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PREPRINT

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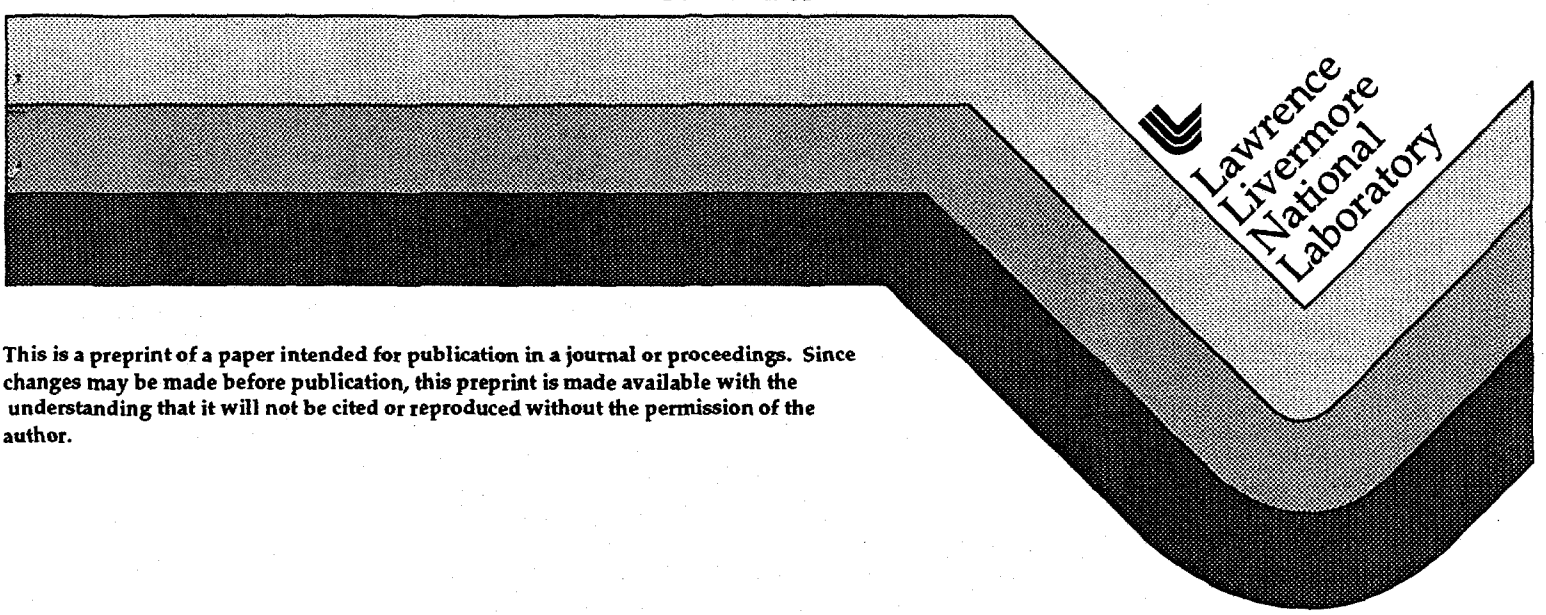

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DOSE ASSESSMENT, RADIOECOLOGY, AND COMMUNITY INTERACTION AT FORMER NUCLEAR TEST SITES

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INTRODUCTION

The United States conducted a nuclear testing program at Bikini and Enewetak Atolls in the Marshall Islands from 1946 through 1958. A total of 66 nuclear devices were tested—23 at Bikini Atoll (total yield of 77 megatons) and 43 at Enewetak Atoll (total yield of 33 megatons). This resulted in contamination of many of the islands at each atoll. The BRAVO test (yield 15 megatons) on March 1, 1954 contaminated several atolls to the east of Bikini Atoll some of which were inhabited.

We have conducted an experimental, monitoring, and dose assessment program at atolls in the northern Marshall Islands for the past 20 years. The goals have been to: 1.) determine the radiological conditions at the atolls, 2.) provide dose assessments for resettlement options and alternate living patterns, 3.) develop and evaluate remedial measures to reduce the dose to people reinhabiting the atolls, and 4.) discuss our results with each of the communities and the Republic of the Marshall Islands government officials to help them understand the data as a basis for resettlement decisions.

The remaining radionuclides at the atolls that contribute any significant dose are ^{137}Cs, ^{90}Sr, $^{239+240}Pu$, and ^{241}Am.

FIELD EXPERIMENTS

We have evaluated all potential exposure pathways: terrestrial food chain, external gamma, marine food chain, inhalation, and cistern/ground water. Our dose assessments indicate that most of the potential dose comes from the ingestion of ^{137}Cs via the ingestion pathway as shown in Table 1. Cesium-137 also contributes to the total dose via the external gamma pathway. The other radionuclides contribute a small portion of the total estimated dose. The contribution of each pathway is shown in Table 2. The terrestrial food chain is the most significant contributor to the total dose accounting for about 90% of the 30 y effective integral dose at Bikini Atoll. Consequently, the diet, particularly the percentage intake of local foods, becomes very important and more detailed discussions and validation of diet models are given in references 1 and 2. The external gamma pathway is next in significance and the other pathways contribute little to the total estimated dose. More detail on the methodology to evaluate each of the pathways can be found in references 1–3; these references also include an uncertainty analysis for the estimated doses.

REMEDIAL MEASURES

The role of ^{137}Cs and the terrestrial foods in the total estimated dose, led to an experimental program to evaluate remedial measures that might remove ^{137}Cs from the soil or block the uptake into food crops. Many types of remedial measures were evaluated including salt water leaching, vegetation cropping, clay and zeolite soil amendments, and excavation of the top 40 cm of the soil column. The excavation of the

surface soil is very effective in reducing the radionuclide inventory and, consequently, any potential dose. However, the environmental impact of removing the coconut grove, other types of food trees, and the surface soil containing the organic matter that has taken centuries to develop, is enormous. One of the more effective and environmentally sound methods found, was the application of potassium (K) to the surface soil. The K can be applied as KCl or a full fertilizer, and natural rainfall transports the K to the root zone. This also happens to be the easiest method to implement of all those we evaluated.

The results of one major field experiment involving coconut trees is shown in Fig. 1. Coconuts were selected for the initial experiments because they are a major food source in the Marshall Islands. Various amounts of K and K+NP were applied to coconut trees in a 12 acre site[4]. The initial K treatment consisted of four equal applications over the first nine months. As can be seen, reduction in the ^{137}Cs concentration of more than 20 fold has been achieved. This provides a significant reduction in the total estimated dose such that all islands could be inhabited and the people would receive annual doses in the range of world-wide background doses. Similar results have been found for other important food crops such as breadfruit, *Pandanus* fruit, papaya, banana and vegetables. This option for reducing the dose to returning populations dose not require removal of the soil and vegetation, and leaves the island soil and vegetation system in tact.

COMMUNICATION AND INTERACTION

An equally important part of our program has been the repeated interaction with the atoll communities. We have had many meetings with the communities at our field experimental sites at their atolls, at their current residential locations, and at our laboratory in Livermore, CA. We have had many hours of discussions at each of these meetings about our dose assessment results, our experimental data, and resettlement options. Over the years these meetings have lead to a continuing interaction between the scientists and the people. The same topics and issues are discussed at each meeting; but also, new topics or questions arise at each meeting as the people develop a greater understanding of the radiation related issues.

The repetition has proved to be very important. The increased interaction between the scientists and the people has over time led to a development of a level of trust in the scientists by the communities. It has also led to an expansion of community interest and understanding of the radiological issues. The trust by the people of our data and reports is very important because these data and communications are the basis from which the people can make an informed decision about the resettlement options at the atolls.

REFERENCES

[1] WILLIAM L. ROBISON, CYNTHIA L. CONRADO, AND KENNETH T. BOGEN, An Updated Dose Assessment for Roneglap Island, Lawrence Livermore National Laboratory, Livermore, CA, UCRL-LR-107036 (July 1994).

[2] INTERNATIONAL ATOMIC ENERGY AGENCY, "A Dose Assessment for a U.S. Nuclear Test Site—Bikini Atoll," Assessing the Radiological Input of Past Nuclear Activities and Events, International Atomic Energy Agency, Vienna, Austria, IAEA-TEC-DOC-775 (July 1994) pp 11–24.

[3] W.L. ROBISON, C.L. CONRADO, AND W.A. PHILLIPS, Enjebi Island Dose Assessment, Lawrence Livermore National Laboratory, Livermore, CA, UCRL-53805 (July 1987).

[4] W.L. ROBISON, AND E.L. STONE, "The effect of potassium on the uptake of 137Cs in food crops grown on coral soils: coconut at Bikini Atoll," Health Physics **62**, 496–511 (1992).

Table I. The Estimated 30-y Integral Effective Dose in cSv for Three Contaminated Atolls in the Marshall Islands when Imported Foods are Available

	Bikini Is.[a]	Enjebi Is.[b]	Rongelap Is.[c]
External	0.91	0.5	0.24
Ingestion			
^{137}Cs	8.9	3.0	0.33
^{90}Sr	0.10	0.10	0.0087
$^{239+240}Pu$	0.011	0.0014	0.0013
^{241}Am	0.0067	0.0014	0.0014
Inhalation			
$^{239+240}Pu$	0.013	0.053	0.0029
^{241}Am	0.0074	0.022	0.0019
Total	10	3.6	0.59

a Bikini Atoll
b Enewetak Atoll
c Rongelap Atoll

Table II. The Estimated 30-y Integral Effective Dose in cSv for Three Contaminated Atolls for the Various Exposure Pathways

Pathway	Bikini Is.	Enjebi Is.	Rongelap Is.
Terrestrial food	9.0	3.0	0.34
External gamma	0.91	0.5	0.24
Marine food	0.0049	0.0021	0.0016
Cistern and ground water	0.016	0.0045	0.00051
Inhalation	0.021	0.077	0.0048
Total	10	3.6	0.59

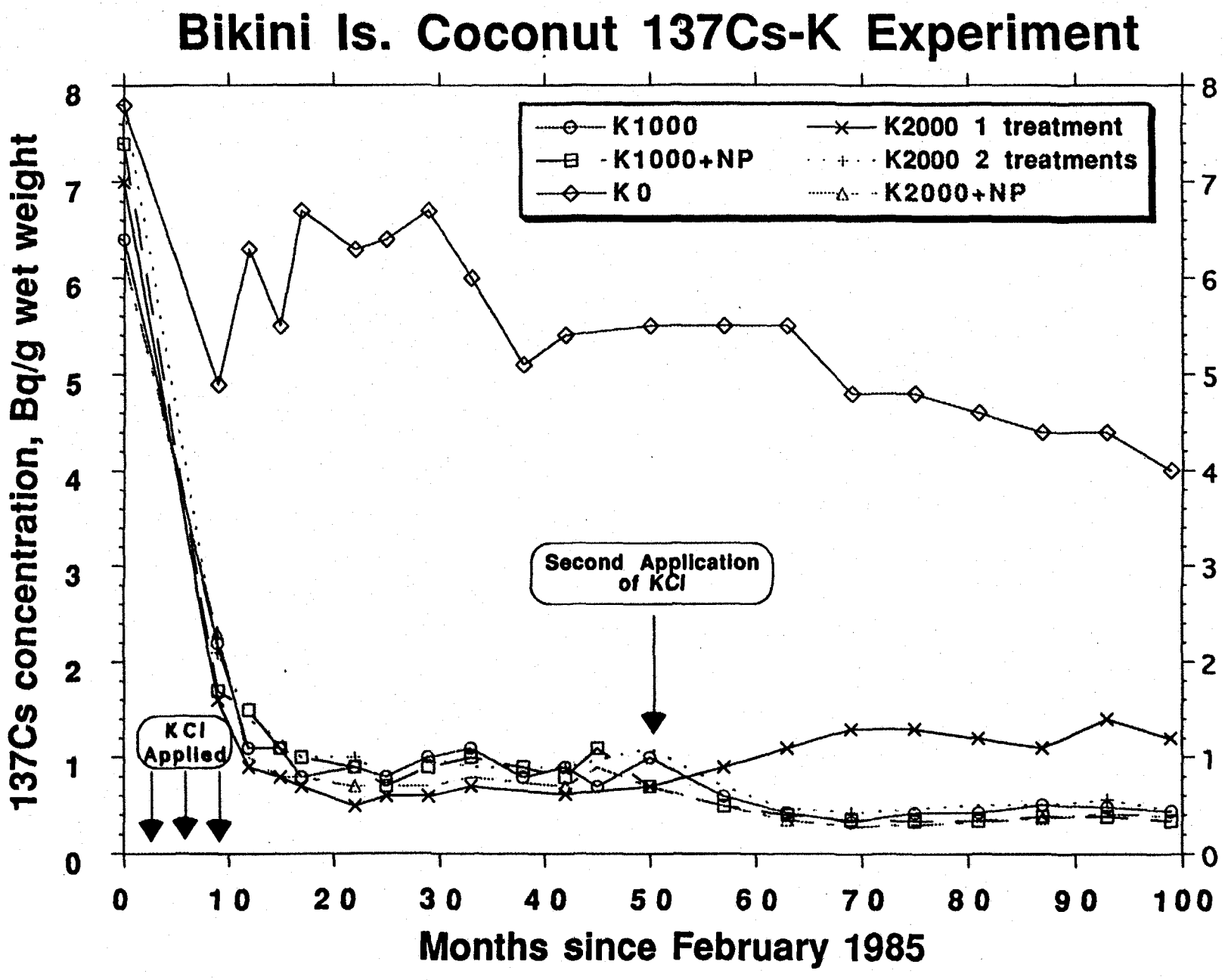
Bikini Is. Coconut 137Cs-K Experiment
137Cs concentration, Bq/g wet weight
Months since February 1985
K1000
K1000+NP
K0
K2000 1 treatment
K2000 2 treatments
K2000+NP
KCl Applied
Second Application of KCl
0
1
2
3
4
5
6
7
8
0
10
20
30
40
50
60
70
80
90
100

Figure 1. K1000 indicates that potassium was applied at 1,000 kg ha^{-1}, K2000 at 2,000 kg ha^{-1}. NP was applied at N = 530 kg ha^{-1} and P = 230 kg ha^{-1}. K = 0 is the control. The K2000 1 treatment (marked with X) indicates the start of a slow increase in the uptake of ^{137}Cs about 4 y after the initial application of K; this row of trees only received the first application, i.e., 1,000 kg ha^{-1} in February 1985.