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RADIOACTIVITY IN THE BIOTA AT ISLANDS OF THE CENTRAL PACIFIC, 1954 - 1958

Evaluations of the radioactive contamination of biological organisms in the vicinity of the Eniwetok Test Site have been made by the Laboratory of Radiation Biology since Operation Crossroads in 1946. In order to determine the geographical limits of the contamination, the area of the surveys was extended, in 1954, to include several islands away from the test site. The "off-site" collecting areas, shown in Figure 1, include locations in the Marshall, Caroline, and Gilbert Islands and were selected because of their direction and distance from Eniwetok as well as their accessibility. Surveys made at these islands in 1954, 1955, 1956, and 1958 showed that in 1956 and 1958 the radioactivity decreased with distance and direction from the test site and that at the islands within a 130-mile radius the radioactivity was approximately ten or more times that of the other islands. Tarawa, an atoll 800 miles to the southeast of the test site, contained very low levels of radioactivity.

The results of studies by several laboratories on the radioactive contamination of areas adjacent to the test site and in the open ocean in 1954 to 1956 have been summarized by

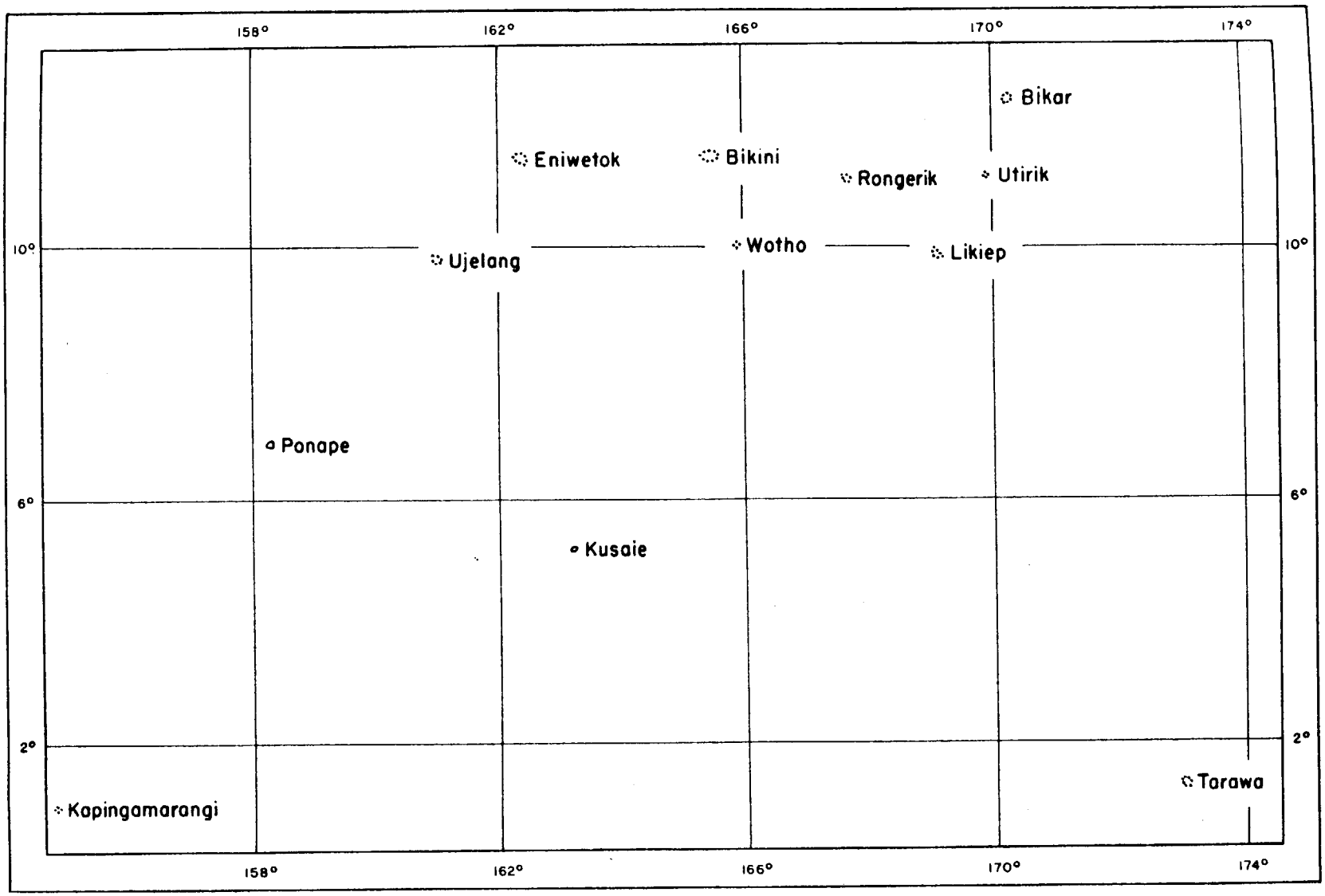

Fig. 1. Collecting stations in the central Pacific in the vicinity of the Eniwetok Test Site.

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oceans were made by the Japanese. One-half of the samples, which were obtained at the port of landing in Japan, were sent to the Laboratory of Radiation Biology for analysis. The analyses made by the National Institute of Health, Tokyo, have been reported by Kawabata (1960).

The present report will be confined to the results of the studies made at the ten "off-site" islands and the one test site island shown in Figure 1, during a period which encompasses three nuclear testing programs at the Eniwetok

Radiation Counter Laboratory Nucleometer Mark 9, Model 3.

The samples collected in 1958 were analyzed for gamma-emitting isotopes with a 3 x 3-inch sodium iodide crystal connected to a Radiation Counter Laboratory 256-channel analyzer. The radioisotopes present in the samples were identified by their gamma energies and for some of the samples the amount of each radioisotope was determined by a subtractive

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[illegible]	factor
K^{40}	409
Cs^{137}	16.5
Zn^{65}	54
Zn^{95}-Nb^{95}	14.5
Co^{57}	8.6
Ce^{144}-Pr^{144}	40
W^{185}	9.6
Ru^{106}-Rh^{106}	66.4

A semiquantitative analysis of a Messerschmidia sample collected in 1956 at Wotho Atoll was made in a single-channel, 50-position, automatic advance gamma spectrometer with a two-inch well-type sodium iodide crystal.

For some of the 1958 samples the amount of Sr^{90} was determined by the precipitation plus ion-exchange method of Kawabata and Held (1958).

Radioactive beta decay data were obtained for some of the 1956 samples.

The common names of the organisms are used in the text and tables. The scientific names are given in Appendix Table M.

RESULTS

Gross Beta Radioactivity

The individual gross beta values plus or minus the 95 per cent counting error from ten collection sites during the interval 1954 to 1958 are given in Appendix Tables A to K. A value identified as background signifies that the counting error was as great or greater than the net count, i.e., the count after background was subtracted. The data from the appendix tables for algae, coconut meat and milk, fish muscle and liver, and sea cucumber muscle are summarized in Table 2.

Table 2. Average gross beta values of samples from Bikini and "off-site" locations in the western central Pacific Ocean, 1954-1958. Values are expressed as μμc/g of wet tissue at time of counting[1], plus or minus one standard deviation.

Location and date of collection	Algae, entire	Coconut		Fish		Sea cucumber
		Meat	Milk	Muscle	Liver	muscle
Off-site						
Bikar						
2-3-55	-	8.6±1.4	7.3±0.32	-	-	-
Kapingamarangi						
7-4-58	-	Background[2]	1.9[2]	-	-	19±8.6
Kusaie						
7-5-56	26±11	-	8.2[2]	86±60	61 ± 37	-
7-3-58	16±7.3	2.1[2]	2.5[2]	2.0[2]	Background[2]	10±5.0
Likiep						
1-22-55	135±76	6.8±3.5	6.4±1.9	3.7±2.4	9.5± 11	175±90
Ponape						
12-16-54	33±16	8.2±2.3	2.3±0	24±15	181±206	-
5-13-56	83±97	-	-	21±24	32±6.4	4.2[2]
7-13-56	23±9.1	3.4±0.26	2.4[2]	-	-	-
9-26-56	78±61	11±1.1	2.2[2]	18±1.9	158± 30	-
7-24-58	56±46	Background[2]	-	5.5±2.0	3.4±1.1	-

[1] Samples counted 2-8 weeks after collection
[2] One sample only

Table 2. (continu

Location and date of collection	A e
Rongerik	
2-3 -55	
Tarawa	
7-5 -56	
7-11-58	
Ujelang	
2-3 -55	
7-18-56	
7-19-58	
Utirik	
5-17-54	1
1-23-55	
7-16-58	
Wotho	
6-18-56	
6-30-58	

[1]Samples counted

[2]One sample only

[3]Samples counted

Table 2. (continued)

Location and date of collection	Algae, entire	Coconut		Fish		Sea cucumber muscle
		Meat	Milk	Muscle	Liver	
Test Site						
Bikini Island						
5-9 -54	-	-	-	1630±1730	24,500±32,300	-
6-22-54	155,000±140,000	-	-	936± 518	67,700±47,300	85,900±15,600
11-2-55	741±518	-	-	22± 19	1,140± 1,010	312±94
9-22-56	5,450± 1,600	94±62	34±6.8	106±7.7	3,450± 395	-
8-28-58[4]	3,960[2]	-	-	-	4,730[2]	-

[2]One sample only

[4](Enyu Island, Bikini Atoll)

[redacted]

samples at the test site with [redacted]

islands, values for Bikini Island have been included in Table 2.

Radioisotopic Composition

The results of the semiquantitative analyses of gamma spectra of samples collected in 1956 and 1958 are given in Appendix Table L; results of quantitative analyses for some of the 1958 samples are given in Table 3. The latter table also includes the results of the Sr^{90} analyses. The samples were not analyzed immediately after collection; consequently the short-lived radioisotopes which might have been present at the time of collection are not included in the results.

DISCUSSION

The highest levels of gross beta radioactivity were found in samples of algae, fish liver and muscle, and sea cucumber muscle from Ujelang, Wotho, Utirik and Rongerik Atolls (Table 2), which are only one hundred to three hundred miles from the test site; however, the levels in coconut meat and milk were low, even at these atolls. The radioactivity of similar samples from the outlying atolls and islands of

ble 3. Radioisotopes in fish, invertebrates and land plants from "off-site" locations July-August, 1958. Values are expressed as μμc/g wet weight plus or minus .95 counting error at time of collection.

ssue	K^{40}	Zn^{65}	Cs^{137}	Co^{57}	W^{185}	Ru^{106}-Rh^{106}	Zr^{95}-Nb^{95}	Sr^{90}
le	9.5 ± 2.3	16 ± 0.86	--	0.73 ± 0.15	--	--	--	--
ed	4.2 ± 0.44	0.68± 0.31	--	2.0 ± 0.064	--	0.55 ± 0.34	--	--
er,muscle	9.1 ± 1.5	--	--	--	--	--	--	--
cle	5.5 ± 0.82	--	--	--	--	--	--	--
le	5.0 ± 0.68	4.5 ± 0.55	--	--	--	--	--	--
er,muscle	6.8 ± 0.77	2.2 ± 0.82	0.17 ± 0.045	--	--	1.7 ± 0.41	--	--
ed	3.5 ± 0.77	16 ± 2.3	--	--	--	--	--	--
men	15 ± 2.2	68 ± 2.0	--	4.0 ± 0.38	--	--	--	0
pace	10 ± 1.3	13 ± 1.0	1.4 ± 0.073	2.4 ± 0.18	37 ± 3.9	3.8 ± 0.86	--	18 ± 0.73[1]
	3.9 ± 0.30	--	--	--	--	--	--	--
t	11 ± 1.5	--	1.7 ± 0.091	1.4 ± 0.20	20 ± 5.9	--	--	0.0082± 0.0068
	1.6 ± 0.19	--	0.27 ± 0.016	--	2.0 ± 0.034	--	--	0.0031± 0.0022
	3.7 ± 0.39	--	0.077± 0.019	--	--	--	--	--
t	3.8 ± 0.12	--	0.095± 0.007	--	1.8 ± 0.18	--	--	0
	19 ± 1.1	--	1.0 ± 0.069	--	21 ± 1.6	--	--	0
	15 ± 0.35	--	1.3 ± 0.037	0.12 ± 0.035	2.0 ± 0.64	--	--	0.086 ± 0.0059
	2.8 ± 0.43	--	0.26 ± 0.10	--	6.8 ± 0.23	--	--	0
	3.0 ± 0.34	--	0.35 ± 0.025	--	3.9 ± 0.64	--	--	0
:	2.6 ± 0.64	--	0.50 ± 0.045	0.29 ± 0.073	10 ± 1.4	--	--	0.018 ± 0.0050
	3.3 ± 0.21	--	0.12 ± 0.013	--	0.77± 0.32	--	--	0
	5.5 ± 0.27	--	0.39 ± 0.015	--	--	--	--	0

[redacted]

		[illegible]		1
Kusaie	7- 3-58	Coconut	Milk	3
		Breadfruit	Fruit	3
Tarawa	7-11-58	"	"	
Utirik	7-16-58	"	"	
Ujelang	7-19-58	Coconut	Milk	2
		"	Meat	3
		Breadfruit	Fruit	2
Kapingamarangi	7-24-58	"	"	3
Ponape	7-25-58	"	"	5

[1]Dry weight basis

[redacted]

number of samples. However, some general conclusions can be made. The algae and fish liver contained the highest levels of radioactivity and the coconut meat and milk were the least radioactive tissues at the majority of the stations.

The samples collected in January-February, 1955, at the atolls east of the test site contained relatively high amounts

of radioactivity, indicating that these islands, Bikar, Likiep and Rongerik (Appendix Tables A, D, F, and K), had become contaminated with the 1954 Bravo test fallout as had Rongelap Atoll. Of special note are the high levels of radioactivity in the island soil, fish liver and viscera and the low levels in the coconut samples collected at Rongerik. Later collections were not made at these islands and we do not know whether further contamination occurred there, as it did at islands to the south and west of the test site.

Birds were sampled only at Ujelang, Bikar and Rongerik in 1955 and at Tarawa in 1956. The 1955 samples contained relatively high levels of beta radioactivity, whereas those from Tarawa contained low levels. The white of a tern egg from Tarawa (Appendix Table G), however, contained more beta radioactivity (99 d/m/g) than any other tissue sampled, and fish, a principal food item of these birds, also contained significant amounts of radioactivity.

Qualitative analyses of gamma spectra also give an indication of the quantity of the isotopes present. Analyses of this kind made shortly after the 1958 collections (Appendix Table L) show that Zr^{95}-Nb^{95} and $Ru^{103,106}$-$Rh^{103,106}$ were the predominant radioisotopes in the samples. Two exceptions were

noted: $W^{181,185}$ contributed the major portion of the radioactivity in Scaevola leaves from Kusaie and in Messerschmidia and Scaevola leaves from Ujelang (Lowman et al. 1959), and Zn^{65} was predominant in fish tissues from Ponape and Utirik. Co^{57} was present usually in lesser amounts, and Co^{58} and Co^{60} were found only in a sample of clam kidney from Ujelang and a fish liver sample from Utirik. Other radioisotopes were present only in a few samples. Cs^{137}, for example, was found in plants from Kapingamarangi and Utirik, $Ce^{141,144}$-Pr^{144} in a few samples from Kusaie, Ponape and Ujelang, and Mn^{54} in fish skin and gut from Ponape and clam kidney from Ujelang. Fe^{59} was detected once only, in a sample of skipjack muscle from Ponape.

The quantitative results of the gamma spectrum analyses shown in Table 3 are based on analyses made approximately eighteen months after the samples were collected; consequently the shorter-lived radioisotopes Zr^{95}-Nb^{95} (half life 65 days), Co^{58} (71 days) Ru^{103}-Rh^{103} (40 days) and Ce^{141} (32 days) had decayed to insignificant or non-detectable levels. In a 161-gram sample of yellow-fin tuna from Ponape, however, Zr^{95}-Nb^{95} were found in low amounts (0.12 μμc/g at time of counting); at time of collection the level of Zr^{95}-Nb^{95} would have been 40 μμc/g. K^{40} was present in all samples analyzed. In some

samples from Wotho, Tarawa, Ponape, and Kapingamarangi, K^{40} contributed the major portion of the radioactivity. Other samples collected at the same time contained $W^{181,185}$, radioisotopes identified with the 1958 fallout. Some samples, such as coconut crab abdomen and whole fish from Wotho, contained Zn^{65}, whereas others, such as land plants, contained none. Some of the land plants contained measurable amounts of the long-lived fission products Cs^{137} and Sr^{90}. The highest level of Sr^{90} was found in a sample of coconut crab carapace from Wotho (18 μμc/g dry). The concentration of this isotope by the carapace of land crabs at Eniwetok has been reported by Held (1957).

The relatively rapid decay of beta radioactivity in some of the samples collected in 1956 at Tarawa, Ponape and Wotho (Fig. 2 A-E) indicates the presence of short-lived isotopes. A gamma spectrum analysis of one of the samples (leaves and stems of a Messerschmidia plant from Wotho) showed that Zr^{95}-Nb^{95} were the predominant radioisotopes in this sample. Thomas et al. (1958) found that these isotopes contributed approximately 84 per cent of the total radioactivity in a duplicate sample. The presence of short-lived isotopes in the 1956 samples indicated recent fallout at these islands.

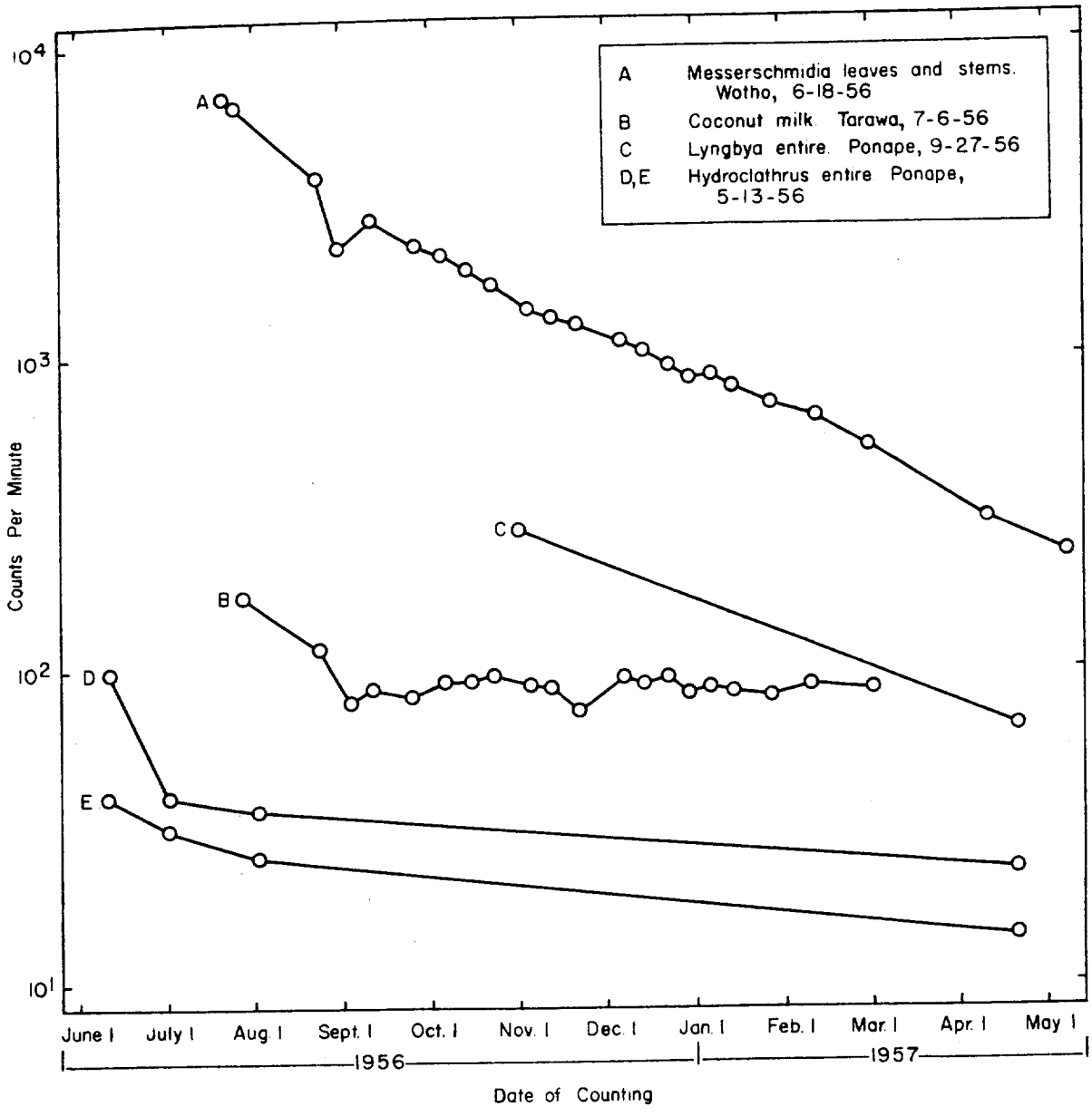

Fig. 2. Beta decay curves of samples collected in 1956.

SUMMARY

1. Surveys were made in 1954 to 1958 to determine the geographical limits of the radioactive contamination from the tests in the central Pacific Ocean.

2. Collections of biological samples and soils were made at one test site island (Bikini) and ten "off-site" islands.

3. The gross beta radioactivity decreased with distance from the test site; in 1956 and 1958 islands within a 130-mile radius contained at least ten times as much radioactivity as the other islands.

4. The levels of radioactivity also were related to direction from the test site. In 1955 the islands to the east contained high levels of radioactivity. In 1956 and 1958 Tarawa, 800 miles southeast of the test site, contained very low levels whereas Kapingamarangi, approximately the same distance to the southwest, contained significantly higher amounts of radioactivity.

5. Zr^{95}-Nb^{95} and $Ru^{103,106}$-$Rh^{103,106}$ were the predominant radioisotopes present in the majority of the samples.

Other isotopes, such as $W^{181,185}$, Zn^{65} and Cs^{137} were present in relatively high amounts in some samples. Sr^{90} was found usually in very low amounts.

APPENDIX