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QUALITATIVE DISTRIBUTION OF RADIONUCLIDES AT RONGELAP ATOLL

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ABSTRACT

The qualitative distribution of radionuclides at Rongelap Atoll as determined approximately five years after contamination by fallout from a thermonuclear device indicates distinct differences between the terrestrial and marine environments. The levels of activity are low, the specific activity being less than the maximum permissible concentration for radioisotopes in food or drinking water of man. Of the wide spectrum of radionuclides concentrated in the surface layers of the soil, Sr^{90}, Sb^{125} and Cs^{137} are the principal isotopes entering into the soil solution. The principal isotopes in the land plants and plant-eating animals such as coconut crabs and the indigenous rats are Cs^{137} and to a lesser degree, Sr^{90}. Bottom sediments contain mainly Sr^{90} and Eu^{155}. The radionuclides in the lagoon water have not been detected but are probably present in minute amounts. Planktonic organisms contain traces of Mn^{54}, Co^{57}, Co^{60}, Zn^{65}, Zr^{95}, Ru^{106} and Ce^{144}. The principal isotope found in the marine algae is Ce^{144}. In the marine invertebrates Co^{60} and Zn^{65} occur most commonly. Corals and coralline algae contain some Sr^{90}, while the fish and sea birds are found to contain mostly Zn^{65}. The presence of Zn^{65}, Cs^{137} and Sr^{90} in the body of the natives reflects a diet of both marine and terrestrial origin.

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In March 1958 a radioecological study of Rongelap Atoll was instituted at the request of the United States Atomic Energy Commission, Division of Biology and Medicine. This report will be concerned with generalizations regarding the distribution of radioisotopes at the atoll in the fall of 1959, some five years after contamination with radioactive fallout.

Rongelap Atoll was accidentally contaminated on March 1, 1954, with radioactive fallout from a thermonuclear device detonated at Bikini Atoll some 80 miles to the west. Gamma dose rates at Rongelap on D + 1 (detonation + 1 day) ranged from 3.5 r/hr at the southern islets of the atoll to 35 r/hr at the northern islets (Dunning, 1957). Eighty-two natives residing on Rongelap Island, in the south, were evacuated and did not return until June 1957. At that time the returning

[1]Title in program for the First Symposium on Radioecology is "Qualitative differences in radioisotopes present in plankton, lagoon bottom, and land plants."

population approached 300 in number but since appears to have stabilized at 230.

Several radiological and biological surveys, primarily of a monitoring nature, were conducted from the time of the first contamination until 1958 (Dunning, 1957). During this time the gamma dose rates over land areas declined at approximately the rate predicted for mixed fission products by Miller and Loeb (1958). Slight rises in gamma dose rate were observed in 1956 and 1958, resulting from tests conducted during these years. However, the total contribution of radioisotopes from these subsequent fallouts amounted to a fraction of one per cent of the amount from the 1954 fallout.

Rongelap Atoll is located in the Marshall Islands, in the Central Pacific Ocean, at about 11° North. It is a typical atoll with a lagoon area of 388 square miles and about 180-foot average depth. The emergent land area is about 3 square miles and is made up of 61 small islets ranging in size from a fraction of an acre to the largest island, Rongelap, which is about 4 miles long and 1/2 mile across at its widest point.

There is one small islet on the western reef and the remainder are strung along the northern, eastern and southern reefs. The islets on the northern reef are not as well developed as those to the east and south. The waters of the lagoon are essentially isothermal (Robinson, 1954). The circulation, generated by the northeast trade winds, is from east to west at the surface with a returning bottom current (Von Arx, 1954). The estimated time for renewal of water in the lagoon is about 30 days.

The parent material of both soils and the lagoon bottom is primarily calcium carbonate originating mainly from coralline algae, corals and foraminifera. There is also some accumulation of pumice drift in the soils.

The natives of the area are Micronesians. Their agriculture is limited in variety of products and the only significant export is copra. About half of the food consumed at the present time is imported. Fish and other marine organisms are eaten but these sources are not exploited as much as they could be. The Rongelapese are almost entirely dependent on cisterns as a source of water. Rainfall in this area is comparatively low and the islets small, so that there is not a well developed fresh water lens. There is, however, some potable water in wells at Rongelap and Eniaetok Islets.

The native style wattle and palm frond buildings have been replaced by plywood and aluminum structures built to Rongelapese specifications by the AEC. Sanitation habits have been altered by the advent of pit toilets.

The terrestrial fauna is limited in variety. The only mammal present is the small field rat, Rattus exulans. The most common birds are the fairy tern, Gygis alba, and the noddy terns, Anous stolidus and A. tenuirostris, which nest in large numbers on some of the uninhabited islets. The reptiles are represented by skinks, geckos, and a blind snake. Land crabs are common, the most spectacular being Birgus latro, the coconut or robber crab. Insects are few, both in number of species and individuals. The most severe pest appears to be the beetle, Brontispa sp., which attacks the coconut palm.

In contrast to the land areas there is a tremendous proliferation of both numbers and variety of organisms on the reefs and in the lagoon. For example, there are over 700 species of fish. Plankton, however, is extremely sparse and as a consequence the water is so clear that green algae are found growing at depths of 180 feet.

Since the question of the effects of radiation on the organisms inevitably arises, it might be well to consider it briefly before going on to the main subject. There is no doubt that the levels of radiation were of sufficient intensity to affect living organisms. However, under actual field conditions and without benefit of study before the addition of radiation as an ecological factor, it is difficult to do more than speculate concerning the cause of the specific anomalies observed. Fosberg (1959) has accurately described the poor condition of the plants at the northern islets of Rongelap and has suggested that the primary cause of this condition is radiation. In our opinion, however, other factors, particularly edaphic factors, have probably been more important than radiation. The fact that the nitrogen content of the soils of the northern islets is lower than that of the rest of the atoll is at least circumstantial evidence that for some time there have been differences between these areas with respect to plant growth. Stone *et al*. (1957) has concluded from studies of *Drosophila* populations at Bikini, Eniwetok, Rongelap and uncontaminated atolls that while there is evidence of genetic changes caused by radiation other factors mask the radiation effects. In short, it is not likely that such questions will be resolved without controlled experimentation with the species involved, under varying conditions, and with an eye toward the possibility of synergistic effects.

Approximately five years after fallout the long-lived fission products Cs^{137} and Sr^{90} are the principal radionuclides found in the land organisms,while the neutron induced radionuclides Zn^{65}, Co^{60} and Mn^{54} are found primarily in the marine organisms.

Still detectable in the soil are Mn^{54}, Fe^{55}, Co^{57}, Co^{60}, Zn^{65}, Sr^{90}, Zr^{95}, Ru^{106}, Sb^{125}, Cs^{137}, Ce^{144} and Eu^{155},which remain concentrated in the upper one to two inches. Where higher levels of radionuclides have been present these isotopes have been reported in a wide variety of organisms. It is likely that most of these radionuclides are actually present in most if not all organisms at Rongelap but that the levels at which they occur are extremely low and so escape detection.

Passing from the soil to the soil solution, the term being used here to mean leachates collected in the field from lysimeters, Sr^{90}, Cs^{137}, and Sb^{125} are the principal nuclides found, although Ru^{106}-Rh^{106}, Ce^{144} and Eu^{155} are also detectable (Cole et al., 1961). Here differences exist with respect to soil type in that the leachates from immature soil,consisting almost exclusively of parent material,contained only Sb^{125} and Sr^{90}. There is to us no evident explanation for this difference.

The ground water probably contains these nuclides since their movement has been detected in leachates to depths of 30 inches, but the levels are so low in ground water that special techniques would have to be developed to detect them.

The land plants contain principally Cs^{137} and Sr^{90}. Mn^{54} and Zn^{65} have been found in plants from the more heavily contaminated islands but are present in relatively insignificant amounts. In general, Cs^{137} accounts for 90 per cent or more of the radioactivity in the land plants and Sr^{90} for the remainder. This is unlike the situation usually found on continental soils and is a consequence of the low potassium content of Rongelap soil. Amendments of potassium to Rongelap soil reduce the uptake of Cs^{137} by plants (Walker et al., in press), and affect the distribution of Cs^{137} within the plant. There are, of course, differences between plant species and plant parts with respect to the relative amounts of potassium and strontium. For example, copra contains very little Sr^{90} as compared with Pandanus fruit, and the basal leaves of various plants contain more Sr^{90} relative to Cs^{137} than do the terminal leaves. This variation is related to differences in mobility between Cs - K and Sr - Ca.

The rats contain Cs^{137} and Sr^{90}, reflecting the radionuclides present in the plants on which they feed. The coconut crab and the land hermit crab *Coenobita perlatus* contain the same isotopes but concentrate Sr^{90}, as has been reported for *Coenobita* from Eniwetok Atoll (Held, 1960).

The occurrence of radionuclides in man at Rongelap has been summarized by Cohn et al. (1960). In 1958 these nuclides were Cs^{137} and Sr^{90}, coming from the food plants, and Zn^{65} coming to man from marine products.

The birds, which feed almost exclusively on marine organisms, contain primarily Zn^{65} and occasionally small amounts of Mn^{54} and Co^{60}. Sr^{90} is also found in small amounts in bird bone and may reflect direct uptake from the ingestion of soil, although there is no direct evidence that this occurs.

Radionuclides in fish are limited to Mn^{54}, Co^{60} and Zn^{65}, the latter being predominant. On a dry-weight basis for a sample of goatfish testes have the highest levels, the liver, gastro-intestinal tract and eyes are lower by about an order of magnitude, and the muscle and bone lower by still another order of magnitude. If the total amount of radioactivity by tissue is considered then bone is the principal depository of Zn^{65} (Joyner, 1961, personal communication). The sources of Zn^{65} for fish are open to question. In some instances invertebrates containing Zn^{65} are known to be consumed by fish found to contain Zn^{65}, but, in general, no definite sources of Zn are known to exist five years after fallout. It is possible that there is concentration of undetectable levels from the sea water or algae. The possibility that most of the Zn^{65} activity in fish is residual appears to be ruled out by the fact that young fish contain relatively high levels.

The marine invertebrates taken as a whole contain a wider spectrum of radionuclides than do the fish. These are Mn^{54},

Co^{57}, Co^{60}, Zn^{65}, Sr^{90}, Ce^{144}, and probably Eu^{155}. The corals contain Co^{60} and are the only invertebrates in which Sr^{90} has been consistently detected. From limited data available thus far it appears that these isotopes were deposited in the skeletal material soon after fallout and have remained localized in portions of the coral colony actively growing at that time. The clams contain mostly Zn^{65}, Co^{57} and Co^{60}. Weiss and Shipman (1957) originally reported the concentration of Co^{60} in the kidney of Tridacnid clams collected at Rongelap in 1956. Animals such as the sea cucumber and spider snail, which ingest large amounts of bottom sediments, contain Ru^{106}, Ce^{144} and probably Eu^{155}.

Of several species of algae sampled in 1959 the only radionuclides detected were Ru^{106}, Ce^{144} and Eu^{155}. In general, the levels of radioactivity in the algae are lower than in the fish or invertebrates.

The plankton contain Mn^{54}, Co^{57}, Zn^{65}, Zr^{95}, Ru^{106}, and Ce^{144} but all in minute amounts. In 1959 plankton samples collected by pumping a total of two and a half million gallons of water were pooled for gamma spectrum analysis and were found to contain only enough of these isotopes for qualitative analysis without resorting to chemical separations. Further analysis has been deferred until other studies with the individual samples can be completed.

The lagoon sediments contain Sr^{90}, Ru^{106}, Ce^{144} and Eu^{155}. The radioactivity is associated mainly with the fines and is concentrated in the top two to four inches, dropping off rapidly with depth.

Radioisotopes other than naturally occurring K^{40} were not detected in sea water although larger samples and more sensitive techniques undoubtedly would have revealed their presence.

In sum, on land, the present distribution of long-lived fission products, Sr^{90} and Cs^{137}, can be expected to remain very much as they are now. The levels of radioactivity will be reduced primarily by physical decay of the radionuclides so long as other factors such as changed agricultural practices or a catastrophic storm do not occur. In the lagoon, the levels of radioactivity will decline more rapidly than on land because of the presence of shorter-lived radionuclides, with the exception of Sr^{90}. The latter does not enter the marine food web to any significant extent and may remain as a tag useful in evaluating the long-term effects of physical forces in the lagoon.

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