Radiological Aspects of the Bikini Atoll Environment
and the Return of the Bikini People

The role of the AEC in the cleanup and rehabilitation of Bikini Atoll was to study radiological conditions, to provide criteria for cleanup to the Department of Defense (DOD) and for rehabilitation to Department of the Interior (DOI), and to perform followup radiological surveys.

By way of introduction, it should be mentioned that AEC studies of radiological conditions at both Bikini and Enewetak Atolls were begun during the period of test operations and there have been periodic surveys by AEC since that time. A considerable body of information of radiation and radioactivity levels was gathered over the years. Late in 1966, the Secretary of the Interior, responding to an inquiry from the Bikini people, requested that AEC make an evaluation of whether these people could be safely returned to their atoll.

It may be helpful to review some of the background for AEC actions at Bikini.

Following the request from DOI, an evaluation of existing data on radiological conditions at Bikini Atoll was made. The finding was that additional information, primarily on current external radiation levels in the atoll, was needed.

An AEC field survey team spent about six weeks at Bikini during the period April-May, 1967, making measurements and collecting soil, plant, fish, and animal samples. The results of the external radiation and soils survey are published in HASL-190 entitled, "External Radiation Levels on Bikini Atoll - May 1967", dated December 1967. A copy of that report is provided (Enclosure 1).

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All the survey results plus reports by J. A. Tobin, District Anthropologist, Marshall Islands District, "The Bikini People, Past and Present" (Enclosure 2), and by James T. Hiyane, District Agriculturist, Marshall Islands District, "1967 Bikini Radiological Resurvey - Marshalls Agriculture Report" (Enclosure 3), were compiled for use in evaluating the conditions that could be expected for return of people who would take up permanent residence in the atoll using the resources of the atoll. Copies of these reports are provided. The findings of the 1967 surveys and comparison data from the previous 1964 survey are used in presenting the radionuclide content of foods contained in Dr. Gustafson's report (Enclosure 4) which is discussed below.

In 1967, the body within the Federal Government charged with providing advice to the President and guidance to Federal agencies regarding standards for the general public, was the Federal Radiation Council (FRC), which was formed in 1959. The Council consisted of the Secretary of Health, Education and Welfare (Chairman), Secretaries of Agriculture, Commerce, Defense, Labor, the Chairman of the AEC, and the Special Assistant to the President for Science and Technology. Staff work and studies were conducted by a working group consisting of senior staff members assigned from the various member agencies. Early in the Bikini studies and deliberations, the FRC working group was briefed by AEC staff on findings and progress. Such briefings were given periodically until the FRC was dissolved and its functions transferred to the Environmental Protection Agency (EPA). Staff of EPA have been kept informed in a similar manner since.

The analytical data on the radiological conditions, and information on the people including their expected life style and diet, were evaluated by Dr. P. F. Gustafson, then of the AEC Division of Biology and Medicine. Detailed dose calculations were made for adults and children. From these deliberations, radionuclides contributing most to exposures were identified as were items of diet containing these radionuclides. The approach to development of these dose estimates for Bikini was very similar to the approach in NVO-140, October 1973, which presented the same kind of information for Enewetak.

AEC established an Ad Hoc Committee of eight highly qualified experts to review the dose estimates and survey results. These consultants reached the unanimous conclusion that it would be radiologically safe to allow the Bikini people to return to their home atoll. The Committee also recommended certain cleanup, rehabilitation, and followup actions that have guided Federal agencies involved. On August 12, 1968, President Johnson made the announcement of the decision to allow the former residents of Bikini to return to their home atoll. A copy of the announcement of the Ad Hoc Committee's recommendations and of the President's decision to return the atoll to the Bikinians is enclosed (Enclosure 5). This announcement contains a list of the members of the Ad Hoc Committee.

As soon as the announcement was made, the High Commissioner of the Trust Territory planned a trip to Kili Island to explain what was to be done and to answer questions. The High Commissioner, who was then

Mr. William Norwood, representatives of the DOI, DOD and AEC, and members of the press, arrived at Kili on August 27, 1968. A meeting was held to discuss the recent decision and there was a question and answer session with Mr. Chutaro acting as interpreter. Questions regarding this meeting have been asked periodically. In May of 1970, the details of this visit were reviewed and a short report containing answers to a number of questions is provided for your information (Enclosure 6).

In the approach to cleanup and rehabilitation of Bikini, three agencies made an agreement on responsibilities as follows:

a. DOD would perform cleanup operations.

b. DOI would carry out the rehabilitation and resettlement program including agricultural rehabilitation and construction of housing and community facilities.

c. AEC would provide guidance on radiological aspects of these programs and conduct followup radiological surveys to confirm exposure estimates and conduct radiological monitoring of personnel as they returned to work or live at Bikini.

In order to get the cleanup phase started right away, DOD and AEC provided sufficient interim funding support until additional funds that were budgeted became available.

Cleanup was a joint effort conducted by DOD and AEC during the period February to October 1969. Radiological support for cleanup was provided by AEC with part coming through a Memorandum of Understanding between AEC and the Environmental Protection Agency (EPA). The report by Smith and

Moore, EPA, referenced in your letter contains results of this effort along with the additional radiation measurements made during cleanup. An additional independent estimate of exposure due to external radiation was made by Smith and Moore for a child born on Bikini Atoll in 1970. The 5, 30, and 70 year values may be compared with Gustafson's estimates for the same times for "External" exposure. Part of the difference between the two sets of values, for instance 3.33 rads in 30 years by Gustafson versus 5.3 rads for Smith and Moore (5,275 mrads is 5.3 rads), comes from a correction made for external radiation contribution from cosmic ray exposures in the reported data used by Gustafson. Note that the reported radiation levels in the Smith and Moore report include natural sources. See footnote on page three of that report. The cosmic ray measurements at Bikini made by the AEC Health and Safety Laboratory (HASL) indicated a dose rate of about 3.4 μR/hr (microroentgens per hour). The 30 year exposure from this source would be 3.4 μR/hr x 24 hr/day x 365 day/yr x 30. This would be about 0.9 R/30 years. A proper comparison of the two values, including natural background for each, would be about 4.2 versus 5.3 rads. It should be noted that these estimates do not include any credit for reduction of exposure that may come from use of coral gravel in the village area or from the shielding provided by housing. Conversely, the Smith and Moore estimates do not include any contribution from internal radioactivity. Since internal radioactivity comes through the food chain the contribution to the total dose from that source will change with time as locally produced foods become available. We plan to continue to make periodic surveys and to update dose estimates as new information is obtained. Such estimates will, of course, include internal doses.

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During cleanup, the agricultural rehabilitation program got underway with removal of vegetation and replanting of coconut trees. Subsequent to that time, construction of houses was started. Comments were provided by AEC staff on use of local sources of sand and coral aggregate for housing construction and on design factors that were considered important in minimizing indoor radiation exposure levels. Lest there be misunderstanding as to the AEC interest in this phase of rehabilitation, it should be pointed out that construction of houses that are good radiation shields was not a prerequisite for return of the atoll. AEC concern is that if there are options in selecting construction materials, for instance, the source of local materials such as sand and coral aggregate, or in the design of the houses, those options giving lower radiation levels in the houses are preferred. This is in accord with the fundamental radiation protection principle of keeping exposures as low as practicable.

Followup radiological surveys were sponsored by AEC at Bikini in 1970, 1972, and 1974. Radiological monitoring of persons resident at Bikini are and will continue to be conducted by Dr. Robert A. Conard of the AEC's Brookhaven National Laboratory as recommended by the Ad Hoc Committee (Enclosure 7). Results of measurements and of analysis of samples collected through 1972 are presented in WASH-1273, "Exposure Rate Reduction on Bikini Island Due to Concrete Dwellings", June 1973 (Enclosure 8), in WASH-1289, "Levels of Environmental Radioactivity on Bikini Atoll", printed in 1974 (Enclosure 9), in NVO-269-8 (Revision 1), "Radiological Resurvey of Animals, Soils, and Ground Water at Bikini Atoll, 1967-1970", February 1971 (Enclosure 10), and in the Smith and Moore report SWRHL-111r, "Report of the Radiological

Cleanup of Bikini Atoll", January 1972 (Enclosure 11). Principal investigators are reviewing a draft report of the 1972 survey. That report will be published when completed.

For several years, personnel radiation monitoring has been carried out on workmen and Bikini People on Bikini by a team from Brookhaven National Laboratory headed by Dr. Conard. During his 1974 visit, Dr. Conard monitored the people on Bikini Island and took samples of the environment. A report of the 1974 results will also be prepared. Preliminary information on the 1974 Bikini survey from Dr. Conard indicates the body burdens of cesium-137 for 18 males and 13 females are very low, about 3-4% of the applicable standard. The addition of coral gravel in the yards of houses appears to reduce radiation levels in the yards by about 50%. It is our current plan to continue such surveys. Our detailed survey plans will, of course, depend upon the actions and desires of the returning people. It is likely that annual field trips will be made initially with less frequent surveys later depending on results obtained. Preliminary data from the latest survey are essentially in agreement with earlier survey findings. Exposure estimates derived from the 1967 and earlier surveys are still valid. Available radiological information is reviewed as each field trip is planned.

One change in the atoll has been construction of houses on Bikini Island. One of the objectives of the 1972 survey effort at Bikini was to determine the reduction in radiation exposure that can be expected because of the time people spend indoors. Table 1 of WASH-1273 presents results of measurements made outside and inside the Bikini houses in various stages of

completion at that time. Table 2 shows that the reduction factor for "Slab Only" is 30%, for "Slab and Walls" is 42-46%, for "Slab, Walls, and Roof" is 44-48%, and for one occupied house is 51%. Note in Table 2 that the average exposure levels outside the houses are less than 44 μR/hr and more than half of the measurements were less than 20 μR/hr. While there had been some scraping of soil where houses were constructed, the layer of coral gravel recommended by the Ad Hoc Committee was not yet in place. Lower levels are expected when this is done, and preliminary results from the 1974 survey indicate this is indeed the case. As for dose rates inside the completed houses ("Slab, Walls, and Roof"), the average level in Table 2 for 10 houses in the center of the building, at a height of 3 feet is 11.2 μR/hr or 96 mR/yr. About one third of this is from natural background. Values reported for 17 houses in the New York area range from 29 to 90 mR/yr. See "Investigations of Natural Environmental Radiation", Science 131, pages 903-906, 1960 (Enclosure 12). It should be pointed out that the source of New York exposures is almost entirely natural radioactivity in the building materials and environs where the levels change little with time. At Bikini, the source is primarily cesium-137 from testing that was deposited in the surrounding soil with very little radioactivity in the materials of construction. Since cesium-137 decays with a half time of 30 years, the external radioactivity levels at Bikini from this source will continually decrease.

As for the guideline for evaluation of exposures at Bikini Atoll, the basic numerical guide for whole body and bone marrow is 500 mrem/yr (millirem per year). The 500 mrem/yr standard is applicable where individual exposures

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can be determined. When the range of exposures is not known, the guide is 170 mrem/yr with exposure determined as an average for the population group. Both of these standards were developed using the assumption that there is no threshhold below which one can be certain there is no radiation injury. The followup surveillance of the Bikini environment and people is planned to assure that exposures will be known for both individual adults and children.

For completeness, there are several additional items that should be mentioned:

a. A question regarding planting coconut in the Peter-Oboe complex.

b. Questions regarding any restrictions on digging foundations for houses and whether work crews could drink well water on Bikini Island.

c. Followup items from the Ad Hoc Committee recommendations relative to a dietary supplement of powdered milk and removal of soil for planting pandanus.

Answers to questions in (a) and (b) above were provided in a letter to High Commissioner Edward Johnson dated June 17, 1971. This guidance specifies that coconut may be planted in the Peter-Oboe complex except for the island of Tare (Eneman). There are no restrictions on digging foundations on Bikini Island and no radiological restrictions on use of well water on Bikini Island. A copy of the letter is provided (Enclosure 13).

The question of the best way to provide a calcium supplement to the diet for people living in Bikini Atoll that will be acceptable to both

adults and children is under consideration. We are considering the possibility of using one or more of several food items, including powdered milk, so as to give a choice to the people. We expect to make suggestions on this followup item before the locally produced pandanus becomes a significant part of the diet. Our followup surveys will check on pandanus plantings to insure that the recommendation of the Ad Hoc Committee regarding soil removal at pandanus planting sites has been implemented. The measurements made and samples analyzed through our periodic surveys will be used as a basis for recommendations as to the time of rehabilitation of islands outside the Bikini-Eneu complex and agricultural redevelopment of islands outside the Bikini Eneu and Peter-Oboe complexes.

In response to the question you raised about the health risks to people who will return to live on Bikini, the data for such risk assessments are available in the recent reports of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) and of the U. S. National Academy of Sciences-National Research Council Committee on the Biological Effects of Ionizing Radiation (BEIR), which we have enclosed (BEIR report, Enclosure 14). As you stated in your letter, it is difficult to present to non-technically oriented people an adequate account of the basis for risk assessment due to low levels of radiation. Wewill offer here only calculated risks which are conservative estimates of the number of cases of genetic defects or malignant disease that might result from an estimated average radiation dose in a population equivalent in size to the Bikini population.

In the following, a linear dose-effect relationship with no threshold will be assumed in accordance with your suggestion. This conservative assumption is also made in the BEIR report. There is considerable scientific evidence for a less conservative, nonlinear and nonthreshold dose-effect relationship. The latter hypothesis assumes some probability of an effect at any dose, however small, but a lesser likelihood of an effect at the low doses under consideration here than would be calculated from the linear hypothesis. Since specific nonlinear relationships have not gained wide acceptance yet, we do not offer calculated risks based on a nonlinear relationship.

The following assumption are made here:

1. A linear relationship between radiation dose and effect for genetic and cancer risks.

2. A population of 600 persons at risk. We assume that the age distribution is similar to that of the general U. S. population. Some assumption regarding age distribution is necessary because of the effect of age on cancer rates; an older population has a greater cancer mortality rate than a younger one. Also, assuming similarity to the U. S. birth rate, 12 births per year can be expected. This figure is likely to be low for the Bikini population. However, simple corrections in the calculated risks can be made if the birth rate is higher.

3. An average annual whole-body radiation exposure of 200 millirems.

4. Incidence of naturally occurring genetic defects and of cancer mortality equal to those of the general U. S. population.

Normally, about 1 in 30 persons may be expected to show some manifestation of genetic disease at birth or during childhood, the periods when serious genetic defects become apparent. This, on the average of 12 births per year assumed to occur in the Bikini population,would yield about 0.36 of a case of a genetic defect before adult life. Exposure of the population to 200 millirems per year is calculated to increase the expectation of genetic defects from 3.0% to 3.2% and the estimated number of defects would be increased from .36 to .38 among the 12 individuals born each year.

With respect to cancer mortality, U. S. vital statistics provide an incidence of about 1 cancer death per year in a population of 600 people. The conservative estimate of the BEIR report is that .0002 deaths may be expected per year per rem. Thus, an annual exposure of 200 mrem would result in an estimated 2.4% increase over the normal number of cancer deaths. This would raise the expected cancer incidence from 1 to 1.024 deaths per 600 people per year.

These estimates of risk can be translated into terms of 1 additional cancer death in 40 years or 1 additional genetic defect in 50 years for the 600 in the population. If a nonlinear dose-effect relationship is ultimately accepted by the scientific community, the risk estimate will be significantly lower.

It must be recognized that in dealing with small populations, statistical variation affects the number of genetic defects or cancer deaths that occur in any one year. Thus, any population of 600 persons in the United States might experience as many as a few cancer deaths in some years and none in

other years through simple random variation. The same random variation applies to the number of genetic defects that might appear in any arbitrary group of 12 births.

In accordance with Roger Ray's suggestion to compare the anticipated effects of radiation levels at Bikini with those of high background areas in the United States, we might mention that Denver, Colorado has a population of about one-half million residents who are exposed to a natural background level averaging 160 mrems. No unusual genetic or cancer incidence has been observed in the Denver population or in the populations of other states having high average altitudes. Such comparisons are not conclusive, however, because socioeconomic and genetic differences may affect cancer rates and, possibly, the incidence of genetic defects.

With this information, we hope that the people of Bikini will be in a better position to compare the health cost that may result from a return to the Atoll with the benefits to be derived from their return.