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AN INTERCOMPARISON OF NATURAL AND TECHNOLOGICALLY ENHANCED BACKGROUND RADIATION LEVELS IN MICRONESIA

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ABSTRACT

The United States Pacific Nuclear Testing Program resulted in local and regional fallout contamination of islands in the central Pacific basin, in an area which is generically known as Micronesia. Most of this contamination affected the Northern Marshall Islands of eastern Micronesia, which either served as the actual test sites or which were in relatively close proximity to them. Since all of the Marshall Islands are low coral islands or atolls, the natural radioactivity content of their soil is among the lowest on earth; and their natural radiation environment is dominated by the contribution of cosmic rays. In contrast, the high islands of the Caroline groups, to the west of the Marshalls, are characterized by volcanic soils having a significant complement of radionuclides in the uranium and thorium chains. Several field trips by S&EP Division personnel to Micronesia between 1975 and 1980 have afforded opportunities to study the natural radiation environments of the coral atolls of the Marshalls and several high islands in the Carolines; and to evaluate the contributions of fallout fission and activation products to the inventories of soil radioactivity in these locations. The analytical methods employed included in situ gamma spectrometry and exposure rate measurements with pressurized ion chamber survey instruments. These measurments were supplemented by laboratory analyses of soil samples. The results of these studies have indicated that significant contributions from radioactive fallout can be evaluated in situ with relative ease on coral islands. In contrast, the higher natural radioactivity content of high island soils,

as well as the greater distance of these islands from the test areas, combine to make evaluations of local fallout contributions from U. S. Pacific tests indistinguishable from the contributions of the world-wide fallout.

INTRODUCTION

Many small-scale radiological surveys were conducted during the 1950's and 1960's at or near the Pacific testing areas in the northern Marshall Islands; however, definitive evaluations of the impacts of residual fallout radioactivity were not made until the 1970's (1-5). These evaluations were conducted on those islands known or suspected to be contaminated by tropospheric fallout from the tests at Bikini and Enewetak Atolls. Environmental studies of peripheral areas in the central Pacific were conducted on a small scale during the testing years (1946-1958) by the University of Washington, and thereafter in 1975, 1979, and 1980 by Brookhaven National Laboratory as well. These studies yielded significant data on background radiation levels in these areas, and form the basis for this report.

The Marshall Islands are all comprised of coral atolls or partially drowned atolls formed by coral limestone accretions on subsiding volcanic bases. Drilling studies at Enewetak established that the limestone cap may exceed 1280 meters in thickness (6). As a result, the contributions of the uranium and thorium series to the radiation environment in the Marshalls are virtually nil. External background radiation levels on those islands which are remote from the test sites are dominated by cosmic radiation supplemented by small contributions from ^{40}K, cosmogenic radionuclides and world-wide fallout. These coral islands exemplify some of the lowest terrestrial radiation environments on earth.

In contrast, the Caroline Islands, immediately west of the Marshalls (Fig. 1) are comprised of high volcanic islands with fringing coral reefs, as well as coral atolls and islands. The high island soils contain ^{232}Th and ^{238}U and their daughters. The additional contributions of gamma emitters among these radionuclides result in background exposure rates (at 1 meter above the ground) which are nearly a factor of two higher than those similarly measured on the coral atolls (Table 1). Contributions of stratospheric and tropospheric fallout are, of course, superimposed on these natural background radiation sources.

METHODS

Data for this study were obtained during three field trip years (1975, 1979 and 1980). The first of the field trips was conducted jointly with the University of Washington, Laboratory of Radiation Ecology (LRE), which was responsible for determining background concentrations of fallout radionuclides in soil and in terrestrial and marine biota (7). Brookhaven National Laboratory (BNL) was tasked with the measurement of external background radiation. Subsequent field trip activities focused on external radiation measurements only.

The measurement sites were generally restricted to the District Centers of the Trust Territory of the Pacific Islands because of their accessibility via commercial airline. The Trust Territory was the United Nations-established region which encompassed most of Micronesia. It is presently being phased out with the formation of several sovereign states within this region. Data are also included for some of the central and southern Marshall Islands which were reached by U. S. Department of Energy field trips ships.

Field measurements of external radiation were conducted with a pressurized ion chamber environmental radiation monitor, and by in situ gamma spectrometry with (5 cm X 5 cm) sodium iodide scintillation detectors. Soil samples were also collected at most of the measurement sites. These were later analyzed in the laboratory for gamma emitters by high resolution gamma spectrometry; and for $^{90}Sr/^{90}Y$, and in some cases ^{239}, ^{240}Pu by radiochemical separation and counting. Data on strontium and transuranics are not included in this report.

The primary purpose of the in situ gamma spectral measurements was to provide a data base for energy dependence corrections for the stainless steel-walled ion chamber detector. As a result the measurements were made at low resolution (100 KeV per channel) from 0 to 2.5 MeV. A programmable calculator was used to fold the gamma spectra into the ion chamber response characteristic to correct for energy dependence in the environmental radiation monitor. Correction factors were typically about +5%.

The ion chamber instrument presented the instantaneous exposure rate digitally in μR/hr based on samplings of the ambient exposure rate a few times per second. The average exposure rate data presented in this report represent the energy-corrected means (±1σ) for ten or more instantaneous readings taken over several minutes.

RESULTS AND ANALYSIS

Table 1 presents the means (±1σ) of exposure rate measurements at various locations in Micronesia. Soil samples (Table 2) from these areas were analyzed for gamma-emitting radionuclides by the University of Washington, Laboratory for Radiation Ecology (3, 7) and by Brookhaven National Laboratory. The vertical distribution of fallout nuclides in the soil was determined by vertical sampling profiles to a depth of 50 cm. Activity concentrations of ^{137}Cs tended to decrease exponentially with depth, with a "relaxation length" of about 5 cm^2g^{-1}. Areal depositions of ^{137}Cs were calculated by integration of the depth distribution determined from the vertical sampling profiles. Exposure rates were then calculated by applying the coefficient for ^{137}Cs at 4.8 cm^2g^{-1} from EML-378 (8). These samples were also analyzed for ^{40}K and for the uranium and thorium chains for which the vertical profile data were averaged at each sample location. The respective exposure rate contributions were calculated from coefficients in HASL-195 (9). The cosmic ray contribution was assumed to be 3.2 μR/hr. (10).

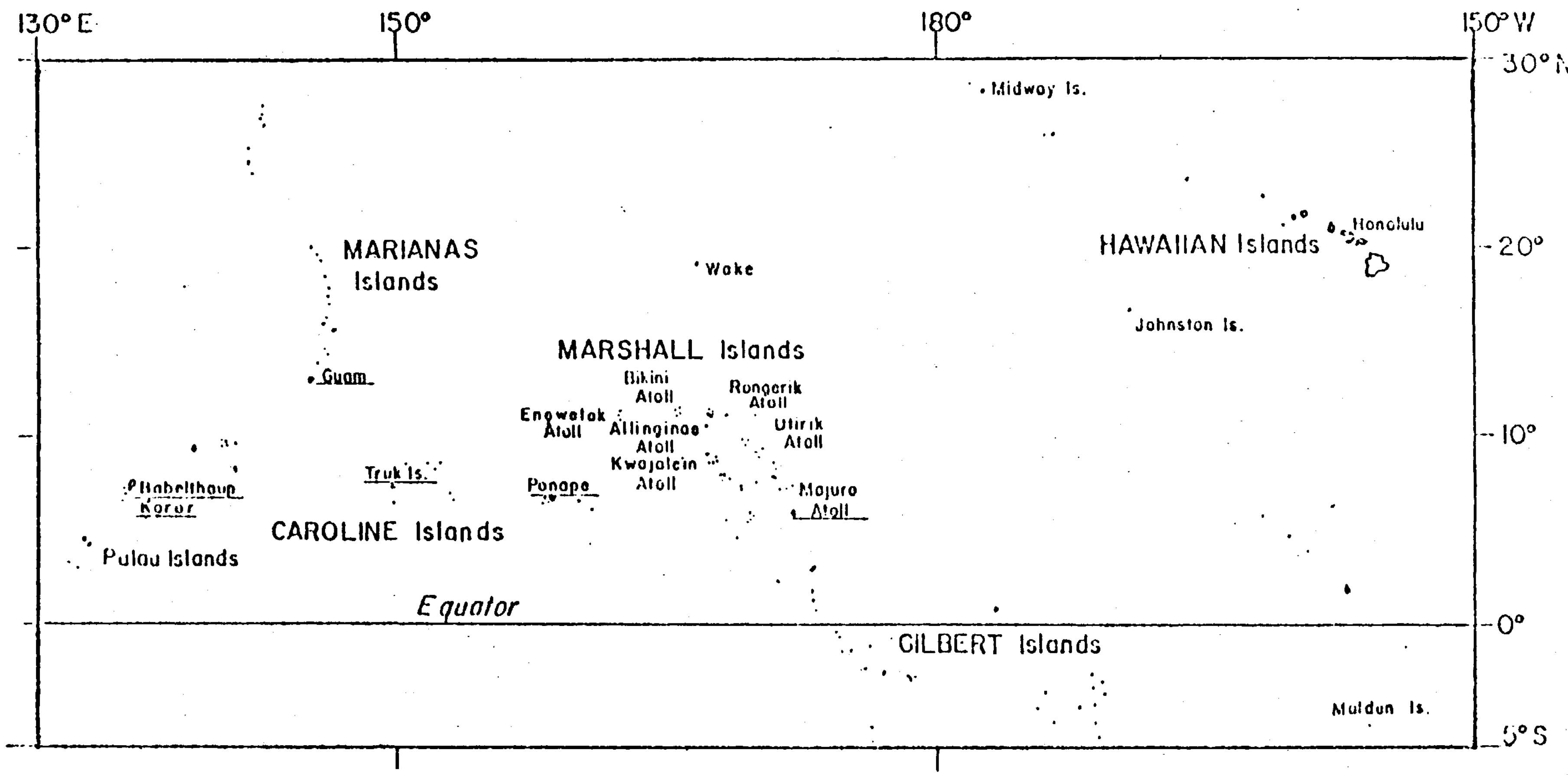
Attempts were made to reconstruct ambient background exposure rates from soil analyses and the cosmic ray contribution at Majuro, Ponape and Truk. These data are presented in Tables 3, 4 and 5. These locations are sufficiently distant (> 500 km) from the test sites (Bikini and Enewetak Atolls in the northern Marshalls) that no evidence could be found to suggest that they received tropospheric fallout from the atmospheric nuclear tests at these sites. Comparisons of measured exposure rates at Majuro with those at Kwajalein, Wotje and Ailuk Atolls in the central and eastern Marshalls (Table 1) tend to support this contention; however, firm conclusions must await the publication of the results of the Northern Marshall Islands Radiological Survey, a large-scale environmental assessment of the regional impact of the testing program performed in 1978.

It should be noted that exposure rates measured at Rongelap and Utirik Atolls, in the northern and northeastern Marshalls respectively, are significantly higher than those in the central and southern islands. Rongelap and Utirik are known to have been contaminated by the Bravo Test on March 1, 1954, and virtually all of the contemporary incremental exposure rates above background at these sites is attributable to residual ^{137}Cs contamination in the soil and vegetation.

The reconstructed exposure rate at Majuro (Table 3) is reasonably close to the measured value. The difference is attributed to the exposure rate contribution from ^{40}K in biota (for which no assessment was included in the calculated value), and to uncertainties in the soil analyses. Tables 4 and 5 present similar analyses for Ponape and Truk, both high volcanic islands in the Caroline group to the west of the Marshalls. These islands differed from Majuro by virtue of the contributions of the uranium and thorium chains in their volcanic soils, and their higher annual rainfall. Comparisons of measured and calculated exposure rates at Truk were excellent. The significant difference between the two values at Ponape is attributed primarily to uncertainties in the soil analyses.

CONCLUSIONS

Background exposure rates may be accurately reconstructed from careful analyses of soil gamma emitters and the contribution of cosmic rays. In situ measurements of exposure rates will reflect significant contributions above background of fallout gamma emitters, especially in locations where contributions of the uranium and thorium chains can be ignored. It is intuitively obvious that a continuum exists geographically between areas which received worldwide and tropospheric fallout and those which received only stratospheric (or worldwide) fallout. The islands of Micronesia exhibit this continuum such that beyond about five hundred kilometers from the test sites it may be impossible to distinguish between the contributions to contemporary environmental exposures from U. S. Pacific nuclear tests and those attributable to multinational worldwide fallout.



130° E
150°
180°
150° W
30° N
20°
10°
0°
5° S
Midway Is.
MARIANAS Islands
Wake
HAWAIIAN Islands
Honolulu
Johnston Is.
MARSHALL Islands
Guam
Bikini Atoll
Rongerik Atoll
Enewetak Atoll
Ailinginae Atoll
Utirik Atoll
Kwajalein Atoll
Truk Is.
Ponape
Majuro Atoll
Babelthaup
Koror
CAROLINE Islands
Pulau Islands
Equator
GILBERT Islands
Malden Is.

FIGURE 1

TABLE 1

EXPOSURE RATE DATA FOR VARIOUS LOCATIONS IN MICRONESIA

LOCATION	ISLAND TYPE (date)	LOCATION	AUG. EXPOSURE RATE (μR/hr.)	NUMBER OF MEASUREMENTS
Majuro, Majuro	Coral Atoll (11/75)	Southern Marshall Is	3.7 ± 0.3	65
Roi-namur Kwajalein	Coral Atoll (9/76)	Central Marshall Is	3.4 ± 0.2	180
Ormej, Wotje	Coral Atoll (9/76)	East Central Marshall Is	3.7 ± 0.3	180
Wotje, Wotje	Coral Atoll (9/76)	East Central Marshall Is	3.8 ± 0.3	119
Ailuk, Ailuk	Coral Atoll (9/76)	East Central Marshall Is	3.8 ± 0.4	135
Utirik,[a] Utirik	Coral Atoll (9/76, 10/77)	Norhteastern Marshall Is	4.1 ± 0.5	270
Aon,[a] Utirik	Coral Atoll (9/76)	Northeastern Marshall Is	4.1 ± 0.3	90
Rongelap,[b] Rongelap	Coral Atoll (9/76, 10/77)	Northern Marshall Is	7.1 ± 1.1	380
Bikini,[c] Bikini	Coral Atoll (9/75)	Northern Marshall Is	~40 (range ~ 10-100)	> 1000
Kolonia, Ponape	High Volcanic (11/75)	Eastern Caroline Is	6.5 ± 0.5	90
Moen, Truk	High Volcanic (11/75)	Central Caroline Is	6.5 ± 0.6	30

(a) Contaminated by Bravo Test, 1954.
(b) Heavily contaminated by Bravo Test, 1954
(c) Pacific Nuclear Test Site. Data from BNL 51003 (5) and UCRL-51879, rev.1. (2).

TABLE 2

AVERAGE GAMMA-EMITTING RADIONUCLIDE CONTENT OF SOME MICRONESIAN SOILS

LOCATION	NUCLIDE	ACTIVITY CONCENTRATION[(a)] OR INTEGRATED AREAL DEPOSITION
Majuro, Marshall Islands	^{137}Cs	0.43 pCi/cm^2
Majuro, Marshall Islands	^{40}K	0.70 pCi/g
Ponape, Eastern Caroline Islands	^{137}Cs	2.51 pCi/cm^2
Ponape, Eastern Caroline Islands	^{40}K	< 0.22 pCi/g
Ponape, Eastern Caroline Islands	U	1.81 ppm
Ponape, Eastern Caroline Islands	Th	9.17 ppm
Truk, Central Caroline Islands	^{137}Cs	4.71 pCi/cm^2
Truk, Central Caroline Islands	^{40}K	< 0.22 pCi/g
Truk, Central Caroline Islands	U	2.18 ppm
Truk, Central Caroline Islands	Th	5.62 ppm

(a) Data derived from soil sample analyses by University of Washington LRE, NVO-269-35(7), and Brookhaven National Laboratory (unpublished data).

TABLE 3

CALCULATED EXPOSURE RATE FOR MAJURO, M. I. BASED ON SOIL

SOURCE	BASIS	CALCULATED (b) EXP. RATE (μR/hr.)
^{137}Cs	Avg. Deposition 0-10° N. Lat. (a) 2.1 pCi/cm²	8.9×10^{-2}
^{137}Cs	Soil Sample Analyses: 0.43 pCi/cm²	1.9×10^{-2}
^{40}K	Soil Sample Analyses: 0.7 pCi/g	3.0×10^{-2}
Cosmic	(a)	3.2
	Total Calculated	3.3 μR/hr.
	Total Measured	3.7 ± 0.3 μR/hr.

(a) UNSCEAR (11)

(b) EML-378 (8), HASL-195 (9)

TABLE 4

CALCULATED EXPOSURE RATE FOR KOLONIA, PONAPE BASED ON SOIL RADIOANALYSES

SOURCE	BASIS (a)	CALCULATED(b) EXP. RATE (μR/hr.)
U chain	Soil Analyses ^{238}U, ^{226}Ra, ^{214}B	1.2
Th chain	Soil Analyses ^{232}Th, ^{228}Th, ^{212}Pb	2.8
^{40}K	(c)	< 0.1
^{137}Cs	Soil Analyses 2.7 pCi/cm²	0.1
Cosmic	(c)	3.2
	Total Calculated	7.4 μR/hr
	Total Measured	6.5 ± 0.5 μR/hr.

(a) Soil data from University of Washington, LRE. NVO-269-35 (7) and Brookhaven National Laboratory (unpublished)

(b) EML-378 (8), HASL-195 (9)

(c) UNSCEAR (11).

TABLE 5

CALCULATED EXPOSURE RATE FOR TRUK[(a)] BASED ON SOIL RADIOANALYSES

SOURCE	BASIS[(b)]	CALCULATED[(c)] EXP. RATE (μR/hr.)
U chain	Soil Analyses ^{233}U, ^{226}Ra	1.4
Th Chain	Soil Analyses ^{232}Th, ^{228}Th	1.8
^{40}K	(d)	< 0.1
^{137}Cs	Soil Analyses 4.7 pCi/cm^2	0.2
Cosmic	(d)	3.2
	Total Calculated	6.7 μR/hr
	Total Measured	6.5 ± 0.6 μR/hr.

(a) Data averaged for Fefan, Moen and Dublon Islands.
(b) Soil data from University of Washington, LRE. NVO-269-33 (7).
(c) EML-378 (8), HASL-195 (9).
(d) UNSCEAR (11).

REFERENCES

1. Enewetak Radiological Survey. U. S. Atomic Energy Commission, Nevada Operations Office Report NVO-140. (October 1973).

2. Gudiksen, P. H., et. al., External Dose Estimates for Future Bikini Atoll Inhabitants. Lawrence Livermore Laboratory Report UCRL-51879 Rev. 1., (March 1976).

3. Nelson, V. A., Radiological Survey of Plants, Animals and Soil at Christmas Islands and Seven Atolls in the Marshall Islands. University of Washington (LRE) Report NVO-269-32. (January 1977).

4. Greenhouse, N. A. and Miltenberger, R. P., External Radiation Survey and Dose Predictions for Rongelap, Utirik, Rongerik, Ailuk and Wotje Atolls. Brookhaven National Laboratory Report BNL-50797. (December 1977).

5. Greenhouse, N. A., et. al., External Exposure Measurements at Bikini Atoll. Brookhaven National Laboratory Report BNL-51003. (January 1979).

6. Pratt, A. R., and Cooper, H. F., The Near-Surface Geology at Enewetok and Bikini Atolls. U. S. Air Force Weapons Laboratory Report AFWL-TR-68-68. (1968).

7. Nelson, V. A., Radiological Survey of Plants, Animals, and Soil in Micronesia. November 1975. University of Washington (LRE) Report NVO-269-35. (January 1979).

8. Beck, H. L., Exposure Rate Conversion Factors for Radionuclides Deposited on the Ground. U. S. Department of Energy, Environmental Measurements Laboratory Report EML-378. (July 1980).

9. Beck, H. L. and de Planque, G., The Radiation Field in Air Due to Distributed Gamma-Ray Sources in the Ground. U. S. Atomic Energy Commission Report HASL-195. (May 1968).

10. Lowder, R. and Beck, H., Cosmic Ray Ionization in the Lower Atmosphere. J. Geophys. Res. <u>71</u>: 4661-68 (1966).

11. Sources and Effects of Ionizing Radiation. United Nations Scientific Committee on the Effects of Atomic Radiation, 1977 report to the General Assembly, with annexes.