APPENDIX C

RADIOACTIVITY IN GUAM AFTER NUCLEAR-WEAPONS TESTING IN THE PACIFIC

Radioactive Fallout in Guam

Guam is about 1,200 miles west of the Marshall Islands at about 10° north of the equator. The trade winds are predominantly from east to west at that latitude. Atmospheric testing began in the Marshall Islands with Operation Crossroads in July 1946. Operation Ivy began in October 1952. On October 31, 1952, the first thermonuclear device, with the code name Mike, was detonated. It had a total yield of 10.4 Mt of which about half was fission energy.

A radiation-fallout monitoring program for Operation Ivy was established in 1952 and coordinated by the New York Operations Office of the Atomic Energy Commission. It consisted of a worldwide network of 111 monitoring stations with at least one in every continent, but it was concentrated in the Northern Hemisphere. One of those monitoring stations was located in Guam. In addition to stationary ground-based monitoring, aerial surveys using low flying aircraft were conducted from several Air Force bases.

Instrumentation during aerial surveys included a gamma-ray detector and a recording unit. It was calibrated at the Nevada Proving Ground to measure exposure rate at 1 meter from the ground. It was capable of measuring dose rates in air from external gamma radiation in the range of 0.0001-10 mGy/h.

An aerial survey over Guam began on November 1, 1952. The resulting data are shown in Figure C.1 (Eisenbud 1953).

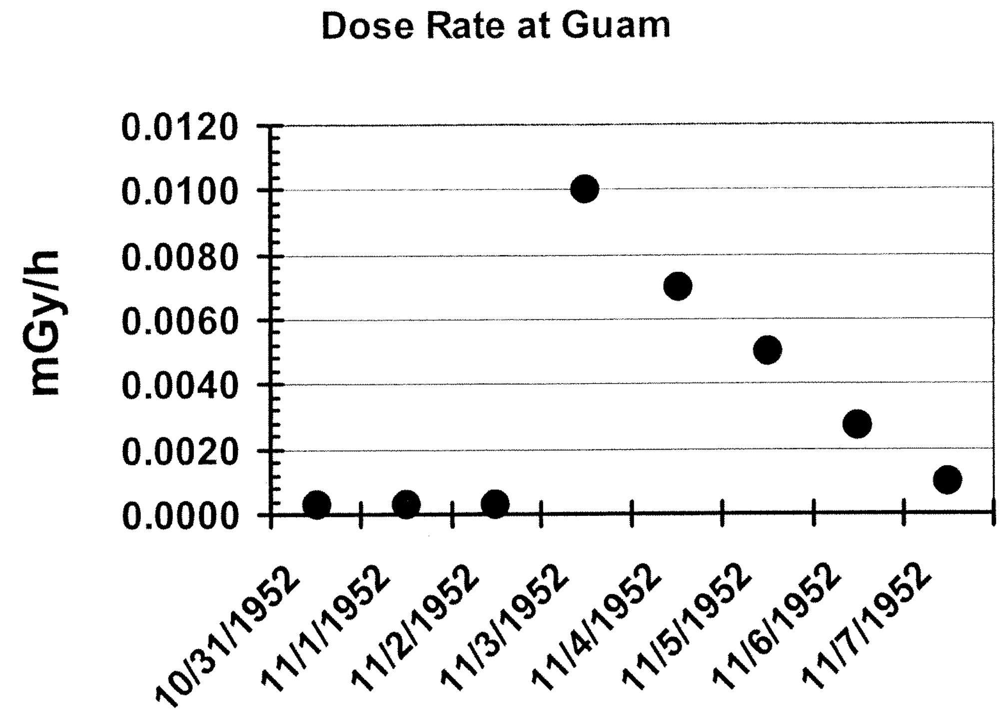

Figure C. 1. Data from aerial surveys in Guam before and after detonation of nuclear test Mike in Marshall Islands during Operation Ivy.

Integrating the dose rate over time produced a total effective dose to persons on the ground of about 0.6 mSv (w_r and w_T = 1.0) from external gamma rays as a result of fallout from Mike. To put that into perspective, we have compared the result with the annual effective dose received from natural background radiation today, as shown in Figure C.2.

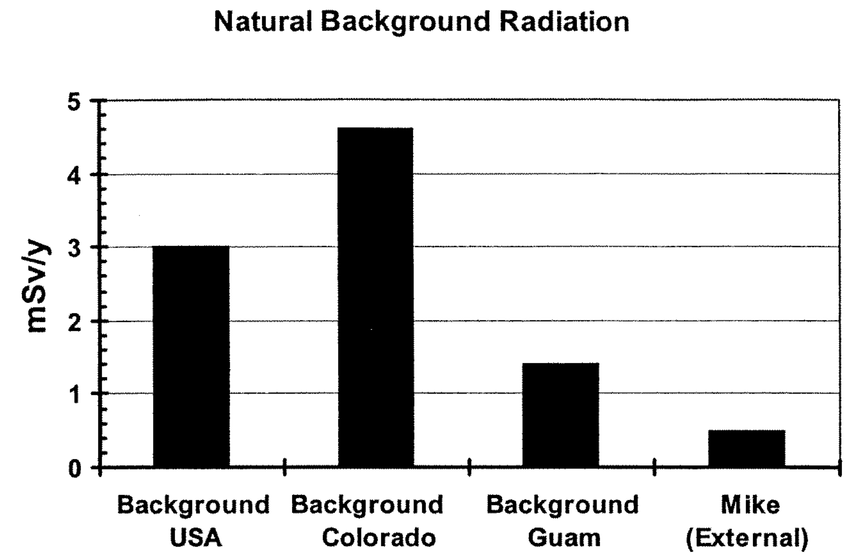

Figure C.2. Annual effective dose rates from natural background radiation in US mainland and Guam and external effective dose in Guam from nuclear test Mike in Marshall Islands during Operation Ivy.

As seen in Figure C.2, the external dose received by residents of Guam from the test was about 20% of the annual effective dose received from natural background radiation in the continental United States and about 50% of the annual effective dose received from current values of natural background in Guam.

To gain an appreciation of the fallout received from other tests, we used data from the ground-based monitoring stations. At each station, 24 hour samples of airborne dust were collected on 30 x 30-cm sheets of adhesive (gummed film). All samples were mailed to the Health and Safety Laboratory in New York City for analysis, where they were ashed and counted for gross beta activity. The total activity on the sample at the time of collection was determined; a power function decay with a coefficient of 1.2 was assumed.

Operation Castle began in 1954. There were 16 tests in 1954, 17 tests in 1956, and 33 tests in 1958. No tests were conducted in 1955 and 1957. Results from the gummed-film data collected at Guam are shown in Figure C.3. The ordinate is the sum of monthly data reported as the deposition of strontium-90 (^{90}Sr) on the surface of the gummed film (Harley et al., 1960).

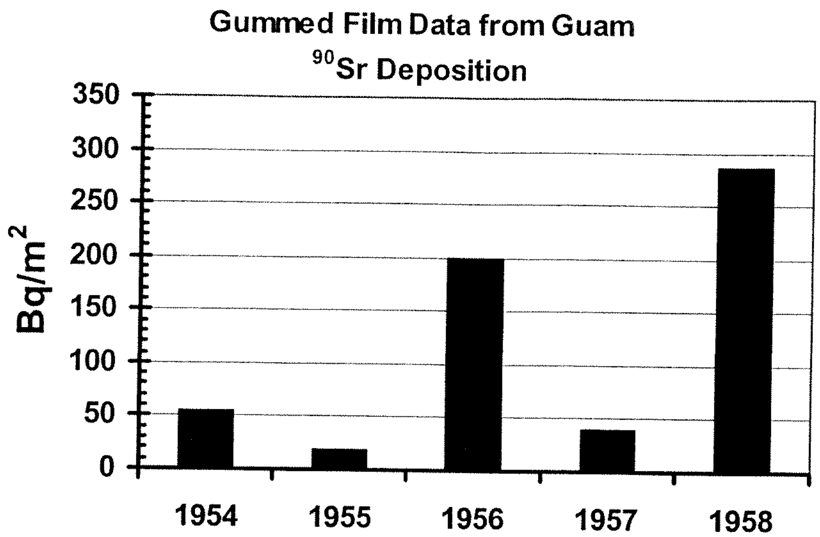

Figure C.3. Annual deposition of ^{90}Sr based on data collected at gummed-film station in Guam.

As mentioned above, there were more than 100 gummed-film stations around the globe. Monthly data from each station have been compiled for the 5-year period of atmospheric testing from 1954 to 1958. The 5 year accumulation of ^{90}Sr during that period for several locations, including Guam, is displayed in Figure C.4.

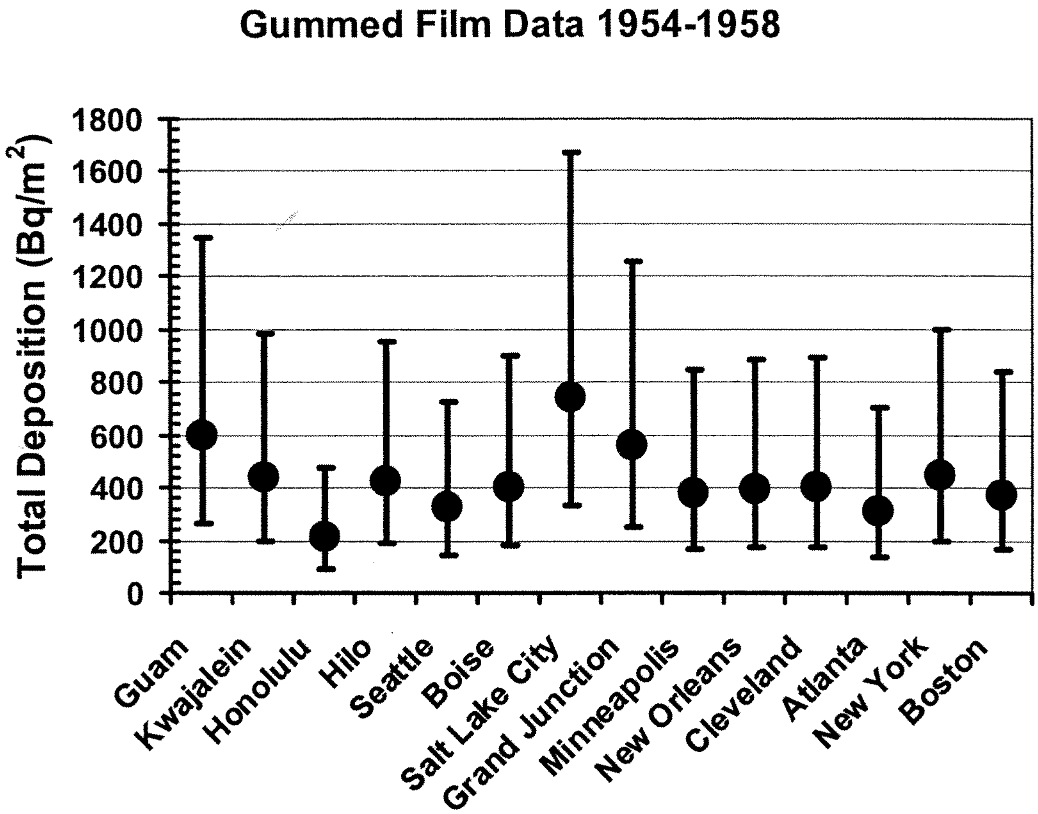

Figure C.4. Deposition of ^{90}Sr from 1954 to 1958 based on data collected at gummed-film stations in Pacific and locations in continental United States. Locations are ordered by longitude to provide rough estimate of distance from Guam.

Figure C.4 shows that Guam did receive radioactive debris from fallout during the nuclear-weapons testing in the Pacific Ocean. The vertical error bars are used in an attempt to show the uncertainty in the gummed-film measurements. They represent the 95% confidence limits based on a lognormal distribution with a geometric standard deviation of 1.5. Uncertainty in the gummed-film method for measuring fallout was probably much greater. The analysis demonstrates that fallout in Guam during that period was similar to that in other parts of the US and its territories.

An extensive radiologic monitoring program was conducted in Micronesia, including Guam. A report was published in 1975 (Nelson, 1975). In general, the data did not indicate that the concentrations of fission-product radioactivity in samples of soil or biota in Guam were greater than the concentration of naturally occurring radionuclides.

The pathway that is responsible for the largest collective doses from radioactive fallout is the intake of iodine-131 (^{131}I) through consumption of fresh milk. The risk to persons in Guam during this period will depend on iodine deposition and consumption of fresh milk. A dose-reconstruction effort will be needed to estimate dose and the associated risk of thyroid cancer.

Cancer Incidence

The petition to Congress to include residents of Guam in RECA claimed that "increased levels of radiation may have led to serious health and environmental problems for life". Figure C.5 shows the cancer incidence in Guam and the entire United States for various periods between 1990 and 1999. The incidence of cancer is not higher in Guam than in the entire United States.

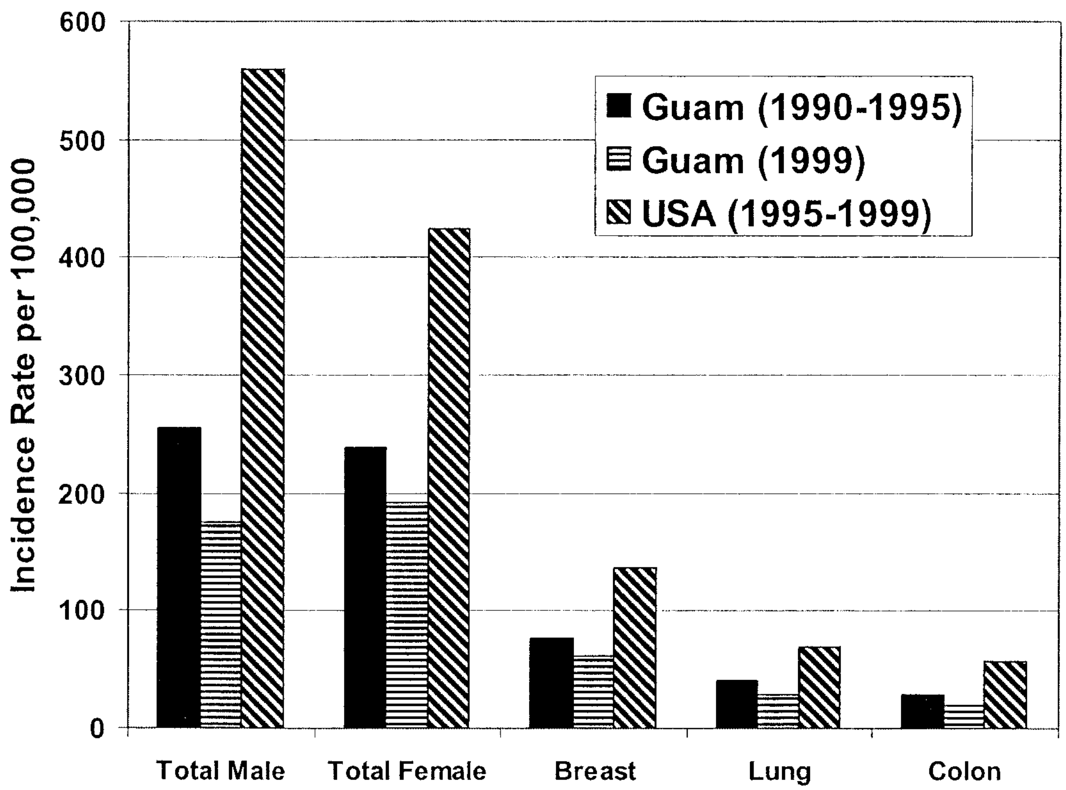

Figure C.5. Cancer incidence in Guam and entire Unites States.

Ship Decontamination in Guam

Operation Crossroads consisted of the first nuclear explosions after the detonations in Hiroshima and Nagasaki near the end of World War II. Their purpose was to examine the effects of nuclear weapons on naval vessels, equipment, and animals. The tests were designed to have a fission yield equivalent to 21 kilotons (21 kT) of TNT, which was similar to the weapons used in Japan. At that time, Crossroads was the largest peacetime military operation ever conducted. It involved more than 45,000 persons, 220 ships, and 160 aircraft.

A fleet of more than 90 surplus and captured ships anchored in the lagoon of Bikini Atoll in the Marshall Islands served as targets. The fleet included Allied and Axis vessels, such as the aircraft carrier USS Saratoga; the battleships USS Nevada, Pennsylvania, Arkansas, and New

York; and the Japanese battleship Nagato. In addition to target vessels, there was a fleet of support ships, including large LCI and LCT infantry landing craft, and YMS mine sweepers; these ships were involved with inter-atoll dispatch, mail delivery and passenger transport.

On July 1, 1946 (local time), test Abel was dropped from a B-29 and detonated at an altitude of 160 meters. On July 23, 1946 (local time), test Baker was detonated. The bomb was encased in a watertight steel caisson and suspended 30 meters beneath a target ship. Shortly after the detonation, a huge water column containing bomb debris was formed. It expanded to 600 meters in diameter and reached an elevation of 2000 meters, and it held a million tons of water. At 10 seconds after detonation, water started to escape the stem of the water column and fall back toward the surface. A wave more than 30 meters high propagated from the stem.

The radioactive fission products created by Abel were atmospherically dispersed, so no extensive deposit of long-lived radioactivity was found on target vessels, and naval personnel could board the surviving targets within a day. After detonation of Baker, most of the radioactive inventory fell into the lagoon. After 2 days, officials recognized that many targets would remain highly radioactive for a long time. The nature and extent of the contamination were unexpected.

As nontarget support ships began to navigate the lagoon, they became contaminated with radioactivity below the water line. Conditions were ideal for ion exchange. Within 3 days, some vessels had a dose rate of 1 mGy per day in the hull of the ship near the water line (Operation Crossroads, 1946). In addition, saltwater lines and saltwater systems that continuously circulated lagoon water began to show increased exposure rates from penetrating gamma rays on external surfaces. It was recognized that algae, rust, sediment, and calcareous materials on or in the ship would absorb radioactivity from the contaminated seawater.

The US Navy monitored the ships closely. It became apparent that natural decay and normal steaming in uncontaminated water would not reduce the radioactivity to negligible amounts. All support ships that had been in Bikini lagoon from July 25 to August 10 were required to have extensive radiation monitoring before personnel could work on their hulls or interior saltwater systems. On September 9, 1946, commanding officers of all nontarget vessels were notified of precautions, monitoring, and clearance procedures. The commanders were frustrated by the disruption of naval operations caused by the almost universal contamination of nontarget vessels. On September 13, 1946, the chief of naval operations charged the Bureau of Ships with the task of developing methods and equipment for decontamination of radioactive ships. The procedures were to be developed with the assistance of scientists with the Manhattan Project.

Several radioactive ships were dispatched to the San Francisco Naval Shipyard. The Navy conducted experiments at the shipyard with the assistance of scientists from Stanford University and the University of California Radiation Laboratory. The tests resulted in adoption of procedures for decontaminating nontarget vessels.

A solution of hydrochloric acid, HCl, (1 normal) was used as a decontaminating agent for all saltwater systems in a ship. Each system was then drained, neutralized, and flushed thoroughly. The material containing the radioactivity was in solution or suspension and was removed from the ship when the acid solution was drained and flushed. Those liquids were released into the harbor, where the dilution factor and settling would reduce concentration of radioactivity to negligible levels.

The external hull of each ship was scraped in dry dock to remove all marine growth. The remaining paint and rust from the underwater hull was wet sandblasted with standard equipment. Sand and all material scraped from the ship's sides were collected and dumped into the sea.

Radiochemical analyses were performed at the University of California on numerous samples of solutions and sediments. They revealed that there was not sufficient long-lived alpha activity to pose a health problem from intake of radioactivity nor was there sufficient residual plutonium to be of concern for security purposes related to fissile materials.

Records indicate that about 18 vessels were dispersed to Guam for decontamination (four LCI(L), eight LCT and six YMS). No data indicated that radioactive materials affected sea life or entered the food chain of residents of Guam.

Summary

An extensive radiologic survey of plants, animals, and soil in Micronesia was initiated after the termination of weapons testing in the Pacific. A report published in 1975 (Nelson, 1975) was reviewed at Lawrence Livermore Laboratory (Hamilton, 2001). The conclusion was that the estimated annual effective dose from residual fallout on Guam due to nuclear-weapons tests was only a small fraction of the dose that residents receive from natural sources of radiation, which is less than in many other locations around the world.

References

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