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EXTERNAL RADIATION LEVELS ON BIKINI ATOLL, MAY 1967

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Health and Safety Laboratory
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EXTERNAL RADIATION LEVELS ON BIKINI ATOLL - MAY, 1967

Harold L. Beck
Burton G. Bennett

Health and Safety Laboratory
U. S. Atomic Energy Commission
New York, New York

and

Tommy F. McCraw

Division of Operational Safety
U. S. Atomic Energy Commission
Washington, D. C.

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ABSTRACT

An intensive radiological survey of the islands of Bikini Atoll was conducted in April-May 1967 for the purpose of determining the levels and components of the external gamma radiation fields in this former weapons testing area. Fourteen islands and the two island complexes of the atoll were surveyed with instrumentation which included a field gamma spectrometer system, a high pressure ionization chamber, scintillation and G.M. survey meters, and thermoluminescent dosimeters. A large number of soil samples were taken for laboratory NaI(Tl) and Ge(Li) gamma spectral analysis. Total exposure rates were found to vary considerably from site to site and island to island. Levels measured over soil ranged from less than 10 μr/hr to over 500 μr/hr. Major contributors to the radiation fields usually included ^{137}Cs, ^{60}Co, ^{125}Sb, and ^{102m}Rh with a large number of other isotopes present. The large amount and consistency of the data indicate that a reliable and comprehensive picture has been obtained of the external gamma radiation environment of the atoll.

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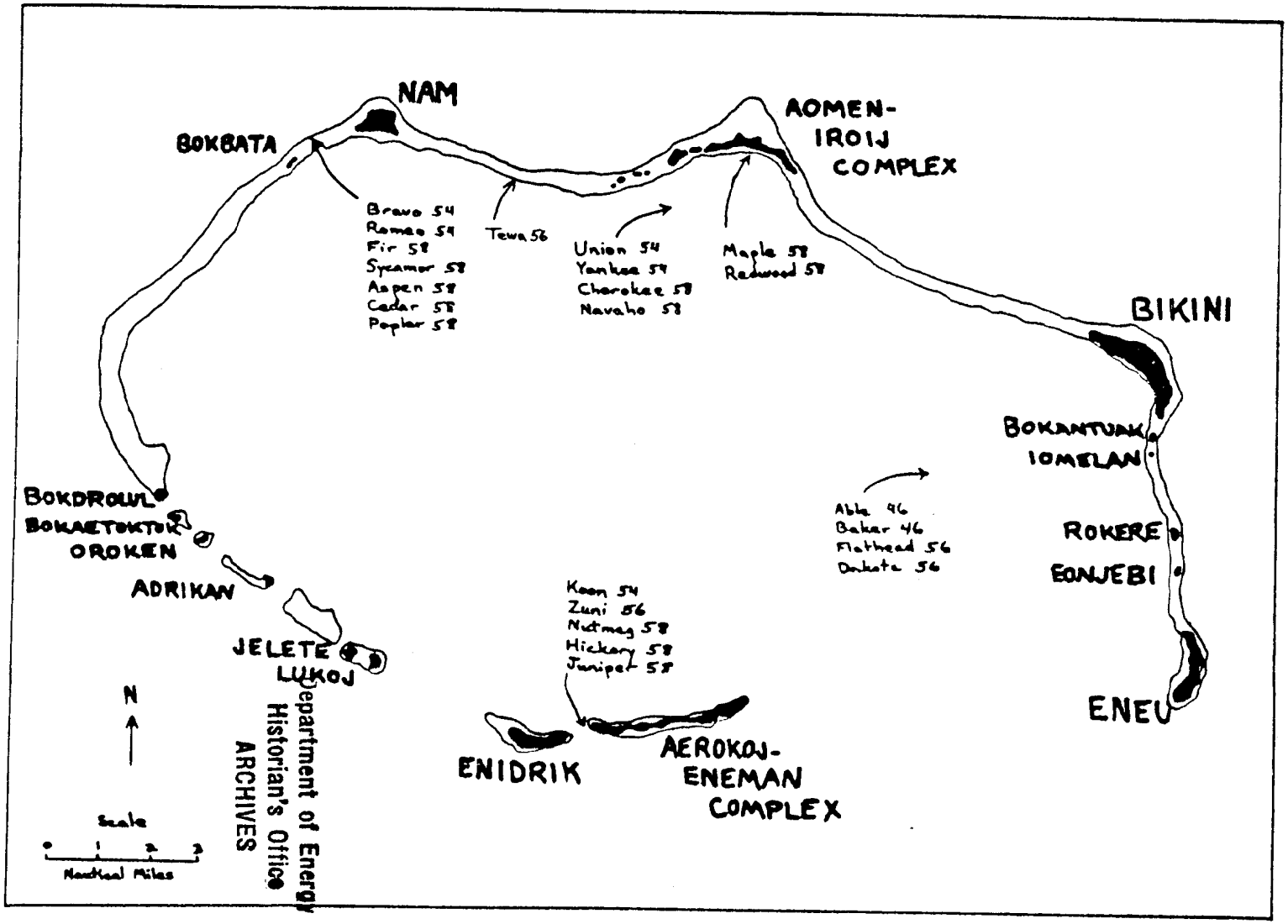

Figure 1. Bikini Atoll

1. INTRODUCTION

A radiological survey of the islands of Bikini Atoll in the mid-Pacific was conducted in late April and early May of 1967, nine years after cessation of extensive testing of nuclear devices in the area. The survey, sponsored by the Division of Biology and Medicine of the U. S. Atomic Energy Commission, included general observations of the prevailing environmental conditions and a detailed investigation of external environmental radiation levels. Exposure rates due primarily to penetrating gamma radiation were measured, and the principal radioisotopes contributing to the total exposure rate on each of the major islands of the atoll were determined.

Bikini Atoll is located in the northern Marshall Islands. The atoll consists of a number of small coral islands surrounding a lagoon 22 miles long and 13 miles wide. Total land area of the atoll is 2.32 square miles, of which 1.25 square miles comprises the three largest islands, Bikini, Eneu, and Nam. Figure 1 is a map of the atoll. The names of the islands differ on the various hydrographic charts, being usually variations of Japanese renditions of the original Marshallese names. On the map in Figure 1 and throughout this report we have used the Marshallese names of the islands.

The testing of nuclear devices at Bikini Atoll occurred during 1946, 1954, 1956, and 1958 and included the detonation of some 23 devices of both fission and thermonuclear types. The locations of the tests and the code name and year of each event are indicated on the map in Figure 1. Most of the shots were detonated on barges anchored in the lagoon or on the atoll reef. Two shots were air drops, Able and Cherokee, two were underwater, Baker and Maple, and three were surface bursts, Bravo, Zuni, and Koon. All of the islands received in varying degrees the resultant radioactive fission and activation products which were spread about the area. Although prevailing winds generally carried the local fallout westward, there were exceptions - notably shot Bravo, when unexpected winds carried the fallout toward the east.

An extensive survey of the atoll was last carried out in 1964, when the emphasis was on examining the radioactivity of flora and fauna and obtaining large numbers of samples of rats, birds, soils, and marine life for laboratory analysis. Thus, the gathering of additional samples of these types on this survey was not a primary requirement. However, a fairly large number of soil samples were taken and brought back for analysis so that the in situ measurements could be supplemented by calculations based on the isotopic concentrations determined by laboratory gamma ray spectroscopy, radiochemistry, and lithium drifted germanium spectroscopy.

The external radiation survey techniques utilized were largely those developed and used by the Health and Safety Laboratory for the past several years in conducting detailed investigations of the properties of the external radiation environment in the United States[1,2,3].

In addition to the survey measurements an experiment of the radiological effects of clearing a particularly heavily vegetated area was carried out on Bikini Island near the beginning of the survey trip.

Besides the authors, who were primarily responsible for the external radiation measurements, the survey team included Edward Held, University of Washington Marine Radiobiologist, the survey leader; his assistant, Robert Erickson; Arnold Joseph of the Division of Biology and Medicine; James Hiyane, Trust Territory District Agriculturist; Jack Tobin, former Trust Territory District Anthropologist; and Francis Tomnovek and Edward Jones of the U. S. Naval Radiological Defense Laboratory (USNRDL) who conducted most of the TLD studies and supplied and serviced the G-M detectors.

The survey team spent a total of 16 working days on the atoll using a U. S. Trust Territory ship, the M S. Militobi, as a base of operations. Fourteen islands and the two island complexes were surveyed. Only the very small island of Adrikan in the southwest corner of the atoll was by-passed. About ten days were spent on the three large islands, particularly Bikini Island (seven days). All of

the members of the team participated in conducting the experiments and gathering the data on external radiation. The data on the marine, plant, rat samples, and agricultural and anthropological observations will be published elsewhere.

In the following sections of this report we discuss in detail the radiation instrumentation, data collection and analysis, and present environmental radiation results for each island. Tables containing data pertinent to external radiation levels on Bikini Atoll conclude the report.

II. INSTRUMENTATION, DATA COLLECTION AND ANALYSIS

A high pressure ionization chamber and a γ-ray spectrometer system were used to obtain in situ exposure rates and spectra. The spectra were then analyzed to determine the individual exposure rates contributed by each major γ-ray emitting isotope in the soil. Because of the bulk and weight of the analyzer system, ionization chamber, and related power supplies, and the resultant difficulty in transporting the equipment from the ship via small boats to the shore and thence in many cases through heavy brush to a survey site, these types of measurements were limited to 16 sites on the three major islands. In all some 29 field spectra were obtained.

A small scintillation counter survey meter and a number of rugged G-M counter survey meters were used to extend the total exposure rate measurements over these islands and to survey the smaller islands. Although the data obtained with these instruments is less accurate for a particular location, their use enabled us to extend our measurements over a fairly large area conveniently and consequently obtain a more complete picture of the variation of radiation levels across the major islands and from island to island.

In addition to these measurements, thermoluminescent dosimeters were placed at a large number of locations on Bikini and Eneu Islands at the beginning of the survey and collected about ten days later and returned to the United States for readout. These passive dosimeters were employed to provide an independent check on the data obtained with the other instrumentation.

Soil samples were also taken at various locations exhibiting unusually high or low activity. All of these samples were returned to the United States for laboratory analysis, however, several were also spectrally analyzed on our 4 in. x 4 in. NaI(Tl) detector aboard ship to obtain identification of the major γ-ray emitters in the sample. At several locations a complete depth profile set of soil

IV. SUMMARY AND CONCLUSIONS

An intensive external radiation survey of Bikini Atoll was carried out during April and May of 1967. Total exposure rates were found to vary considerably from island to island and from site to site on a given island. Levels measured over soil ranged from less than 10 μr/hr to over 500 μr/hr. (External gamma radiation levels in the United States due to naturally occurring emitters in the soil range from 0 to about 20 μr/hr.) On Bikini and Eneu Islands the major contributor by far to the total exposure rate was found to be ^{137}Cs with minor but significant contributions from ^{60}Co and ^{125}Sb. On Nam and other islands closer to blast sites ^{60}Co was the main contributor with important contributions from ^{125}Sb, ^{102m}Rh, and sometimes ^{137}Cs. Other isotopes, including ^{207}Bi, ^{155}Eu, ^{152}Eu, ^{65}Zn, ^{106}Rh, ^{101}Rh, ^{144}Ce, and ^{241}Am, were also detected occasionally.
The range of radiation levels on each island are summarized below.

SUMMARY OF RADIATION LEVELS - GAMMA EXPOSURE RATES
(μr/hr)

Island	Exposure Rate Range	Major Contributors
Bikini	10-120	^{137}Cs
Weathered Areas	10-30	
Close-to-Shore	20-40	
Island Center	50-80	
Hot Spots	80-120+	
Eneu	2-10	^{137}Cs
Nam	10-330	^{60}Co, ^{137}Cs
Outer Edge	10-30	
Island Center	15-150	
N.E. Corner	110-330	
Bokantuak, Iomelan, Rojkere, Eonjebi	3-10	

Aerokoj-Eneman Complex:		
Aerokoj, Aerokojlol	1-10	*
Bikdrin, Lele	6-10	*
Eneman	1-570	^{60}Co, ^{125}Sb, ^{102m}Rh
East Eneman	1-10	
West Eneman	20-570	
Enidrik	3-235	^{60}Co, ^{125}Sb, ^{102m}Rh
East Enidrik	3-30	
West Enidrik	10-235	
Lukoj	60-200	^{60}Co, ^{125}Sb, ^{102m}Rh
Jelete	60-130	*
Oroken	15-45	*
Bokaetoktok	10-35	*
Bokdrolul	20-50	
Bokbata	10-30	^{60}Co, ^{137}Cs
Aomen-Iroij Complex:		
Aomen	5-20	*
Lomilik	20-330	^{60}Co, ^{125}Sb
Odrik, Iroij	10-40	*

*No soil sample or field spectra measurements.

It should be noted that these are the ranges of our measurements. It is quite likely that there are locations where the local exposure rates are higher than the upper limits given in the table.

Since ^{137}Cs has a half life of 30.5 years as compared to half lives of 2.7 and 5.2 years for ^{125}Sb and ^{60}Co, respectively, the exposure rate levels on islands where ^{137}Cs was the major contributor, most importantly Bikini, can be expected to persist at almost the current levels for some time to come with only slight reductions due to decay and weathering. Studies of ^{137}Cs penetration into soils usually have indicated that in undisturbed soils with high organic content very little penetration of ^{137}Cs takes

place after the first 1 or 2 years after deposition[6,7]. Since in 1967 the soil samples indicate most of the activity is still in the first inch of soil we can probably discount weathering as an important factor in lowering the exposure rates on Bikini Island. The levels on Nam and on some of the other larger complexes, where ^{60}Co and other relatively short-lived isotopes are the major contributors, although at present in general higher on the average than Bikini Island, will decrease more rapidly and in a few ^{60}Co half-lives will probably exhibit levels generally much lower than Bikini Island. Since the soil on some of these islands contain very little organic material, weathering may result in an even more rapid decrease in exposure rates. Thus, the levels on Bikini Island itself are likely to be the limiting factor in assessing the long term hazards to any future population living on the atoll and centered on Bikini Island.

The consistency of the various portable detector, ionization chamber, TLD, and spectrometer results indicate we have obtained a reliable and comprehensive picture of the external gamma radiation environment on the atoll. The soil sample results, although not as consistent with the other data as could be desired due to the problems of obtaining representative samples in a very inhomogeneous distribution, do nevertheless substantiate the field spectrometric predictions as to the relative importance of various emitters in the soil. The importance of the field spectrometric measurements in expanding and increasing the information of the survey meter readings again illustrates the utility of such a system in undertaking an environmental radiation survey. Comparable data on the composition of the radiation field could only have been obtained by analyzing hundreds of carefully obtained soil samples, if at all.

The data in this report should form a solid basis for estimating external dose to a returning population as a function of time after return, assuming with the aid of the survey team's anthropologist various realistic models for their living conditions, areas of habitation, and daily habits.

ACKNOWLEDGEMENTS

The authors wish to thank the many staff members of the Health and Safety Laboratory who cooperated in making this project a success. We would like to particularly acknowledge the aid of Colin Sanderson of HASL who performed the gamma spectrometric analyses of the soil samples. We again acknowledge the efforts of the other members of the survey party in gathering the data discussed in this report.