of the sunken ships.

THE PLACES WHERE THE THINGS THAT ARE RADIOACTIVE ARE AT BIKINI

The picture at the right shows the places where the radioactive things are within the soil. Plutonium and americium are in the upper part of the soil. Cesium and strontium are in the soil that is shallow and also in that

which is deep. At Bikini cesium and strontium are the radioactive things that produce the highest amount of radiation. On the northern islands of Enewetak there was more plutonium and americium than at Bikini and the U.S. Government could scrape some of them off because they were near the surface. However, they could not remove the strontium and cesium because they are deeper in the soil.

At Bikini the U.S. Government did pick up all scrap metal and removed scrub growth before the people returned in 1970. The scrap metal was moved to deep water in the ocean and lagoon.

The map on page __ shows where the radioactive things are at the Bikini Atoll. We see that all of the islands in the Bikini atoll have radioactive things. Next to the map of Bikini is a map of Enewetak Atoll showing where the radioactive things are at this atoll. Here we see that the amounts of radioactive things are smaller than at Bikini. The islands in the south of the Enewetak Atoll have a very small amount of radioactivity.

THE WAYS RADIATION ENTERED PEOPLE'S BODIES

People received radiation from radioactive things at Bikini Atoll while they lived there in 2 ways. 1 - radiation that came from the soil and penetrated people's skin and entered the body; 2 - the things that are radioactive in some of the foods that people ate, in some of the water they drank, or in the air they breathed produced radiation inside the body.

The radiation that came up out of the soil came from the cesium and cobalt that was near the surface. Part of the radiation from the cesium and

soil that was deep was unable to reach people because of the thickness of the soil.

As is shown in the picture on page 9, there were radioactive materials in the soil, some in the places where the roots of plants grew. All plants get their food from the soil through their roots. Now, as these plants get their food, some of the things that are radioactive in the soil go up the trunks to the branches and to the fruits.

When people ate the fruits, they also ate the radioactive things there. We can consider that these foods were radioactive. Also, if animals ate these plants, they also ate the things that are radioactive. And if people ate these animals, they also ate the radioactive things that were in the meat. Even if people had cooked food that contained things that are radioactive, the radioactive things in the food would not have gone away.

Since there are radioactive things in the lagoon, there may also be small amounts in the fish. If people ate fish, the amount of radioactivity they received was very small because of the small amounts of radioactivity in the fish.

If radioactive things entered the body, some of them have left it by now and some remains in it, and radiation will continue to come from those left in the body.

THE POSSIBLE EFFECTS OF RADIATION IN PEOPLE'S BODIES

Marshallese people have called radiation "poison." However, the way poison works and the way radiation works are different. Usually, when poison

enters a persons' body (like drinking bleach, kerosene, DDT, etc.) his body is quickly harmed - it can be within a few minutes or days. However, if harm were to come from radiation, it would usually take a long time for it to appear - it could be after many years.

The body contains a number of organs such as lungs, liver, skin. Each of these organs has very small parts called cells that join together to form (all parts of) the body. Remember that there is radiation that has always been a part of the world, and there is radiation that come from atomic bombs. Scientists believe that the more radiation a person receives the more harm he might have. Both the radiation that has been a part of the world and that from atomic bombs can cause harm to the cells of the body. In addition there are other things such as smoking that cause the same kind of damage to cells in the body. Sometimes this kind of damage can come just from the body itself. If this kind of damage occurs, it can cause diseases called cancer.

All cells increase by dividing. It is through this normal process of dividing that growth and repair of the body occur. Cancer happens when cells in the body are damaged and rapidly grow and increase in number more than they should. By doing this, they destroy the healthy parts of the body and can make people get sick. Some people can recover from cancer, but others may not.

Cancer occurred all over the world before there were atomic bombs. For example, if there were 100 people who died around the world from any cause, about 15 of them would have died from cancer. The diseases of cancer continue to occur around the world.

The cancers that are caused by radiation are no different from the cancers that are caused by other things. If the diseases of cancer appear

among the people who have received radiation, they would be no different from those that appear in other people around the world. The scientists have found that a radioactive element that came from the atomic bomb tests can cause cancer in the throat (in the thyroid). This radioactive material remains only a few months, so that it is gone from Bikini Atoll today.

Among the people of any country there are children born with diseases and infirmities that are inherited. Some of these are: deafness, blindness, malformations, mental retardation, etc. These kinds of defects occurred in the Marshall Islands before the atomic bomb tests and they continue to occur today. In a community in which people have received radiation, there might be an increase in the number of children born with defects.

THE WAYS THAT SCIENTISTS KNOW THE AMOUNT OF RADIATION A PERSON RECEIVES

Everybody in the world has some radioactive materials in their body. People cannot know by themselves how much radiation is in any thing or in their bodies because they cannot see it, hear it, taste it, smell it, or feel it. Only instruments can reveal this. There are instruments for measuring things that are radioactive in the soil and in food; there are those for measuring the radiation that comes from the soil. Scientists use these instruments to get information in order to be able to estimate the amount of radiation that people can receive if they live in an area containing radioactive things.

The picture at the left shows the instrument that scientists use to measure the amount of gamma radiation that comes from radioactive materials in

the body. Scientists have brought this instrument to Bikini to measure the amounts of radioactive things in the bodies of the Bikini people. The scientists found that as the food-bearing trees began to produce fruit, the amount of radioactive things in the bodies of the people increased. By 1978, the amounts of radioactive things in peoples bodies were higher than scientists had estimated when the people were told that they could return. This is the reason that they were removed from Bikini Atoll.

Scientists can use this machine to measure the amount of cesium and cobalt in a person, but this device is not able to measure plutonium, americium, and strontium. The way they measure these three things, they take urine and measure the amount of things that are radioactive in it. From doing this they are able to estimate how much plutonium, americium, and strontium is in a person's body.

THE AMOUNT OF RADIATION THAT HAS BEEN ESTABLISHED (A LIMIT IS IMPLIED)

(RADIATION STANDARDS)

No one is absolutely certain how much radiation a person can receive and not have harm to his body. Around the world, many groups of scientists and doctors are studying this subject. The names of some of these organizations are: International Commission on Radiological Protection, U.S. Environmental Protection Agency, and the International Atomic Energy Agency. To protect people from the harm they might receive from radiation, and based upon the information they have found, these organizations have recommended some amounts of radiation that people should not exceed. These organizations also

recommend that people try to take care that the amount of radiation that enters their bodies should be as small as possible. This means that people should stay away from areas where the amount of radiation is known to be high and should not eat foods grown in such areas. Many governments have approved these recommendations.

Therefore, the U.S. government has established an amount of radiation for the American people that they should not exceed. This amount is the same as the amount that organizations above have recommended. They call this amount that they have established a "radiation standard," and the standard is expressed in "millirem."

The U.S. government has established that a person should not receive more than 500 millirem in one year. Also they established that the average amount of radiation a man or a woman who lives in the United States may receive over a 30-year period should not be more than 5000 millirem. The U.S. government tries to ensure as much as possible that the amount of radiation its citizens receive in everyday living or working is lower than the figures above.

The measurements of the Bikini people made by the scientists in 1978 indicated that some of the Bikini people were receiving more radiation each year than this standard. A few of the people were receiving amounts of radiation about twice as large as the standard. Because this amount of radiation was received for a short time, the harm expected will be very small.

However, the U.S. government believed that it was in the best interest of the Bikini people to move them so that the possible harm that could result from additional amounts of radiation will not occur.

10

THE WAYS THAT SCIENTISTS ARE ABLE TO ESTIMATE THE AMOUNT OF RADIATION A PERSON MIGHT RECEIVE IF HE LIVES WHERE THERE IS RADIATION FROM THE ATOMIC BOMB

As a result of many studies and measurements, scientists are able to estimate the amount of radiation that people might receive if they live on an atoll where radiation from the atomic bomb is present.

They dig many holes, some shallow and some deep, take portions of soil from them, and measure the amount of radiation in each of these portions of soil. They examine salt water from the ocean and the lagoon and water from brackish wells. They take fish and other sea life and study them. They also examine the amount of radioactive things that food-bearing trees and other plants take from the soil. They also examine the radioactivity in the dust in the air.

This is the information that the scientists find as a result of the activities above.

1. The amount of things that are radioactive on each of the islands.
2. What kind of radioactive things are on each of these islands.
3. Where in the soil these radioactive elements are.
4. The amount of radiation that comes from the soil.
5. The amount of things that are radioactive in the soil that will enter foods, plants and animals.
6. How much the lagoon and the ocean are radioactive and also food from them, such as fish, crabs, lobsters, clams, etc.
7. How much the brackish wells and drinking water are radioactive.

8. How many radioactive things are in the dust in the air that people will breathe.

Even with all of this information it is difficult to know the amount of radiation a person will receive because we do not know how much of each kind of food each person eats. Some foods have more of things that are radioactive than other foods. A person who eats more of the foods that have more of the things that are radioactive will receive more radiation. A person who eats smaller amounts of these foods will receive less radiation.

WHY THE PEOPLE WERE ALLOWED TO RETURN TO BIKINI ATOLL

In 19__ the Bikini people asked the U.S. government to permit them to return to their homeland. The U.S. government cleaned up the scrap left from the tests and the scientists measured the amounts of radioactivity in the soils, water, and fish. From this information they estimated the amounts of radiation that the people might receive when they returned. Because these estimates were lower than the standard, the people were allowed to return in 1970.

In these estimates measurements of radioactive things in foodstuffs were not possible on the islands because food-bearing trees were not present. Estimates of the amount of radioactive things in fruits from these trees were made from information from other places around the world. Because the soils of the Bikini Atoll (and other atolls) are different from soil at these other places, it was found that the fruits contained more cesium than was anticipated. In addition, estimates of the amounts of food from these trees

that would be eaten by the people have since been found to be low. Thus, when the coconut trees and other food-bearing plants reached an age where fruits became available, this cesium was transferred to the bodies of the people.

When these high radiation levels were found in the people in 1978, it was realized that the initial estimates of the amount of radiation were low and the people were removed from the atoll.

DIFFERENCES BETWEEN BIKINI ATOLL AND ENEWETAK ATOLL

Some people wonder why the U.S. government did not clean up Bikini Atoll the way they did Enewetak Atoll.

The reason is that the atom bomb tests had different effects on the two atolls. Some of the differences are given below.

1. The northern islands on the Enewetak Atoll had much more plutonium and americium in the soils than does Bikini Atoll. This was because of the difference in the types of tests at the two atolls. It was noted earlier that plutonium and americium remain radioactive for many, many years and that the plutonium and americium remain near the surface of the soil. Therefore, some of the plutonium and americium at Enewetak could be removed by shallow scraping without destroying the island. This meant that when the strontium and cesium disappeared, the island could be used. Without the cleanup, the northern islands of the Enewetak Atoll would never have been used. However, the strontium and the cesium on the northern islands of Enewetak Atoll remained even after the cleanup.

2. At Enewetak, the atom bomb tests were done in the northern islands. As a result, the things that are radioactive are mostly in these northern islands and the southern islands have few things that are radioactive. At Bikini Atoll, the things that are radioactive are on all of these islands. There is no island that is free from radiation.

THE UNDERSTANDINGS THAT HAVE BEEN ACHIEVED FROM THE MEASUREMENTS

From the measurements that have been explained earlier in this book and a better understanding of the foods people eat, scientists have estimated again the amounts of radiation that people might receive if they lived on Bikini Atoll. The results of these studies are given on pages ___ through ___. The information on these pages gives the amount of radiation people might receive if they were to spend different amounts of time each year on the islands of Eneu and Bikini. This information shows the amount of radiation that would be received if no food came from other places and also if ships arrived regularly with food from outside. This information also shows the amount of radiation people would receive if food from outside did not arrive 25% of the time. All of this information is given so that the Bikini people can better understand the importance of the foods and the places they live.

Some people may ask why they cannot return and live on Eneu only because the amount of radiation people might receive is below the standard if food from the outside is available. The U.S. government believes that living on the small island of Eneu and not visiting Bikini and other islands would be very difficult for the people. To protect the health of the people, the U.S.

government believes that return to the atoll should be delayed until people can go to the island of Bikini and other islands of the atoll. The estimated times until the amount of radiation a person will receive at Bikini atoll will be below the standard are given on page ___.

Scientists using this [and other] information can estimate the numbers of people who might get sick or unhealthy according to the amount of radiation they receive. A scientific organization in the United States named The National Academy of Sciences - National Research Council's Committee on the Biological Effects of Ionizing Radiation has estimated the number of people who might die from cancer and the number of infants who might be born physically or mentally defective as a result of radiation. If people lived on Eneu or Bikini, the number of people who might die from cancers caused by radiation and the number of infants who might be born with health defects caused by radiation are given on pages ___ to ___. These numbers depend upon the information of the scientists in the organization named above.

All the numbers on pages ___ to ___ depend upon the information the scientists obtained. However, further studies are being done on these matters. If new information causes significant changes in these numbers, the people of Bikini will be informed.

THE AMOUNT OF RADIATION THAT A PERSON MIGHT RECEIVE IN ONE YEAR
IF HE LIVED ON BIKINI ATOLL

If People Live ↓	If they will eat food from their atoll only	If they will eat food from their atoll with food from the outside	Food from outside does not arrive 25% of the time
1. All the time on Eneu.	714 millirem	354 millirem	444 millirem
2. 11 months per year on Eneu and 1 month on Bikini. All food from Eneu.	768 millirem	405 millirem	496 millirem
3. 6 months on Eneu per year and 6 months on Bikini.	3270 millirem	1689 millirem	2084 millirem
4. All the time on Bikini.	5823 millirem	3021 millirem	3722 millirem

Remember that the U.S. standard is 500 millirem in one year.

THE ESTIMATED ADDITIONAL NUMBER OF PEOPLE WHO MIGHT GET CANCER AS
A RESULT OF THE RADIATION RECEIVED IN THE FIRST 30 YEARS

If People Live ↓	If they will eat food from their atoll only	If they will eat food from their atoll with food from the outside	Food from outside does not arrive 25% of the time
1. All the time Eneu	0.46	0.22	0.28
2. 11 months per year on Eneu and 1 month on Bikini.	0.49	0.26	0.31
3. 6 months on Eneu per year and 6 months on Bikini.	4.2	2.1	2.6
4. All the time on Bikini.	9.2	4.6	5.8

For numbers 1 and 2 scientists believe that 200 people would live on Eneu.

For number 3, scientists believe that 200 people would live on Eneu and 200 people would live on Bikini Island.

For number 4, scientists believe that 500 people would live on Bikini Island.

THE AMOUNT OF RADIATION THAT A PERSON MIGHT RECEIVE IN 30 YEARS
IF HE LIVED ON BIKINI ATOLL

If People Live ↓	If they will eat food from their atoll only		If they will eat food from their atoll with food from the outside		Food from outside does not arrive 25% of the time	
	Whole Body	Bone Marrow	Whole Body	Bone Marrow	Whole Body	Bone Marrow
1. All the time Eneu.	4,600 millirem	5,800 millirem	2,400 millirem	2,800 millirem	2,950 millirem	3,550 millirem
2. 11 months per year on Eneu and 1 month on Bikini. All food from Eneu.	3,000 millirem	6,100 millirem	2,800 millirem	3,200 millirem	3,350 millirem	3,925 millirem
3. 6 months on Eneu per year and 6 months on Bikini.	22,000 millirem	26,000 millirem	12,000 millirem	13,000 millirem	14,500 millirem	16,250 millirem
4. All the time on Bikini	40,000 millirem	46,000 millirem	21,000 millirem	23,000 millirem	25,750 millirem	28,750 millirem

Remember that the U.S. standard is 5000 millirem in 30 years.

THE ESTIMATED ADDITIONAL NUMBER OF CHILDREN WHO MIGHT BE BORN WITH HEALTH
OR MENTAL DEFECTS AS A RESULT OF THE AMOUNT OF RADIATION
RECEIVED IN THE FIRST 30 YEARS

If People Live	If they will eat food from their atoll only	If they will eat food from their atoll with food from the outside	Food from outside does not arrive 25% of the time
1. All the time on Eneu.			
2. 11 months per year on Eneu and 1 month on Bikini.			
3. 6 months on Eneu per year and 6 months on Bikini.			
4. All the time on Bikini.			

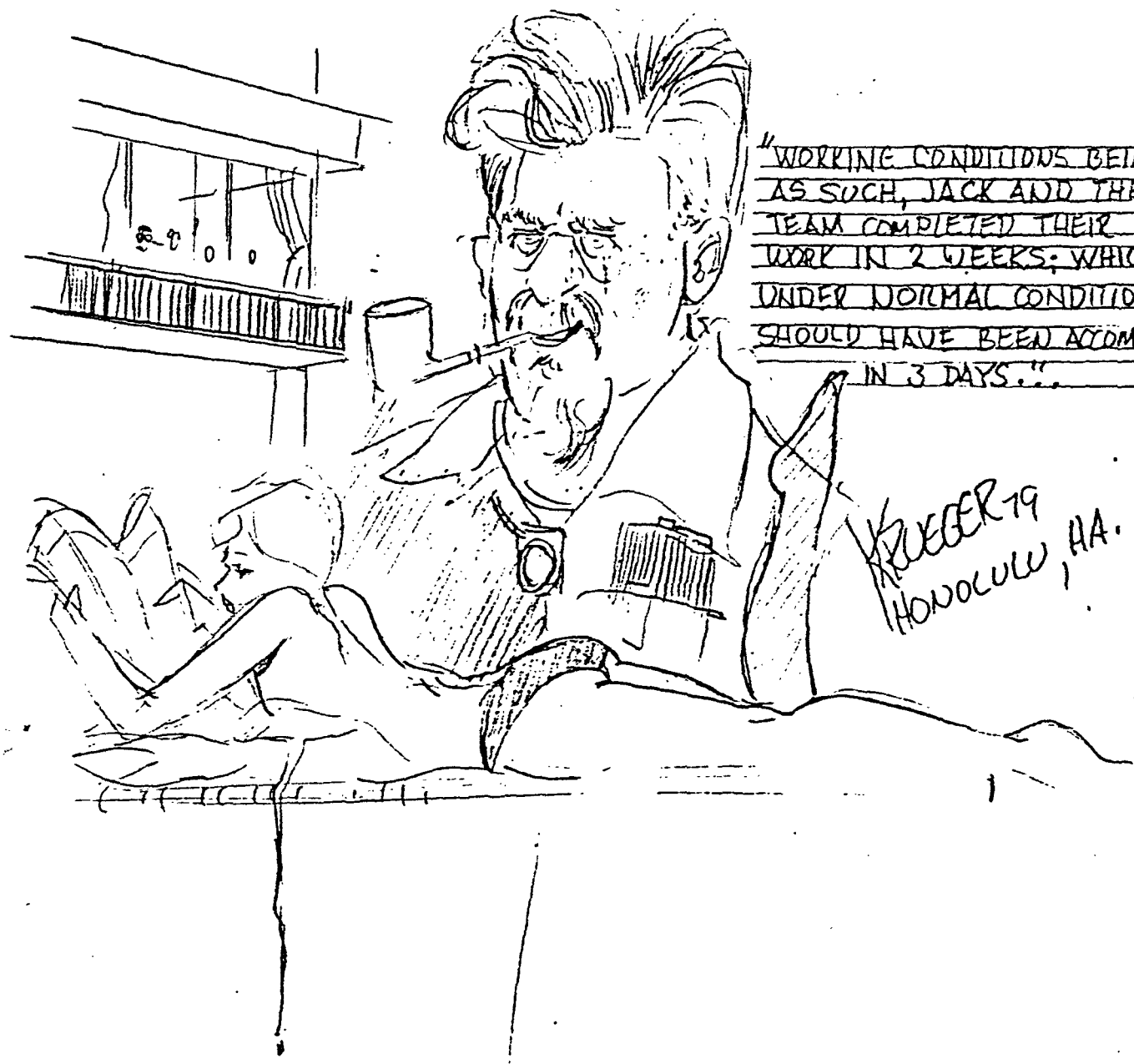
FINAL REMARKS

The scientists who wrote this book realize that many of the concepts described here are difficult to understand. But they hope that the information in the book will help the people to understand why the U.S. government believes that the people should not return to Bikini Atoll until the amount of radiation that people will receive is below the standard.

B

"WORKING CONDITIONS BEING AS SUCH, JACK AND THE TEAM COMPLETED THEIR WORK IN 2 WEEKS; WHICH, UNDER NORMAL CONDITIONS SHOULD HAVE BEEN ACCOMPLISHED IN 3 DAYS."

KRUEGER 79
HONOLULU, HA.



Because the numbers of these radioactive atoms are very large, some of them are ~~constantly~~ changing at any time and are giving off radiation.

Because the numbers of these radioactive atoms are very large, some of them are ~~constantly~~ changing at any time and are giving off radiation.

HARVESTING COCONUT STEMS

By: Alfonso M.R. Mendoza*

B.
HawkSummary

Coconut in the Philippines dates back to pre-Spanish time and since then, has developed into a major industry with 14 million people depending on it. It is however characterized by low productivity because of the increasing number of aging palms and the lack of adequate cultural management inputs. Hence, the government has launched a massive replanting programme to cover the 2.3 million hectares devoted to coconut, which will involve the cutting down of 6 million trees annually.

For technical and economic reasons, it is necessary to properly dispose coconut trunks, hence the great desirability to develop economic uses of the coconut logs. Investigations are now going on along this line, and some limited experiences have been obtained on coconut stem logging, as discussed in this paper.

Introduction

The coconut, Cocos nucifera L. has been cultivated in the Philippines even before the coming of the Spaniards. The Spanish authorities, realizing the economic importance, required the planting of coconuts in 1642. From thereon, the coconut industry grew to become a major crop of the country. By 1910, millions of trees were bearing. Coconut now occupies 2.3 million hectares, providing livelihood to about 14 million people. The Philippines is the leading coconut producer and contributes about 70% to the international trade in coconut products.

Coconut belongs to the palm family, growing favourably within 20° north and south of the equator. It can thrive in altitude as high as 900 meters. As a monocotyledon, coconut has neither

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Diliman, Quezon City, Philippines

a taproot nor a rootstock, but instead thousands of long roots ranging from 1500' to 11,360. The root may extend laterally to about 25 meters while vertical penetration to a depth of 6 meters depending on soil conditions. The trunk or stem attains a considerable height, 20 meters or more depending upon variety, age and environment. With tall coconuts, the base is markedly swollen, whose diameter may reach 1 meter but rarely exceeds 30 to 40 cms at man's height. The crown has some 30 opened leaves supporting fruit bunches at different stages.

The coconut industry is characterized by low productivity. This is due largely to poor quality planting materials, aging palms, and the lack of the necessary cultural requirements. The growing number of old unproductive trees requires the launching of a massive replanting program utilizing high yielding precocious hybrids.

The Replanting Program

The coconut replanting program of the Philippines is a massive undertaking to replace unproductive trees with hybrids. It will cover the whole coconut area at a pace of 60,000 hectares a year. At this rate, it will take about 40 years to complete the cycle, thus making the replanting program a perpetual activity. At the end of the cycle the earliest replants may then be ready for replanting. It is expected that much improved hybrids shall be developed as we progress in the implementation of this replanting program.

Aside from the use of highly productive hybrids, the replanting program will involve the adoption of the required cultural practices and inputs. The mechanics and the criteria in determining priority areas will be set up, to be supplemented with the experiences to be gained in the pilot replanting project being undertaken. The replanting proper commences in 1980, with 1,700 hectares to be replanted, gradually increasing to 60,000 hectares annually beginning 1985. Land preparation which include clear cutting of old

file B

ORIGIN OF RISK COEFFICIENTS

I. BEIR-I
 A. Cancer (Tables 3-3 and 3-4)

	<u>BEIR-I</u>		<u>Derived</u>	
	Cancer Deaths/year in U.S. from 0.1 rem/year (pop=197,863,000)		Cancer Deaths/10 ⁶ person rem	
	<u>Absolute</u>	<u>Relative</u>	<u>Absolute</u>	<u>Relative</u>
Leukemia	516	738	26	37
Other Cancers				
30 year elevated risk	1,210	2,436	61	123
lifetime elevated risk	1,485	8,340	75	421
<hr/>				
Range	1,726-2,001	3,174-9,078	87-101	160-458

B. Birth Defects (page 2)

5 rem/30 years → 100-1800 cases of dominant diseases and defects per year (3.6 million births/year)=0.05% incidence per year (5 X this at equilibrium)

In addition--a few chromosomal defects and recessive diseases and a few congenital defects due to single gene defects and chromosome aberrations

Total incidence is 100 to 27,000/year at equilibrium=0.75% at equilibrium or 0.1% in the first generation

Overall ill health: 5% - 50% of ill health is proportional to mutation rate

Using 20% and doubling dose of 20 rem, 5 rem per generation → 5% increase in ill health

5%/5 rem in 30 years at equilibrium
 or 1%/5 rem in first generation = 0.2%/rem - 30 year dose

II. BEIR-III

A. Cancer (Table V-4)

Lifetime Risk of Cancer Death
(deaths/10⁶/rad)

Model	Single exposure to 10 rad		Continuous Exposure to 1 rad/yr	
	<u>Absolute</u>	<u>Relative</u>	<u>Absolute</u>	<u>Relative</u>
L-Q, $\overline{LQ-L}$	77	226	67	182
L-L, $\overline{L-L}$	167	501	158	430
Q-L, $\overline{Q-L}$	10	28	----	----

B. Birth Defects--pages 166-169
(mean parental age = 30 years)

1 rem per generation (1 rem parental exposure) per 10⁶ live offspring → 5 to 75 birth defects, this is 0.0005
--0.0075%--First generation

Spontaneous rate is 10.7%, thus 1 rem will increase the rate from 10.7% to 10.7005--10.7075%

$$\frac{.0005}{10.7} = 0.000047 = 0.0047\%$$

$$\frac{.0075}{10.7} = 0.0007 = 0.07\%$$

Risk Estimates based on BEIR-III

	Total Person rem	Cancer Risk				30-yr Whole body dose (rem)	Birth Defects (5-15/10 ⁶ /rem)	Spontaneous Number	% Increase
		Relative		Absolute					
		L-Q* 182	L-L 430	L-Q 67	L-L 158				
1	3054	.556	1.31	.205	.483	2.8	.0019-.029	139	.02
2	6108	1.11	2.63	.409	.965	5.4	.0038-.056	139	.04
3	25450	4.63	10.94	1.71	4.02	24.0	.0167-0.25	139	.18
4	47846	8.71	20.57	3.21	7.56	44.0	.0306-0.46	139	.33
5	3461	.63	1.49	.23	.547	3.2	.0022-.033	139	.024
6	6617	1.20	2.85	.44	1.05	5.9	.0041-.062	139	.045
7	957	.174	.41	.064	.15	1.4	.0006-.009	85.6	.011
8	1978	.36	.851	.133	.313	2.8	.0012-.018	85.6	.021
9	1085	.197	.467	.073	.17	1.6	.00068-.0103	85.6	.012
10	2105	.383	.905	.141	.33	3.0	.0013-.0193	85.6	.023
11	446	.081	.192	.0298	.0705	.96	.00028-.0042	58.85	.007
12	910	.166	.39	.061	.144	1.9	.00056-.0084	58.85	.014
13	520	.095	.224	.035	.082	1.1	.00032-.0049	58.85	.0083
14	953	.173	.41	.064	.151	2.0	.00059-.0088	58.85	.015

*Risk coefficient

eg $\frac{2.8 \text{ rem} \times 5 \times 139}{10.6}$

eg 182/10⁶ man rem

ESTIMATED RADIATION DOSES TO RESIDENTS OF
ENEU AND/OR BIKINI ISLANDS ASSUMING VARIOUS LIVING PATTERNS**

Residence Island	Years on/ Years off	Time on Eneu (%)	Time on Bikini (%)	Imported Food (50% of Diet)	Maximum Annual Dose (Millirem)** to Bone Marrow	30 Year Dose (Millirem)***	
						Whole Body	Bone Marrow
Bikini	Permanent	0	100	No	6200	44,000	47,000
Bikini	Permanent	0	100	Yes	3300	24,000	25,000
Eneu	Permanent	100	0	No	780	5,400	6,000
Eneu	Permanent	100	0	Yes	390	2,800	3,000
Eneu	Permanent	90	10	No	830	5,900	6,500
Eneu	Permanent	90	10	Yes	440	3,200	3,400
Eneu	1/1	100	0	No	540	2,800	3,100
Eneu	1/1	100	0	Yes	280	1,400	1,500
Eneu	1/1	90	10	No	590	3,000	3,300
Eneu	1/1	90	10	Yes	330	1,600	1,700
Eneu	1/2	100	0	No	540	1,900	2,100
Eneu	1/2	100	0	Yes	280	960	1,030
Eneu	1/2	90	10	No	590	2,000	2,200
Eneu	1/2	90	10	Yes	330	1,100	1,200
Eneu	1/3	100	0	No	540	1,500	1,700
Eneu	1/3	100	0	Yes	280	760	810
Eneu	1/3	90	10	No	590	1,600	1,800
Eneu	1/3	90	10	Yes	330	860	920

* Doses are rounded off.

** Federal Radiation Council exposure limit is 500 millirem per year to the maximum exposed individual (numerical value given is three times the average)

*** Federal Radiation Council exposure limit is an average of 5,000 millirem to a population.

These values are best estimates based upon the most complete information available. Furthermore, these are average values based upon averaged parameters (e.g., soil concentration of radionuclides, food concentrations of radionuclides, diet); any specific individual might receive radiation exposure higher or lower than these values depending upon islands visited, amount of various foods consumed, etc. (No claim is made as to

B

Island Average pCi/g 0-5 cm

<u>Island Code</u>	<u>Island Name</u>	<u>90 Sr</u>	<u>239+240 Pu</u>	<u>241 Am</u>
B1	Nam	10 (23)*	60 (25)	20 (32)
B2	Iroiij	5.4 (6)	8.3 (1)	7 (9)
B3	Odrik	8.5 (11)	8.5 (11)	3.3 (5)
B4	Lomilik	39 (16)	17 (16)	4.9 (16)
B5	Aomen	11 (9)	4.6 (9)	3.2 (9)
B6	Bikini	96 (13)	12.8 (13)	8.2 (13)
B10	Rojkere	17 (3)	4.1 (3)	2.9 (3)
B12	Enu	2 (4)	0.37 (4)	0.22 (4)
B13	Aerokojlol	0.74 (13)	1.4 (13)	0.35 (13)
B15	Lele	2.8 (4)	1.2 (4)	0.19 (4)
B16	Enemon	17 (6)	10 (5)	1.5 (6)
B17	Enidrik	11 (32)	6.1 (31)	1.3 (32)
B18	Lukojj	116 (3)	20 (3)	4.5 (3)
B19	Jelete	179 (2)	13 (2)	4.7 (2)
Bikini Atoll Average		47	12	4.4

PRELIMINARY
 THESE NUMBERS ARE BASED ON INCOMPLETE DATA.
 DATE 7-29-80

* Numbers in parenthesis are the number of samples analyzed for each island.

4	> 75	> 20	10-25
3	25-74	10-19	5-10
2	10-24	1-9	1-5
1	< 10	<	< 1
			> 20