RADIOLOGICAL MONITORING PROBLEMS IN CIVIL DEFENSE

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DEFINITION OF THE PROBLEM

The unit of exposure to ionizing radiation is the roentgen (r). One roentgen of X – or gamma-radiation produces 2.08 x 10^9 ion pairs in passing through one cc. of air, corresponding to 83.8 ergs per gram of air. The rep (roentgen equivalent physical) corresponds to 93 ergs per gram of water or animal tissue. The rem (roentgen equivalent man) is the rep/RBE where RBE is relative biological effect and is assigned the value of 1 for gamma rays, X-rays and beta particles; 10 for protons, 20 for alpha particles, 10 for fast neutrons, and 5 for thermal neutrons. For gamma rays and beta particles, which represent the most common hazard, RBE is unity, so that either the rep or roentgen can be used as a measure of hazard. Most instruments are calibrated in roentgens and in counts per minute. As a rough approximation, for the average mixed fission products, 1 mr (0.001r) per hour equals 4,000 counts per minute.

Tolerances in food, air, and water are usually expressed in microcuries per cc., a microcurie giving rise to 3.7 x 10^4 counts per second or 2.2 x 10^6 counts per minute. On disintegration of radioactive materials, rays and particles are projected in all directions, so that a particular geiger tube can be positioned to count only a small fraction, usually 10% of the total counts; hence 220,000 counts per minute represents a rule of thumb figure for the counts from 1 micro-curie.

The external environmental hazard is due almost entirely to gamma rays because of the low penetrating power of alpha particles (helium ions) and beta particles (electrons). Alpha and beta particles are a serious hazard in ingested food and water because of their tendency to concentrate in specific organ sites and because, with their low penetrating power, they tend to produce all their potential damage within a short distance from their place of localization.

The tolerances for radioactivity following an atomic burst are much greater than peace-time tolerances because of the rapid rate of decay of radioactivity in the fission products. The decline of activity following an atomic burst may be predicted approximately by the formula:

$$A_1 t_1 = A_2 t_2 \quad \text{or} \quad A_2 = A_1 \frac{t_1}{t_2}$$

A_1 is the radioactivity measured at a particular time (t_1) after the burst and A_2 is the radioactivity predicted at some future time, t_2. For instance, suppose a certain area measures 40 r per hr at 2 hours after the burst, how long would it take for the radioactivity to fall to 1 r per hr.?

$$A_1 t_1 = A_2 t_2$$
$$40 \times 2 = 1 \times t_2$$
$$t_2 = 80 \text{ hours, or 3 days, 8 hours.}$$

ENVIRONMENTAL GAMMA RAY TOLERANCE

The standard AEC gamma ray limit for the environment in which routine work is being carried on is 0.006 r per hour, or 0.3 per week. In case of an emergency, much higher doses will be allowable, as indicated in Table I.

TABLE I

PROBABLE EARLY EFFECTS OF ACUTE RADIATION DOSES OVER WHOLE BODY

Acute Dose	Probable Effect
0 – 25 r	No obvious injury.
25 – 50 r	Possible blood changes, but no serious injury.
50 – 100 r	Blood cell changes, some injury, no disability.
100 – 200 r	Injury, possible disability.
200 – 400 r	Injury and disability certain, death possible.
400 r	Fatal to 50%
600 r or more	Fatal.

It is obvious from the above table that a dosage of 25 r is permissable in case of emergency. Monitor team members would be permitted to run a red line at 10 r per hr., outside of which rescue and salvage missions could be performed with little hazard. In an area measuring 10 r per hour at 1 hour after the burst, the cumulative dose in 8 hrs would be 22r. Emergency hospitalization, shelter, and feeding operations would be set up outside a green line measuring 0.1. r per hr at 1 hr after the burst. It will be necessary to remonitor the areas in order to be sure that there is a normal rate of decay of the bomb residues, $A_1 t_1 = A_2 t_2$. In the case that radiological warfare (such as the cobalt bomb) is combined with atomic warfare, and radiation is not declining at the end of 2 hours, the red exclusion line will be relocated at 1 r per hour and the green safety line at 0.01 r per hour.

MAXIMUM PERMISSIBLE RADIATION LEVELS IN AIR, WATER, AND FOOD IMMEDIATELY AFTER THE BURST

The natural radioactivity of air amount to 10^{-9} microcuries per cc. The peacetime limit set by the AEC for air is 10^{-8} microcuries per cc. At 50% geometry, this amounts to 0.01 counts per min. per ml. so that 400 l would have to be filtered to yield a reading of 1 mr per hr. No tolerances have been established for air following an atomic burst. It may be assumed that 50% of any aerosol reaches the alveoli of the lungs, and that in the case of insoluble particulate materials half of this, or 25% of the original aerosol, is retained indefinitely. The inhalation of radioactive dust should be avoided and masks used wherever possible, especially since 20,000 liters of air are inhaled per day. A practical limit, based on the tolerance for radioactivity in water, is 6×10^{-5} microcuries per cc., so that the filteration of 1 l. would yield 1.5 mr per hour.

The natural radioactivity of water varies with the source, but averages about 10^{-8} microcuries per cc. The peacetime limit set by the AEC is 10^{-7} microcuries per cc., corresponding, at 10% geometry, to 22 counts per min. per l. or 0.005 mr. per hr. (a negligible quantity). Immediately following an atomic burst, a tolerance limit of 3×10^{-2} microcuries per cc. has been established. This amounts to 6600 counts per minute per cc. at 10% geometry, or 1.65 mr per hr. per cc., which is easily measurable with a portable geiger counter. The radioactivity is due to beta-emitters and decreases rapidly with time. The water may be consumed for a maximum of thirty days. If measurement is delayed beyond the first hour after the burst, the maximum permissible limit becomes smaller in accordance with the equation

$$A_1 t_1 = A_2 t_2$$

The maximum permissible limit for food is set the same as that for water.

DECONTAMINATION

Painted and metallic surfaces are more easily decontaminated than more porous materials, as indicated in Table II.

TABLE II

DECONTAMINATION EFFECTIVENESS

Surface	Paint	Metal	Concrete	Brick	Asphalt	Wood
Decontamination Agent						
Water	50%	50%	----	----	----	----
Detergents	90%	50%	----	----	----	----
Citric Acid, Citrates or Versene	75%	good	----	----	----	----
Organic Solvents	good	----	----	----	----	----
Caustics	100%	----	----	----	----	----
Acids	----	100%	----	----	----	----
Wet Sand-blasting	100%	100%	good	good	good	----
Flame Cleaning	good	----	fair	fair	----	fair

In decontamination, personnel must be protected, with masks, from inhalation or ingestion of spray or dust. After decontamination, the contaminated solutions, sand, etc., must be disposed of safely, or they too will represent a hazard. In many cases it will be desirable to wait until the radioactivity has decayed to 0.1 r per hr., or preferably lower, before putting the equipment back into use. Since this level is 16 times AEC tolerance, close check on blood counts of personnel and records of total cumulative exposure should be kept, with eventual replacement of equipment or rotation of personnel to avoid health hazard.