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Medical Status of Marshall Islanders in 1959, Five Years after Exposure to Fallout Radiation[1]

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Running heading

Effects of Fallout Radiation on Marshallese

Background

This discussion concerns a brief account of the present health status of the Rongelap people who were exposed to the heaviest dose of radiation from accidental fallout in March 1954 following detonation of an experimental nuclear device at Bikini in the Marshall Islands. An unpredicted shift in winds caused deposition of significant amounts of fallout on four nearby inhabited Marshall Islands and on 23 Japanese fishermen aboard their fishing vessel, the Lucky Dragon. (See Figure 1.) Sixty-four inhabitants of the island of Rongelap, 105 nautical miles away from the detonation, received the largest fallout — an estimated dose of 175 r of whole-body gamma radiation, indeterminate beta ray dose to the skin from contamination of the skin and internal absorption of radioactive fission products. Eighteen Rongelap people away on a nearby island (Ailingnae) where less fallout occurred received about 69 r with proportionately less contamination of the skin and internal absorption of radionuclides. Dis-

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cussed in earlier reports [C r o n k i t e , et al (1956); C o n a r d , et al (1958)] were 28 American Servicemen on Rongerik Atoll who received about 70 r and 157 Marshallese on Utirik Atoll who received about 14 r. The exposed people were evacuated to Kwajalein in the Marshall Islands by air and sea about two days after the accident. Extensive examinations were carried out during the first three months after exposure and these findings have been reported in detail [C r o n k i t e , et al (1956)]. In view of the radioactive contamination of their home island of Rongelap, the people were subsequently moved to a village provided for them at Majuro Atoll where followup medical surveys were carried out and reported on at six months [B o n d , et al (1955)], one

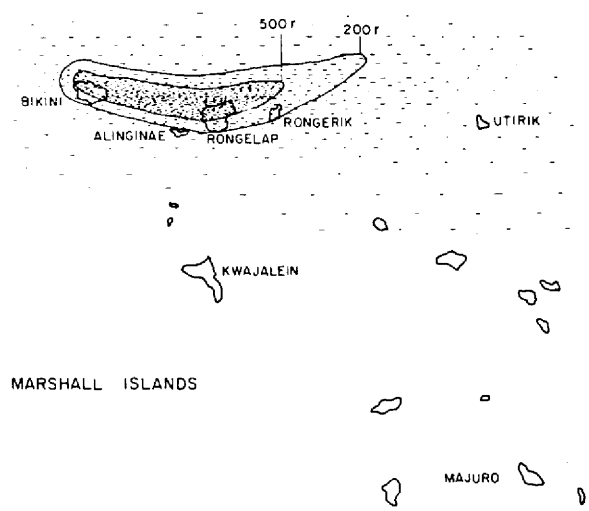

Fig. 1: Map of fallout area, Marshall Islands, March 1954

year [C r o n k i t e , et al (1955)], two years [C o n a r d , et al (1957)] and at three years [C o n a r d , et al (1958)], and four years [C o n a r d , et al (1959)]. By June 1957 radioactivity levels on Rongelap were considered acceptable for habitation and the people were returned to their home island. The four year post-exposure survey [C o n a r d , et al (1959)] was carried out at Rongelap Atoll. By 1956 a large group of unexposed Rongelap people (relatives) had joined the exposed Rongelap people and returned to Rongelap with them. This unexposed group has increased in size to 200 people and served as a much better comparison population group than did the earlier comparison group of people which were randomly selected at Majuro Atoll.

Observations

The latest findings are based on the annual medical survey carried out at Rongelap in March 1959 at five years after exposure. About 100 exposed people including their children and 200 unexposed people were examined. Since the data are not yet completely analyzed, the statements made concerning this survey must be considered as preliminary in nature. The survey was conducted by a 20 man medical team from various institutions in the United States under the direction of Brookhaven National Laboratory. The examinations included medical histories, complete physical examinations, and blood and other laboratory examinations. In addition body burdens are being determined from spectrographs of gamma ray activity of 175 Rongelap individuals and from numerous radiochemical analyses of urine samples.

Acute effects of gamma irradiation

During the first 24 to 48 hours after exposure about 2/3 of the Rongelap people experienced anorexia, nausea, and a few vomited and had diarrhea. Many also experienced itching and burning of the skin and a few complained of lachrymation and burning of the eyes. Following this they remained asymptomatic until about two weeks after the accident when cutaneous lesions and loss of hair developed due largely to beta radiation of the skin. It was apparent when the people were first examined, a few days after exposure, that the lymphocytes were considerably depressed and that significant doses of radiation had probably been received. The dose of radiation proved to be sublethal since no deaths occurred which could be directly related to radiation exposure. However, it is probable that the dose was in the high sublethal range judging by the degree of hemopoietic depression that developed. In addition radiochemical analyses of the urine also showed that definite amounts of radioactive material had also been absorbed internally.

The changes during the past five years in the mean peripheral blood levels of the more heavily exposed group of 64 Rongelap people receiving approximately 175 r of whole-body radiation are shown in Figures 2, 3 and 4. The white blood cell levels of the exposed group were depressed to about half those of the unexposed comparison population during the first two months but no related untoward effects were observed in these people. No increased incidence of infection was observed and no therapy (antibiotic or otherwise) was given specifically for their leukopenia. Mean blood platelet levels were also significantly depressed to about 30 per cent of the unexposed levels by the fourth

week. No bleeding associated with the platelet depression was noted and blood transfusions were not necessary. Erythrocytes as measured by hematocrit levels were not significantly depressed.

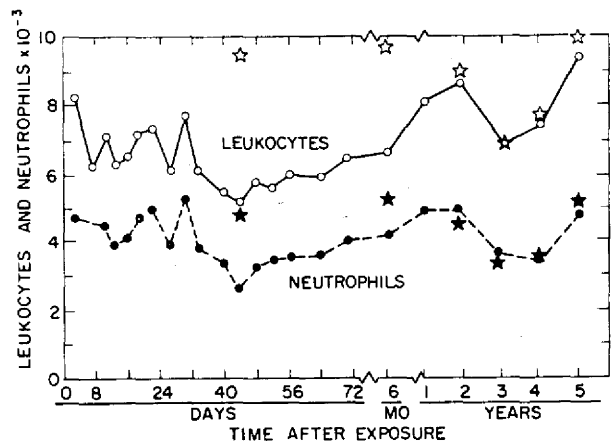

Fig. 2: Mean neutrophil and white blood counts of exposed Rongelap people from time of exposure through five years post-exposure. Stars represent mean values of comparison populations

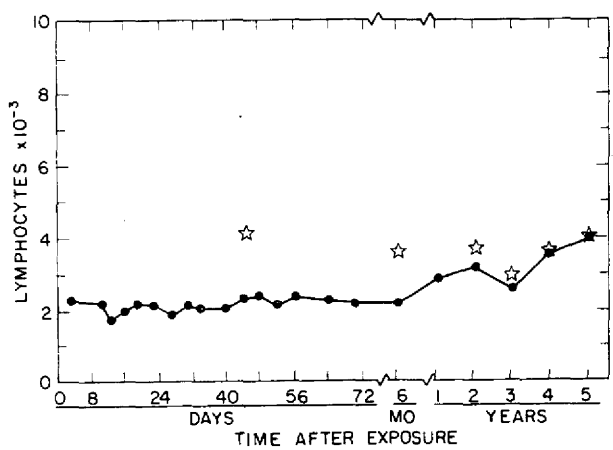

Fig. 3: Mean lymphocyte counts of exposed people from time of exposure through five years post-exposure. Stars represent mean values of comparison populations

Following this early depression, the blood elements slowly recovered, some elements faster than others. The neutrophils were first to reach comparison population levels by about one year post-exposure (Fig. 2). The lymphocytes

returned more slowly and even at two and three years post-exposure the mean levels were slightly below the unexposed mean levels (Fig. 3). By four years they had reached the unexposed levels and remained so at the time of the five year survey. Platelet levels showed the slowest recovery (Fig. 4). A rapid recovery trend followed the early depression, after which there was slower increase with mean levels remaining consistently below the unexposed mean population level. At the five year survey the males were about 13 per cent and the females 11 per cent below the corresponding mean levels of the comparison population, though the individual platelet counts were within the normal range. The mean red blood count, hemoglobin and hematocrit levels, were about the same in the exposed as in the unexposed group.

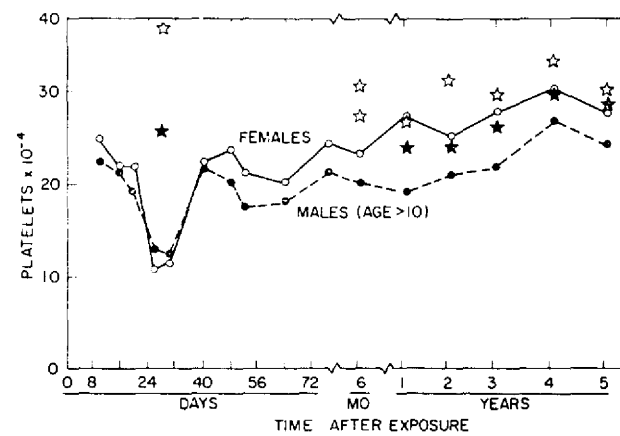

Fig. 4: Mean platelet counts of exposed Rongelap people from time of exposure through five years post-exposure. Stars represent mean values for comparison populations

The 18 Rongelap people who had received about 70 r at Ailingnae Island showed less severe early hemopoietic depression but have also shown a similar slow recovery rate of lymphocytes and platelets as noted in the more heavily exposed group.

The incidence of diseases, infectious or non-infectious, has remained about the same in the exposed as in the unexposed population. Three deaths have occurred: one in a 46 year old man during the second year after exposure from hypertensive heart disease which had been present at the time of exposure; the second in a 78 year old man at three years after exposure of coronary heart disease complicating diabetes; and the third in a 36 year old man at four years after exposure of acute varicella.

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During the first six weeks over half of the exposed people lost weight even though their diet was satisfactory and appetites good during this period. This possibly reflects an effect of radiation exposure on general metabolism. However, factors associated with a change in environment cannot be ruled out as being responsible.

There were no abnormalities noted at birth in four babies irradiated in utero; two in the first trimester, one in the second trimester, and one in the third trimester.

The five year survey revealed that the people were generally in a good state of health and nutrition. The incidences of diseases was about the same in the exposed and unexposed groups. One case of ovarian cancer developed during the past year in a 61 year old exposed woman.

Late effects of gamma irradiation

Late effects of radiation exposure constitute an important part of the examinations in the Marshallese. Very little is known about such effects in human beings. From experiences with the Japanese exposed at Hiroshima and Nagasaki and from animal studies, certain late effects of radiation may possibly develop in the Marshallese. Results of observations for such effects will be presented accompanied by appropriate discussion related to findings of others.

Shortening of life span. Thus far the three deaths in the exposed group represent about the same death rate as has been observed in the Marshall Islands as a whole over the same period of time (about seven deaths per 1000 per year).

Numerous investigators have reported shortening of the life span of animals exposed to acute and chronic radiation [Blair (1956), Bennett (1953), Brues and Sacher (1952) and others]. The chronic exposure of radiologists in the United States was claimed to result in shortening of their average life span compared with other physicians [Dublin and Spiegelman (1958), Warren (1956)]. In view of these findings, some life shortening may be expected in the Marshallese, although in view of the small size of the population, it may be difficult or impossible to detect such an effect.

Premature aging and degenerative diseases. From clinical observations over the past five years the impression is that the exposed Marshallese do not appear to have aged faster nor be older than unexposed Marshallese of the same age. No doubt the subtle changes which occur with aging would be difficult to detect over this short period of time. The incidence of degenerative diseases has been about the same in the exposed and unexposed groups.

An attempt is also being made to study aging from a more quantitative clinical approach. Certain criteria usually associated with aging that can be easily obtained on physical examination are recorded as nearly quantitatively as possible either by direct measurement or estimation of degree of severity of criteria in a scale from 0 through 4 +. This work is in the early stages and will not be reported at this time. The approach is believed worth investigating since many animal studies indicate late radiation changes that closely resemble advanced or premature aging [Blair (1952), Cassarett (1956), Alexander (1957)].

Malignancies, leukemia. One case of ovarian cancer (verified by biopsy at operation) in a 61 year old exposed female was noted during the past year, the first case of malignancy noted in either the exposed or unexposed group. There is no reason to incriminate radiation in the etiology of this case, particularly in view of the early time of appearance.

Since leukemia is the earliest type of neoplasia associated with radiation to develop, examination of the Marshallese has included blood smears stained for alkaline phosphatase of neutrophils and the numbers of basophils per 4000 white cells per individual, but no evidence of decreased alkaline phosphatase in the neutrophils nor increased basophil counts indicative of incipient leukemia was noted. An increased incidence of leukemia has been reported in radiologists [March (1947), Ulrich (1946), Warren (1956)], in children receiving therapeutic radiation in infancy for thymic enlargement [Simpson and Hemplemann (1957)], in children exposed *in utero* from diagnostic x-ray examinations of the mothers [Stuart, et al (1956)], and in patients receiving x-irradiation for treatment of ankylosing spondilitis [Court-Brown and Doll (1957)]. In survivors of the atomic bombs in Japan [Maloney and Kostenbaum (1955)], the incidence of leukemia was significantly increased, but nevertheless the total incidence was low. Therefore, since the exposed Marshallese population is small, it does not seem likely that leukemia will be observed as a result of their radiation exposure.

Cataracts. During the past five years repeated slit lamp ophthalmological observations in the Marshallese revealed no opacities typical of the radiation-induced type. The induction of opacities of the lens by radiation is a well established fact in man. In the Japanese exposed to the atomic bombs opacities of the lens, including about 10 severe cataracts, have been observed [Cogan, et al (1949, Sinsky (1955)]. Merriam and Fecht (1957) on the basis of clinical cases of radiation-induced opacities calculated that 200 r was the minimum dose of gamma or x-irradiation resulting in lens opacities. Therefore, the dose of radiation received by the Marshallese may be too low to result in such changes.

Reproduction. It has long been recognized that reduced fertility may be induced by ionizing radiation in man by relatively small doses, possibly even in the dose range that the Marshallese received. Transient effects on fertility may have taken place in this group, but such effects were not observed. Studies such as sperm counts were not feasible. No amenorrhea was noted in the exposed women. Birth rate during the past five years in the exposed group was not reduced and, if anything, appears to have been higher than in the unexposed comparison population or in the Marshallese people generally. Therefore, the degree of sterility that may have been induced was not detectable based on these findings.

A somewhat greater prevalence of miscarriages and stillbirths has been noted in the exposed women but, due to the paucity of vital statistics in the Marshallese and the small number of people involved, the data are not readily amenable to statistical analyses.

Growth and Development. Anthropometric measurements on the Marshallese children have revealed findings, previously reported [Conard, et al (1957)], which were interpreted as suggestive of a slight lag in growth and development in the exposed children during the first few years after exposure. However, certain inconsistencies in the ages of the children were found and the data are being re-evaluated based on more exact age data obtained during the last survey. The results of this evaluation are not complete enough to make any statements at this time. Such an effect would not be inconsistent with the findings of Greulich, et al (1953) and Reynolds (1952) who reported slight growth retardation and delayed maturation in the Japanese children following exposure to the atom bomb.

Genetic effects. Specific studies for genetic effects of their radiation exposure have not been conducted in the Marshallese. The babies born of irradiated parents have shown no gross abnormalities that can be detected on routine physical examinations. In view of the generally negative findings in the first generation offspring of the irradiated Japanese reported by Neel and Schull (1956), it seems unlikely that genetic studies in the Marshallese will be fruitful.

Effects of beta irradiation of the skin

About 90 per cent of the people in the more heavily exposed Rongelap group developed beta burns of the skin beginning about two weeks after exposure (Fig. 5). A lesser number of people also developed spotty epilation of the scalp (Fig. 6). The burns occurred as a result of fallout deposition on parts of the body not covered by clothing. Most of the burns were superficial and healed

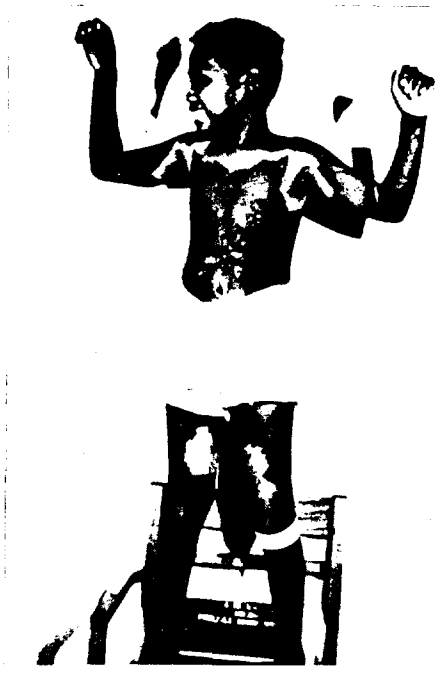

Fig. 5: Extensive lesions in Marshallese boy at 3 weeks after exposure

Fig. 6: Epilation in the head of a young girl about 3 weeks after exposure

within a few weeks, but about 15 per cent of the people had deeper burns which healed with some atrophy, scarring, and pigment aberration (Fig. 7 and 8). Complete regrowth of normal hair occurred in all cases by six months. Gross and microscopic descriptions of the lesions were given in detail in the earlier reports. The past survey revealed that there were 12 cases which showed residual atrophy, scarring and pigment aberrations at the site of deeper lesions. However, none showed evidence of pre-malignant or malignant change.

Fig. 7 : More severe burns on the feet of a young boy at 4 weeks post-exposure

Fig. 8 : Atrophy and scarring of the skin of the feet at one year after healing of lesions. Same case as in Fig. 7

Internal Irradiation

The Rongelap people lived under conditions of severe radioactive contamination of their island for two days following the accident until they were evacuated from their island. This was reflected in significant absorption of radioactive materials, from inhalation ingestion of contaminated food and water. Radiochemical urine analyses during the first 24 days showed internal levels of isotopes which were roughly estimated as follows in microcuries: Iodine$^{131-135}$, 6.4; Strontium^{89}, 1.6; Barium^{140}, 2.7; rare earths, 1.2; and smaller amounts of Cesium^{137}, Strontium^{90}, and Ce-Pr^{144}. Radioiodine probably delivered a dose of 100—150 rep to the thyroid glands of the people but absorption of radioisotopes was too small to result in any apparent acute effects. Rapid diminution of body levels of these isotopes occurred so that by six months urinary activity was barely detectable by gros counting methods.

Only the indirect method for estimating the body burden based on urinary excretion rates was available until two years ago when a direct method of measuring body levels of gamma emitting isotopes became possible through the

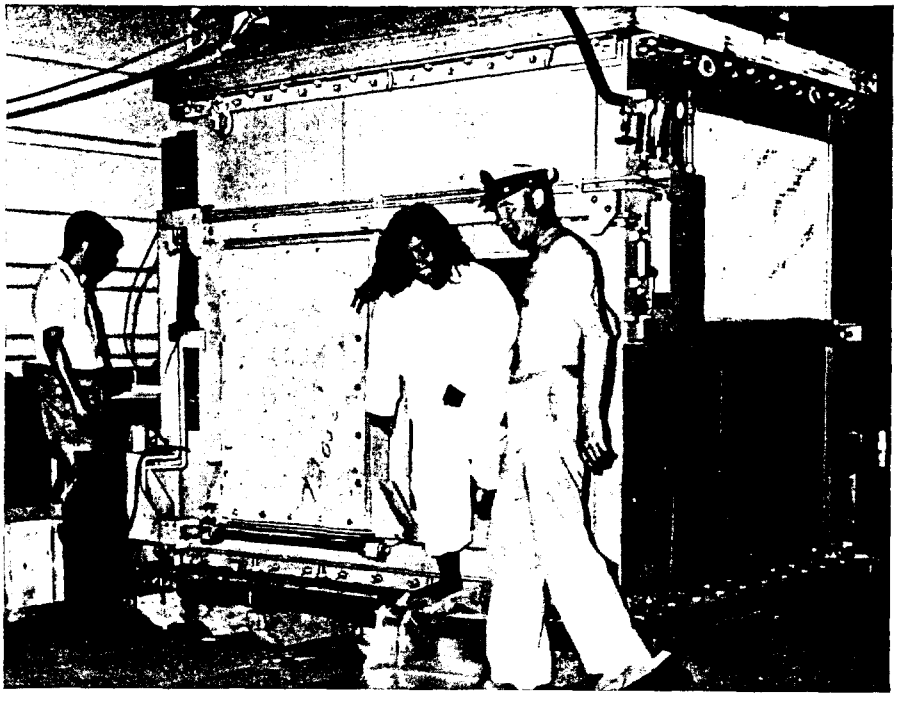

Fig. 9: Steel room used for gamma spectroscopy

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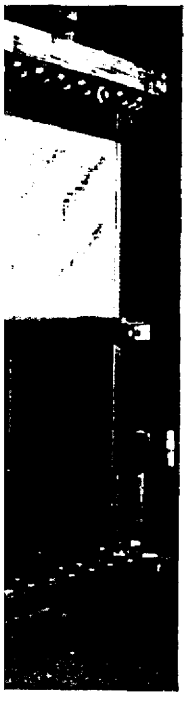

use of crystal detectors and a gamma spectrum analyzer in conjunction with a thick-walled steel room to lower background radiation. With this arrangement it was possible to measure directly very low levels of radioisotopes. Several Marshallese were measured by this procedure at the Argonne National Laboratory in 1957. Later a steel room, constructed specifically for these surveys (Fig. 9), was taken aboard Navy vessels to Rongelap for the four and five year surveys where a large number of Rongelap people have been measured at their home island.

Rongelap Island remains slightly radioactively contaminated but is considered safe for habitation. This is reflected by an increase in body levels of radionuclides since the return of the people to their island. Based on gamma spectroscopy of the isotopes, it has been estimated that during the first year after their return Cs^{137} increased by factors as high as 60 resulting in a body burden of 0.68 μc. Zn^{65} (which is selectively concentrated by the fish, a main item of the Rongelap diet) increased to an estimated mean body burden of 0.36 μc urinary. Excretion rates of Sr^{90} increased by a factor of about 20. Increase in body burdens of isotopes occurred equally in unexposed and exposed populations and the levels in the exposed group are about the same as in the unexposed group living there.

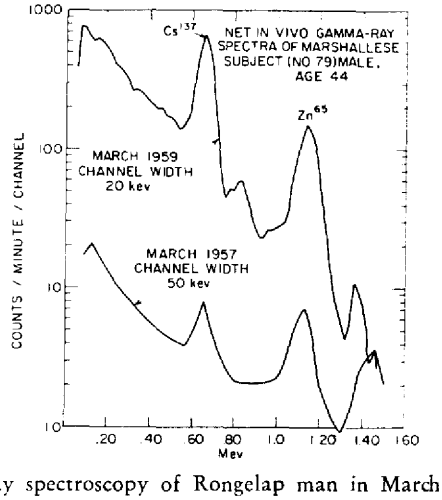

Fig. 10: Gamma ray spectroscopy of Rongelap man in March 1957 and March 1959

Based on preliminary analyses of data from the most recent survey period, eight to twenty months after the return to Rongelap, it appears that the people are approaching an equilibrium with their enviroment. The body burdens of Cesium^{137} appear to be slightly lower than the previous year while the Zinc^{65} body burden increased about 8%. The Strontium^{90} analyses, unfortunately, are

not yet available. The body burdens estimated above are far below the maximum permissible levels; Cesium^{137} is about 16 per cent and Zinc^{65} about 10 per cent of their respective maximum permissible levels for non-industrial populations. In Figure 10 the increase in body levels of isotopes is shown in the gamma spectrographs of a Rongelap man before (1957) and 20 months after returning to Rongelap. The background radiation resulting from residual contamination on the island presently averages about 0.04 mr/hr which represents a dose of about 350 mr/yr.

Present Status

It is apparent that the Rongelap people have recovered from the acute effects of their radiation exposure and the examinations now emphasize detection of possible late effects of irradiation about which little is known in man. No acute effects have been observed related to the internal absorption of radionuclides and late effects are not expected, due either to their initial intake or to subsequent low levels acquired from living on the slightly contaminated island of Rongelap.

However, the habitation of these people on the island affords the opportunity for a most valuable radiation ecological study. Since only small amounts of radioisotopes are necessary for detection with present sensitive measuring equipment, the several radioisotopes present on the island can be traced from the soil through the food and into the human being where tissue and organ distributions, biological half lives and excretion rates can be studied.

Summary

A medical survey of the Marshallese people in March 1959, five years after exposure to fallout radiation, showed that the people had recovered from the acute effects of their radiation exposure and appeared to be generally in good health. The following specific statements can be made in regard to their radiation health status:

1. No illnesses or diseases were found that could be directly associated with acute radiation effects.

2. One case of cancer and three deaths have occurred, but with no direct relation to radiation effects.

3. Fertility does not appear to have been affected. The incidence of miscarriages and stillbirths appears to be somewhat higher than in the unexposed Marshallese, but a deficiency of vital statistics precludes definite conclusions as to whether or not this is a radiation effect.

4. Suggestive evidence of slight lag in growth and development of exposed children noted previously is being re-evaluated on the basis of better age data obtained during the latest survey.

5. Blood platelet levels are within the normal range but somewhat below that for the unexposed population.

6. Only 12 cases show residual changes in the skin from beta burns. None show any evidence of cancerous change.

7. Possible late effects of radiation such as shortening of life span, premature aging, increased incidence of leukemia and malignancies, increased incidence of degenerative diseases, opacities of the lens of the eyes, and genetic changes have not been detected.

8. The original body burdens of internally absorbed fission products appear to be too low to have produced any acute or to be causing long-term effects.

9. The return of the people to the slightly contaminated island of Rongelap has resulted in some increase in body burdens of Cesium^{137}, Zinc^{65} and Strontium^{90}. However, the levels are far below the accepted maximum permissible limits and it is not believed any untoward effects will result.

Résumé

Un contrôle médical de la population des îles Marshall, 5 ans après l'exposition de l'irradiation du „fallout", a démontré que la population s'était bien récréée des effets aigus de l'exposition et apparait dans un état général de bonne santé. Les observations suivantes concernannt leur exposition aux rayons ont été faites:

1. Il n'y avait pas de maladies en connexion avec les effets d'irradiation.

2. Il y avait un cas de cancer et 3 morts, cependant sans relation à des effets d'irradiation.

3. Il paraît que la fertilité ne soit pas affectée. L'incidence d'avortements et de mort-nés paraît être un peu plus élevé que dans la population Marshallaise non exposée, mais par manque de statistique de vie il n'est pas possible de faire une conclusion s'il y a une dépendance d'un effet d'irradiation.

4. Une légère réduction en croissance et dévelopement des enfants exposés aux rayons qu'on croyait avoir trouvée dans des contrôles précédents sera évaluée de nouveau sur la base de dates d'age plus exactes gagnées cette fois.

5. Le nombre des plaquettes sanguines est entre les limites normales, mais un peu au dessous de la valeur de la population non exposée.

6. Seulement 12 cas montrent des changements permanents de la peau resultant des brulures de rayons béta. Aucun montre une évidence d'une transformation cancéreuse.

7. Des effets tardifs d'irradiation comme abréviation de la vie, vieillesse préliminaire, incidence surélevée de leucémie, tumeurs, incidence surélevée de maladies dégénératives, aopacité de la lentille de l'oeil et des changements génétiques n'ont pas été trouvés.

8. La charge du corps par absorption interne de produits de fission nucléaire semble être trop basse pour avoir produit n'importe quel effet aigu ou tardif.

9. Le retour de la population à l'île de Rongelap contaminée légèrement, a élevé un peu l'irradiation du corps par Caesium^{137}, Zinc^{65}, et Strontium^{90}. Cependant les valeurs sont bien au dessous de la dose maximale permissible et on ne peut pas attendre un effet négatif par conséquent.

Zusammenfassung

Eine ärztliche Untersuchung der Marshallinselbewohner im März 1959, fünf Jahre nach der Exposition einer Fallout-Bestrahlung, zeigte, daß die Bevölkerung sich von den akuten Auswirkungen der Strahlenexposition erholt hatten und im Durchschnitt in guter gesundheitlicher Verfassung war. Die folgenden speziellen Feststellungen hinsichtlich der Strahlenbelastung konnten getroffen werden:

1. Keine Krankheit wurde gefunden, die direkt in Zusammenhang mit der akuten Strahlenbelastung gebracht werden könnte.

2. Ein Fall von Karzinom und drei Todesfälle waren vorgekommen, jedoch ohne direkte Verbindung zu der Strahlenbelastung.

3. Die Fruchtbarkeit scheint nicht in Mitleidenschaft gezogen worden zu sein. Die Häufigkeit von Abort und Totgeburt scheint etwas höher als bei unexponierten Marshallbewohnern zu sein, aber das Fehlen einer Bevölkerungsstatistik erlaubt keinen definitiven Schluß, ob dies der Strahlenbelastung zugeschrieben werden kann oder nicht.

4. Eine vermutete geringfügige Verzögerung im Wachstum und der Entwicklung exponierter Kinder, die bei früheren Untersuchungen festgestellt wurde, wird jetzt erneut bearbeitet auf der Basis genauerer Lebensaltersdaten, die bei der letzten Untersuchung gewonnen wurden.

5. Die Zahl der Blutplättchen liegt innerhalb des normalen Bereiches, aber etwas niedriger als bei der unexponierten Bevölkerung.

6. Nur 12 Fälle zeigten übriggebliebene Hautveränderungen von Betaverbrennungen. Keiner zeigt einen Hinweis für karzinomatöse Veränderungen.

7. Mögliche Späteffekte der Bestrahlung, wie Verkürzung der Lebensdauer, vorzeitiges Altern, erhöhte Anfälligkeit für Leukämie und bösartige Krankheiten, vermehrte Anfälligkeit für degenerative Erkrankungen, Linsentrübungen im Auge oder genetische Veränderungen, wurden nicht entdeckt.

8. Die Gesamtkörperstrahlenbelastung durch innerlich absorbierte Spaltprodukte scheint zu niedrig zu sein, um eine akute Veränderung oder chronische Veränderungen hervorzurufen.

9. Die Rückkehr der Bevölkerung zu der leicht verseuchten Insel Rongelap hat zu einer Erhöhung der Gesamtkörperbelastung geführt durch Caesium^{137}, Zink^{65} und Strontium^{90}. Der Spiegel dieser Isotope ist jedoch weit unterhalb der zulässigen Höchstgrenze und es ist nicht anzunehmen, daß sich hieraus eine ungünstige Einwirkung ergeben wird.

Acknowledgments

The success of a mission of this type depends on the assistance of many individuals and organizations. The author wishes to express his sincere appreciation to those who participated and others too numerous to mention whose efforts contributed to the successful completion of the survey. Particular gratitude is expressed to Dr. C. L. Dunham and his staff of the Division of Biology and Medicine of the Atomic Energy Commission, Dr. L.E. Farr and many others at the Brookhaven National Laboratory, and the Department of the Navy and Trust Territory officials for their enthusiastic support.

References

Alexander, P.: Accelerated ageing — A long term effect of exposure to ionizing radiations. Gerontologia 1: 174—193 (1957).

Bennett, L. R., S. M. Chastain, J. S. Flint, R. A. Hansen and A. E. Lewis: Late effects of roentgen irradiation. I. Studies on rats irradiated under anoxic anoxia. Radiology 61: 411—419 (1953).

Blair, H. A.: A formulation of the relation between radiation dose and shortening of life span. Prod. Internat. Conf. on the Peaceful Uses of Atomic Energy 11: 118—120 (1956), United Nations, New York.

Blair, H. A.: A formulation of the injury, life span, and dose relations for ionizing radiations. U. of Rochester A.E.C. Report, UR-206 (1952).

Bond, V. P., R. A. Conrad, J. S. Robertson and E. A. Weden: Medical examination of Rongelap people six months after exposure to fallout. April 1955 WT-937, Operation Castle Addendum Report 4. 1A.

Brues, A. M., and G. A. Sacher: Analysis of mammalian radiation injury and lethality. 1952 Chapter 23 in Symposion on Radiobiology, ed. J. J. Nickson, John Wiley and Sons, New York, pp. 441—465.

Cassarett, G. W.: Acceleration of ageing by ionizing radiation. Abstract J. Gerontology 11: 436 (1956).

Cogan, D. G., S. F. Martin, and S. J. Kimura: Atom bomb cataracts. Science 110: 654—655 (1949).

Comfort, A.: Natural ageing and the effects of radiation. Radiation Research Supplement 1: 216—234 (1959).

Conard, R. A., L. M. Meyer, J. E. Rall, A. Lowery, S. A. Bach, B. Cannon, Medical survey of the Marshallese two years after exposure to fallout radiation. J. A. M. A. 164: 1192—1197 (1957).

Conard, R. A., L. M. Meyer, J. E. Rall, A. Lowery, S. A. Bach, B. Cannon, E. Carter, M. Eicher and H. Hechter: Medical Survey of the Rongelap and Utirik people three years after exposure to radioactive fallout. June 1958 BNL 501 (T-119).

Conard, R. A., L. M. Meyer, J. S. Robertson, W. W. Sutow, W. Wolins and H. Hechter: Effects of fallount radiation on a human population. Radiation Research Supplement 1: 280—295 (1959).
Cronkite, E. P., V. P. Bond and C. L. Dunham: ed. 1956, Some Effects of Ionizing Radiation on Human Beings. U. S. Gouvernment Printing Office, Washington, D. C. TID 53 58.
Cronkite, E. P., C. L. Dunham, D. Griffin, S. D. McPherson and K. T Woodward: Twelve month post-exposure survey on Marshallese exposed to fallout radiations. Aug. 1955 BNL 384 (T-71).
Court-Brown, W. M., and R. Doll: Leukemia and aplastic anemia in patients irradiated for ankylosing spondylitis. 1957 Med. Research Council, Special Report Series No. 295, London, H. M. S. O.
Dublin, L. I., and M. Spiegelman: Mortality of medical specialists 1938—1942. J. A. M. A. 137: 1519—1524 (1948).
Greulich, W. W., C. S. Crismon and M. L. Turner: The physical growth and development of children who survived the atomic bombings of Hiroshima and Nagasaki. J. Pediatric 43: 121—145 (1953).
March, H. C.: Leukemia in radiologists. J. A. M. A. 135: 135—179 (1947).
Merriam, G. R., Jr., and E. F. Focht: A clinical study of radiation cataracts and the relationship to dose. Am. J. Roentgenology, Radium Therapy and Nuclear Medicine 77: 759—785 (1957).
Maloney, W. C., and M. A. Kastenbaum: Leukemogenic effects of ionizing radiation on atomic bomb survivors in Hiroshima City. Science 121: 308—309 (1955).
Neel, J. V., and W. J. Schull: The effect of exposure to the atom bomb on pregnancy termination in Hiroshima and Nagasaki. 1956 Nat. Ac. Sciences, Nat. Research Council Publication No. 461.
Reynolds, E. L.: The growth and development program of the Atomic Bomb Casualty Commission. Analysis of observations on maturation, body build and posture taken in 1951 on 4,800 Hiroshima children. 1952 NYO — 4459.
Simpson, C. L., and L. H. Hempelmann: Association of tumors and roentgenray treatment of thorax in infancy. Cancer 10: 42—56 (1957).
Sinskey, R. M.: The status of lenticular opacities caused by atomic radiation. Am. J. Ophth. 39: 285—293 (1955).
Stewart, A., J. Webb, D. Giles and D. Hewitt: Malignant disease in childhood and diagnostic irradiation in utero. Lancet 2: 447 (1956).
Ulrich, H.: Incidence of leukemia in radiologists. New England J. Med. 234: 45—46 (1946).
Warren, Shields: Longevity and causes of death from irradiation in physicians. J. A. M. A. 162: 465—468 (1956).