THIS DOCUMENT CONSISTS OF 6 PAGES
COPY NO. 3 OF 4 SERIES A

~~TOP SECRET~~ 12 August 1945

MEMORANDUM:

SUBJECT: Toxic Effects of the Atomic Bomb.

No lingering toxic effects are expected in the area over which the Bomb has been used. The bomb is detonated in combat at such a height above the ground as to give the maximum blast effect against structures and to disseminate the radioactive products as a cloud. On account of the height of the explosion, practically all of the radioactive products are carried upward as a column of hot air and dispersed harmlessly over a wide area. In New Mexico the height of the explosion was very low since the bomb was not dropped but was exploded just above the ground on a tower.

Available information both by theoretical calculations and actual measurements indicates that the primary toxic hazard which may be encountered after the explosion at the center of impact is that of radiation. The intensity is a small fraction of the original amount. The intensity is indicated by the following: $I = \frac{K}{T^{1.2}}$ I = Intensity in Roentgens; K = Constant. T = time in hours

The radiation measured at the site of the crater (130' in diameter) in the New Mexico test indicated that several hours after the blast the radiation intensity near the center of the crater was approximately 150 roentgens* per hour. This intensity diminished very rapidly as one proceeded away from the crater and was so small as to be negligible at a distance of several

*The roentgen is a unit of radiation measurement. It combines intensity and time. One roentgen represents the absorption of 84 ergs per gram of body tissue.

~~TOP SECRET~~

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thousand yards from the crater. Three weeks after the blast the decay rate had reduced the radiation intensity to such an extent that at a distance of three to four hundred yards from the crater the radiation was only .5 roentgens per hour. The radiation intensity in the center of the crater was still high, however, and from a biological point of view would be considered lethal for uninterrupted occupation of more than a few weeks. This lethal area probably involves a diameter of 100 to 200 yards.

The radiation following the blast is caused by the presence of a tremendous number of radiactive particles which emit both gamma and beta rays. Both decay at approximately the same rate. The gamma rays are very penetrating, are similar to X-Rays, and are of great concern biologically since they can easily pass through to the most vital structures of the body. The beta particles have less energy and have a very short range so that at best they can only pass through the skin from an external radiating beta source. The underlying vital structures of the body are not injured; the skin, however, can be very severely damaged. If the beta rays are introduced into the body by inhalation or by ingestion as in eating contaminated food, the biological effects may be fully as serious as those due to gamma rays. For the most part, however, the beta rays are of little consequence.

The radiation produced by the blast divides itself into two portions; that which becomes imbedded and intermingled in the debris and dust of the crater and that which rises in the ball of fire and ensuing smoke and dust. The latter is divided into two classes, that radiation which is produced in the blast and that secondarily induced by radiation of dust particles. The secondarily induced radiation decays almost immediately. Present indications are that most of the radioactivity which rises with the ball of fire and column of smoke and remains suspended in the air is rapidly dissipated by wind and

thermal convection currents which soon reduces the radiation to very low levels and in a few hours to a negligible one. In the very unlikely and unanticipated case that these radioactive particles should be suddenly precipitated to the ground, the amount of radiation could be very high but would remain so for only a short period of time. Any attempt to predict the amount of activities deposited from the column of smoke and dust would be very inaccurate since the following factors, among others, would have great influence upon the precipitation of this material:

a. Meteorological conditions: humidity, temperature, wind velocity, levels and degrees of inversion, rain (this is very unlikely to occur because of the tremendous force of the rising cloud).

b. Character of the terrain as built up area, presence of large amounts of vegetation, hills, etc.

c. The height above the ground at which the bomb explodes—the higher above the ground the explosion occurs, the lower the radiation and intensity at the point of impact will be.

The amount of radiation and the length of time during which it is received directly determines the degree of biological toxicity. Considerable information is available from recent experimentation and previous experience from X-ray and gamma rays used in medicine and biology. It is established that the lethal dose of gamma rays is approximately 700 to 800r administered to the body, if delivered within one to two days. Much smaller intensities are lethal if delivered repeatedly. For example: 10 r delivered daily to the entire body for 150 to 200 days would prove lethal in most cases. The dose of radiation from which the body would recover fully and which can be repeated indefinitely is less than 1r per day — .1r per day has long been a recognized safe standard for workers in laboratories. This naturally includes a wide

margin of safety. The biological changes immediately following a lethal dose delivered in a few days are severe prostrations, nausea and vomiting, bloody diarrhea becoming severe and protracted; leukopenia and lymphocytopenia result followed by thrombocytopenia which produces hemorrhagic disturbances in the body. Death may occur within a few days or may be postponed for various periods up to 60 days. Radiation effects may produce deleterious changes without actually causing immediate death. These biological disturbances are usually manifested by severe and protracted anemias and severe leukopenia. Sharp reduction of the white cells are the earliest changes following sub-lethal doses. Other sub-lethal changes which occur are sterility, both temporary and permanent; epilation, both temporary and permanent; chronic skin conditions usually of a permanent nature. Various body tissues such as bone, nerve and muscle are insensitive to radiation and not easily affected.

The only manner in which possible biologic damage may be predicted is to determine the radiation levels at the sites of the craters. These levels may be determined by various radiation meters, and an ample supply of these is being shipped to General Farrell. The following is an over-simplified table of probable injury for active troops:

	Acute exposure within 1 - 24 hrs.	Prolonged exposure * 1 week	2 weeks
Limit of Safety Some blood changes with complete recovery	30r	50r	60r
25% slightly injured, will recover	50r	75r	100r
50% slightly injured	75r	100r	150r
(75% slight to moderate injured (25% permanent damage	100r	150r	200r
50% permanent damage 100% injured	200r	250r	300r

*This presumes no further radiation.

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ABSTRACT

The available information indicates that any biological toxicity at the crater site would be due to radioactive material. The dosage measured at the center of the crater in the New Mexico test indicated dosage of 150r per hour immediately following the blast but diminishes very rapidly so that after several weeks at a point four hundred yards from the crater the radiation was .5r per hour. Areas more distant than 400 yards from the crater had very low radiation intensity and could be considered safe.

The radioactive material emits beta and gamma rays. The gamma rays—like X-rays, are likely to be more serious because of the ability to penetrate deeply into the body.

The radioactivity induced by the blast divides itself generally into two portions: that embedded in the debris and dust of the crater and that blown into the air. That portion thrown up into the air is usually much greater and is rapidly dissipated.

A total dose of 700 - 800r in one day is usually lethal. The generally accepted safe level for indefinite daily exposure is .1 per day which naturally provides an ample margin of safety.

DEFINITIONS

Roentgen	One roentgen is that amount of radiation which when absorbed in .001293 grams of air produces one electrostatic unit of charge of either sign.
Lymphocytopenia	Reduction of lymphocytes, a special but necessary white blood cell, about 30% of the total white cells.
Leukopenia	Reduction of white blood cells.
Thrombocytopenia	Reduction of blood platelets, a particle in the blood which initiates blood coagulation.
Erg	The energy or work done in giving one gram an acceleration of one centimeter per second.
Epilation	Loss of hair, anemia, reduction in the number of red blood cells.
Hemorraghic	Pertaining to hemorrhage or bleeding.