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Calculations

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From: SIDNEY MARKS

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

Received WP - 4/13/79 RM copy
All corrections made.
As sent to HP Journal on
4/19/79

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 ^{137}Cs 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 ^{137}Cs 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 involvment 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 ^{40}K, ^{60}Co and ^{137}Cs. 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 ±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}Cs + ^{60}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 make from jekaru) and waini (drinking coconuts). The maturation time of the coconut~~e~~ 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, [illegible] 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

I.D.#	Date	Location	Potassium grams	^{137}Cs NCi	Bq
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 $^{137}\mathrm{Cs} = \dfrac{3(\mathrm{cts})^{1/2}}{900\mathrm{x}370\mathrm{x}8.6\mathrm{x}10^{-3}}$ = 0.7 nCi or 26 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 Kilograms	Age	Years on Bikini	1974[1]			1977[2]			1978					1979				
				Potassium	^{137}Cs		Potassium	^{137}Cs		Potassium	^{60}Co		^{137}Cs		Potassium	^{60}Co		^{137}Cs	
				grams	µCi	kBq	grams	µCi	kBq	grams	nCi	Bq	µCi	kBq	grams	nCi	Bq	µCi	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 Kilograms	Age	Years on Bikini	1974[1]			1977[2]			1978					1979				
				Potassium	^{137}Cs		Potassium	^{137}Cs		Potassium	^{60}Co		^{137}Cs		Potassium	^{60}Co		^{137}Cs	
				grams	µCi	kBq	grams	µCi	kBq	grams	nCi	Bq	µCi	kBq	grams	nCi	Bq	µCi	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	-	-	-	-	-
x̄	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		126 198	0.051 0.29	1.9 11	119 169	0.641 3.23	24 120	97.6 180	1.42 14.8	53 550	0.631 5.88	23 220	132 179	0.67 3.2	25 118	0.32 2.4	12 89

[1] CO 75

[2] CO 77

Table 4

Bikini Female Adult WBC Results 1974 through 1979

Medical ID	Weight in Kilograms	Years on Bikini	Age	1974[1] Potassium grams	1974[1] ^{137}Cs µCi	1974[1] ^{137}Cs kBq	1977[2] Potassium grams	1977[2] ^{137}Cs µCi	1977[2] ^{137}Cs kBq	1978 Potassium grams	1978 ^{60}Co nCi	1978 ^{60}Co Bq	1978 ^{137}Cs µCi	1978 ^{137}Cs kBq	1979 Potassium grams	1979 ^{60}Co nCi	1979 ^{60}Co Bq	1979 ^{137}Cs µCi	1979 ^{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	1.41	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	1.52	56	-	-	-	-	-
6032	63	3	32	-	-	-	96.4	1.88	70	100	5.49	200	3.07	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	2.08	77	-	-	-	-	-
6113	54	4	25	-	-	-	91.7	0.534	20	91	2.33	86	1.03	38	107	1.1	41	0.30	11
6065	52	4	19	-	-	-	101	0.734	27	93	2.39	88	1.06	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	1.27	47	95	1.0	37	0.31	11
6109	50	4	15	-	-	-	110	0.621	23	88	1.49	55	0.411	15	106	0.53	20	0.060	2.2
6046	85	1.75	43	-	-	-	94.3	0.833	31	100	3.81	140	2.10	78	-	-	-	-	-
6098	60	3	16	-	-	-	91.4	0.706	26	93	2.38	88	.891	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	1.50	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	1.44	53	-	-	-	-	-
934	74	6	43	-	-	-	98.8	2.23	83	110	10.8	400	5.48	200	-	-	-	-	-
6062	54	4	21	-	-	-	96.8	0.840	31	79	2.53	94	1.44	53	-	-	-	-	-
6035	77	6	20	-	-	-	113	0.573	21	100	4.94	180	2.78	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	2.28	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	3.89	140	-	-	-	-	-
865	54	7	45	59	0.018	0.67	89.4	0.558	21	78	1.70	63	1.31	49	-	-	-	-	-
6050	62	2	22	-	-	-	-	-	-	81	3.42	130	1.40	50	-	-	-	-	-
x̄	65		31	93	0.059	2.2	96.1	0.911	34	89	3.15	120	1.68	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	1.01	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	0.411	15	66	0.32	12	0.060	2.2
				100	0.12	4.3	113	2.23	83	110	10.8	400	5.48	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	1978 Potassium Grams	1978 ^{60}Co nCi	1978 ^{60}Co Bq	1978 ^{137}Cs µCi	1978 ^{137}Cs kBq	1979 Potassium grams	1979 ^{60}Co nCi	1979 ^{60}Co Bq	1979 ^{137}Cs µCi	1979 ^{137}Cs 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					
x̄	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
x̄	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 65	0.35 0.59	13 22	0.042 0.26	1.6 9.6

Table 6

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

					1978				1979				
					^{60}Co		^{137}Cs			^{60}Co		^{137}CS	
Medical ID	Weight kilograms	Years on Bikini	AGE	Potassium Grams	nCi	Bq	μCi	kBq	Potassium grams	nCi	Bq	μCi	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
x̄	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
x̄	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) ± 3.4 kBq (0.0093 μCi)	22	21 kBq (0.57 μCi) to 120 kBq (3.2 μCi)	48 kBq (1.3 μCi) ± 27 kBq (0.73 μCi)	36(1)	23 kBq (0.63 μCi) to 220 kBq (5.9 μCi)	90 kBq 2.4 μCi) ± 49 kBq 1.3 μCi)	17	12 kBq (0.32 μCi) to 89 kBq (2.4 μCi)	37 kBq (1.0 μCi) ± 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) ± 2.3 kBq (0.063 μCi)	20	20 kBq (0.53 μCi) to 83 kBq (2.2 μCi)	34 kBq (0.93 μCi) ± 17 kBq (0.47 μCi)	32	15 kBq (0.41 μCi) to 200 kBq (5.5 μCi)	62 kBq (1.7 μCi) ± 37 kBq (1.0 μCi)	16	2.2 kBq (0.060 μCi) to 36 kBq (0.98 μCi)	16 kBq (0.44 μCi) ± 8.9 kBq (0.24 Ψi)
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) ± 7.6 kBq (0.21 μCi)	6(2)	27 kBq (0.73 μCi) to 77 kBq (2.1 μCi)	53 kBq (1.4 μCi) ± 21 kBq (0.56 μCi)	4	2.0 kBq (0.055 μCi) to 28 kBq (0.76 μCi)	10 kBq (0.27 μCi) ± 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) ± 8.5 kBq (0.23 μCi)	3	28 kBq (0.74 μCi) to 76 kBq (2.1 μCi)	46 kBq (1.3 μCi) ± 25 kBq (0.66 μCi)	2	5.6 kBq (0.15 μCi) to 10 kBq (0.27 μCi)	7.8 kBq (0.21 μCi) ± 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) ± 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) ± 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) ± 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 kkBq (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 ^{137}Cs body burden data were obtained from S. Cohn, Brookhaven National Laboratory, Medical Department.

Table 8

Comparison of Observed Versus Expected Reduction Factors

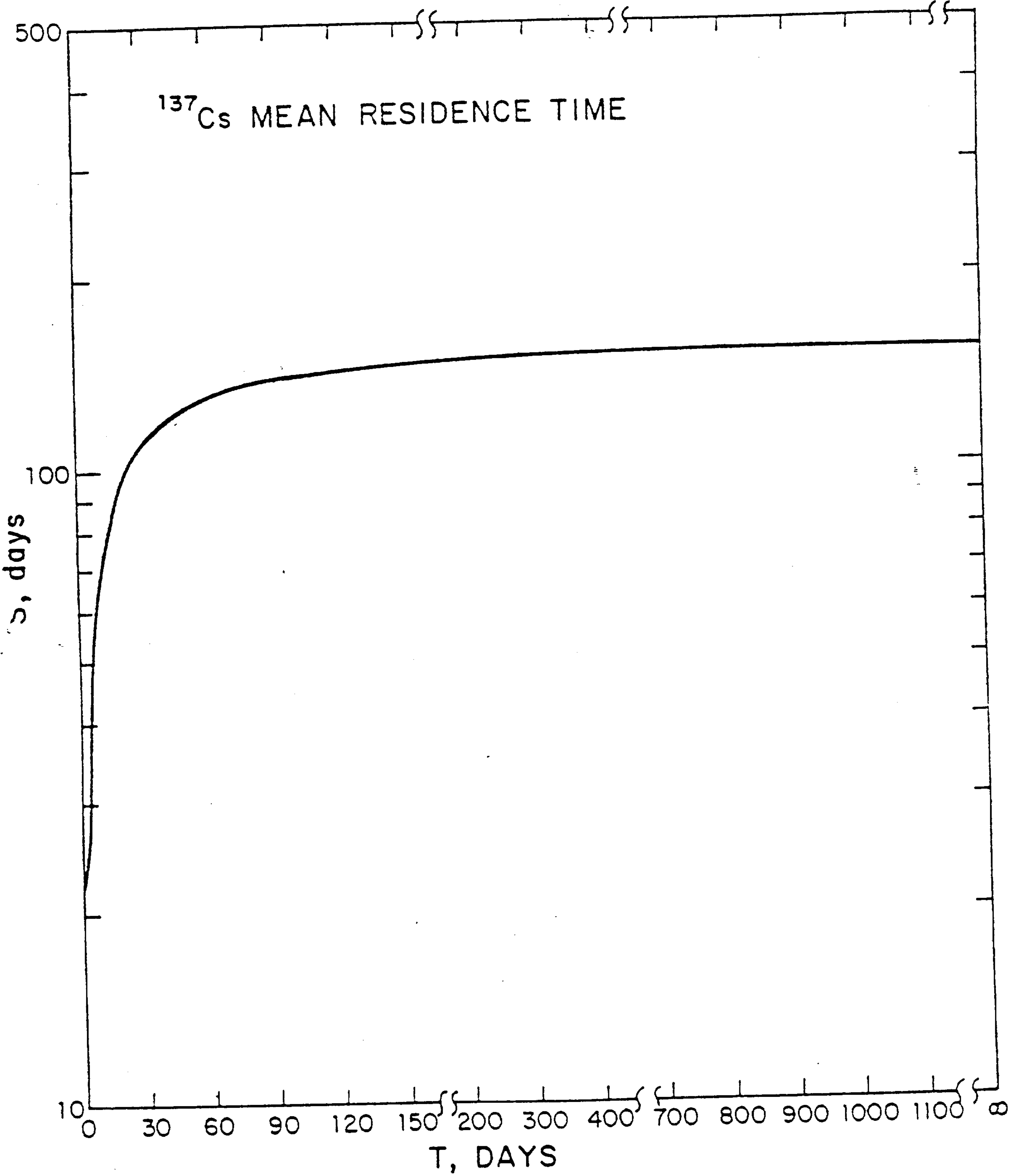
Description	# of Persons	Mean Reduction Factor
Expected Reduction Factor for Adult Males(1)	NA	2.4
Observed Reduction Factor for Adult Bikini Males	17	2.3
Expected Reduction Factor for Adult Females(2)	NA	3.5
Observed Reduction Factor for Adult Bikini Females	16	3.8
Expected Reduction Factor for Children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

NA = Data Not Available

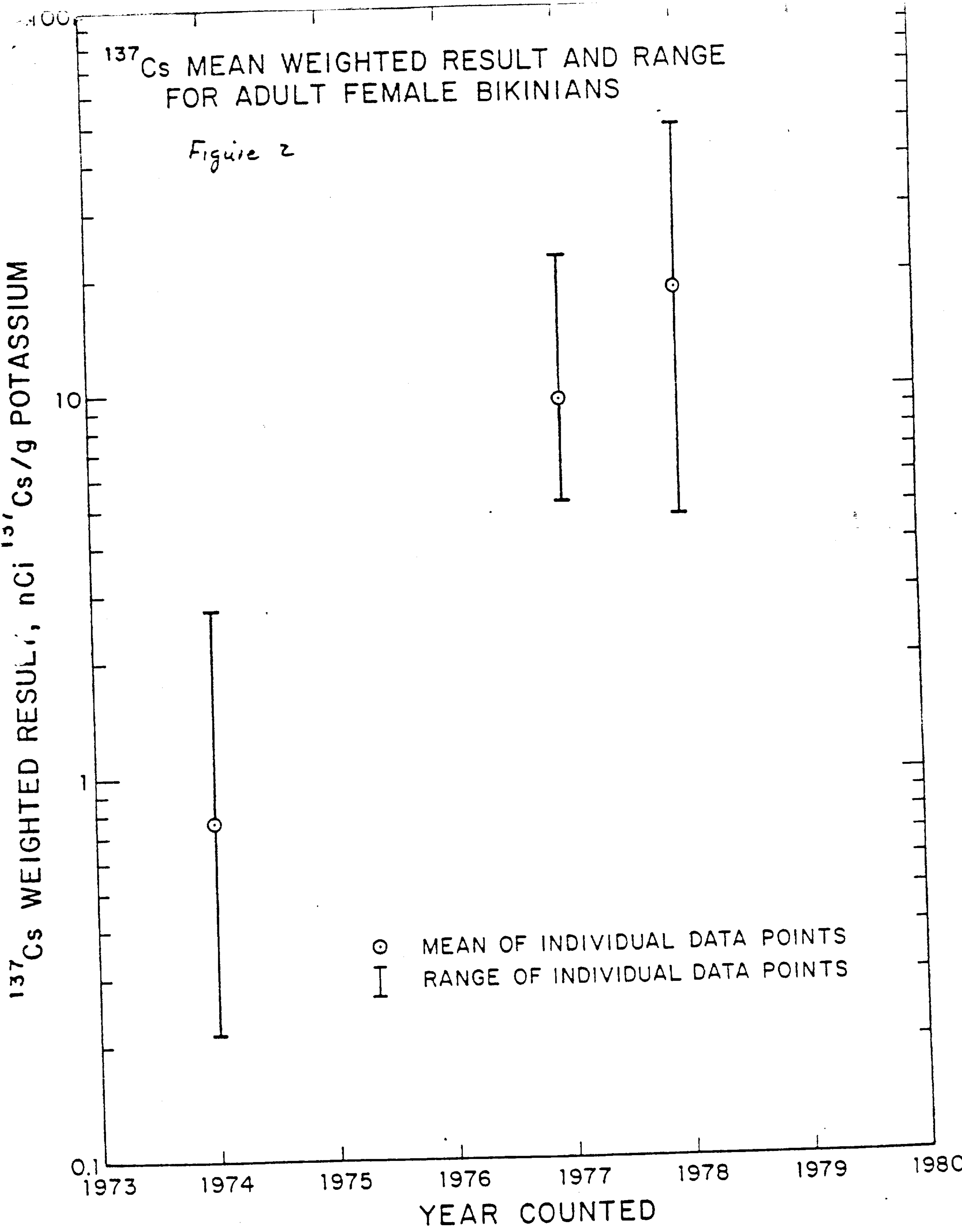
(1) Effective half time obtained from ICRP Publication 10A (ICRP 71).

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

Figure 3

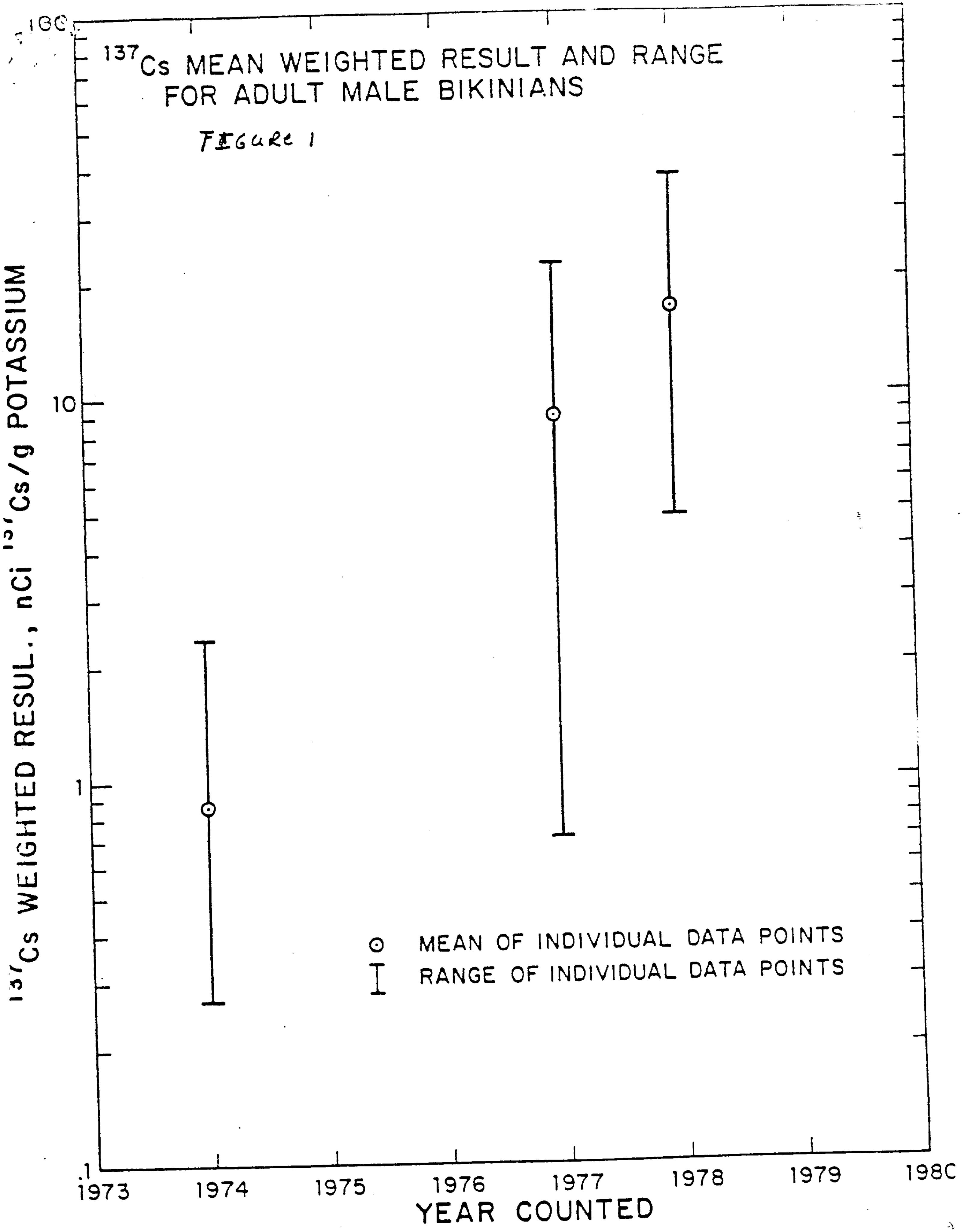


¹³⁷Cs MEAN RESIDENCE TIME
500
100
10
, days
0
30
60
90
120
150
200
300
400
700
800
900
1000
1100
∞
T, DAYS



^{137}Cs MEAN WEIGHTED RESULT AND RANGE FOR ADULT FEMALE BIKINIANS
^{137}Cs WEIGHTED RESULT, nCi ^{137}Cs/g POTASSIUM
100
10
1
0.1
1973
1974
1975
1976
1977
1978
1979
1980
YEAR COUNTED
⊙ MEAN OF INDIVIDUAL DATA POINTS
I RANGE OF INDIVIDUAL DATA POINTS

Figure 2



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

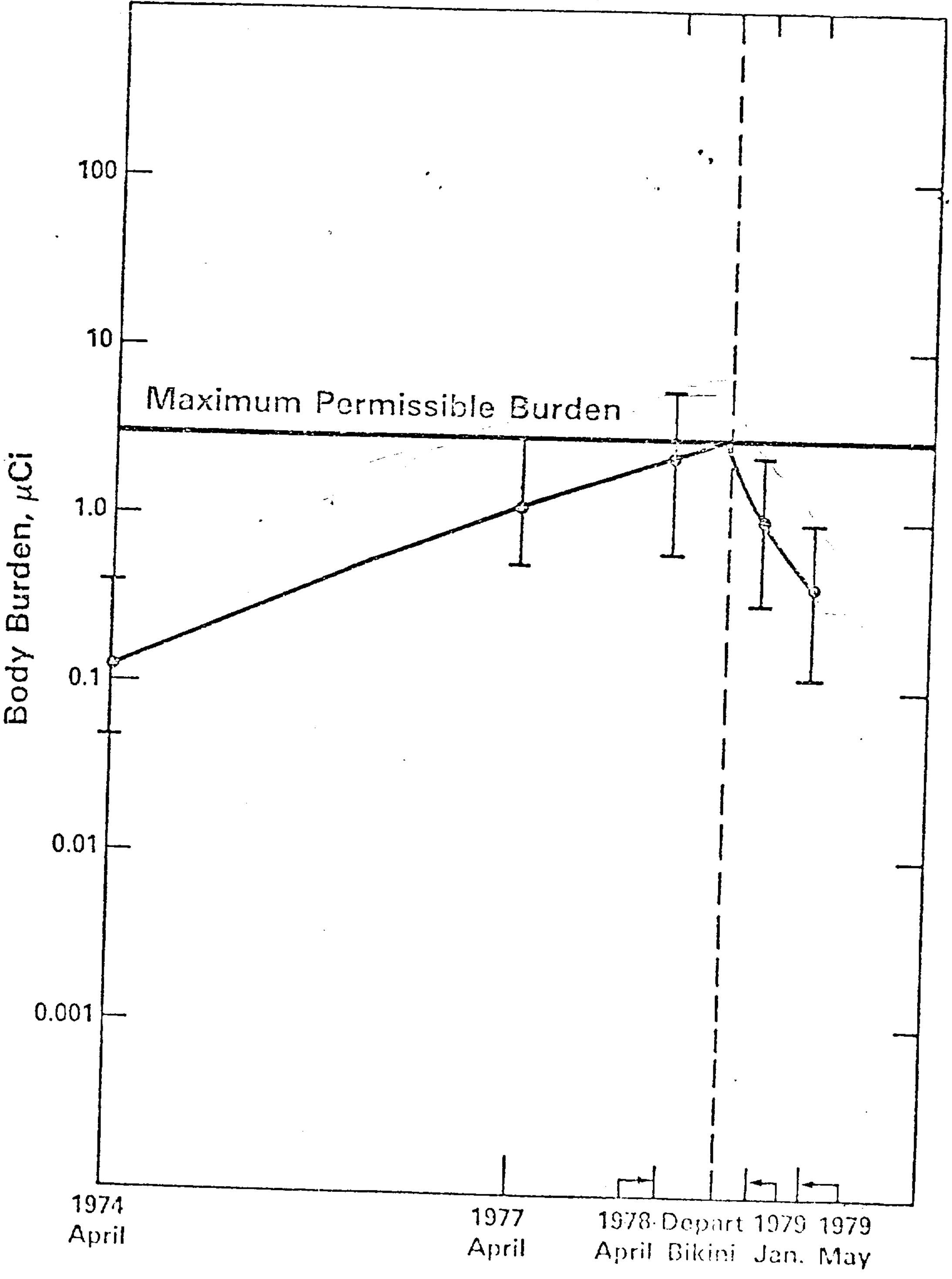
FIGURE 1

b

^{137}Cs Body Burden History for Adult Bikini Males

Mean and Range vs. Time

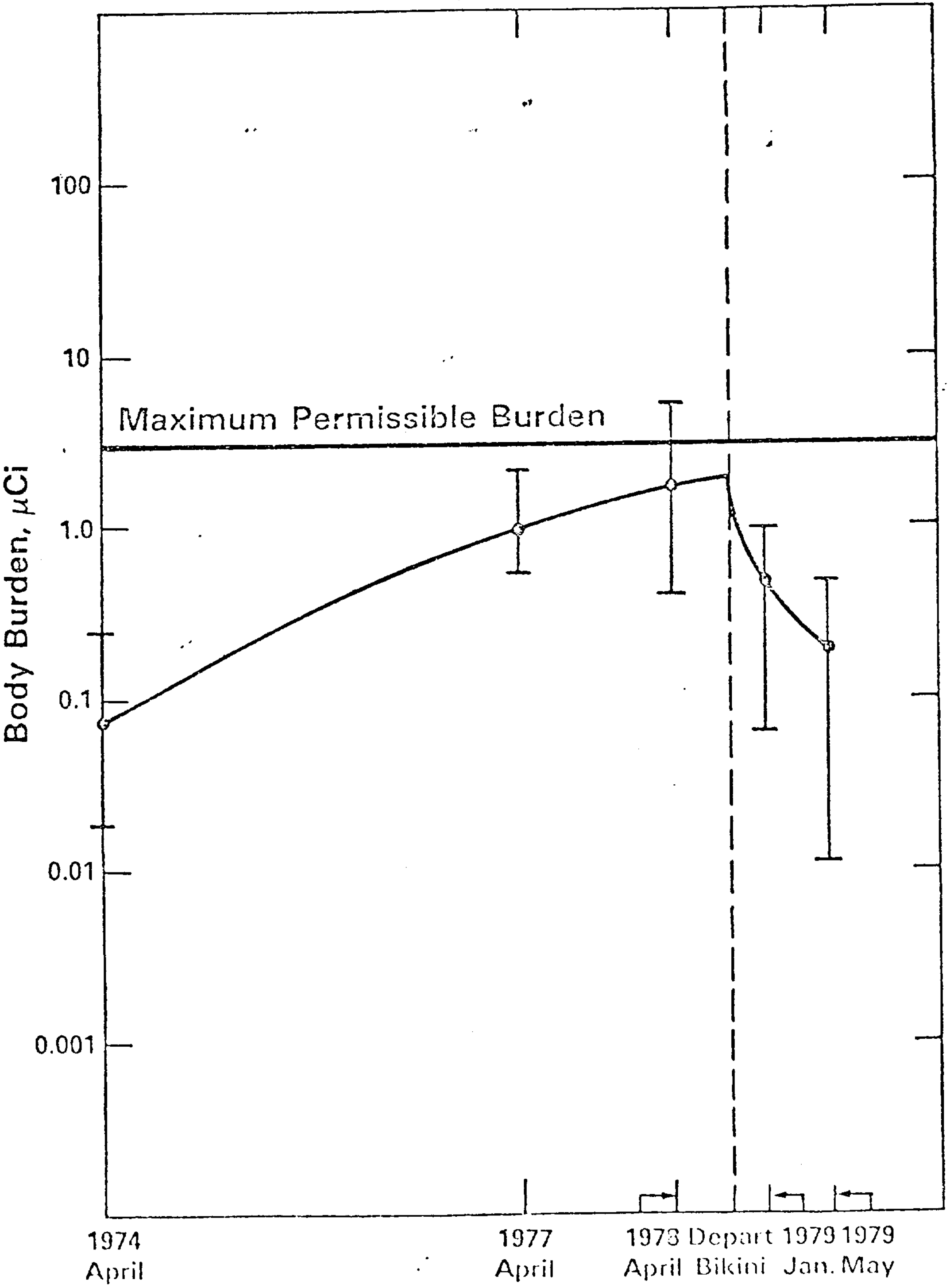
24 JAN. 1980



^{137}Cs Body Burden History for Adult Bikini Females

Mean and Range vs. Time

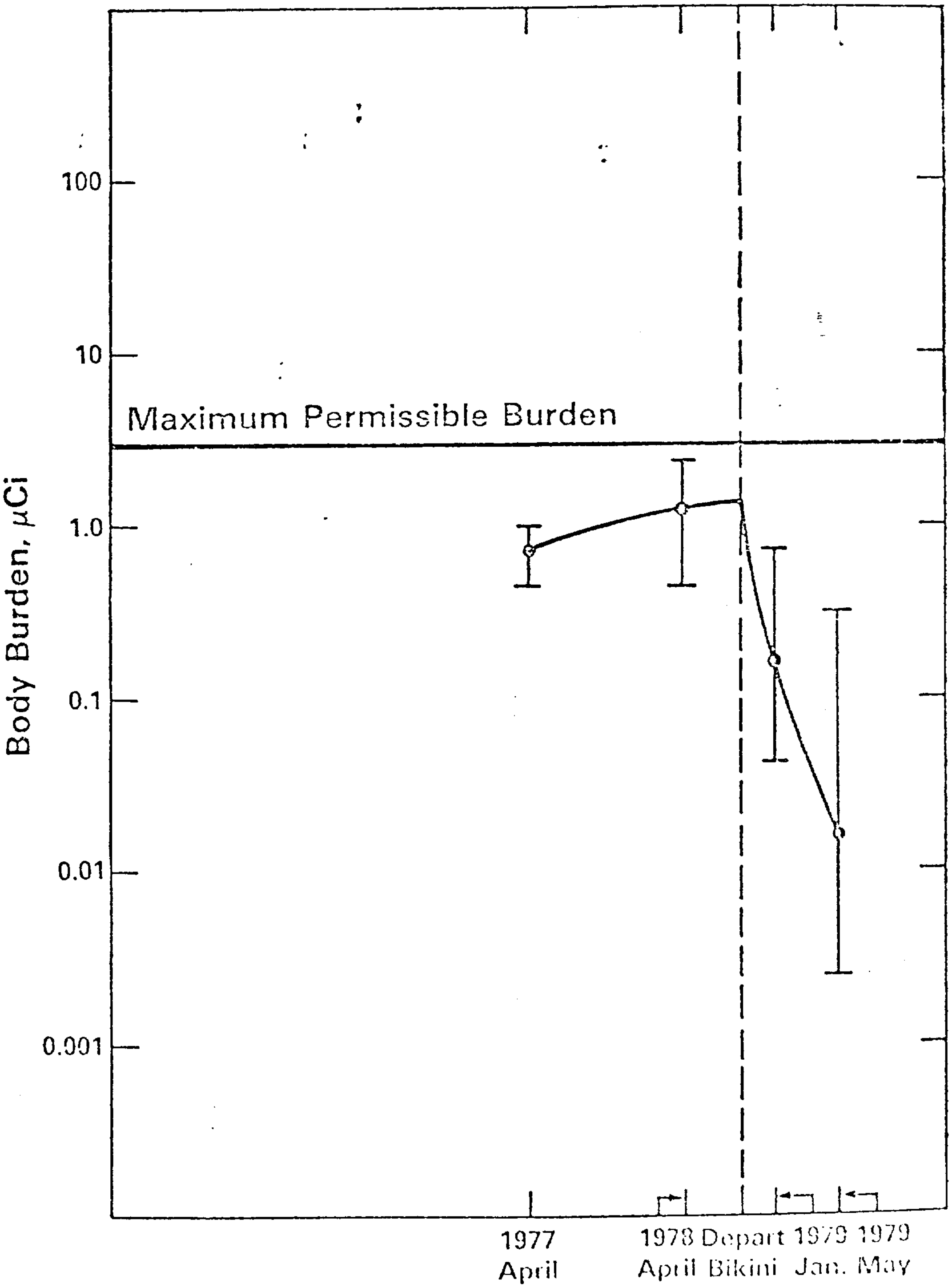
24 JAN. 1980



^{137}Cs Body Burden History for Bikini Youths

Mean and Range vs. Time

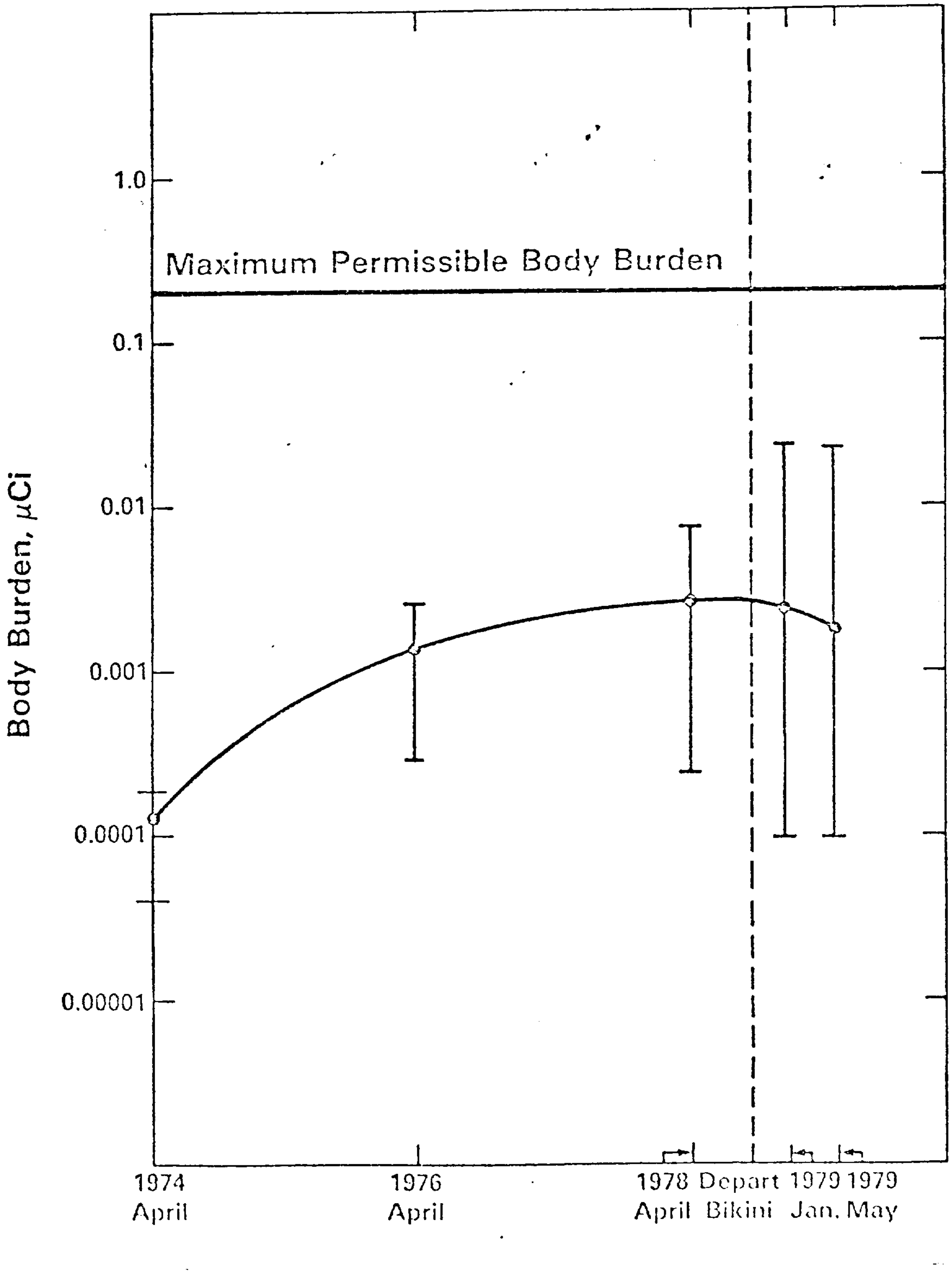
24 JAN. 1980



^{90}SR-^{90}Y Body Burden History for Adult Bikini Males

Mean and Range vs Time

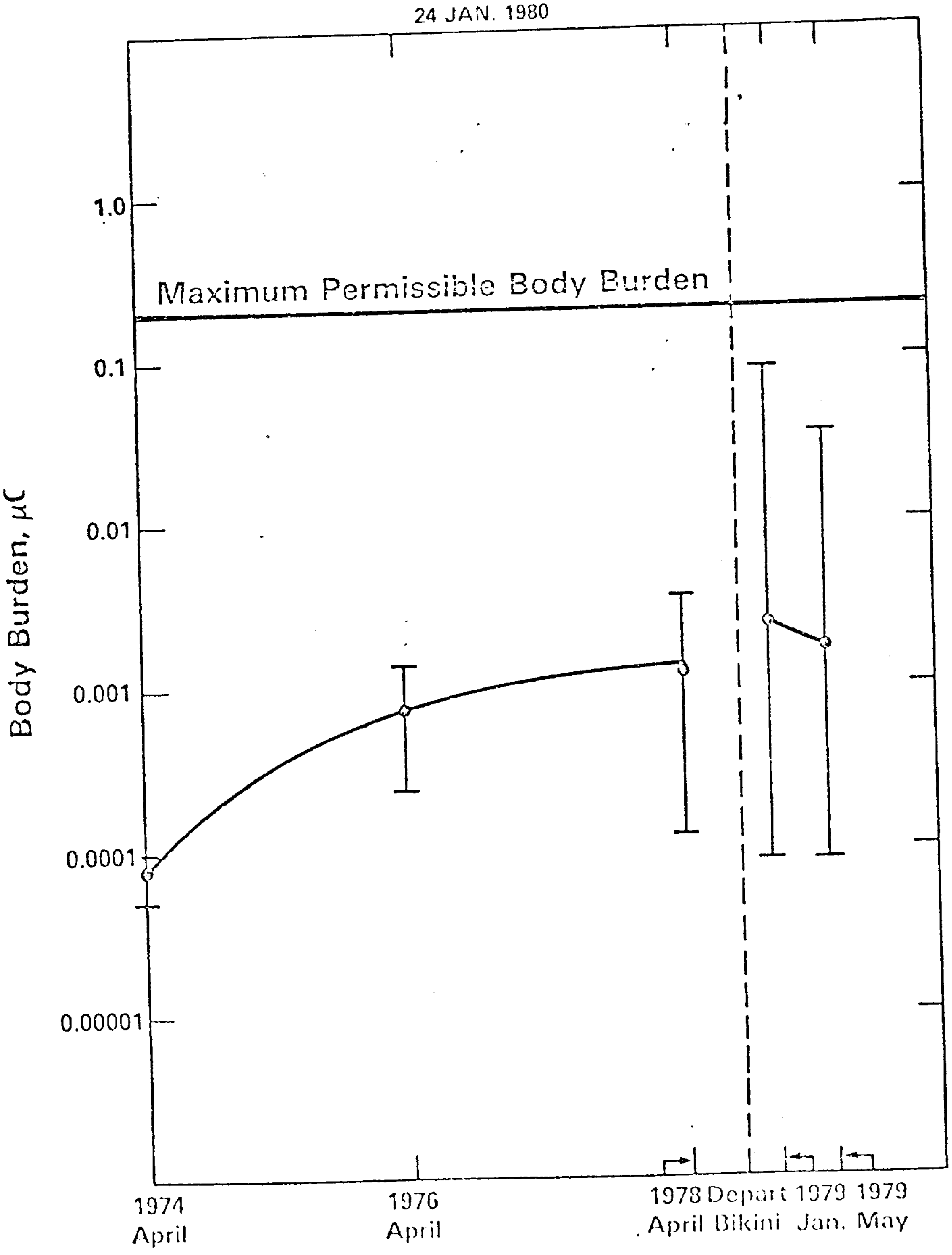
24 JAN. 1980



^{90}SR-Y Body Burden History for Adult Bikini Females

Mean and Range vs Time

24 JAN. 1980



^{90}SR-^{90}Y Body Burden History for Bikini Youth

Mean and Range vs Time

24 JAN. 1980

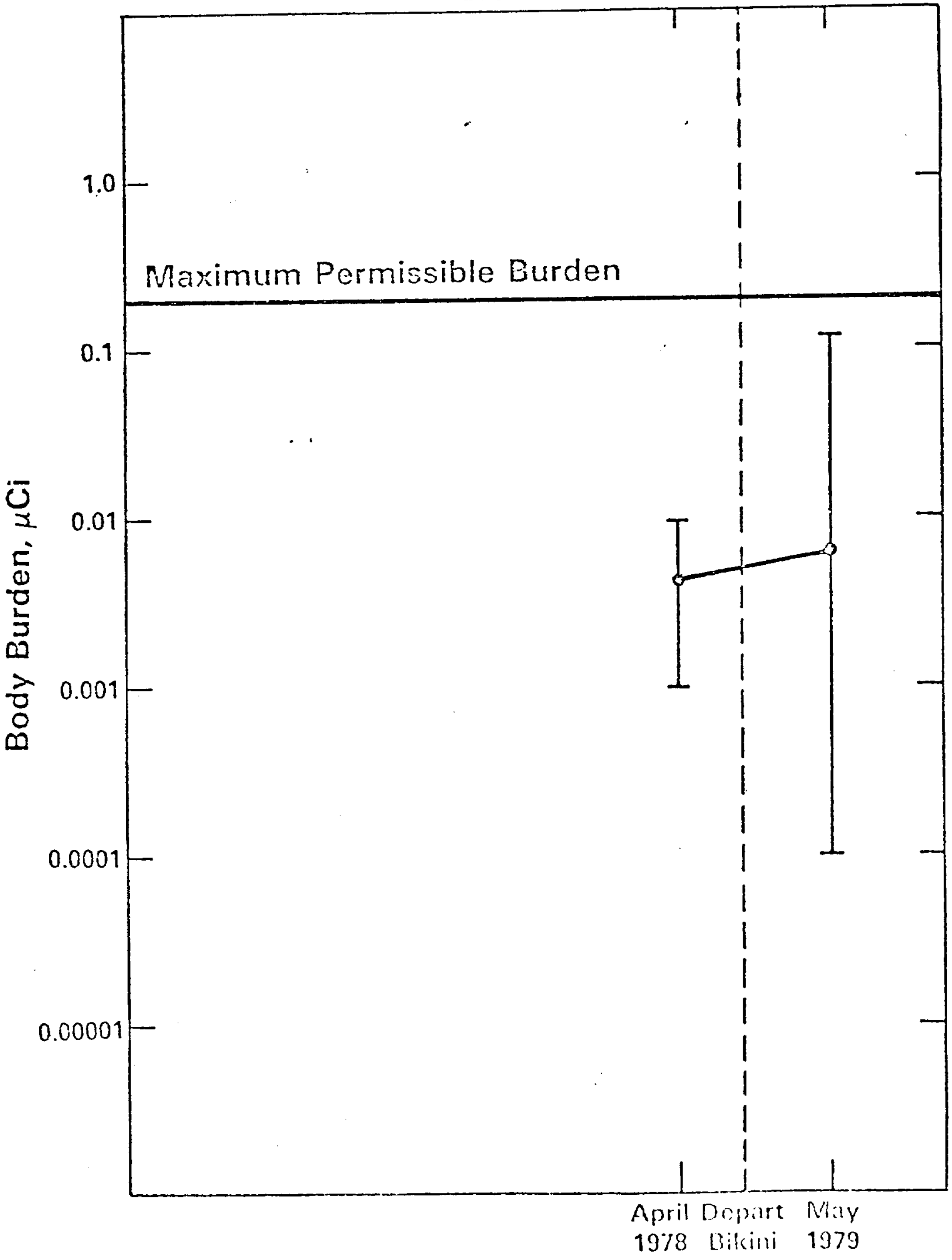


Figure 1

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

250 nCi increments

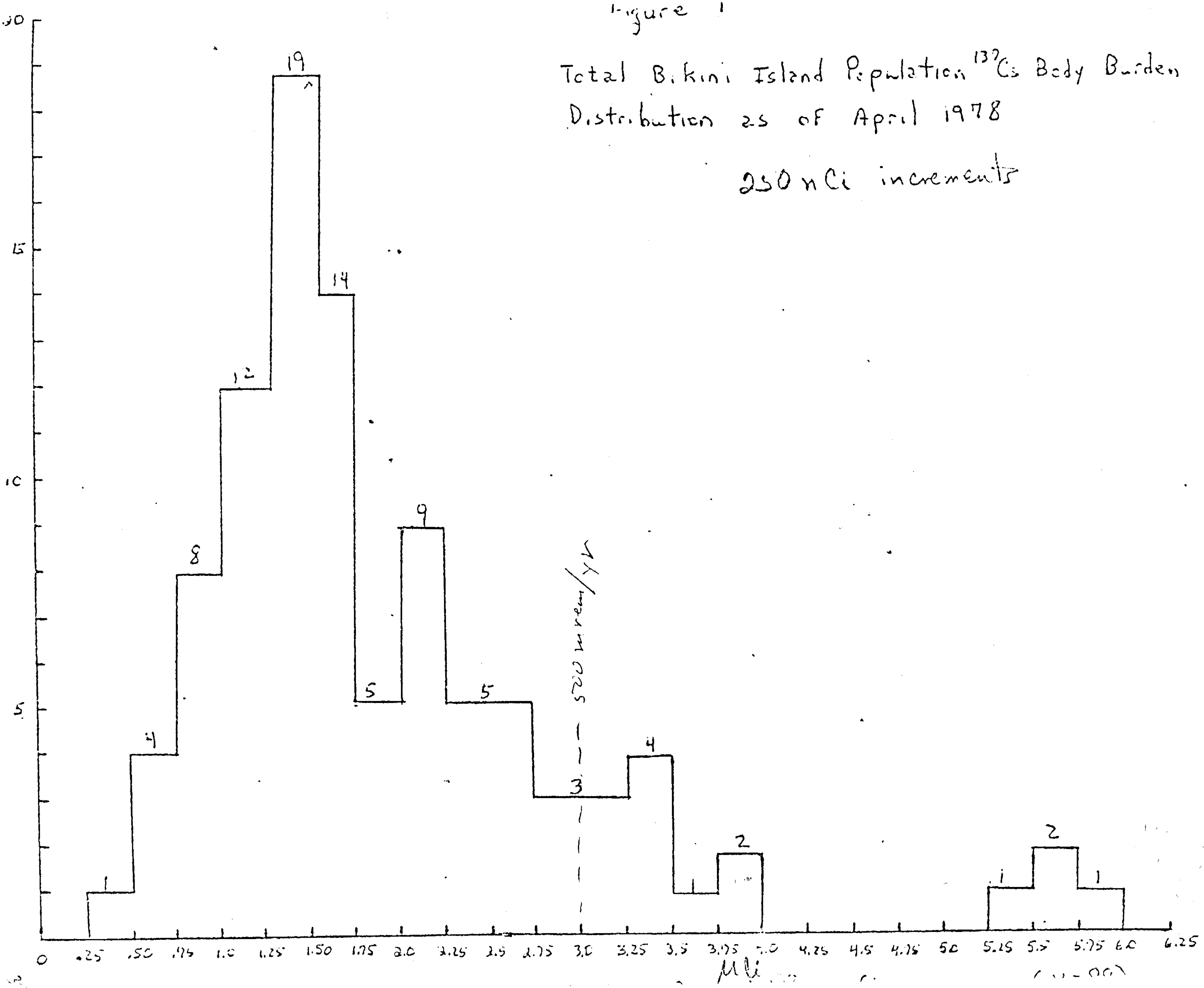
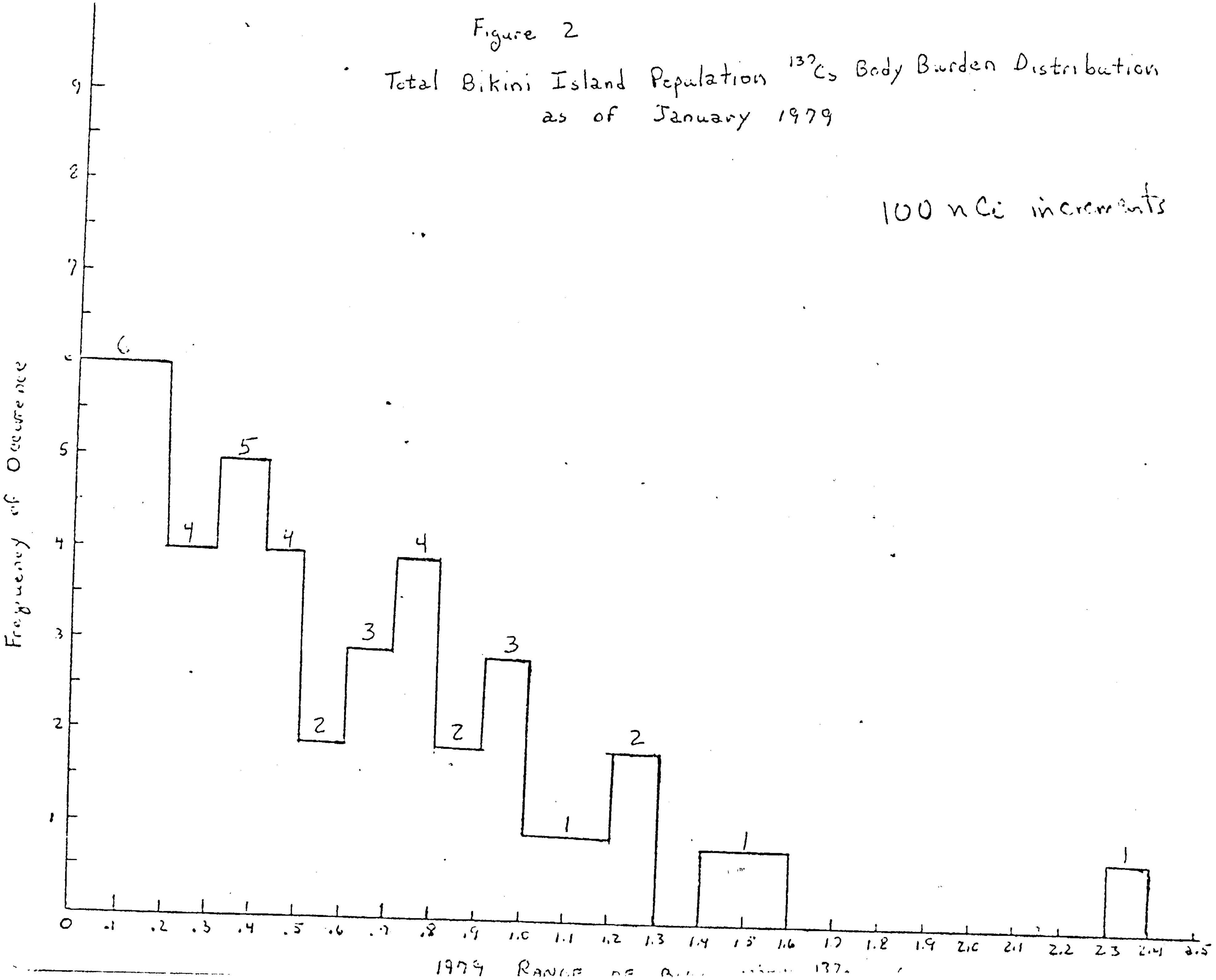


Figure 2

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



Bikini Households (1975)

Age	Male	Female	Total
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	16	8	24
	382	403	785

Cancer Incidence (Persons who returned to Rikini)

Based on 140 Rikini residents Actually removed

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

average male bone marrow dose	72.36/50	1.45 rem
average femal bone marrow dose	56.2/49	1.15

1.45 × 70 101.50 person-rem

1.15 × 70 = $\underline{80.29}$ person rem

181.79 person-rem

Total person rem : 182

BEIR I relative $458/10^6 \times 182$ = 0.0834 .08

absolute $87/10^6 \times 182$ = 0.0158 .02

0.0158 → 0.02

0.0834 → 0.08

BEIR III

		Coef.			
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

B

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% of 300 = 32 ≈ 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

Total parental dose: 2.44 rem

1/2 = 1.22

1.22 rem × 0.2%/rem = 0.244 % increase

30 natural incidence × 0.00244 increase = 0.0732 ≈ .07

Total Birth Defects = 15 + 0.07

BEIR III

1.22 rem × 0.01%/rem = 0.000122

30 × .000122/rem = 0.0037

0.004

[illegible]

99 Bikini Residents

Revised for basis of 140 people

Based on Bone Marrow Doses

Cancer Deaths

Total Person Rem = 128.56 ≈ or 128

BEIR I

Relative	1972	318/10⁶ man rem	0.0403 Cancer deaths
		458/10⁶ 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 natural causes

Revised for basis of 140 people

Total whole body dose

124.790 rem

Ave (n = 99) = 1.26   1.26 rem X 0.2%/rem = 0.2521 % increase

based on 0.2%/rem   11 X 0.0025 = 0.0275 increased birth defects

based on 0.01%/rem   1.26 rem X 0.01%/rem = 0.0126 % increase

11 X 0.000126 = 0.0014 increased birth defects

Bases for calculation of [illegible]
"The [illegible] of [illegible] [illegible] Britain [illegible]

B

I Assumptions

~~[illegible]~~

Estimates of cancer & genetic risks for the British population were based on a number of assumptions. Some of these assumptions resulted from consultation with ~~[illegible]~~ ~~[illegible]~~ other scientists including members of the BEIR committees.

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 ~~B[illegible]~~ values as given in BEIR-I rather than the [illegible] values [illegible] [illegible] of the [illegible] shown in Table V-4 of BEIR-III.

2. For [illegible] [illegible] risk both the relative and [illegible] [illegible] the [illegible] [illegible] [illegible] were used to give a range of uncertainty. The absolute risk coefficient was a known value, is less variable with the population & is not dependent upon the [illegible] [illegible] [illegible] incidence which is not known [illegible]

the Bikini population. The relative risk coefficient gives a higher value, but since it is based on the spontaneous cancer incidence, which is unknown for the Bikini population, it is probably less reliable than the estimate ~~[illegible]~~ calculated from the absolute risk coefficient.

3. For estimating increased cancer incidence, 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 neither BEIR I or BEIR III is very clear about what is meant by parental dose, thus it is not clear whether ~~the~~ birth defects estimate is based on the dose to one parent or ~~[illegible]~~ both parents. If in the latter case the ~~dose~~ 30-yr [illegible] [illegible]
We assumed the 30 yr risk of 0.0[illegible] [illegible] was based on [illegible] parent's dose would be doubled, [illegible] included. Also because we believe the risk coefficient from BEIR I was slightly conservative [illegible] comparison to BEIR III, we elected to use the

30 year whole body dose as [illegible] p — not doubled.

5. For #140 persons who returned to Bikini & were counted 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 genetic 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 genetic dose = 2.44 rem

genetic dose used in calculation = 1.22 rem

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

7. The spontaneous ~~[illegible]~~ incidence of birth defects was taken to be 10.5% of all live births ~~[illegible]~~ [illegible]

8. The ~~[illegible]~~ normal incidence of cancer deaths was assumed to be 15%. ~~The value which is [illegible] than~~ less than the approximate 20% ~~[illegible]~~ given for the U.S. population was used because ~~[illegible]~~ the Bikini people have not probably been exposed to as much [illegible] of environmental carcinogens. The people [illegible] in U.S. [illegible] because of limited medical care and prevalence of other risks such as drowning, poisoning etc ~~[illegible]~~ ~~[illegible]~~ the causes of death are probably higher in the Bikini population than in the U.S. population. ~~[illegible]~~ We also anticipated the average life span was less than in the U.S. population, which might tend to reduce the number of ~~[illegible]~~ [illegible] 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. See in the Appendix for evidence showing that the largest [illegible] [illegible] [illegible] [illegible] [illegible]

II Population Estimate

To estimate the number of births, deaths & the magnitude of the Bikini population after 30 years, information was used from the first draft of the Marshall Islands 5 year Health Plan prepared by the the Trust Territory Department of Health Services Office of Health Planning & the Finance 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~~ This probably makes little real difference in view of the uncertainties in the risk ~~estimating~~ coefficients [illegible]. 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. As [illegible] accepted the population [illegible] Majuro are quite dissimilar from the Bikini [illegible] because they have [illegible] a more [illegible]

For the estimates ~~we used~~ the last 5 or 6 year average of the data was used because they are probably the ~~as being~~ most representative of current conditions. From this, ~~we~~ the following [illegible] 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 ~~an island~~ Bikini Atoll. Values for other initial populations ~~may be~~ 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 ~~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 radition dose, taken here as 30 years.

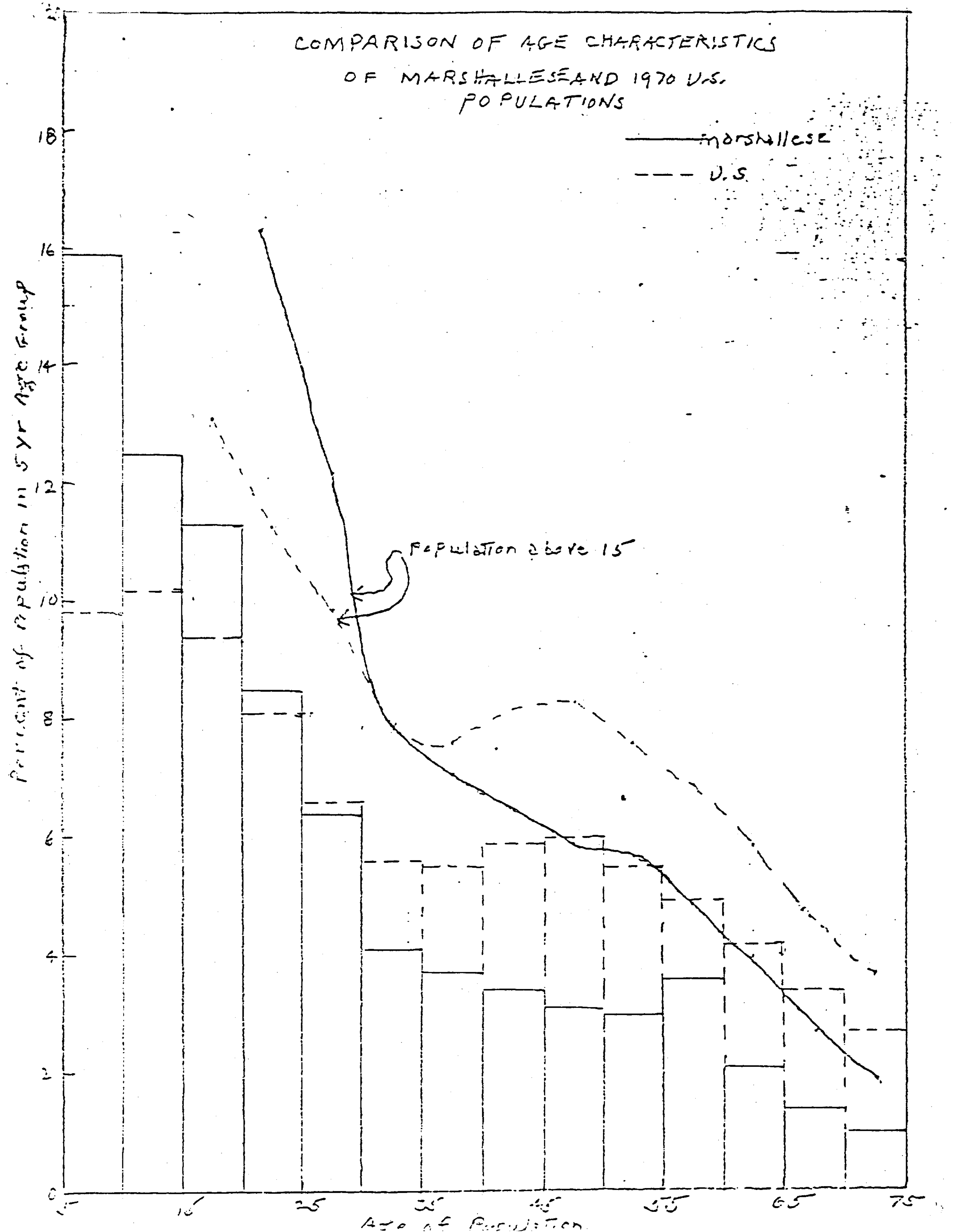
Because This integral cannot be solved analytical, An approximate solution was obtained by calculating this function for each of 30 years and summing. This gave 8949 rads for the total population including the original 550. The total dose received by the original 550, assuming that all live for the 30 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 ~~I~~ also ~~took a brief look at~~ examined 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~~ suggest that if the ~~two~~ natural cancer rates of 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 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 Estimates~~

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 140 (the number that returned to Bikini):

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

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

For a population of 235:

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

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

For A Population of 350

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

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

[illegible] was prepared [illegible] agency [illegible] the U.S. Government had accepted the risk coefficient in BEIR. Thus we were constrained to use risk coefficients from BEIR-I or BEIR-III. While not included ~~in~~ in the printed book, risk estimates 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)		Derived Cancer Deaths/10^6 person rem	
	Absolute	Relative	Absolute	Relative
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
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 87/10^6 person-rem and the maximum by 458/10^6 person-rem. Thus these two risk coefficients [illegible] define a range of estimated cancer risk.

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 these amount at equilibrium. The 1800 cases equal an increase of 0.05% incidence per year first generation or 0.25% at equilibrium.

In addition there would be 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 1100 to 27,000/year. Thus at equilibrium ~~0.75% 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 → 5% increase in ill health. would [illegible]

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

For estimating ~~the~~ the potential ~~[illegible]~~ genetic derived health defects in the Bikini population it was decided to use a risk coefficient ~~[illegible]~~ of 0.2% per rem in first generation, ~~[illegible]~~

~~[illegible]~~

~~[illegible]~~ [illegible]

recognizing that it was probably very conservative.

B. BEIR-III

1. Cancer (Table V-4)

Lifetime Risk of Cancer Death

(deaths/10^6/rad)

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

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

1 rem per generation (1 rem parental exposure) per 10^6 live offspring ⟶ 5 to 75 birth defects, this is 0.0005 --0.0075%--First generation

Since the Spontaneous rate is given as 10.7%, for 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 gives

$$\frac{0.0005}{10.7} = 0.000047 = 0.0047\%$$ increase and

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

IV Calculation of Risk

Table 1 gives the radiation dose values provided by Dr. [illegible] for use in developing estimates of increased health risks in the [illegible] Report.

A. Risks For 14 Different Living Conditions.

1. ~~Cancer Risks~~ Table 2 shows the calculations for ~~the~~ estimates of increased cancer risk for 14 different living conditions. ~~The [illegible] data [illegible]~~

2. Birth defect risks

Table 3 gives the calculations for the estimates of Birth defects. ~~The [illegible]~~ [illegible] ~~[illegible]~~

B. Risk estimates based on BEIR III

1. Table 4 gives risk estimates based on BEIR III risk coefficients. These were calculated for comparison purposes only & were not used in the [illegible] analysis. The highest ~~[illegible]~~ estimates for cancer risk result ~~[illegible]~~ from using the linear relation with risk 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
[illegible]	Eneu	Permanent	90	10	No	830	5,900	6,500
[illegible]	Eneu	Permanent	90	10	Yes	440	3,200	3,400
[illegible]	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
[illegible]	Eneu	1/3	100	0	No	540	1,500	1,700
[illegible]	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

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Risk Estimates based on BEIR-III

75

	1 Total Person rem	Cancer Risk 2 Relative L-Q* 182 *	 L-L 430	 4 Absolute L-Q 67	 L-L 158	6 No. of Births	7 30-yr Whole body dose (rem)	8 Birth Defects (5-75/10^6/rem)	9 Spontaneous Number	10 % Increase ***
1	3054	.556	1.31	.205	.483	[illegible]	2.8	.0182 .27 ** .0019-.029	139	0.19 .02 **
2	6108	1.11	2.63	.409	.965	[illegible]	5.4	.0038-.056 .035 .527	139	0.38 .04
3	25450	4.63	10.94	1.71	4.02	1300	24.0	.156 2.34 .0167-0.25	139	1.68 .18
4	47846	8.71	20.57	3.21	7.56	1300	44.0	.0306-0.46 .286 4.29	139	3.1 .33
5	3461	.63	1.49	.23	.547	[illegible]	3.2	[illegible] .312 .0022-.033	139	0.22 .024
6	6617	1.20	2.85	.44	1.05	[illegible]	5.9	.0041-.062 .038 .575	139	0.414 .045
7	957	.174	.41	.064	.15	[illegible]	1.4	.0044 .084 .0006-.009	85.6	0.098 .011
8	1978	.36	.851	.133	.313	[illegible]	2.8	.0012-.018 .011 .168	85.6	0.196 .021
9	1085	.197	.467	.073	.17	[illegible]	1.6	.0066 .096 .00068-.0103	85.6	0.112 .012
10	2105	.383	.905	.141	.33	[illegible]	3.0	.0013-.0193 .012 .18	85.6	0.21 .023
11	446	.081	.192	.0298	.0705	550	.96	.0026 .04 .00028-.0042	58.85	0.068 .007
12	910	.166	.39	.061	.144	550	1.9	.00056-.0084 .0052 .078	58.85	0.13 .014
13	520	.095	.224	.035	.082	550	1.1	.0030 .00032-.0049 .045	58.85	0.076 .0083
14	953	.173	.41	.064	.151	550	2.0	.0055 .00059-.0088 .0825	58.85	0.14 .015

*Risk coefficient

eg 182×10^{-6} man rem

eg $\frac{2.8 \text{ rem} \times 5 \times 139}{10^{-6}}$ (10^6)

** eg. $\frac{2.8 \text{ rem} \times 5 \times 1300 \text{ birth}}{10^6}$

*** Based on highest value from column 8 absolute risk model and are slightly lower than those ~~[illegible]~~ for the absolute model in Table 2. Thus, as far as ~~[illegible]~~ estimates of cancer risk are concerned, the values obtained using risk coefficients from BEIR I [illegible] are in the same [illegible] range as those obtained using risk coefficients from BEIR III,

~~[illegible]~~

Risk estimates for health defects obtained using the risk factor from BEIR-I give values about 2 times those obtained using the ~~[illegible]~~ ~~[illegible]~~ ~~[illegible]~~ bigger ~~[illegible]~~ value of the range of risk ~~coeff~~ factors given in BEIR III. If BEIR-III ~~[illegible]~~ [illegible] [illegible] [illegible] ~~[illegible]~~ represent a ~~[illegible]~~ ~~[illegible]~~ [illegible] realistic assessment of the [illegible] [illegible] [illegible] [illegible] genetic effects than the ~~[illegible]~~ factors in BEIR I for overall health effects, then the estimates in ~~[illegible]~~ [illegible] the [illegible] [illegible] ~~[illegible]~~ ~~[illegible]~~ may be [illegible] [illegible] 3.

Bikini ~~Resident~~

Estimates of radiation doses received by persons who resided at Bikini for about 10 years until August 1978

A. Bone Marrow Doses - Calculation of average dose (values in mrem)

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	820
1300	1600	900	1400
1500	710	1200	1100
1900	2100	2100	760
900	1400	1500	1500
2100	1900	410	300
310	1600	400	1400
1500	1900	1300	620
370	1600	340	670
1300	3000 (maximum value)	1500	56,200 mrem
2300	72,360 mrem	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 rem
2600	72.36 rem	2200	males 72.36
2600	56.20 rem	430	females 56.20
1600	128.56) $\frac{128.56}{99}$ = 1.298 =	1500	128.56

1.3 rem [illegible]

B. Whole Body dose

Males

Identification Number	Age	Total whole body dose (mrem)		
6001	66	1400	X	
6127	13	1500		
6130	29	300		
6076	39	1300		
813	23	1200		
6019	48	1100	X	
6132	12	1500		
6066	32	830		
6070	28	2200		
6118	22	1200		
6117	22	1400		
6128	31	1800		
6015	11	870		
6033	27	2000		
6007	35	300		
6008	32	1400		
6071	32	350		
863	27	1200		
6086	46	2100	X	
6067	32	1700		
6073	24	1400		
6072	20	460		
6119	17	1700		
864	51	1900	X	
966	56	3200	X	highest value
6009	6	2200		
6049	8	1900		
6042	7	580		
6014	5	1500		
6012	7	2400		
6016	10	2400		
6013	5	1600		
6005	38	700		
6135	35	500		
6125	35	2100		
6067	56	1700	X	
6002	65	670	X	
6006	37	490		
6096	48	1100	X	
80	69	330	X	
6017	49	2300	X	

	1	2	3	4
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 under age 40		53,730	average = 1364.87 [illegible]	~~1.31~~ [illegible]
Total for all Males 50		70,530	average = 1410.6 [illegible]	1.[illegible]
over 40 11/50				

Female

Individual No. #	1 Age	2 total whole body dose	3
6111	32	250	
6097	19	950	
6115	43	1600	X
6109	15	760	
6091	13	1300	
6046	43	600	X
6061	32	1400	
6122	70	1600	X
6030	10	1600	
6129	13	850	
6027	6	1200	
6010	8	2000	
6105	5	1500	
6059	19	400	
6124	54	390	X
6058	18	1200	
6036	27	340	
6110	32	1400	
6051	19	1200	
6092	8	2400	head of relative
6080	7	310	
6038	6	1400	
6103	9	1600	
6028	7	1800	
6044	6	2200	
6062	21	1100	
6034	46	1800	X
865	45	1300	X
6050	22	710	
6094	10	2100	
6112	35	420	
6035	20	1400	
6045	22	270	
6108	24	730	
6063	24	1100	
525	37	470	
934	43	2100	✓
6106	6	1100	
6025	5	1300	
6113	25	880	
6060	22	790	

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

total in 41 under age 40 — 44320 — x̄ = 1080.98 mm

54710 — x̄ = 1116.55 mm

Total in all 49 families

over 40, 8/49

Total [illegible] 54.7 mi

70.5

125.2

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

I. Assumptions (c/lc) —— CENTER

Estimates of cancer and birth defect~~s~~ 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. 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.

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 conservation.

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 = $164 \sim 160$

Births in 30 years = $1277 \sim 1300$

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

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

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

For a population of 235:

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

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

For a population of 350:

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

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

III. Risk Coefficients

CENTER & 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)		Derived Cancer deaths/10^6 person rem [illegible]	
	Absolute	Relative	Absolute	Relative
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 87/10^6 person rem and the maximum by 458/10^6 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

Fil3 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 defect~~s~~ 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

1. Cancer (Table V-4)

Lifetime Risk of Cancer Death

(deaths/10^6/rad)

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

2. Birth Defects--pages 166-169 A

(mean parental age = 30 years)

- 1 rem per generation (1 rem parental exposure) per 10^6 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 diferent 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 compar~~at~~ision 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 concenred, 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 bith 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.

B

Eneu - 100%

30 year dose - 3000 mrem

pop - 550

Total Man rem : 1,650,000 man-mrem = 1650 person rem

Risk Coefficients	Relative	Absolute
BEIR - I	310/10⁶ person rem	95/10⁶ person rem
BEIR - I [illegible]	568	115
BEIR - III	182	67

Cancer Death.

BEIR I $\frac{310 \times 1650}{10^6} = \frac{511,500}{10^6} = 0.5$ $\frac{95 \times 1650}{10^6} = \frac{156,[illegible]}{10^6}$

$\frac{160 \times 1650}{10^6} = \frac{264,000}{10^6} = 0.23$ 0.16

$\frac{458 \times 1650}{10^6} = \frac{755,700}{10^6} = 0.76$

[illegible] 15% 83 X 0.004 X 3 = 0.996

[illegible] incidence [illegible]

3 rem · 30 yr

[illegible] 10% 55 X 0.004 X 3 = 0.[illegible]

[illegible]

BEIR I ([illegible]) $\frac{568 \times 1650}{10^6} = 0.937000$ $\frac{115 \times 1650}{10^6} = 0.1[illegible]$

BEIR III $\frac{182 \times [illegible]}{10^6} = 0.300300$ 67 [illegible] = 0.110550

75

[illegible] file B

[illegible]

[illegible] mean [illegible]

[illegible]

24 [illegible]

[illegible]

2 per [illegible]
4 per [illegible]

22 [illegible]

[illegible] based on 1300 line [illegible]

+ 55[illegible]

Pop

[illegible]

11.[illegible]

13

[illegible]

[illegible]

[illegible]

[illegible] 20

[illegible] 10

[illegible] ?

[illegible] 22 - 4[illegible] [illegible]

[illegible] x [illegible] [illegible] 2 - [illegible]

Ruben Zackhras, Acting President and Minister of Transportation and Communications

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, anthropologist 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 booklets, 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 ~~B~~Kiklon - Secretary of Health
Car~~e~~men Bigler - Director of Public Affairs
~~Mr~~ Jerre Bennett - Curriculum/Learning/Training Center
(U.S.)

[illegible]

Bill--

Here is a list of people who are officials in the Marshallese Government. They are in our files but I honestly don't know if you met with them.

Iroij Joannes Peter
John Abraham, Magistrate
Sam Livai, Councilman
Abner Edward, Councilman
Benji Gideon, Councilman
Renton Joannes, Councilman
Iroij Benton Abraham
Saimon Samson, Councilman
Saul Abraham, Councilman
Lombwe Mark, Councilman
Sam Luke, Councilman
Moses Abraham, Councilman
Balik Paul, Councilman
Alik Jorem, Councilman
A_ata Kabua, President
Oscar DeBrum, Chief Secretary

[illegible] AEC/ERDA [illegible]

Check this list please and let me know if there are more names I should add.

Linda

We need to compare this with Carl Unruh - they report

[illegible]

as Minister of Transp & Communication

Bickhram
Kabua
Andrike
Jesse
Samuel
Beckham
Bennett
McKay
Capelle
Madison

Tesler Edw
Jesse [illegible]
Robert Gibson

Also - Carmen Bigler

Need to get Roster of Govt people from Carl

Dear

On behalf of Mr Carl Amend of Dr Ray Raaltman and myself I want to thank you for ~~the~~ [illegible] meeting with us the week of September 30. [illegible] It was very helpful to hear your views on how [illegible] information about radiation [illegible] might be communicated to the people of the Marshall Islands. We [illegible] expect to have ~~a plan to accomplish this~~ [illegible] prepared for consideration by the United States Department of Energy & the Department of Interior within the next few weeks, ~~a plan~~

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

[illegible]

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

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 (Allyn)~~
JA Smith
~~WL Templeton (Bill~~)
~~RC Thompson (Roy)~~
~~CM Unruh (Carl)~~
B Wachholz (Bruce
JM Weisgall

1. Reexam of old material
2. Review art work
3. Rev of new material — Jack, C, + [illegible]
4. Write [illegible] mat'l of [illegible] —

~~Need for [illegible]~~

Level of cost in Islands

# of Seeds

1
2
3
4
5
6
7
8
9
10

W + WO

14 W

50 imported
50% split accord [illegible]
islands

1 100% on Enew W + WO imported food
550 people all local food from Enew

2 90% on Enew 10% Bikini W + WO import
all local from Enew

(3. 50% – 50% W + WO
local food 50 – 50)

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

5. 350 people – 100% Enew
Initially 1 year on Enew + 1 year Kili
With + WO imported
local food from Enew

(6. Same – 1 year on + 2 y/r)

7. 350 people – 98% Enew 2% Bikini
Initial 1 year on Enew / Bik + 1 year off [illegible]
With + WO imported food
local food all from Enew

8. 233 people 100% on Enew
1 year on + 2 years off
with + WO imported food
[illegible]

(9. 235 people 100% [illegible] [illegible])
1 on + 1 off W & W/O local food
local food from [illegible]

10. 235 people 90% [illegible] [illegible]
1 W & W/O local food
local food from

14 total

When do we get [illegible]?
[illegible] –
All day June 17 – ?

Corresponding [illegible] [illegible] –
for [illegible]
[illegible] 1977

[illegible]

June 10

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

Procedure for ~~AlicexxRayxxMelexanxand~~x translation work on paragraphs requiring small amount of work:

- 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?

[illegible]

PROCEDURES FOR SECRETARY

- Pick up material from out~~XXXXXX~~ folders 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 63 will have person in [illegible]

[illegible]
[illegible]
[illegible]
Ray Baalman
Bill Bair 14
[illegible]
Alice Buck
Jack Healy
Meleran Jelke
Keorong Sam
Martha Stifter

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
copies?
at the end ~~to Mel f~~
~~Keorong keep their~~
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.

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

Jonan *radiation* eo iolap *(average)* bwelen juon armij emaroñ boke iumin 30 yio:
ilo aoleben enbwinnin *(whole body)* . . . . millirem
ilo nonnonmej iloan dri *(bone marrow)* . . . . 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 . . . . %
[illegible] 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*. 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.

Jonan loñlok in ajiri ro bwelen remaroñ lotaktok kin naninmij in utamwe ilo yio kein 30 iman . . . . %
[illegible]

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.

. . . . millirem

. . . . millirem
. . . . millirem

. . . . %

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 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)

1

Jonan *radiation* eo elaptata bwelen juon armij emaroñ boke iumin juon yio . . . . millirem

The largest amount of radiation one person might receive during 1 year

Jonan *radiation* eo iolap *(average)* bwelen juon armij emaroñ boke iumin 30 yio:

ilo aoleben enbwinnin *(whole body)* . . . . millirem

ilo nonnonmej iloan dri *(bone marrow)* . . . . millirem

Average amount of radiation a person might receive over 30 year

Jonan lōñlok in *cancer* ko bwelen remaroñ walok ilo yio kein 30 iman . . . . %

The increase of cancer that might occur within the next 30 year

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*, 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.

Jonan lōñlok in ajiri ro bwelen remaroñ lotaktok kin naninmij in utamwe ilo yio kein 30 iman . . . . %

[illegible] children born with health defects [illegible] within the next [illegible]

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.

. . . . millirem

. . . . millirem

. . . . millirem

. . . . %

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 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 *radiation* eo elaptata bwelen juon armij emaroñ boke iumin juon yio . . . . *millirem*

The largest amount of radiation one person might receive during 1 year

---

Jonan *radiation* eo iolap *(average)* bwelen juon armij emaroñ boke iumin 30 yio:

ilo aoleben enbwinnin *(whole body)* . . . . *millirem*

ilo nonnonmej iloan dri *(bone marrow)* . . . . *millirem*

Average amount of radiation a person might receive during 30 years

---

Jonan lõñlok in *cancer* ko bwelen remaroñ 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*, 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

---

Jonan lõñlok in ajiri ro bwelen remaroñ lotaktok kin naninmij in utamwe ilo yio kein 30 iman . . . . %

[illegible] children born with health defects within [illegible]

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

---

. . . . *millirem*

. . . . *millirem*

. . . . *millirem*

. . . . %

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 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-b

3

Jonan *radiation* eo elaptata bwelen juon armij emaroñ boke iumin juon yio . . . . millirem

The largest amount of radiation one person might receive during 1 year

---

Jonan *radiation* eo iolap *(average)* bwelen juon armij emaroñ boke iumin 30 yio:

ilo aoleben enbwinnin *(whole body)* . . . . millirem

ilo nonnonmej iloan dri *(bone marrow)* . . . . 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 . . . . %

[illegible]

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

---

Jonan lōñlok in ajiri ro bwelen remaroñ lotaktok kin naninmij in utamwe ilo yio kein 30 iman . . . . %

[illegible]

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

---

. . . . millirem

. . . . millirem

. . . . millirem

. . . . %

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 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

80-C

(1)

4

Jonan *radiation* **eo elaptata bwelen juon armij emaroñ boke iumin juon yio** . . . . The largest amount of [illegible] one person might receive during 1 year	*millirem*	. . . .	*millirem*
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)* . . . . Average am[illegible] a person might receive during 30 years	*millirem*	. . . .	*millirem*
Jonan lōñlok in *cancer* **ko bwelen remaroñ walok ilo yio kein 30 iman** . . . . The [illegible] might [illegible] 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 . . . . [illegible]	%	. . . .	%

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)

5

Jonan *radiation* eo elaptata bwelen juon armij emaroñ boke iumin juon yio . . . . millirem

[illegible] one person might receive [illegible] 1 year

Jonan *radiation* eo iolap *(average)* bwelen juon armij emaroñ boke iumin 30 yio:

ilo aoleben enbwinnin *(whole body)* . . . . millirem

ilo nonnonmej iloan dri *(bone marrow)* . . . . millirem

Average [illegible] 30 years

Jonan lōñlok in *cancer* ko bwelen remaroñ walok ilo yio kein 30 iman . . . . %

[illegible]

Melelen, bwe elane enaj wor 35 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*.

[illegible] 35 people die within the next 30 years [illegible] other than that caused by radiation [illegible] there might be an additional who die [illegible]

Jonan lōñlok in ajiri ro bwelen remaroñ lotaktok kin naninmij in utamwe ilo yio kein 30 iman . . . . %

[illegible]

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*.

[illegible] 235 [illegible] born with health defects [illegible] 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.

. . . . millirem

. . . . millirem

. . . . millirem

. . . . %

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 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

80-c

(3)

c

Jonan *radiation* eo elaptata bwelen juon armij emaroñ boke iumin juon yio . . . . *millirem*
[illegible]

Jonan *radiation* eo iolap *(average)* bwelen juon armij emaroñ boke iumin 30 yio:
ilo aoleben enbwinnin *(whole body)* . . . . *millirem*
ilo nonnonmej iloan dri *(bone marrow)* . . . . *millirem*
[illegible] 30 years

Jonan lōñlok in *cancer* ko bwelen remaroñ walok ilo yio kein 30 iman . . . . %
[illegible]

Melelen, bwe elane enaj wor 35 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*.
[illegible] would be 35 people die within the next 30 years [illegible] other than that caused by radiation [illegible] there might be an additional [illegible] who die [illegible]

Jonan lōñlok in ajiri ro bwelen remaroñ lotaktok kin naninmij in utamwe ilo yio kein 30 iman . . . . %
[illegible]

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*.
[illegible] if there were 235 [illegible] born with health defects [illegible] from any cause other than radiation left from atomic bombs within the next 30 years, there might be an additional [illegible] children born with defects caused by radiation left from atomic bombs.

. . . . *millirem*

. . . . *millirem*
. . . . *millirem*

. . . . %

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 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

80-D

Jonan *radiation* eo elaptata bwelen juon armij emaroñ boke iumin juon yio . . . . *millirem*

[illegible]

Jonan *radiation* eo iolap *(average)* bwelen juon armij emaroñ boke iumin 30 yio:

ilo aoleben enbwinnin *(whole body)* . . . . *millirem*

ilo nonnonmej iloan dri *(bone marrow)* . . . . *millirem*

[illegible]

Jonan lõñlok in *cancer* ko bwelen remaroñ walok ilo yio kein 30 iman . . . . %

[illegible]

Melelen, bwe elane enaj wor 35 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*.

[illegible] 35 [illegible]

Jonan lõñlok in ajiri ro bwelen remaroñ lotaktok kin naninmij in utamwe ilo yio kein 30 iman . . . . %

[illegible]

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*.

[illegible] 235 [illegible]

. . . . *millirem*

. . . . *millirem*

. . . . *millirem*

. . . . %

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 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

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

. . . . *millirem*

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

. . . . *millirem*
. . . . *millirem*

Jonan lōñlok in *cancer* ko bwelen remaroñ
walok ilo yio kein 30 iman . . . . %
The [illegible] 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 [illegible] 53 people [illegible] within the next 30 years [illegible] other than that caused by radiation left from atomic bombs, there might be an additional [illegible] who die from [illegible] caused by radiation left from atomic bomb

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 . . . . %
[illegible]

. . . . %

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 [illegible] 350 [illegible] born with health defects [illegible] from any cause other than radiation left from atomic bombs within the next 30 years, there might be an additional [illegible] 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

The [illegible] radiation one person might [illegible] during 1 year

---

Jonan *radiation* eo iolap *(average)* bwelen juon armij emaroñ boke iumin 30 yio:

ilo aoleben enbwinnin *(whole body)* . . . . millirem

ilo nonnonmej iloan dri *(bone marrow)* . . . . millirem

Average [illegible] dose a person might receive during 30 years

---

Jonan lōñlok in *cancer* ko bwelen remaroñ walok ilo yio kein 30 iman . . . . %

The [illegible] might [illegible] within [illegible]

Melelen, bwe elane enaj wor 35 **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 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 lōñlok in ajiri ro bwelen remaroñ lotaktok kin naninmij in utamwe ilo yio kein 30 iman. . . . . %

The [illegible] children born with health defect within the [illegible]

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.

. . . . millirem

. . . . millirem

. . . . millirem

. . . . %

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 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

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*
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)*** . . . . Average amount of radiation a person might receive during 30 years	*millirem*	. . . . *millirem*
Jonan lōñlok in ***cancer*** **ko bwelen remaroñ walok ilo yio kein 30 iman** . . . . The increased chance of dying of cancer 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.*** **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

Jonan lōñlok in ajiri ro bwelen remaroñ lotaktok kin naninmij in utamwe ilo yio kein 30 iman . . . . The increased chance 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, 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 *radiation* eo elaptata bwelen juon armij
emaroñ boke iumin juon yio . . . . *millirem*
[illegible] 1 year

Jonan *radiation* eo iolap *(average)* bwelen juon armij
emaroñ boke iumin 30 yio:
ilo aoleben enbwinnin *(whole body)* . . . . *millirem*
ilo nonnonmej iloan dri *(bone marrow)* . . . . *millirem*
Average [illegible]

Jonan lōñlok in *cancer* ko bwelen remaroñ
walok ilo yio kein 30 iman . . . . %
[illegible]

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.*
[illegible] 53 [illegible]

Jonan lōñlok in ajiri ro bwelen remaroñ lotaktok
kin naninmij in utamwe ilo yio kein 30 iman. . . . . %
[illegible]

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.*
[illegible] 350 [illegible]

. . . . *millirem*

. . . . *millirem*
. . . . *millirem*

. . . . %

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 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

103

Jonan *radiation* eo elaptata bwelen juon armij emaroñ boke iumin juon yio . . . . *millirem*

[illegible] the person might receive [illegible] 1 year

Jonan *radiation* eo iolap *(average)* bwelen juon armij emaroñ boke iumin 30 yio:

ilo aoleben enbwinnin *(whole body)* . . . . *millirem*

ilo nonnonmej iloan dri *(bone marrow)* . . . . *millirem*

[illegible]

Jonan lōñlok in *cancer* ko bwelen remaroñ walok ilo yio kein 30 iman . . . . %

[illegible]

Melelen, bwe elane enaj wor 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 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 . . . . %

[illegible] children born with health defects within the [illegible]

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

---

. . . . *millirem*

. . . . *millirem*

. . . . *millirem*

. . . . %

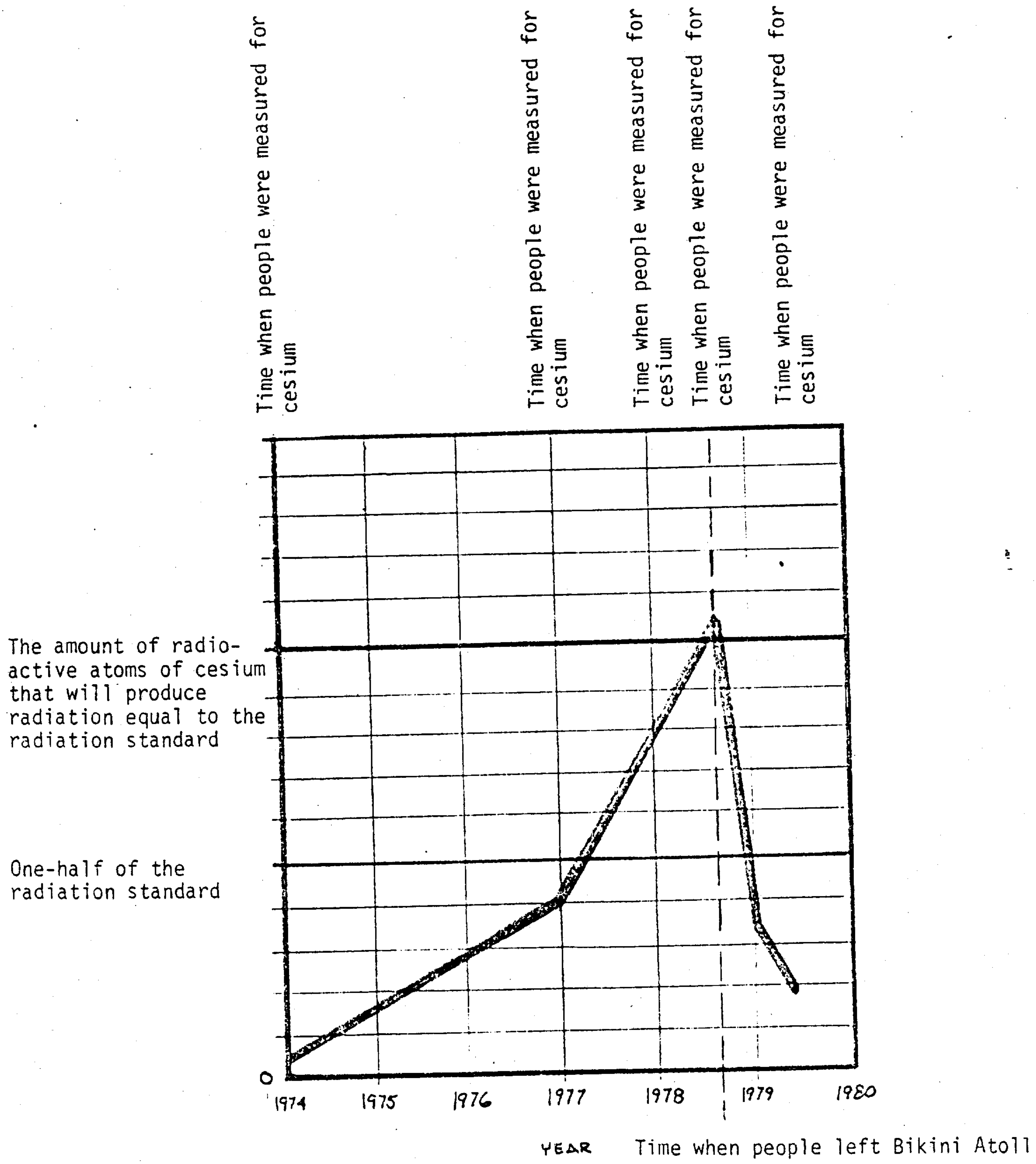
Melelen, bwe elane enaj wor armij remij ilo yio kein 30 iman jen jabrewot *cancer* ijellokin *cancer* ko rej walok jen *radiation* eo ej walok jen *atomic bomb*, emaroñ bar kobatok ro rej mij jen *cancer* ko rej walok jen *radiation* eo ej walok jen *atomic bomb*.

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 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


Time when people were measured for cesium
Time when people were measured for cesium
Time when people were measured for cesium
Time when people were measured for cesium
Time when people were measured for cesium
The amount of radioactive atoms of cesium that will produce radiation equal to the radiation standard
One-half of the radiation standard
0
1974
1975
1976
1977
1978
1979
1980
YEAR
Time when people left Bikini Atoll

B

¶ 4 — section 3 in Person 2 [illegible]
spelling of island names
Islands VS islands

¶ 119 — ?
[illegible]

26a [illegible]

32 — why change last sentence (

12 — Used to confirm [illegible]

42 — NATO (

[illegible] — [illegible]

([illegible] 1978
(A [illegible]

[illegible]

[illegible]

¶ 9 — [illegible]

33 [illegible]

Banana
Page 8 — The islands

[illegible] Kooy [illegible]

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 20510

Tel 456 — 6272

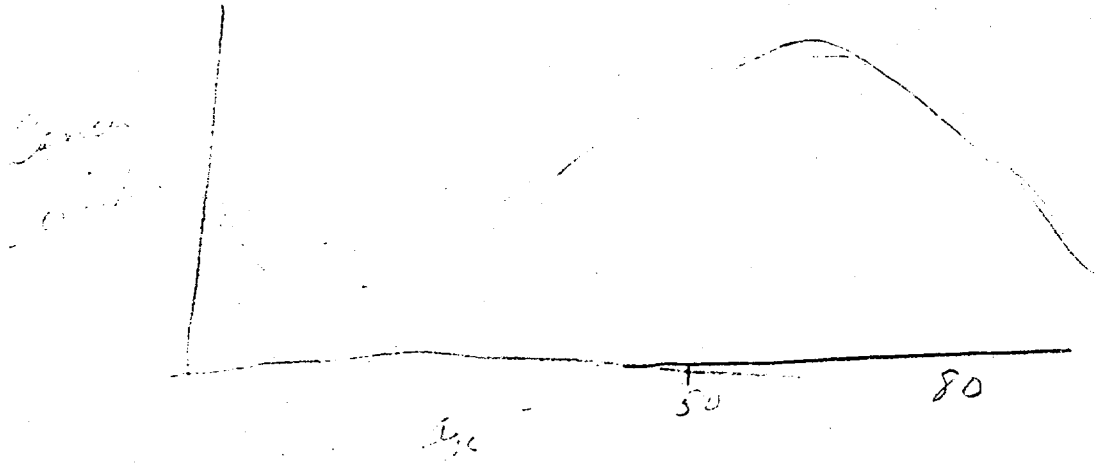
Nick Carter

629 - 3205

The way Radiation affects the body

How Radiation can affect people's body

[illegible]



Title – The Meaning of
Radiation at [illegible] Atoll

Me

~~[illegible]~~ Meaning

glossary —

Perhaps we should have stressed ~~the~~ radionuclides as toxic substances — ~~a~~ a special kind of poison

~~radionuclides [illegible] [illegible] poisons with~~

Some ~~[illegible]~~ poisons lose their power to harm people
— bacteria etc. die
— chemicals

Radioactive Poisons

Some last for seconds
minutes

Some last for 1 or 2 days — [illegible]

Some radionuclides last [illegible] for ever

[illegible] last for 1+ [illegible]

Two groups —
to clean up

to plant
ate with Americans + ate fish
some canned + some [illegible]
[illegible]
Some trees were not cut [illegible]

After Americans [illegible] did get [illegible] ?

George — a Japanese American — [illegible]
Food was brought from Kwajalein

[illegible] Bikini [illegible]
[illegible]
[illegible]
[illegible] request
The other group — [illegible]
[illegible]

Went to Bikini about [illegible]
[illegible]
[illegible] + among [illegible]
we [illegible] plan the [illegible] of [illegible] ?
We will have [illegible] not [illegible]
to [illegible]
[illegible] — [illegible]
What [illegible] ?

Calls him – Thurs
Sat.
Tues

What do Bikinians 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 foods were tested?

amount of [illegible]

Will we [illegible] health?

HENCHI BALOS

MOSES LEWES

[illegible] (?) MARK

[illegible] [illegible] - must go through skin

(include
Actual data on food?)

show Iodine? dose for different foods

Info - radionuclides in water, fish

27 —

Names of [illegible] —
dose to [illegible] lungs, etc [illegible]
absorb into blood

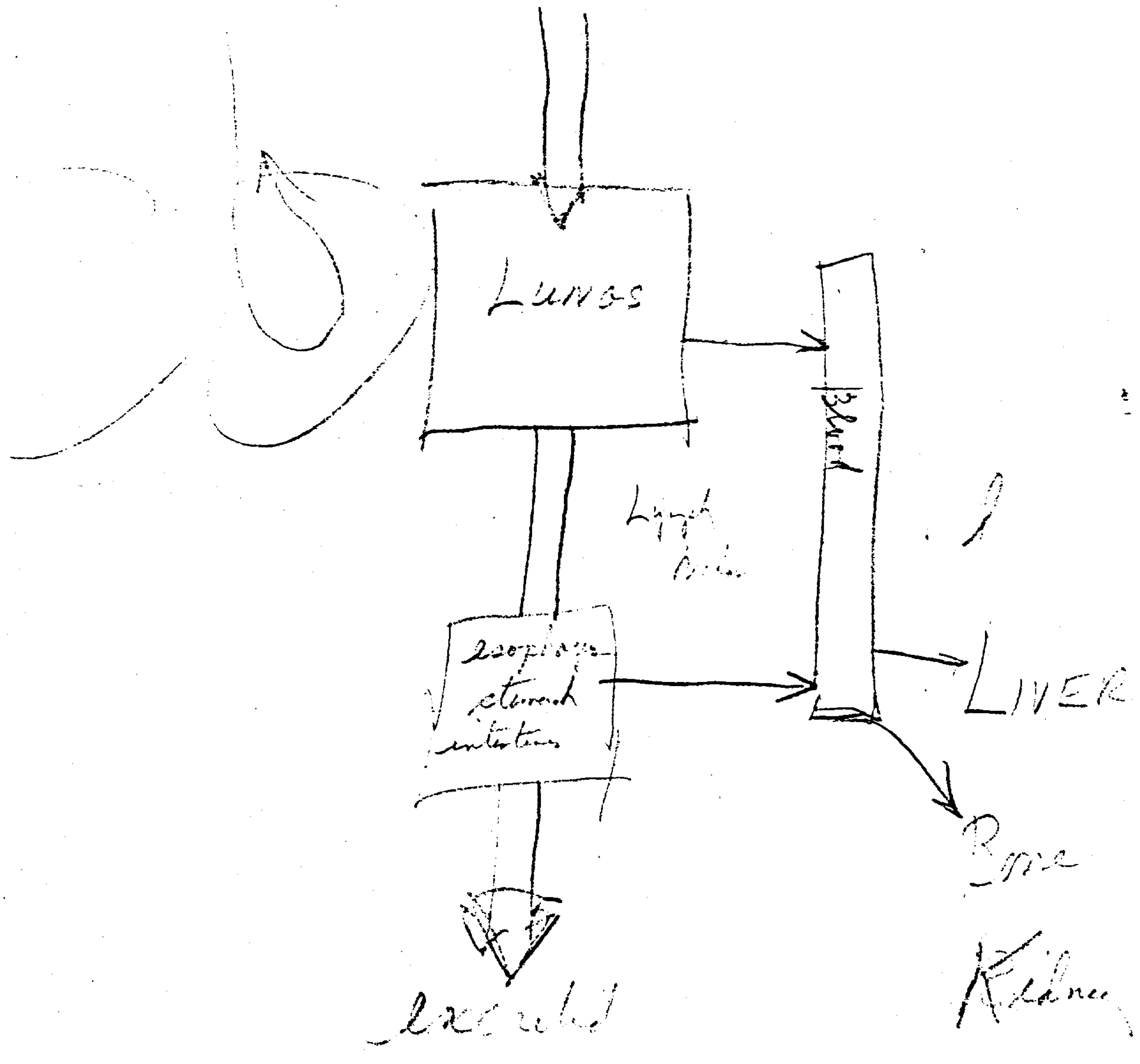
#26

ie. half life
chart

Bone marrow

$$\begin{array}{rl} .7 & \text{Sa} \\ .07 & \text{S2} \\ \underline{.4} & \text{Est} \\ 1.\cancel{1}7 & \end{array}$$

$$\begin{array}{r} 6 \\ 6\cancel{4} \\ \underline{30} \\ 100 \end{array}$$


Lungs
Blood
Lymph
esophagus
stomach
intestines
excreted
LIVER
Bone
Kidney

Coconut

Pandanus

Breadfruit

Arrowroot

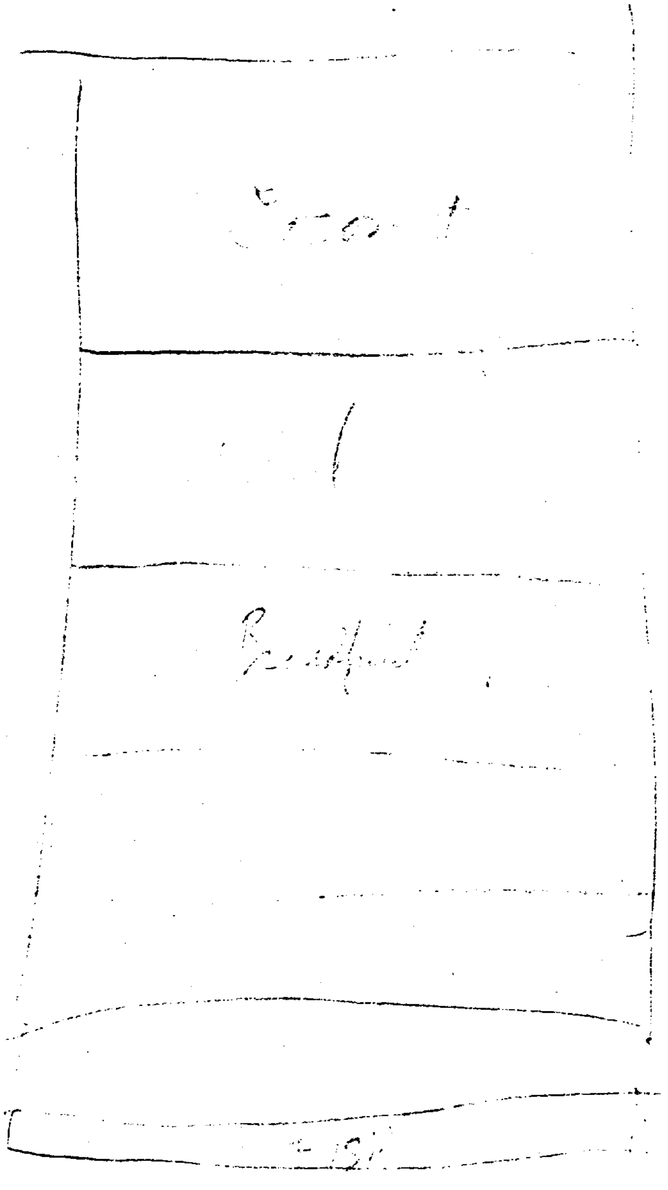
Fish

Pumpkin

Banana

Papaya

Sand



New Chart - page 9

Call Robeson -

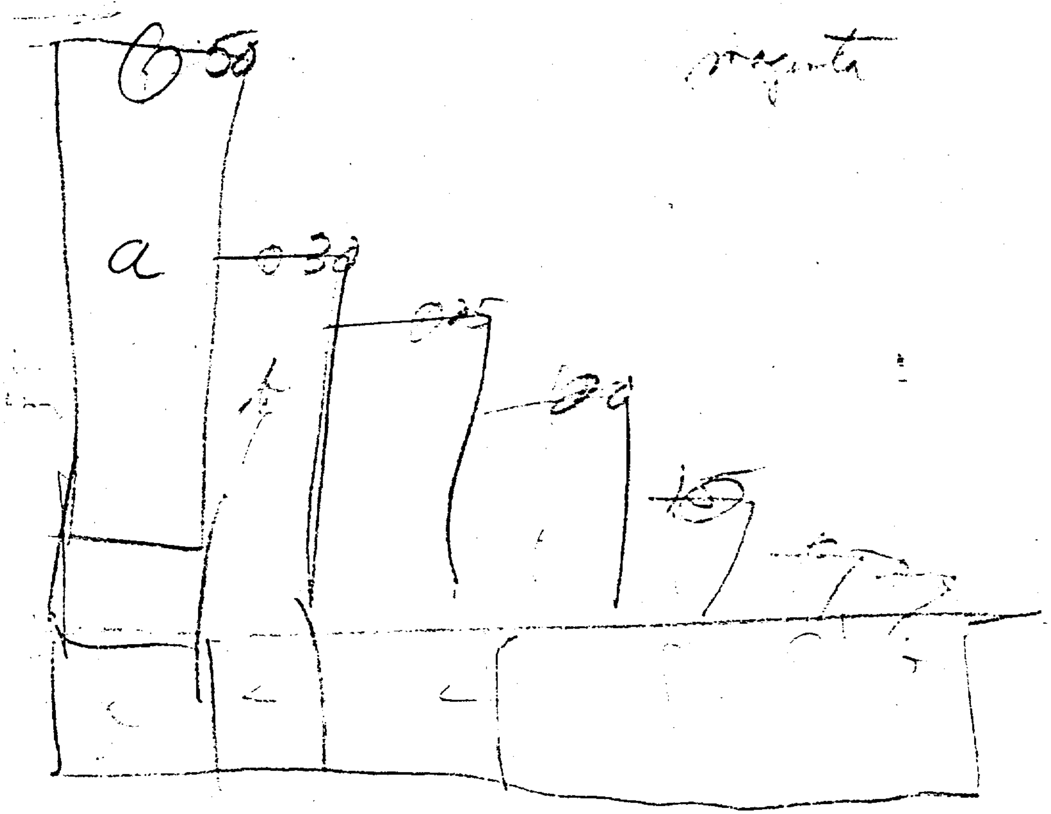
[illegible] Use

magenta

Radiation

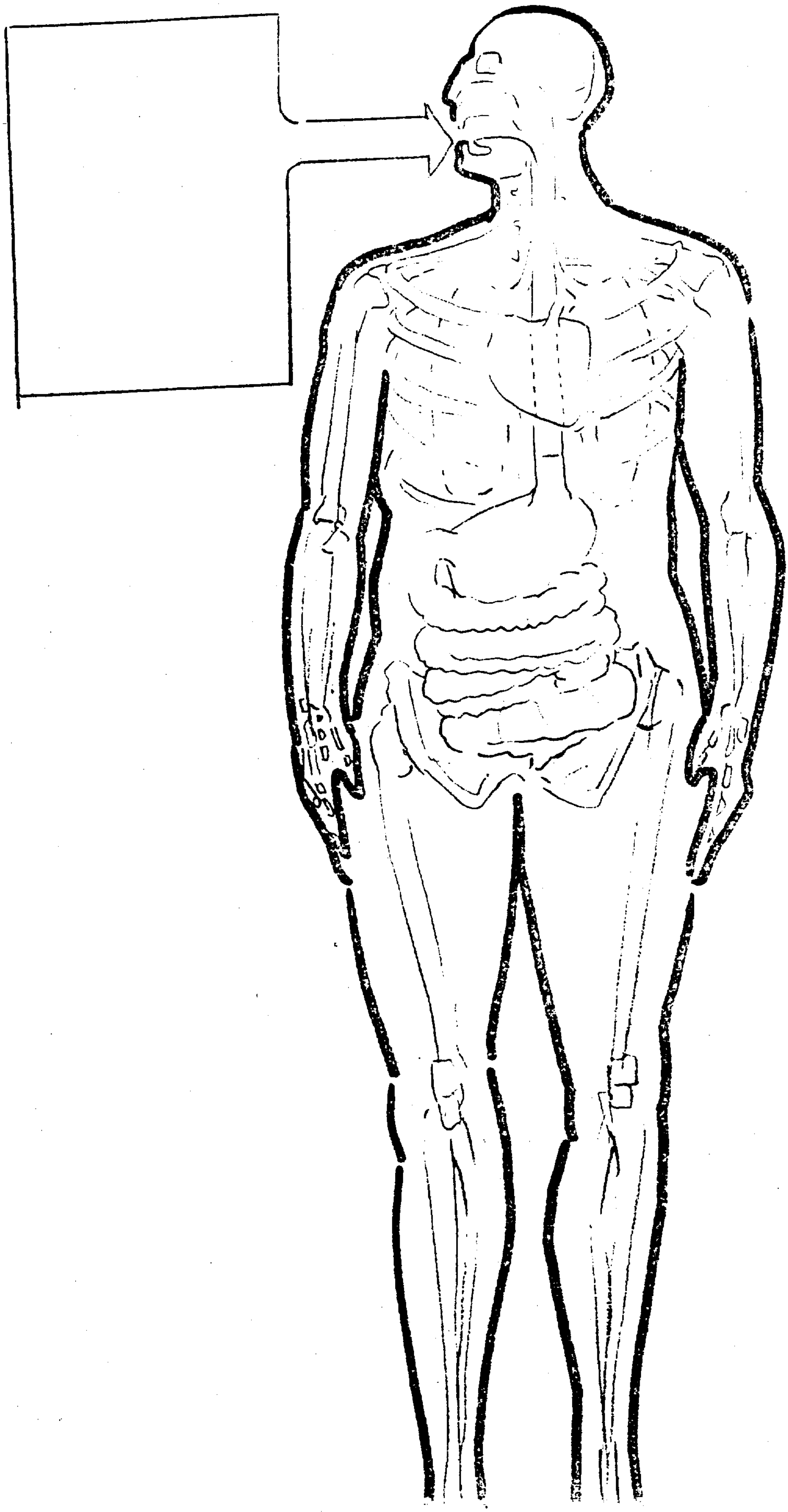
~~Radiation~~

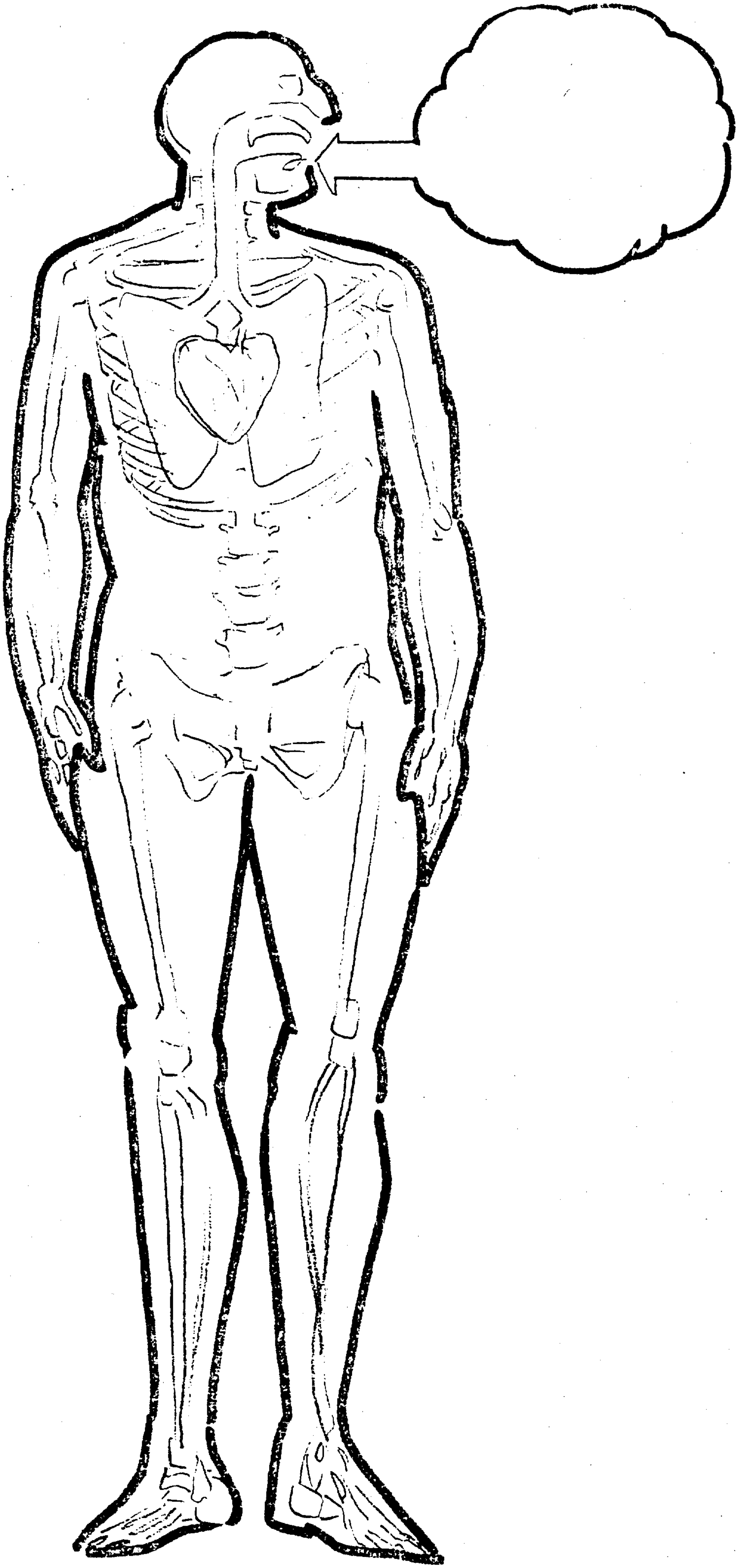
Amount of Radiation atoms in foods

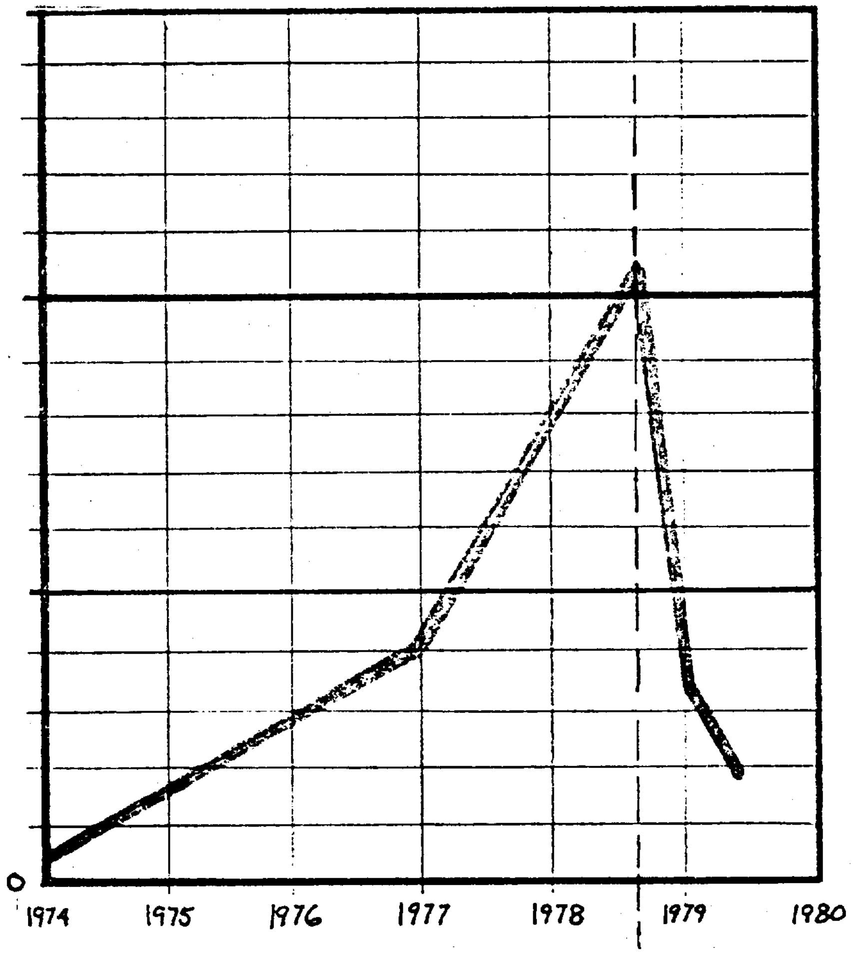


fish
bread fruit
pandanus
clams [illegible]
coconut
coconut crabs
papaya
[illegible]
squash
[illegible]

B






0
1974
1975
1976
1977
1978
1979
1980
YEAR

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 but 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

FORM 659 12/75

LOS ALAMOS SCIENTIFIC LABORATORY
FACSIMILE TRANSMISSION HEADER

To [illegible] (MS 3.150 [illegible] MS 150)

FROM	
J. W. Healy	
ORGANIZATION: H-DO	MAIL STOP: 400
PO BOX 1663, LOS ALAMOS, NEW MEXICO 87545	

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W. J. Bair	Battelle Pacific Northwest Lab. Richland, Washington	8-444-6540	444-731

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April 10 8

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APR 10 9 49 AM '80

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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 test.

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.

2

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.

3

125

Conversation with [illegible]

Bikini

1. Why Bikini cannot be cleaned up like Enewetak

Wiesgall

1. What happened on Bikini re fallout
plume of fallout pattern
2. How different from Enewetak
3.

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

5. What is risk to people who have been there

6. What would ~~physician~~ be in 2 yr rotation?
(Bikini diving)
7. Info on small islands - south end of atoll

8.

Bruce to get
Pop. - for Enewetak 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 Enewetak 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 cobalt 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.

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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 thw 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

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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.

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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.

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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.

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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.

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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.

B

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

[illegible]

b.

HARVESTING COCONUT STEMS

By: Alfonso M.R. Mendoza*

Summary

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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a toproot 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)

	BEIR-I		Derived	
	Cancer Deaths/year in U.S. from 0.1 rem/year (pop=197,863,000)		Cancer Deaths/10^6 person rem	
	Absolute	Relative	Absolute	Relative
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
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/10^6/rad)

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

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

1 rem per generation (1 rem parental exposure) per 10^6 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 182/10^6 man rem

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

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	950	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

Island Code	Island Name	^{90}Sr	$^{239+240}$Pu	^{241}Am
B1	Nam	10 (23)*	60 (25)	20 (32)
B2	Iroij	54 (6)	8.3 (1)	7 (9)
B3	Odrik	8.5 (15)	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	Eneu	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	Lukōj	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.

6	> 75	> 20	10 - 20
3	25 - 74	10 - 19	5 - [illegible]
2	10 - 24	1 - 9	1 - 5
	< 10	<	< 1
			> 20