RADIATION TOLERANCE FROM FALLOUT IN PROTECTIVE STRUCTURES*

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This paper is concerned with the protective role of shelters as related primarily to the hazards of close-in fallout radiation associated with nuclear detonations. The formation of such fallout occurs in the following manner. The intense heat of the fireball, as it touches the surface of the ground, incinerates earthen material to an ash-like state, drawing it into the cloud where it becomes mixed with radioactive residue from the bomb detonation. Because of the heavy particulate nature of the material it is deposited within an area of several hundred miles. The hazards associated with fallout are due primarily to gamma and beta irradiations associated with the fission products in the fallout material. In some cases alpha-emitting isotopes may be present, but these are likely to be present only in small amounts. Neutron radiation is not associated with fallout but is emitted with gamma radiation at the time of detonation, and, as is true with blast and thermal effects, is of concern only in the immediate area of the detonation.

Effects of Fallout in an Open Field

When an individual is exposed to fallout in an open field, there are three types of hazards to which he is subjected: first, that of penetrating whole-body gamma radiation; second, that due to irradiation of the skin from deposit of fallout material on the body; and third, that of internal absorption of radioactive materials from air breathed and food and water consumed. Our experience with 82 Marshallese people who were accidentally exposed to such fallout on Rongelap Island in the Pacific in 1954, following the experimental detonation of a thermonuclear device, exemplifies these three types of hazards.[1,2] The island was dusted with white ashen material which fell for a time estimated at up to 16 hours following the detonation. Since their flimsy, thached palm huts offered little protection, the natives lived under the most extreme conditions of fallout contamination for the two-day period before evacuation was possible. The majority received an estimated whole-body dose of 175 rads of gamma radiation, and sufficient contamination of the skin to result later in widespread beta burns and loss of hair. In addition, measurable amounts of radionuclides were detected in their urine from internal absorption of fallout materials. Gamma radiation caused a reduction in their blood cells to about half-normal levels and proved to be the most serious of the hazards to which they were exposed. Fortunately, the dose was just short of lethal, and no deaths or serious consequences (such as bleeding or infections from lowering of their blood levels) were apparent. The return of blood levels toward normal was evident within one year. Beta burns and epilation began to appear about two weeks after exposure in about 90 per cent of the people. They occurred largely on areas that were not covered by clothing at the time of exposure. Most burns were superficial and healed within a few weeks, though there were a few that were more serious, resulting in painful ulcerations and requiring longer healing time. Loss of hair on the head was spotty and temporary with regrowth occurring within six months. Based on radiochemical urine analyses it was estimated that during the two days prior to evacuation, the average individual body burdens for the principal isotopes were as follows: Sr^{89}, 1.6-2.2 μc; Ba^{140}, 0.34-2.7 μc; Rare Earth Group, 0-1.2 μc; I^{131} (in thyroid gland), 6.4-11.2 μc; Ru^{103}, 0-0.013 μc; Ca^{45}, 0-0.19 μc; and Fessile Material 0-0.16 2 gm.[1] Absorbed material radioiodines were the most hazardous isotopes, and it was calculated that the dose to the adult's gland was 150 rads and to the child's gland approximately 1,000 rads. The rapidity of isotope elimination from the body was noteworthy: no acute effects associated with the presence of these isotopes were detected.

The findings of subsequent surveys suggest that possibly some late radiation effects are evident in the Marshallese.[2] These include slight retardation

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of growth and development in some exposed male children; a slight increase in miscarriages and stillbirths in exposed women during the first five years after exposure; and an increase in pigmented moles in areas of beta burns. During the past three years, six cases of nodules of the thyroid glands among the exposed people have occurred. Five of these were not malignant and appeared in children, and one was a cancerous nodule in an adult woman. These are undoubtedly related to exposure of the thyroid gland to radioiodines absorbed from the fallout, and emphasize the importance of radioiodines in early fallout situations.

These studies have helped place the hazards of fallout in proper prospective. It is clear that penetrating gamma radiation is by far the most serious hazard.

The Role of Protective Structures in Fallout Situations

Let us examine the importance of protective structures as related to each of the hazards of fallout.

Gamma hazard. Attenuation of the gamma radiation is the most important role of protective structures in regard to fallout. In order to understand the importance of this fact, let us examine the possible effects of such radiation on man when delivered to the whole body in a relatively short period of time. Several categories of effects can be based on the prognosis related to radiation dose.[3] With very large doses, greater than 600 rads, survival is improbable. With doses greater than 600-700 rads, and in the thousands of rads, brain damage and gastrointestinal damage would be so severe that death would occur within the first 4-5 days and no treatment would be capable of life-saving. With doses between 200-600 rads survival is possible. With this degree of exposure, blood-cell destruction is the predominant effect, and may result in infections, bleeding, and possibly death. Figure 1 shows blood changes and clinical signs in cases where survival is possible (200-600 rads). With doses below 200 rads survival is probable, since the blood-cell destruction per se will be insufficient to result in death. One must remember that other stresses, such as physical trauma, blast injury, thermal burns, sickness, starvation, and thirst will undoubtedly lower the dose at which survival is possible.

Since reliance on blood counts as an index of the degree of blood cell destruction will not be likely under the conditions considered, it should be noted that there are certain signs that will roughly indicate the severity of radiation exposure. The severity of the nausea, vomiting, and diarrhea during the early period after exposure and the duration of these symptoms are important indications of the extent of exposure. Later, the appearance of fever, infections, and bleeding from the gums or other parts of the body will also serve as indications of severity of exposure (see Figure 1).

Importance of bone marrow dose. It is clear that the degree of destruction of blood-forming cells is the critical factor in the "survival possible" dose range of radiation. The dose to the bone marrow, where blood cells are formed, thus becomes the all-important consideration. Blood-forming marrow is encased in bone that varies considerably in depth in various parts of the body (from a few cm to 11 cm or more, with an average depth of 5 cm).[4] Therefore, the critical dose could be considered roughly at the 5-cm body depth. Attenuation of the gamma radiation through the shielding structures will result in considerable degradation and scattering of the incident radiation so that a good portion of the measured radiation may be too soft to reach much of the critical organ system (the bone marrow). Furthermore, bone covering the marrow may further attenuate radiation. It is not believed likely that the photoelectric effect produced in bone will seriously alter the dose to the bone marrow.[5,6] If one can insure a dose to the bone marrow of not over 200 rads in 24 hours in an uncomplicated case, survival should be probable. It would be ideal to have radiation-detection instruments in protective structures, which would measure the total absorbed dose at 5 cm body depth.

The dose rate is another important factor to be considered. Protraction of radiation is known to reduce the effect. Thus, further radiation at more protracted dose rates over the ensuing days after fallout could be tolerated, perhaps 100 rads the second day and lesser amounts thereafter. This dose schedule would allow for more free movement of personnel after the first day or so.

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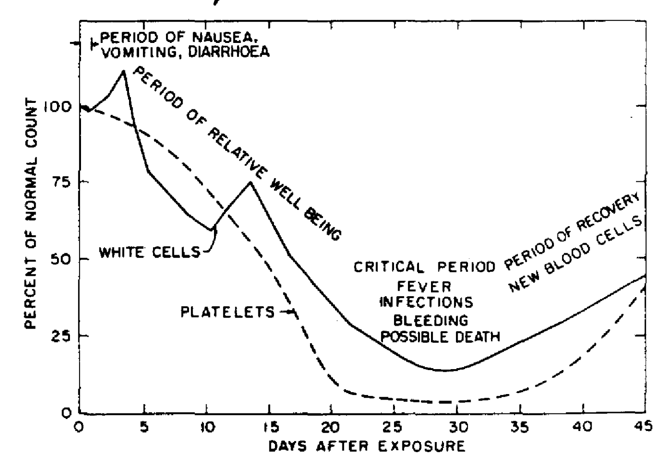

Figure 1. Schematic graph showing major blood changes and clinical signs for radiation doses where survival is possible (200-600 rads).

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The quality of the radiation (specific ionization, linear energy transfer) would be a consideration only in regard to the neutron irradiation. However, some experimental work indicates that in dogs, at least, the relative biological effectiveness of fast neutrons for bone-marrow damage is about the same as for gamma radiation.[7]

Skin irradiation. In regard to the hazard of skin burns from fallout, shelters would offer complete protection. The small amounts of fallout material that might sift into a closed shelter would be negligible with regard to skin irradiation. In personnel who are contaminated when they enter the shelter, radiation skin burns can be prevented simply by removing contaminated clothing and washing the skin, or simply wiping the skin with a damp cloth. Clipping the hair or even shaving the head may be indicated if the hair and scalp are heavily contaminated.

Internal irradiation. The hazard of internal absorption of fallout should not be significant in the shelter. Except for closed underground shelters, most will require no air filtration or special ventilation systems, since sufficient air to maintain life will filter through cracks in doors, windows, etc.[8] In such situations, it is possible that temperature and body odors might cause some discomfort, but under the circumstances they would be of negligible importance. During the period when fallout is actually falling—only a matter of hours—the shelter should be kept closed except for short periods when a door or window may be opened to refresh the air. Thereafter no special ventilation precautions should be necessary.

Treatment of Radiation Casualties

With regard to treatment of radiation casualties associated with nuclear warfare, the importance of using protective structures as a prophylactic treatment for avoiding exposure to penetrating radiation, skin contamination, or internal absorption cannot be overemphasized. Because of the chaotic circumstances at such a time, and the shortage of trained medical personnel, the use of active treatment for serious radiation effects will necessarily be limited and inadequate. It is important to recognize that fatal radiation casualties, for which treatment will be of little avail, will succumb within a few weeks after exposure, whereas those who may survive, and can be benefited even by limited treatment, will probably not develop full signs of radiation illness for two to three weeks. By that time radiation levels will be greatly reduced and such persons may be channeled to aid stations or hospitals for more definitive treatment than can be offered in most shelters.

References

1. Cronkite, E.P. et al., Effects of Ionizing Radiation on Human Beings. Report on Marshallese and Americans Accidentally Exposed to Radiation from Fallout and Discussion of Radiation Injury in Human Beings, U.S. Government Printing Office, 1956, pp. 1-106.
2. Conard, R.A. and A. Hicking, Medical Findings in Marshallese People Exposed to Fallout Radiation. Results from a Ten-Year Study. J.A.M.A. 191, No. 19, May 10, 1965.
3. Cronkite, E.P., V.P. Bond, and R.A. Conard, Diagnosis and Therapy of Acute Radiation Injury, Chapter 10 in Atomic Medicine, Fourth Edition, Eds. C.F. Behrens and E.R. King, The William and Wilkins Co., Baltimore, 1964, pp. 238-250.
4. International Commission on Radiological Protection, Report of Committee IV (1953-1959) on Protection against Electromagnetic Radiation above 3 mev and Electrons, Neutrons, and Protons, Pergamon Press, Inc., New York, 1964, pp. 1-44.
5. Wilson, R. and J.A. Carruthers, Measurement of Bone Marrow Dose in a Human Phantom for Co^{60} γ Rays and Low Energy X-Rays. Health Physics 7: 171, 1962.
6. Spiers, F.W., The Influences of Energy Absorption and Electron Range on Dosage in Irradiated Bones. Brit. J. Radiol. 22: 521, 1949.
7. Bond, V.P. and J.S. Robertson, Comparison of Mortality Responses of Different Mammalian Species to X-Rays and Fast Neutrons; in Biological Effects of Neutron and Protron Irradiation, Vol. 2, pp. 365-377, International Atomic Energy Agency, Vienna, 1964.
8. An Evaluation of the Need for Filtration Systems to Protect Sheltered Personnel from Radioactive Fallout; Naval Research Co. 3-9 Brookhaven National Laboratory, Upton, New York, Office of Naval Research ACR-72, May 1962.