2

UWFL-91

GAMMA DOSE RATES AT RONGELAP ATOLL, 1954–1963

May 1965

Laboratory of Radiation Biology
University of Washington
Seattle, Washington

UNITED STATES ATOMIC ENERGY COMMISSION · DIVISION OF TECHNICAL INFORMATION

LEGAL NOTICE

This report has been reproduced directly from the best available copy.

Printed in USA. Price $3.00. Available from the Clearinghouse for Federal Scientific and Technical Information, National Bureau of Standards, U. S. Department of Commerce, Springfield, Virginia 22151.

USAEC Division of Technical Information Extension, Oak Ridge, Tennessee

UWFL-91
BIOLOGY AND MEDICINE (TID-4500)

GAMMA DOSE RATES AT RONGELAP ATOLL, 1954-1963

Edward E. Held

Laboratory of Radiation Biology
University of Washington
Seattle, Washington

Lauren R. Donaldson
Director

May 1965

Work performed under Contract AT(45-1)1385 with the United States Atomic Energy Commission.

GAMMA DOSE RATES AT RONGELAP ATOLL, 1954-1963

ABSTRACT

Rongelap Atoll was contaminated with fallout from a thermonuclear device on March 1, 1954. Gamma-dose rates on D + 1 ranged from 3.5 r/hr to 35 r/hr. Until 1959 the decline of gamma-dose rates measured in the field followed the theoretical decay of mixed fission products from U^{235} calculated by Miller and Loeb. The reduction of gamma dose rates to approximately half the predicted levels in 1959-63 probably reflects the downward movement of the long-lived gamma-emitter Cs^{137} in the soil. Redistribution of fallout had little effect on gamma dose rates except in the intertidal zone. It is concluded that predicted gamma dose rates from fallout based on the theoretical decay curve of radionuclides from fission of U^{235} would tend to be equal to or greater than actual levels.

GAMMA DOSE RATES AT RONGELAP ATOLL, 1954-1963

INTRODUCTION

Rongelap Atoll, Marshall Islands, was accidentally contaminated on March 1, 1954 with radioactive fallout from a thermonuclear device detonated at Bikini Atoll some 80 miles to the west. Eighty-two natives residing on Rongelap Island were evacuated and repatriated in June 1957. The atoll, its inhabitants and its economy have been briefly characterized[1]. The decline of gamma dose rates resulting from the fallout is discussed in this report.

RESULTS

Dose rates on D + 1

Gamma dose rates at Rongelap Atoll on D + 1 (time of detonation plus one day) were estimated to be 3.5 r per hour at the inhabited islet of Rongelap in the south and 35 r per hour at uninhabited Lomuilal islet in the northern part of the atoll[2], Fig. 1. These estimates were based on extrapolations of measurements made two days after initial fallout[2]. The subsequent decline of gamma dose rates, based on survey meter readings taken three feet above the ground at Rongelap and Kabelle islets, is compared with the theoretical decay[3] in Figs. 2 and 3. The theoretical curve is based on fission products from slow neutron fission and the assumptions that there is no fractionation and that the radionuclides are distributed over an infinite plane, while at Rongelap measurable amounts of activity remained on the trees. The actual measurements fit closely to the theoretical decay curve for Rongelap islet and at least for the first four years after fallout at Kabelle islet in spite of the assumptions made in determining the theoretical curve and the variability of the field measurements. The measurements on one small islet may vary by a factor of more than three, even when the identical instrument is used by the same person.

<u>Decline following first storm</u>

About two weeks after initial contamination there was a storm with heavy rain, and a subsequent reduction in gamma dose rate somewhat greater than would have been expected on a theoretical basis[2,4], (Fig. 2).

<u>Fallout in 1956 and 1958</u>

The rises in gamma dose rates in 1956 and 1958 were due to operations Redwing and Hardtack. Even though there was a measurable amount of contamination, as was seen by the short-lived radionuclides present and by following the beta decay rates in plants collected in 1958, the total contribution was a fraction of one per cent of the fallout deposited in 1954. Therefore the Redwing and Hardtack fallout are insignificant when considering the long-range picture.

Selection of areas and reproducibility of repeated measurements

In March 1958, stakes were set out in various parts of Rongelap islet in an attempt to provide a means of repeating measurements at identical locations. Stakes proved to be unsatisfactory since they only served to attract the curious, which resulted in trampling and disturbance of the areas and in some cases removal of the stakes. A practical solution to this problem was to select general areas within which measurements were to be taken. These areas were located with relation to pathways, roads, buildings, and measured distances from landmarks. In each general area measurements were taken over different types of vegetation, soil, the pathways themselves, over litter, and under Pandanus trees and other tall plants. In August 1958, the set of measurements was repeated three times at Rongelap islet and twice at both Eniaetok and Kabelle islets. At Rongelap islet the average for each set of readings ranged from 0.046 to 0.067 mr/hr. At Eniaetok the range of the average readings was 0.073 to 0.079 mr/hr and at Kabelle islet, 0.137 to 0.178 mr/hr.

Local differences in dose rates at three feet

The highest levels measured were generally under trees, particularly under Pandanus trees where litter had accumulated. The highest levels at Rongelap islet in 1955 were measured in the remaining palm-frond huts where fallout remained trapped in the roof and the wall thatching. Readings one inch above the floor were lower than those at three feet above the ground and readings close to the walls and roof were highest of all. There were relatively high readings over some open areas where soil algae were abundant. The soil algae form a crust roughly one centimeter thick and retain most of the radionuclides from fallout.

Return to background level

The return to background level, $\angle$ 0.02 mr/hr, occurred first, as would be expected, in the intertidal zone, except for a few small areas of beach rock covered with a film of algae. Levels of $\angle$ 0.02 mr/hr were measured in July, 1957 in the intertidal zones at Kabelle and Rongelap islets and in the newly constructed village on Rongelap islet. Construction of the village entailed the removal of the thatched huts and bulldozing of a considerable part of the area.

Local differences in dose rates at one inch

Survey meter readings were also taken at one inch above the ground with the beta shield both open and closed. There was no apparent correlation between these readings and the gamma dose rate readings at three feet, except in a very general way, but such readings were useful in selecting areas from which to sample and indicated local distribution of the activity. For example, when measurements were made one inch over the ground with the shield open in 1959, the levels were higher after the litter was removed from the soil and there were markedly higher levels of activity over areas covered with soil algae than over bare sand. Attempts also were made with a survey meter to determine local differences in activity in trees. This was unsuccessful, since the general levels of activity masked local effects within the trees, even though laboratory analyses showed that the activity in lichens and mosses collected from the bark was several times higher than in the bare portions of the trees. The use of survey meters to determine the vertical distribution of activity in soil pits was impracticable due to the high background levels from surrounding contamination and the fact that the bulk of the radioactivity was in the surface inch or less of soil.

Film badges

In September 1959, film badges sealed against moisture were exposed at Rongelap and Kabelle islets to measure gamma doses in different areas. The badges were provided and set out by Radiation Safety personnel at the Pacific Proving Ground. The limit of detection was an accumulated dose of 10 mr. Three badges were placed at each location, one suspended by strings three feet above the ground and away from tree trunks, one three feet above the ground attached to a tree, and one on the ground. Gamma dose rates measured with a survey meter at each location indicated that the accumulated dose in 69 out of 116 film badges would be in excess of 10 mr, but less than 20 mr. The results were, however, negative for all badges. The discrepancy between the doses calculated from the survey meter measurements and those obtained with film badges may be explained by differences in sensitivity of the two methods to the gamma energies present in the field. Calibration was based on a radium standard rather than on actual fallout material. This discrepancy does not invalidate the decline curves in Figs. 2 and 3 since the theoretical curve (solid line) is based on measurements with a survey meter similar to those used for the various measurements made. However, the discrepancy does point out that while relative levels of activity can be determined accurately by any one type of measurement, absolute values depend on calibration with radioactive sources having the same range and proportion of energies as the fallout material.

DISCUSSION

Decline and fallout composition

It has turned out in practice at Rongelap Atoll that when a large number of survey meter readings are taken and these are averaged, a pattern of decline of gamma-dose rates consistent with the theoretical decay for mixed fission products emerges. This is true even though the theoretical curve is based on the decay of mixed fission products from U^{235} distributed uniformly over an infinite plane and disregards differences in both the composition and distribution of fallout radionuclides in the actual field situation. The fallout at Rongelap consisted of mixed fission products and neutron-induced radionuclides from a thermonuclear device. The induced activities contributing to the gamma activity are of shorter half life than the long-lived fission product, 30-year Cs^{137}. It therefore might have been expected that the early decline in gamma dose rates at Rongelap would have been more rapid than the theoretical decay of mixed fission products alone. As the art of producing thermonuclear devices progresses the fission yield per kiloton will decrease. There will be a higher proportion of induced radionuclides to fission products and the decline of gamma dose rates will be more rapid. Therefore, in the future, long-range predictions of residual gamma dose rates based on the Rongelap experience would be likely to yield higher values than would actually occur.

Fractionation of fallout

In addition to the differences in composition of fallout from different devices and variations in measurements there is fractionation of the radionuclides, a change in species composition with time or distance from origin. The various factors involved in fractionation are discussed in detail in the Congressional Hearings, 1959[5] and with specific reference to the March 1, 1954 explosion in "The Effects of Nuclear Weapons," 1962[4].

Redistribution of fallout

Reduction of gamma-dose rate levels due to redistribution of fallout possibly occurred during the first storm after fallout (Dunning, 1957), but thereafter redistribution had very little effect on the gamma dose rates during the first four years after fallout. The exception, of course, is the relatively rapid decline of radioactivity in the intertidal zone. Such rapid decline would also be anticipated in areas in which there is heavy erosion. An example is the man-made erosion by bulldozers in the village area at Rongelap. The reduction of gamma dose rates following the storm could have been due to the washing of fallout material from the leaves of the vegetation and perhaps also to some shielding effect by additional moisture in the soil. It was certainly not due to rapid vertical movement of material in the soil. Analysis of soil leachates and soil cores shows that vertical movement of radionuclides in atoll soils is very slow. For example, cores taken in immature soils in 1963 still contained 90 per cent of the activity in the top centimeter. However, the reduction of gamma-dose rates to approximately half the predicted levels in 1959-63 probably reflects the downward movement of the long-lived gamma-emitter Cs^{137} in the soil. Cesium-137 and Sb^{125} are very slowly leached in the atoll soils while other gamma-emitters, Ce^{144}-Pr^{144}, Eu^{155}, Zn^{65}, Co^{60}, and Mn^{54} tend to remain at the surface(1,6,7). Although the gamma-dose rate values at Rongelap islet in 1959-63 fall on the theoretical curve, it appears that the levels due to the 1954 fallout have fallen below values predicted by the theoretical curve here also. Since the theoretical curve had reached background levels by 1959 it would be expected that the sum of gamma-dose rates due to the fallout and due to background would be approximately twice background.

CONCLUSIONS

The Rongelap experience has shown that the decline of gamma dose rates can be approximated from the decay curve for

U^{235} fission products in a local or intermediate fallout situation. As instrumentation, techniques of calibration and the predictability of the radionuclide spectrum from nuclear devices continue to improve, so will the usefulness of gamma-dose rate measurements for predicting the decline of gamma-dose rates. Practically speaking, the reliability of such measurements will depend upon the experience and judgement of the individuals making the measurements, the variety of environmental situations encountered and the time available for making such measurements. Their reliability is further substantiated by the fact that the levels of specific radionuclides in the various land organisms at different islands were roughly correlated with the gamma dose rates. Errors in predicted levels will tend to be conservative, i.e., higher than actual levels.

RECOMMENDATIONS

It would be useful in any future operations to have available known mixtures of radionuclides simulating the fallout radionuclides for a particular device, or better, a sample of the raw fallout material collected at each site to be studied. This mixture could then be used to calibrate instruments, film badges and chemical dosimeters as time went on and as the spectrum of gamma-energies changed. Comparison of the decay of gamma-dose rates from the mixture, with decline of gamma-dose rates in the field, would give a more accurate indication of the overall effect of the redistribution of radionuclides on the gamma dose rates.

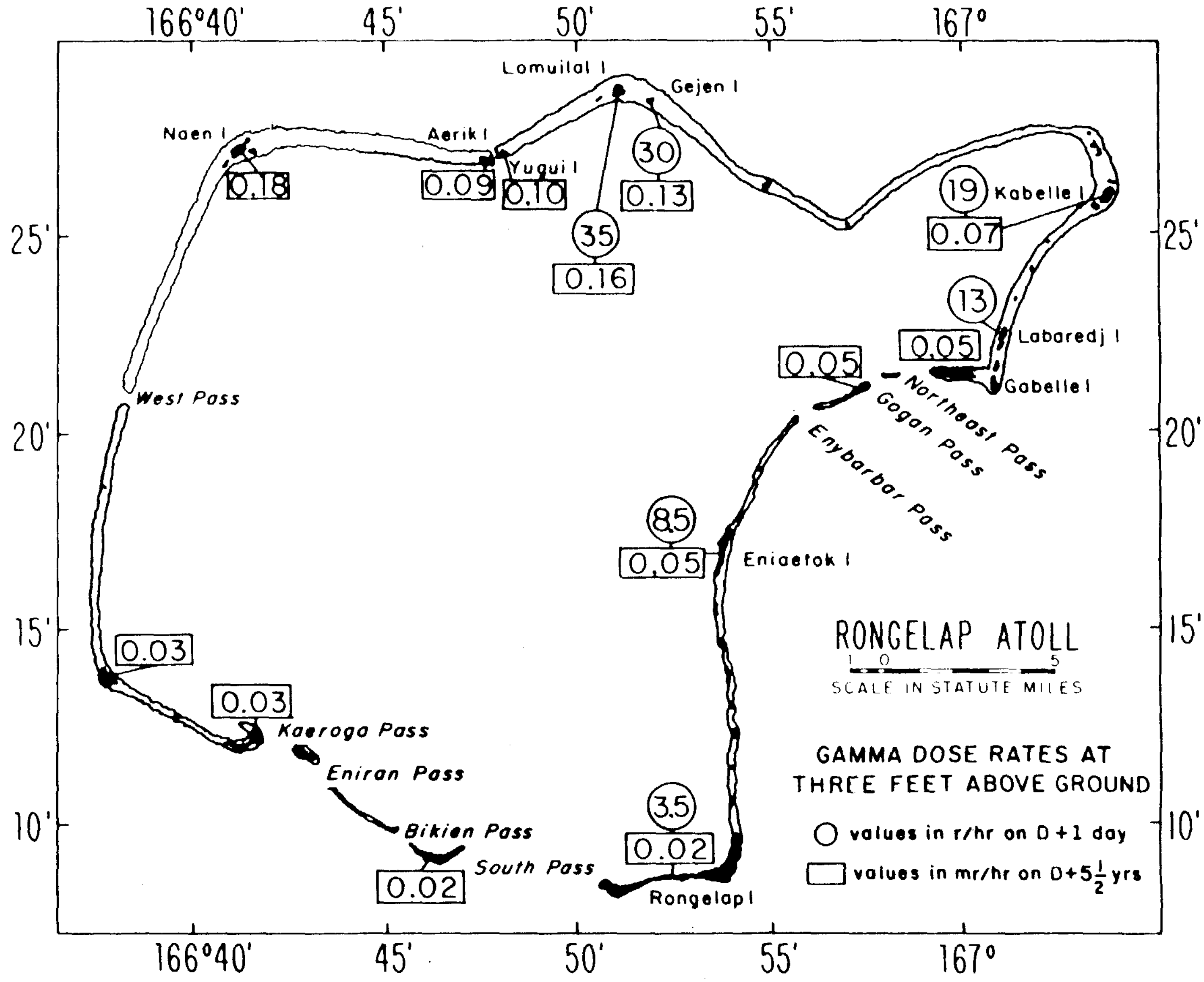

Fig. 1. Gamma Dose Rates on D + 1 Day and D + 5-1/2 Years.

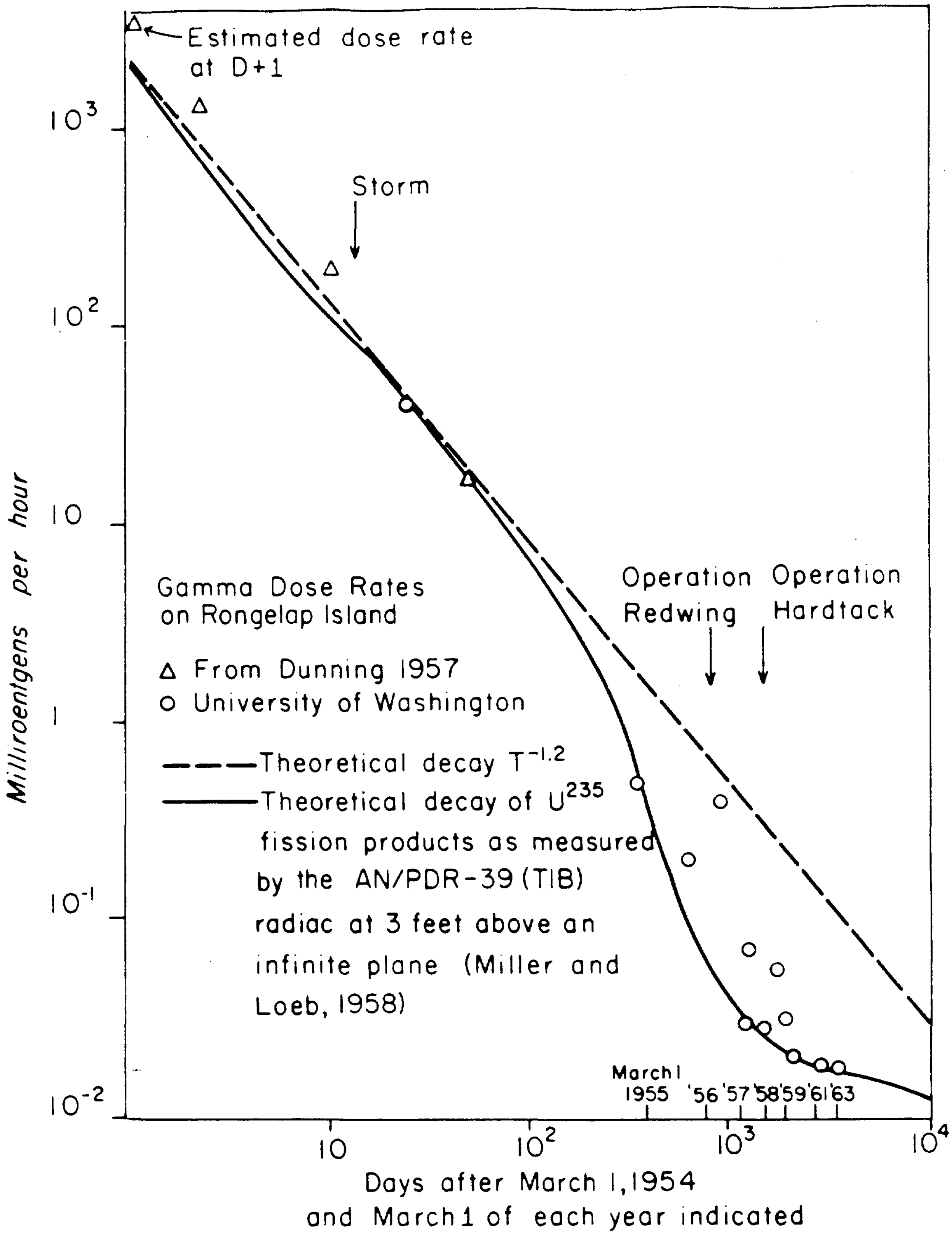

Fig. 2. Decline of Gamma Dose Rates at Rongelap Island.

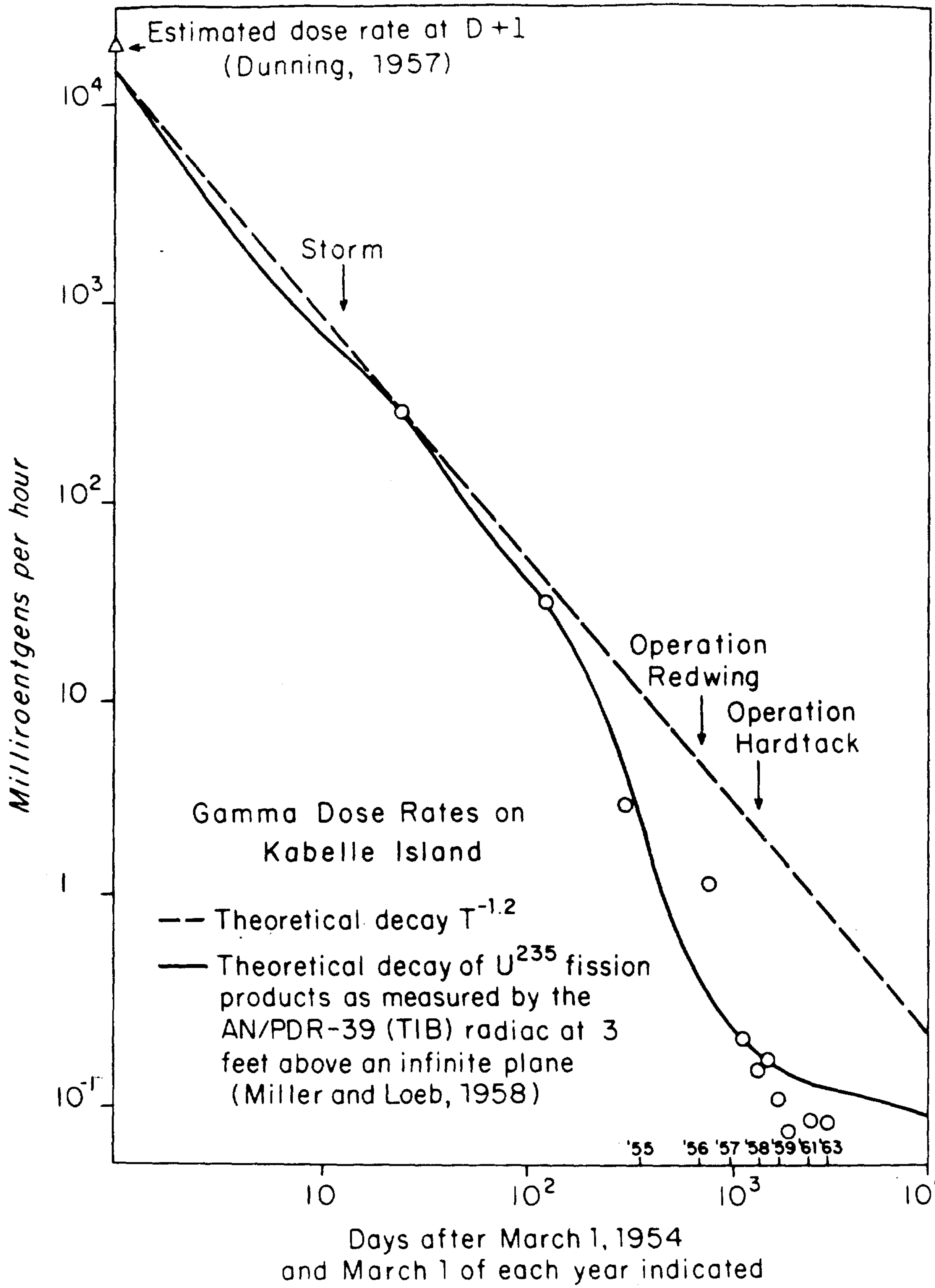

Fig. 3. Decline of Gamma Dose Rates at Kabelle Islet.

REFERENCES

1. E.E. Held, Qualitative Distribution of Radionuclides at Rongelap Atoll. In Radioecology, Schultz and Klement (Editors), Reinhold Pub. Corp. and the American Institute of Biological Sciences, New York (1963).

2. G.M. Dunning (Editor), Radioactive Contamination of Certain Areas in the Pacific Ocean from Nuclear Tests. U.S. Atomic Energy Commission (1957).

3. C.F. Miller and P. Loeb, Ionization Rate and Photon Pulse Rate of Fission Products from Slow Neutron Fission of U^{235}. USNRDL-TR-247 (1958).

4. S. Glasstone (Editor), The Effects of Nuclear Weapons. U.S. Atomic Energy Commission (1962) (See especially p. 460 and following).

5. Fallout from Nuclear Weapons Tests, Hearings Before the Special Subcommittee on Radiation of the Joint Committee on Atomic Energy, Congress of the U.S. 86th Congress, 1st Session, U.S. Government Printing Office (1959). (See especially V. 3, pp. 1969-76).

6. D.W. Cole, S.P. Gessel and E.E. Held, Tension Lysimeter Studies of Ion and Moisture Movement in Glacial Till and Coral Atoll Soils. Soil Sci. Soc. of Amer. Proc. 25, 4(1961).

7. E.E. Held, S.P. Gessel, L.J. Matson and R.F. Billings. Autoradiography of Sectioned Soil Cores. Proceedings of the Symposium on Radioisotope Sample Measurement Techniques in Medicine and Biology, I.A.E.A. (1965). (In Press)

Bikini-Eniwetok Studies, 1964
Part I and II, University of
Washington, Laboratory of Radiation
Biology, UWFL-93, September
15, 1966