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EFFECTS OF FALLOUT RADIATION ON A HUMAN POPULATION[1]

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I. Introductory remarks.

This report concerns the present status of the 82 Marshallese people from Rongelap Atoll, 4 years after the accidental exposure of this population to significant amounts of fallout radiation. The accident occurred following the detonation of a large thermonuclear device during experiments at Bikini in the Pacific Proving Grounds. An unpredicted shift in winds caused deposition of significant amounts of fallout on 4 nearby inhabited Marshall Islands and on 23 Japanese fisherman aboard their fishing vessel, the Lucky Dragon. Sixty-four inhabitants of the island of Rongelap, 105 nautical miles away from the detonation, received the largest fallout; viz. an estimated dose of 175 r whole-body gamma radiation, beta lesions of the skin and epilation from contamination of the skin and slight internal absorption of radioactive material. Also 18 Rongelap people away on a nearby island (Ailingnae), where less fallout occurred, received only about 69 r. (Discussed in earlier reports but not in this report were 28 American servicemen on Rongerik Atoll who received about 70 r and 157 Marshallese on Utirik Atoll who received about 14 r.) The people were evacuated to Kwajalein in the Marshall Islands by air and sea about 2 days after the accident. Extensive examinations were carried out during the first 3 months after exposure and these findings have been reported in detail.(12) In view of the radioactive contamination at their home island of Rongelap, the people were subsequently moved to a village provided for them at Majuro Atoll where further follow-up medical surveys were carried out and reported on at the following periods after exposure: 6 months, (5) 1 year, (13) 2 years,(9) and 3 years.(10) Details of the 4 year findings are being published.(11) By June, 1957 the radioactivity levels on Rongelap were considered safe for habitation and the people were returned to their home island where the present examinations were carried out. An LST was furnished by the Navy to transport the medical team from Kwajalein to Rongelap and to act as a base of operations. An unfortunate mishap occurred at the completion of the survey when a plane transporting the medical equipment was forced to jettison nearly all of the equipment and some of the data and records into the ocean. Important losses included x-ray films of the children's bones for the growth and development studies and the gamma spectroscopic data. In view of the importance of the latter data, a return trip to Rongelap with new equipment was made to obtain the data again 2 months later.

The medical team for the four year survey consisted of 22 doctors and technicians including personnel from Brookhaven National Laboratory, the U. S. Public Health Service, Naval Medical Research Institute, the Naval Radiological Defense Laboratory, and Marshallese from the Trust Territory medical group.*

II. Examinations.

A. History and physical examinations

Histories were taken by a Marshallese practitioner with particular emphasis on the interval history during the past year.

Complete physical examinations were carried out on both exposed

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* Recent survey material presented represents findings of the entire team. This paper was not written by all members of the team and the conclusions presented do not necessarily represent their viewpoints. Detailed findings of the 4 year survey are being published.(11)

and comparison populations, including examination of the skin, with color photography of selected lesions; ophthalmological studies including slit-lamp observations, visual acuity, and accommodation; growth and development studies in children (less than 20 years of age) including anthropometric studies; ECG records on all subjects over 40 years of age; and other x-ray examinations as deemed necessary.

B. Laboratory Examinations

Hematological examinations included 3 complete blood analyses (total white counts, differential, platelet counts by phase microscopy, and hematocrit by the microhematocrit method) done at about weekly intervals. Sera were obtained for total protein determinations by proteinometer, protein bound iodine, and starch electrophoresis studies. An intestinal parasite survey of the population was carried out by examining the stools of 190 people for ova and parasites. Pooled urines and a few sufficiently large samples from single individuals were obtained from both the exposed and unexposed groups for radio-chemical analyses of Cs^{137} and Sr^{90}. Whole-body counts with gamma spectroscopy were obtained on board the ship by placing the individuals in a massive steel room with 4-inch thick walls, with the necessary crystals and electronic equipment attached. The steel room was constructed at Brookhaven National Laboratory and was transported to Rongelap via commercial ship and LST.

C. Difficulties associated with examinations

Several difficulties associated with the examinations of the Marshallese should be mentioned:

(1) The language barrier made the examinations difficult since very little English is spoken by the Marshallese. However, sufficient interpreters were available to assist the medical team.

(2) The lack of vital statistics to be found on the Marshallese imposes a serious difficulty in interpretation and evaluation of the medical data.

(3) The uncertainty of exact ages of some of the Marshallese, largely due to lack of written birth records. It came to light during the past examinations that there were some uncertainties in the ages of children. It is hoped that these ages may be established more firmly so that the growth and development studies in the children may be placed on a firmer basis.

(4) Difficulties in obtaining what could be considered as entirely adequate populations to act as comparison groups for the irradiated people. Three separate groups have been used for comparison in the past. Though each group matched well for age and sex, the first two groups proved unsatisfactory due to difficulties in locating the people for subsequent examinations. Fortunately, by 3 years post-exposure, it was found that a large group of Rongelap people who had been away from their home island at the time of the accident had returned to live with their fellow Rongelap people. Because they were of the same stock and matched reasonably well for age and sex, these people were uniquely appropriate to serve as a comparison population. They returned to Rongelap with the other Rongelapese and were used again as the comparison population for the 4 year survey.

III. Results.

The present status of the Marshallese people will be brought up to date by a brief summary of the past findings accompanying the present findings.

During the first 24 to 48 hours after exposure, about two-thirds of the Rongelap people experienced anorexia and nausea. A few vomited and had diarrhea. At this time many also experienced itching and burning of the skin and a few complained of lacrimation and burning of the eyes. Following this, the people remained asymptomatic until about 2 weeks after the accident, when cutaneous lesions and patchy loss of hair developed due to beta irradiation of the skin. Hematological examinations showed increasing depression of peripheral blood elements, and radio-chemical examinations of the urine revealed the presence of detectable radioactivity in the samples.

During the first few months many of the people showed a slight weight loss. It is not known if this was associated with irradiation effect or environmental change.

A. Hematological findings

Figures 1 and 2 show chronologically the changes (in absolute mean counts) that have occurred in peripheral blood elements of the 64 Rongelap people who received the largest dose of radiation. Similar but less marked changes have occurred in the 18 Rongelap people who were on Allingnae Atoll at the time of exposure.

1. WBC. The leukocytes largely reflected the changes that occurred in the neutrophiles (see Figure 1) and will not be discussed separately. Unexplained changes in the mean level of blood elements have occurred from year to year in both exposed and unexposed populations.

2. Neutrophiles. During the first few weeks after exposure, the neutrophiles fluctuated considerably, then gradually fell to a low of about 50% of the comparison population at about the sixth week. (Figure 1). Recovery was slow, and it was not until the one year examination that the counts returned to the comparison population level and have been found to be essentially the same as the unexposed group at 1, 2, 3, and 4 years post-exposure.

3. Lymphocytes. By the third day after exposure the mean lymphocyte level had fallen to about 55% in the adults and 25% in the children of the unexposed comparison population. (Figure 1). The levels remained low longer than the neutrophiles and have been very slow in recovering. There was little recovery by 6 months but an upward trend has since occurred. After 3 years the lymphocytes were slightly below the mean level of the comparison population for all age groups and distributional studies of individual counts showed more lower counts in the exposed groups. The 4 year study showed the highest level thus far attained (3600 cells/mm^3 compared to 3700 cells/mm^3 in the unexposed people) and recovery of this blood element is considered almost complete. However, a scattergram of the individual counts plotted according to age and accumulative distribution curves showed more of the counts to be lower than in the unexposed population.

4. Platelets. There was a steady reduction in the platelets in the peripheral blood after exposure reaching a low of about 30% of the unexposed group by the fourth week. (See Figure 2). A rapid recovery trend was then followed by a fluctuating, slow recovery pattern, the males showing slower recovery than the females. Even at 4 years post-exposure the platelet production does not appear to have recovered completely. The counts were higher than a year ago but compared with mean unexposed levels were about 12% lower in the males (greater than 10 years of age) and 9% lower in the females. A scattergram (Figure 3) shows individual counts in the males and the mean curve of the controls plotted against age. The counts are preponderantly below the control curve. This trend is not as marked in the females.

5. Eosinophiles and monocytes showed depression and recovery roughly paralleling the neutrophiles. Eosinophilia is present in all the populations studied. During the past survey the differential counts showed eosinophilia

above 5% in about half of the people of both groups.

6. Hematocrit. Erythropoeitic activity as evidenced by hematocrit readings has not shown any remarkable change since exposure. The values have been consistently on the low side of normals, according to American standards, particularly in the females in both exposed and unexposed people. The hematocrit readings after 4 years were about the same as found at 3 years and about equal to the comparison population level.

B. Physical findings

1. Diseases. There have been no diseases, infectious or non-infectious, that could be related to irradiation effects. No antibiotics, blood transfusions, or other specific therapy has been used either prophylactically or therapeutically in the Marshallese, even during the acute period when maximum depression of the blood elements was noted. The incidence of diseases in both the exposed and comparison populations has been about the same. Even when leukocyte depression was greatest (the levels reaching about half of the levels of the comparison population at about 5 to 6 weeks post-exposure) there was apparently no increased susceptibility to infection. An epidemic of upper respiratory infection that occurred at this time showed no greater incidence or severity in the exposed people compared to the unexposed. There was no bleeding associated with a maximum depression of platelets (11 individuals had platelet counts between 35,000 and 65,000). The people have since sustained epidemics of measles, chicken pox, upper respiratory infections, and gastroenteritis without untoward reactions. A limited study of the immune response at 3 years post-exposure showed that the antibody response to tetanus toxoid antigenic stimulus was not significantly different in the exposed and unexposed people at that time. During the past year 5 exposed children and 1 unexposed child presumably had infectious hepatitis. No other serious illnesses were reported.

Three deaths have occurred in the exposed people. The first was in a 46 year old man who died of hypertensive heart disease 1 year post-exposure. He had had the disease at the time of irradiation. The second death occurred in a 78 year old man at 2 years post-exposure. He was a diabetic of long standing and died apparently of coronary heart disease. A third death occurred in April, 1958 in a 38 year old man. (He was in the group which received 69 r.) Death was due to pneumonia complicating a severe case of chicken pox. In none of these cases was there any evidence that death was due to irradiation exposure.

2. Growth and development studies. Cross-sectioned data on height and weight and bone age determinations for the 2 and 3 year surveys gave an impression of lag in growth and development in the exposed children compared with unexposed children. However, in an attempt to obtain more accurate birth dates of the children on the 4 year survey, it was found that ages of some of the children which were thought to be established were in question. The absence of recorded birth information seriously complicates the determination of the accuracy of given chronological ages and dates of birth. More definitive evaluation of the data will be possible when verification of the birth dates is completed. Detailed geneological and biological histories are being compiled to establish the most probable birth dates of each of the children. (Unfortunately the 1958 roentgengrams of the wrist and knee, intended for assessment of osseous maturation, were lost at sea.)

In addition to cross-sectioned studies, longitudinal studies of incremental growth data and bone maturation studies over the period since exposure will be undertaken when ages of the children are more firmly established.

3. Ophthalmological findings. Ophthalmological examinations including slit-lamp studies at yearly intervals have not revealed any opacities of the lens that might be associated with irradiation effects. No differences in visual acuity between exposed and unexposed people have been noted. The 3 and 4 year examinations revealed an increase in incidence of pterygium in the exposed population. Arcus senilis and senile cataracts are of slightly higher incidence in the exposed group but have not shown an increase since exposure. In general most of the Marshallese people examined have superior vision and accommodation compared to our standards. The incidence of glaucoma, myopia, retinal arteriosclerosis, and squint are low. Many of the people have large corneas which will be further studied.

4. Fertility. It has not been possible to show even a temporary sterility on the basis of comparison of frequency of pregnancies in the exposed with the unexposed people. There have been 18 healthy babies born in each of the exposed and unexposed groups since the accident. The pregnancies were distributed fairly evenly over the 4 year period.

5. In utero effects and effects on pregnancy. Four fetuses were irradiated in-utero. One was in the first, two in the second, and one in the third trimesters. Full term deliveries resulted in apparently normal babies. There were 5 miscarriages or babies born dead or dying shortly after birth. Lack of vital statistics in this regard makes it impossible to evaluate these findings with certainty. However, from comparison with

small numbers of unexposed people, it does not appear that this number is excessively high.

6. Other findings common to both exposed and unexposed Marshallese.

a. Nutrition. The diet of the Rongelap people is extremely limited in variety although the caloric intake appears to be adequate. They appear to maintain satisfactory nutritional status without gross vitamin deficiency except at the time of the 4 year examinations about 12 children were found to have mild night blindness. This defect was corrected with vitamin A therapy.

b. Diseases. The paucity of findings associated with degenerative diseases in the Marshallese people is striking. While the population examined is too small to permit any valid statistical analysis, the clinical impression is that diseases such as atherosclerosis and hypertension are considerably less common and of less severity than in a comparable group of our population. Electrocardiographic tracings revealed a low incidence of positive findings and the general age appearance of the tracings is younger than would be expected. This is in contrast to the general impression that these people age more quickly and possibly have a shorter life span. No cases of malignancy have been seen in the populations under discussion. There has been a general feeling that conditions such as peptic ulcer, hernia, varicose veins, hemorrhoids, and vaginal prolapse are much less common than one might anticipate in examining a random group of people of similar age in our society. One interesting finding has been the high incidence of kyphoscoliosis. The cause is not apparent. Skin infections, particularly with tenia versicolor and impetigenous lesions in children, have been quite prevalent though dermatophytosis of the feet has been of low incidence. Extensive dental caries was commonly found.

c. Congenital anomalies. The incidence of congenital anomalies is believed to be higher than found in Americans. The increase may be due to the fact that these people have been living in a relatively isolated area for some 2000 years with prevalent consanguinous matings.

d. Laboratory findings of interest.

Eosinophilia is prevalent. As pointed out about half of the people have greater than 5% eosinophiles in their differential counts. An intestinal parasite survey at the 4 year study revealed stools positive for various parasites in about 80 to 85% of the people. However, hookworm was the only parasite noted which is generally associated with eosinophilia, but the incidence was too low (about 2% of the people) to account for the generally high eosinophile counts. The prevalence of skin diseases may be partly responsible. Another possibility is that the incidence of trichinosis infestation may be high. (Pigs are used for meat and rats are numerous on the island.) This will be a subject of further study. The low incidence of hookworm would not account for the low hematocrit readings. In fact, there was no correlation in individuals between hematocrit, parasite infestation or eosinophilia. The tendency toward low hematocrits may be related to nutritional deficiency of iron or proteins but there is no good evidence that these factors are involved.

These people generally show high total serum protein levels (mean of 8 g) with increased gamma globulin (mean of 2.4 g). The explanation for these findings is not immediately apparent.

An unexpected finding is a generally high protein bound iodine value (mean value for the population of 9.4 μg/100 ml.) The explanation for this is not apparent, particularly in view of the fact that the people do not clinically appear to be hyperthyroid. Serum cholesterols and creatinine levels were found to be within normal limits.

C. Beta lesions of the skin, epilation

Multiple beta lesions of the skin, mainly on the areas of the body not covered by clothing, and spotty epilation associated with beta lesions of the scalp appeared in many of the people beginning 12 - 14 days after exposure and continuing over the following few weeks. Most of the lesions were superficial and were characterized by thickening and pigmentation of the skin accompanied by mild itching and burning. Desquamation followed with healing and repigmentation over the next few weeks. Regrowth of hair began about 3 months after exposure with complete return of normal hair by 6 months. About 20% of the cases exhibited more severe lesions which ulcerated but, in all except one severe ear lesion, complete healing occurred within a few weeks. Microscopic changes were characteristic of radiation effects with the epidermis showing the greatest damage. About 14 cases continue to show residual changes at this time characterized by mild scarring and atrophy and varying degrees of decreased and, in some cases, increased pigmentation. In no case, either grossly or microscopically, has any malignant or pre-malignant change been observed.

D. Internal absorption of radioactive isotopes

At present the accumulated evidence supports an assumption made initially that following contamination by fallout the radiation dose from external sources would be higher than that from internally deposited sources. Because, however, so relatively little is known about the mechanisms and consequences of internal deposition of fission products, study of this phase of the problem was among the first of the studies undertaken in 1954 and has continued to be a part of subsequent re-examinations of the exposed population.

A few short-lived radioisotopes, I^{131}, Sr^{89}, and Ba^{140}, accounted for most of the activity found in urine specimens obtained during the first

24 days after the contaminating event. Analysis of the 24 day urines performed 2 years later showed that the samples also contained some Sr^{90} and Cs^{137}. Sr^{90} activity in the urine decreased from 12 d/m/l in the 24th day specimens to 0.34-1.41 d/m/l in the 1957 specimens. Sr^{90} analyses on urine samples taken in the 4 year survey have not been completed. The Cs^{137} urinary activity fluctuated, decreasing from 174 d/m/l on the 24th day to 33 d/m/l in 1956, and then increasing to 137-370 d/m/l in 1957.[6] Preliminary analysis of the 1958 data indicate that the Cs^{137} activity in urine increased by a factor of 100 over the 1957 levels. (Two residents of Utirik Atoll who had been living on their island since several months after its accidental contamination in the 1954 fallout had urinary Cs^{137} activities of 11,653 and 3,735 d/m/l in 1957.)

As part of the 3 year post-exposure survey 4 of the Rongelap people were brought back to Argonne National Laboratory where a more direct measurement of the internally deposited gamma emitting radioisotopes was obtained.(15) Cs^{137} was identified as being the most prominent gamma emitter and the presence of the neutron-induced radionuclide Zn^{65} was discovered. Analysis of the spectra indicated an average body burden of .02 microcuries of Cs^{137} and .03-.07 microcuries of Zn^{65} in the Rongelap residents. Two Utirik residents similarly measured had 0.22 and 0.41 microcuries of Cs^{137} and .482 and .229 microcuries of Zn^{65}.(16)

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Comparison of spectra in various groups of people at Rongelap Atoll in 1958 shows that there is little difference between those exposed in the 1954 fallout and those not exposed. A small group of people who moved from a non-contaminated island to Rongelap island only 2 1/2 months previous to the present survey had less than one-half the Cs^{137} level and less than one-third of the level of Zn^{65} of the Rongelap residents. A group of 56 people who had been living, until a month before the survey, on a slightly more contaminated island about ten miles to the north showed slightly higher Cs^{137} peaks than the inhabitants of Rongelap Island.

Because the 1958 data has not been subjected as yet to the thorough analysis, the quantitative statements regarding the body burdens are preliminary. However, on the basis of counts made with appropriate standards corrected for absorption and geometry, it is estimated that the body burdens of Cs^{137} is 0.5-1.5 μc and 1.0-3.0 μc of Zn^{65}. (The body burden of the Rongelap people of Cs^{137} at 1 day after exposure in 1954 is estimated as having been about 0.01-0.02 μc.)

The spectra of whole body gamma activity seen in 1957 and in 1958 of one of the Rongelap residents are compared in Figure 4. In both spectra Cs^{137} and Zn^{65} are responsible for most of the gamma activity, but the 1958 levels of both are much higher than those seen in 1957. An additional peak is seen at 1.6 mev in the 1958 spectrum. This peak was a prominent feature of the background spectrum and has tentatively been ascribed to La^{140}. It is probable that the Ba^{140}-La^{140} isotopic pair resulted from fallout contamination from the 1958 Pacific test series. The ship containing the steel room was slightly contaminated before proceeding from Eniwetok to Rongelap.[7]

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7. The absence of peaks except at 1.6 mev and the fact that external procedures such as washing down the decks and removing contaminated deck paint definitely lowered the background inside the room (from about 70,000 cpm to about 25,000 cpm total counts) indicated that the contamination was outside the steel room.

Low levels of Ba^{140}-La^{140} were also present on Rongelap as indicated by the low levels of this isotope in the spectra of some of the people measured on Rongelap. It should be noted that not all of the subjects showed a distinct peak at 1.6 mev. For example, the spectrum shown in Figure 5 has very little net activity above 1.2 mev. The presence of the large 1.6 mev peak in the background, however, makes it difficult accurately to evaluate the K^{40} peak at 1.46 mev, which shows up clearly in the 1957 spectrum.

The differences between the 1957 and 1958 body burdens of Cs^{137} and Zn^{65} reflect the different levels of these isotopes in their diet. It is not known whether they have reached equilibrium with the increased amounts of these isotopes in their present environment. Because of the relatively short biological half lives of Cs^{137} and Zn^{65}, little of the present levels can be attributed to the original activity which was absorbed in 1954. Therefore most of the activity represents Cs^{137} and Zn^{65} ingested relatively recently.

B. Late effects

The acute effects of exposure of this population to fallout radiation have subsided. That the dose of whole-body gamma radiation had been in the sublethal range was substantiated by the following findings: the early symptoms of nausea and vomiting were mild, transitory, and did not recur; the hematopoietic depression was insufficient to result in clinical evidence of increased susceptibility to infection or in gross bleeding; no obvious effects on fertility, or on children who were irradiated in-utero, or on the course of pregnancies were noted; and lastly, no deaths have occurred that appeared to resemble acute or late radiation deaths that have been described. At 4 years post-exposure, the only remaining evidences of the initial radiation exposure to be found are (1) the lag in complete recovery of certain peripheral blood elements to the levels of the comparison population; (2) remaining residua of the beta lesions of the skin; and (3) low levels of remaining radioisotopes absorbed internally.

Late effects of radiation exposure have not been seen, but certain of the more fundamental of these effects that have been observed in animals and to a lesser extent in man will be mentioned in relation to the Marshallese.

1. Shortening of life span (2,3,6) has not been evident. The 3 deaths that have occurred in the exposed population do not appear to indicate a higher mortality rate than seen in the comparison populations. From these observations it would appear that some of the higher estimates of life shortening per roentgen may be too high.

2. Premature ageing (1,4,7,14) is difficult to assess. From observations over the past 4 years the impression is that the exposed people have neither aged faster nor appear older than similarly aged unexposed Marshallese. No doubt the subtle changes which occur with ageing would be difficult to detect over this period of time. During the 4 year survey, data has been collected in an attempt to obtain semi-quantitative estimates of biological age by scoring the degree of certain criteria such as greying of the hair, skin looseness, skin retractility, arcus senilis, retinal arteriosclerosis, accommodation, blood pressure, etc. These data have not been completely analyzed yet.

3. Degenerative diseases have not been found to be increased in the exposed people. No malignancies have been detected. In the irradiated Japanese an increased incidence of leukemia has been noted.(17,18) There have been no cases of leukemia or leukemic tendency noted in the Marshallese. (No cases have shown decrease in alkaline phosphatase of neutrophiles nor have increased levels of basophiles been noted.) Since the incidence of malignancy or leukemia would be expected to be relatively low with the dose of

irradiation received and since such a small population is involved the probabilities are good that such effects will not be observed in the Marshallese.

4. Ophthalmological changes related to late effects of radiation (8,20) have not been seen. Slit-lamp observations over the past 4 years have revealed no polychromatic plaques or cataracts. No differences were found in visual acuity in the exposed and unexposed children.

5. Genetic effects. No specific studies for genetic effects have been conducted. However, no abnormalities have been noted in the 18 babies born of irradiated parents. In view of the generally negative findings in the studies of the first generation offspring of the irradiated Japanese (19) it is unlikely that genetic studies in this group will be fruitful.

6. Beta irradiation. No late effects of beta irradiation of the skin such as chronic radiation dermatitis or pre-malignant or malignant changes have been found in the Marshallese.

7. Body burdens of radioactive isotopes. The present body burdens of radioactive isotopes absorbed from both the initial contaminating event and from the present habitation on Rongelap are far below the accepted tolerance levels and the hazard from this exposure is unlikely to result in any late effects.

Even though as pointed out, the radioactive contamination of Rongelap island is considered perfectly safe for human habitation, the levels of activity are higher than found in other inhabited locations in the world. The habitation of these people on the island therefore affords a most valuable ecological radiation study on human beings. Since only small amounts of isotopes are necessary for tracer studies, the various radioisotopes present can be traced from the soil, through the food chain, and into the human being, where the tissue and organ distribution, biological half-lives, and excretion rates can be studied. Such investigations will be done by the use of whole-body gamma spectroscopy of the people and of sample materials, and by radio chemical analysis of soil, food, and human excreta.

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Legends for Figures

Figure 1. Chronological changes in leukocytes, neutrophiles and lymphocytes in Rongelap people following exposure to 175 r of whole body radiation from fallout. Points represent mean counts of population ≥15 years of age. Open points are mean counts of comparison population used at that time.

Figure 2. Chronological changes in platelets of Rongelap people following exposure to 175 r of whole body radiation from fallout. Points represent mean counts of males ≥15 years of age and females of all ages. Stars represent comparison population mean counts at that time.

Figure 3. Scattergram of individual 1958 platelet counts, males, plotted against age with mean curves of the 3 year and 4 year comparison population males plotted according to age.

Figure 4. Gamma spectrographic data on Rongelap male (No. 79) comparing 3 year body burden of gamma isotopes obtained at Argonne National Laboratory when he had been living on an uncontaminated island with body burden at 4 years when he had been living on Rongelap nearly one year.

Figure 5. Body burden of gamma isotopes in Rongelap man (No. 50) after living on Rongelap island for nearly one year.

References

1. Bennett, L. S., Chostain, S. M., Flint, J. S., Hansen, R. A., and Lewis, A. E., Radiology 61, 411 (1953).

2. Berlin, N. I. and Di Maggio, F. L., Air Force Special Weapons Project AFSWP-608 (June 28, 1956).

3. Blair, H. A., Proc. Intern. Conf. on Peaceful Uses of Atomic Energy, Vol. 11, pp. 118-20, UN, New York (1956).

4. Blair, H. A., Atomic Energy Project Rept. UR-206 (1952).

5. Bond, V. P., Conard, R. A., Robertson, J. S., and Weden, E. A. Jr., Operation Castle Addendum Report 4.1A, WT-937 (April 1955).

6. Brues, A. and Sacher, G., in "Symposium on Radiobiology" pp. 441-65, Wiley, New York (1952).

7. Cassarett, G. W., "Acceleration of Aging by Ionizing Radiation." UR-492 (1955).

8. Cogan, D. G., Martin, S. F., and Kimusa, S. J., Science 110, 654 (1949).

9. Conard, R. A., Huggins, C. E., Cannon, B., Lowery, A., and Richards, J. B., J. A. M. A. 164, 1192-7 (1957).

10. Conard, R. A., Meyer, L. M., Rall, J. E., Lowery, A., Bach, S. A., Cannon, B., Carter, E. L., Eicher, M., and Hechter, H., Brookhaven Natl. Lab. BNL-501 (T-119) (1957).

11. Conard, R. A., Meyer, L. M., Robertson, J. S., Wolins, W., Sutow, W. W., Lowery, A., Urschel, H. C., Goldman, M., Hechter, H., Eicher, M., Barton, J. M., and Carver, R. K., "Medical Survey Marshallese, March 1958, Four Years After Exposure to Radioactive Fallout." To be published as Brookhaven Natl. Lab. Report.

12. Cronkite, E. P., Bond, V. P., and Dunham, C. L., Editors, "The effects of ionizing radiation on human beings: A report on the Marshallese and Americans accidentally exposed to radiation from fallout and a discussion of radiation injury in the human being." U. S. Govt. Printing Office, Washington, D. C. (1956).

13. Cronkite, E. P., Dunham, C. L., Griffin, D., McPherson, S. D., and Woodward, K. T., Brookhaven Natl. Lab. BNL-384 (T-71) (1955).

14. Furth, J., Upton, A. B., Christenberry, K. W., Benedict, W.H., and Moshman, J., Radiology 63, 562 (1954).

15. Miller, C. E., Marinelli, L. D., Rowland, R. E., and Rose, J. E., Nuclear Sci. NS-3, 90-6 (1956).

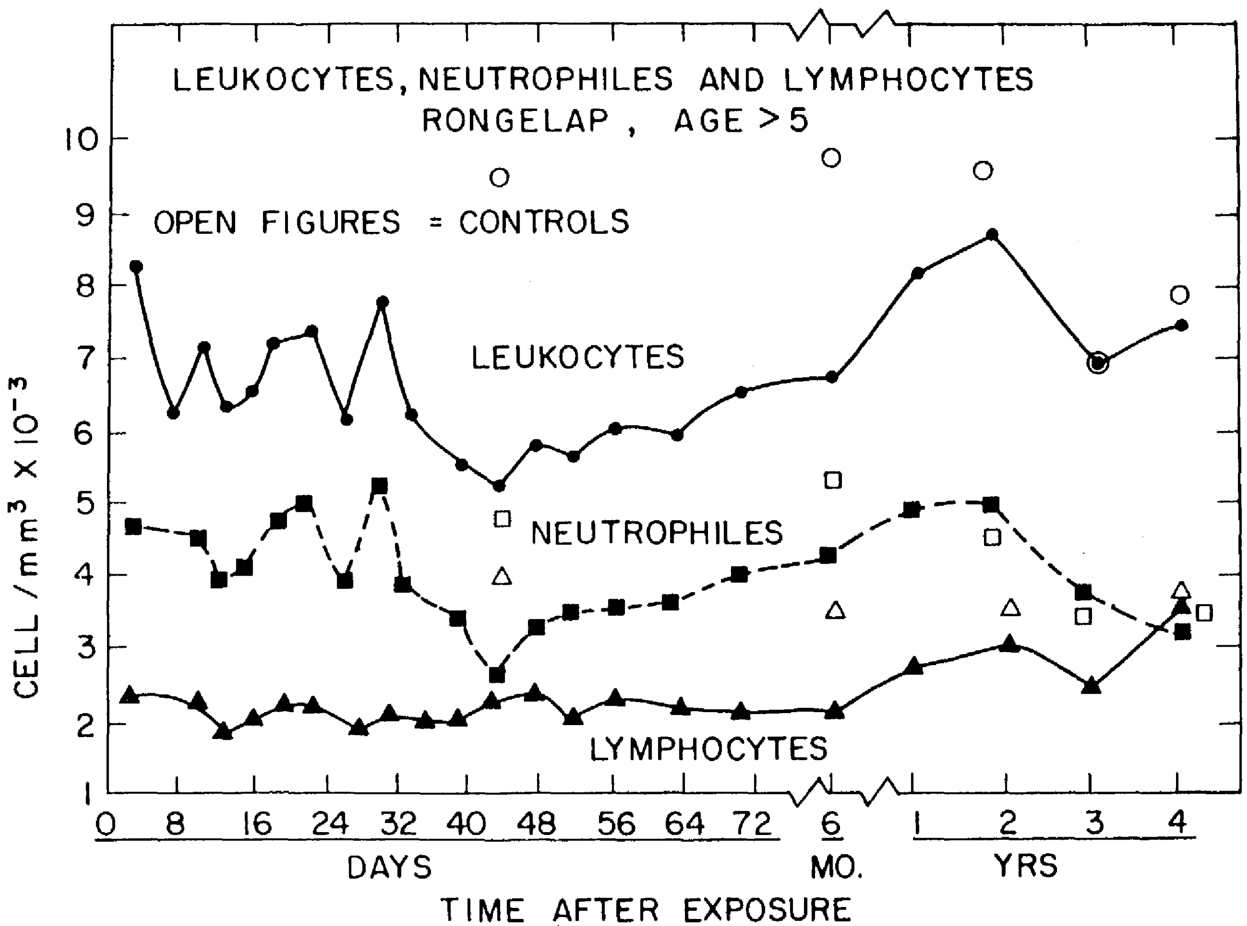
16. Miller, C. E. and Steingraber, O. J., Argonne Natl. Lab. Semiannual Rept. ANL-5755, pp. 53-7 (1957).

17. Moloney, W. C. and Lange, R. D., Blood 9, 663-85 (1954).

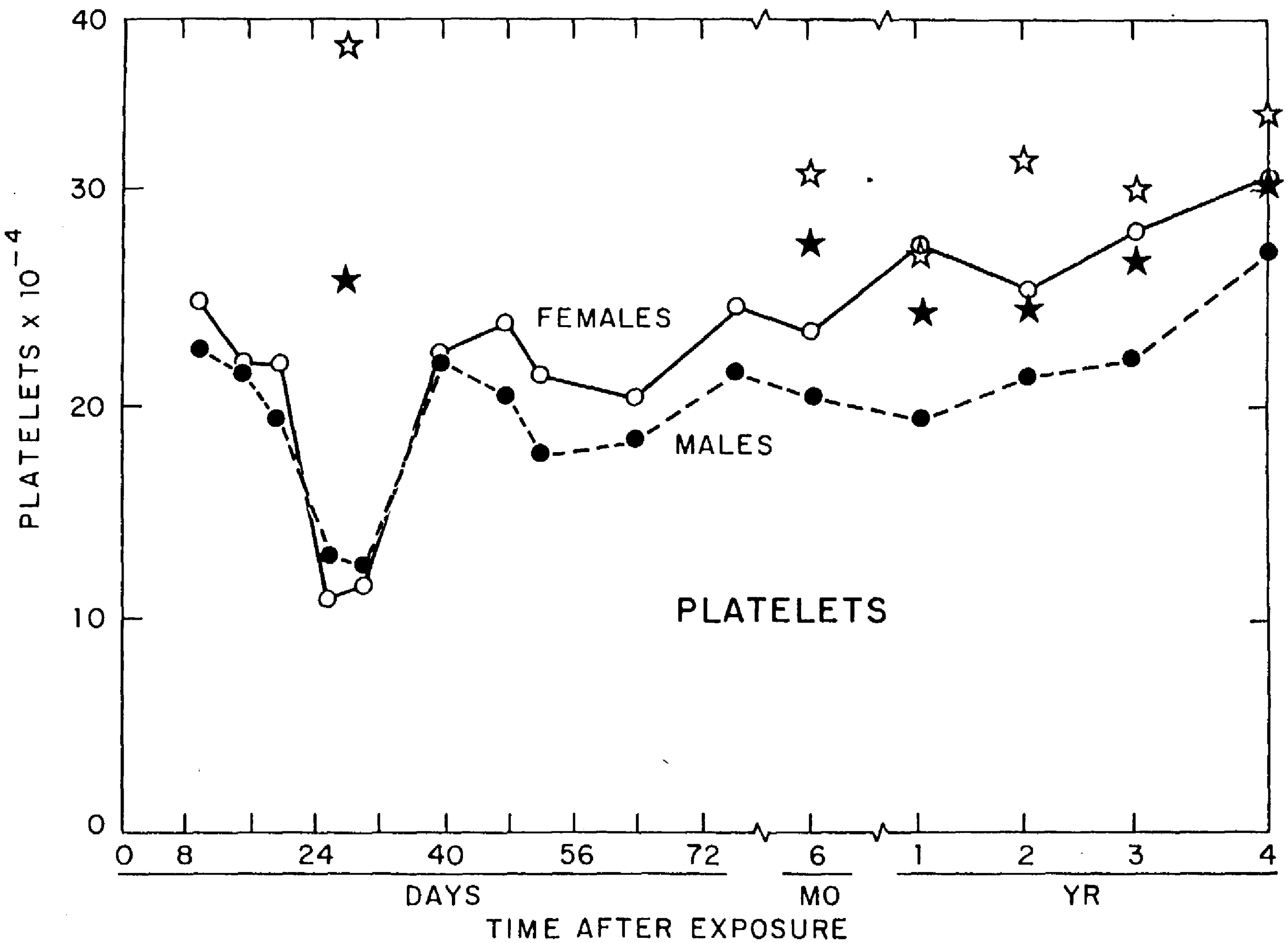
18. Moloney, W. C., New Engl. J. Med. 253, 88-90 (1955).

19. Neel, J. V., Morton, N. E., Schull, W. J., McDonald, D. J., Kodani, M., Takeshima, K., Anderson, R. C., Wood, J., Brewer, R., Wright, S., Yamazaki, J., Suzuki, M., and Kitamura, S., Japan. J. Genetics 28, 211-18 (1953).

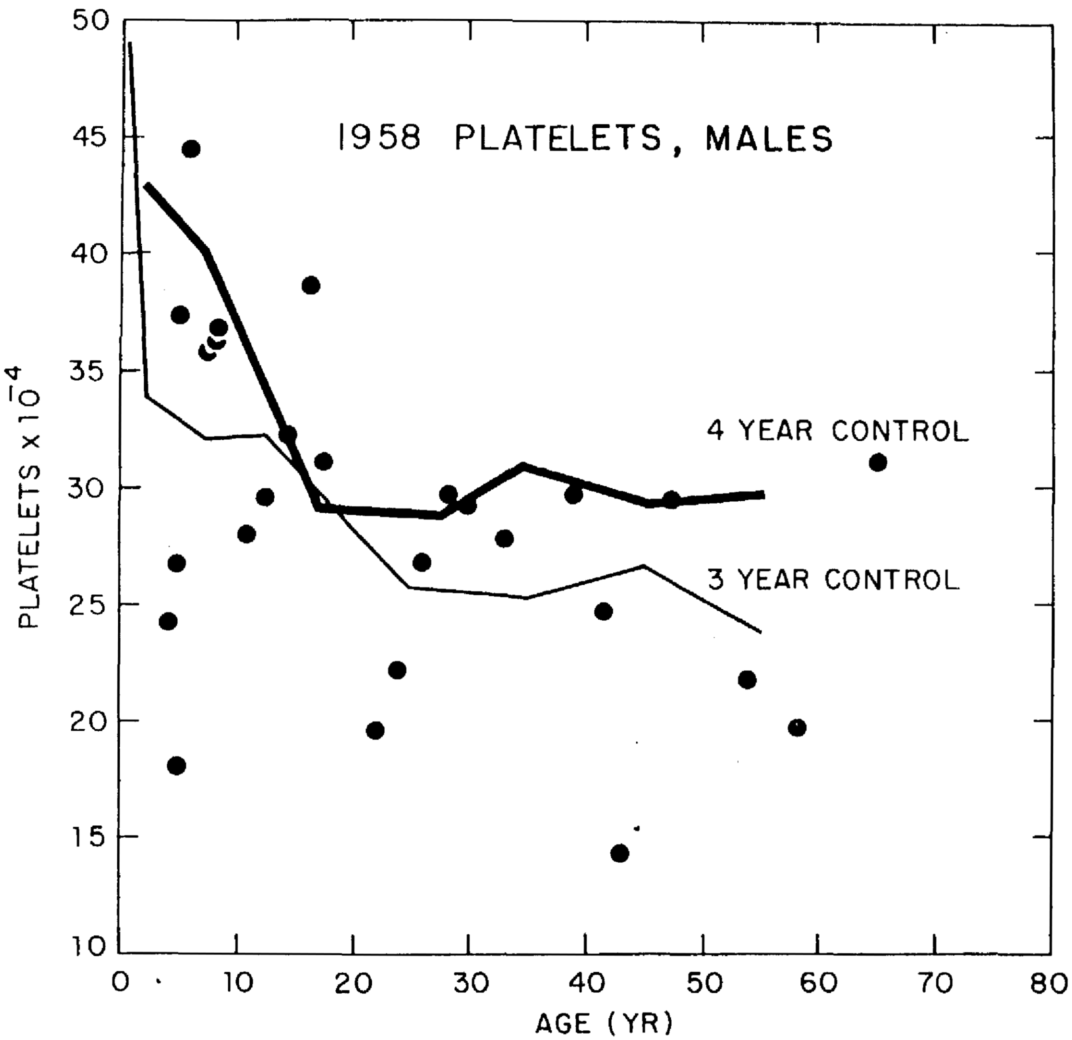
20. Sinskey, R. M., Am. J. Ophthalmol. 39, 285 (1955).



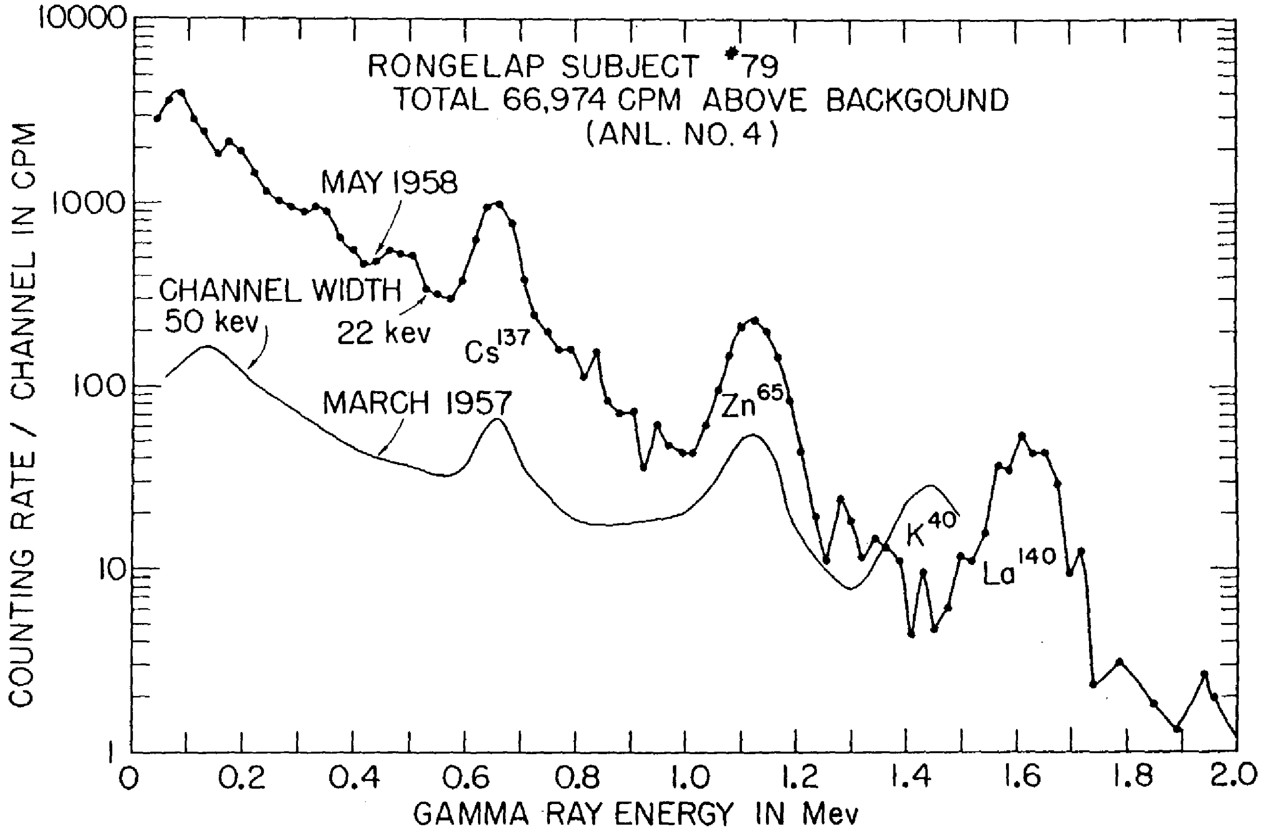
LEUKOCYTES, NEUTROPHILES AND LYMPHOCYTES
RONGELAP, AGE > 5
OPEN FIGURES = CONTROLS
LEUKOCYTES
NEUTROPHILES
LYMPHOCYTES
CELL / mm3 X 10-3
1
2
3
4
5
6
7
8
9
10
0
8
16
24
32
40
48
56
64
72
6
1
2
3
4
DAYS
MO.
YRS
TIME AFTER EXPOSURE



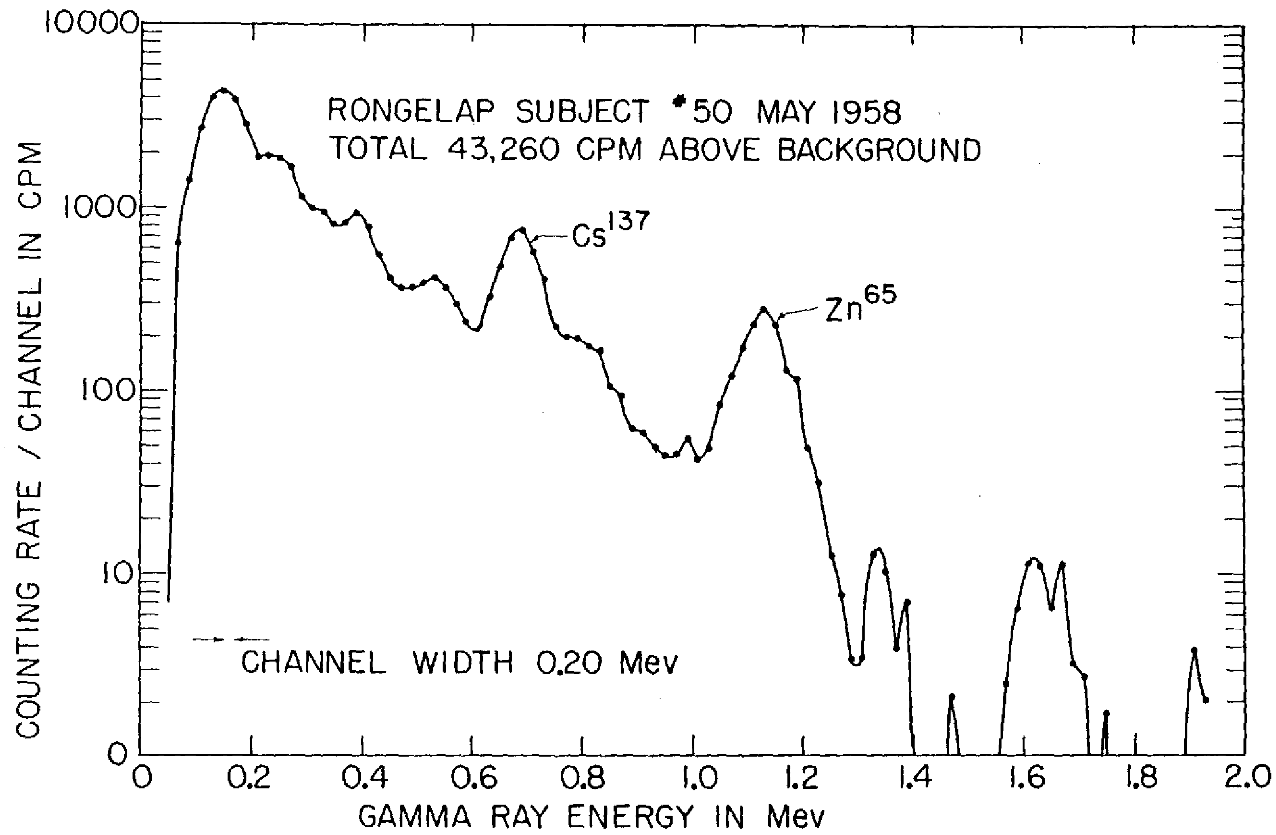
PLEASE REFER TO



PLEASE REFER TO NEG # 6-398-58



PLEASE REFER TO NEG # 6-468-58



PLEASE REFER TO NEG # 6-467-5.

.1151

3/1/59 Rongelap (2 blood samples)

~ 3/15 Utirik