MAXIMUM PERMISSIBLE LEVEL OF RADIO ACTIVITY IN DRINKING WATER

by

P. C. GUPTA

Defence Science Laboratory, Delhi

ABSTRACT

The possibilities for contamination of water by radio-activity due to radioisotopes which can be ingested by drinking contaminated water have been discussed. The factors on which hazards associated with radioactive contamination have been dealt with in detail. The maximum permissible level of radioisotopes in water as laid down by the I.R.P.C., U.K. and U.S.A. are compared. To meet emergencies certain emergency permissible levels of radioactivity have been suggested, giving the importance of these levels. Lastly, some precautionary measures for protection and methods for decontamination have been explained.

Introduction

There is no way of escaping exposure to ionizing radiations. All living subjects on the earth are constantly exposed to radiation—both external and internal. It has been estimated that the total amount of external radiation to which man is subjected is 0·0003 r/day. This is produced by Cosmic rays and radioactive elements in the air as well as in the ground. Internally, there are three principal radioisotopes present in man's body throughout his life, that is K^{40}, C^{14} and Ra^{226}. Over a period of seventy years a 70 Kg man will receive from these natural radioactive elements approximately 2r, which is about 0·0001 r per day. In other words we may say that radioactivity is a universally occurring, natural phenomenon. It is only when the body is exposed to too much of it for a long time that the damage results. The probability of the damage is much more when the radioactive material is taken into the body. Radioactivity is also a serious hazard to which water supplies may be exposed. Therefore, the problem of drinking water contaminated with radioactive dust particles is an important one in view of the above facts.

Possibilities for contamination

The problem of water supply to the armed forces in the battlefield under conditions of radioactive contamination is of great importance, because, most of the sources of water supplies might be the targets of nuclear attack. Appreciable contamination might result if the water reservoirs were in the range of a heavy fallout from a surface burst.

Possibilities for ingestion

Soldiers may have to drink water contaminated with radioactivity in emergency conditions or when pure water is not available. By drinking contaminated water, soldiers may take various radioisotopes inside their bodies. These isotopes on disintegration give different types of ionizing radiations such as alpha-rays, or beta-rays followed by highly penetrating gamma-rays.

The radio-isotopes entering the body through drinking water are deposited in various parts of the body (Table I). Strontium-89 and Sr^{90}, Ba^{140}, Ca^{40} etc. deposit on bones, I^{131} entirely goes to thyroid and Na^{24} and Cl^{36}, circulate throughout the body and cause damage by radiating for long time.

The metabolic action of ingested material, therefore, depends very markedly on its chemical nature, some elements such as sodium are rapidly excreted; others are absorbed and retained in different organs of the body. The hazards associated with radioactive contamination of water depends upon the following factors:—

(*a*) *The biological half-life* or the average time which lapses before 50 per cent of the material is eliminated from the body.

(*b*) *The radioactive half-life* or the time interval in which the activity decreases to one half. This determines the total number of disintegrations that can take place with the life of the individual. If the activity is $3 \cdot 7 \times 10^{10}$ disintegrations per second, the amount of radioactive material is 1 curie.

(*c*) *The specific ionization of the radiation emitted.* All ionizing radiations, in their interaction with biological tissues, produce ionization, but the resulting damage is slightly different in each case. For example, in the case of alpha particles which are massive and less penetrating, the energy is dissipated within a short distance. This causes extremely dense ionization per unit distance along the track of the particle, whereas, with gamma rays of equal energy, the ions are spread over a very long distance mainly because the gamma rays are highly penetrating. This difference in the concentration of ionization per unit length of the track has great importance because the damage of the tissue is dependent on this specific ionization.

(*d*) *The energy liberated per disintegration.* Those radioisotopes which liberate more energy per disintegration will cause more damage than those which liberate less energy.

(*e*) *The way of distribution in the body.* The radioisotope which has more affinity to get deposited in critical organ (Table I) is much more damaging than an isotope which is distributed throughout the body.

Consequences

Even minute quantities of radioactivity above the normal may shorten life span and increase considerably the incidence of cancer, anaemia, leukaemia, etc. Observations on the effect of radioactivity on the lifespan of human beings lead to the estimate that 1 roentgen (unit of radiation) of exposure shortens life expectancy by about 2·5 days. On this basis we can say that even the normal unavoidable background radiations of about 10 roentgen may shorten life by about 1 month on the average.

The main hazards of Sr^{90} in drinking water are due to its long biological and radiological half-life and its bone-seeking character.

Maximum permissible total body burden

In assessing the internal hazards of radioactive substances the most important thing to know is the "maximum permissible total body burden." It is defined as that quantity of radioactive substance which can be retained in the body for prolonged periods without causing any untoward effects or appreciable bodily injury to a person at any time during his life time.

Maximum permissible level

The nature of the damage produced by radiation is such that there is no definite boundary between "safe and unsafe levels of exposure" unless, we wish to define the safe levels of exposure as 'no exposure'. However, the concept of a maximum permissible level of exposure naturally gives the impression that it forms such a boundary.

To avoid internal damage to the body by radiations, the International Radiological Committee has suggested a level of radioactivity which would cause no appreciable bodily injury to a person irradiated to it at anytime during his life. This level has been called "Maximum Permissible Level of Radioactivity". It is believed that a person may be exposed to this level of radioactivity continuously for a long period without any risk. The permissible levels of various radioisotopes in drinking water are given by the International Radiological Protection Committee (Table 1):

TABLE I

Table 1 : Maximum permissible level of radio isotopes in body and water.

Isotopes	Critical organ	Half-life: Radioactive	Half-life: Biological	Types of radiations	Microcurie in total body	Microcurie per c.c. in water
Barium–140	Bone	12·8 days	200 days	β & γ	5	5×10^{-4}
Calcium–45	Bone	152 ,,	1800 ,,	β	65	1×10^{-4}
Chlorine–36	Total body	$1 \cdot 6 \times 10^{8}$,,	29 ,,	β	200	4×10^{-3}
Iodine–131	Thyroid	8 ,,	120 ,,	β & γ	0·6	6×10^{-5}
Phosphorus–32	Bone	14·3 ,,	1200 ,,	β & γ	10	2×10^{-4}
Plutonium–239	Lungs	$8 \cdot 8 \times 10^{6}$,,	360 ,,	α & γ	0·02	1×10^{-6}
Radium–226	Bone	$5 \cdot 9 \times 10^{5}$,,	16000 ,,	α & γ	0·1	4×10^{-8}
Sodium–24	Total body	15 hours ,,	19 ,,	β & γ	15	8×10^{-3}
Strontium–89	Bone	53 ,,	4×10^{3} ,,	β	1	8×10^{-7}
Strontium–90	Bone	9×10^{3} ,,	4×10^{3} ,,	β	1	8×10^{-7}
Sulphur–35	Skin	87 ,,	22 ,,	β	100	5×10^{-3}

Key and Kenny, the Medical Research Council Protection Committee, UK, have approved the following Maximum Permissible Level of Radioactivity in drinking water for continuous use.

TABLE II

Permissible Level of Radioactivity in Water in U.K.

Isotope	Maximum permissible level of radioactivity in drinking water in microcurie per c.c.	
	α-ray activity	β-ray activity
Radium	4×10^{-10}	..
Other –ray α emitters	$2 \cdot 4 \times 10^{-9}$	..
Calcium	..	2×10^{-8}
Strontium	..	2×10^{-8}
Other β-ray emitters	..	1×10^{-6}

Wolmann & German state that in USA there is no general agreement about the permissible radioactivity in drinking water. However, they have proposed certain maximum permissible levels (Table III).

TABLE III

Permissible level of Radioactivity in Water in USA

Isotopes	α-ray activity (per c.c.)	β-ray activity (per c.c.)
Phosphorus	..	3×10^{-5}
Strontium	..	2×10^{-5}
Radium	4×10^{-8}	..
Plutonium	1×10^{-6}	..
Unknown Sources	1×10^{-6}	1×10^{-7}

The above figures were calculated on the assumption of a daily intake of 2·5 litres of water by a person. No particular harm is expected if the recommended values are exceeded for a short time.

War conditions

Water supplies are likely to be contaminated in a large scale in atomic warfare and particularly in ground bursts. Under war conditions, the emergency Permissible Levels have been recommended to the soldiers in the field for ten days (Table IV) before a decontaminated water supply can be found.

TABLE IV

Emergency Permissible Levels of Radioactivity in drinking water in period immediately following Atom Weapons Explosion in War.

Time after burst	Microcurie per c.c. in water
12 hours	$1 \cdot 8 \times 10^{-1}$
1 day	6×10^{-2}
2 days	2×10^{-2}
10 days	1×10^{-2}

Scope of emergency levels

It is emphasized that the above are not peace time permissible levels of radioactivity for either long or short time consumption. These values, however, are permitted during periods of emergency. The period should not exceed one month after a nuclear explosion, as the remaining long-lived radioactivity carries an increasing hazard for human consumption.

Detection

Civilian, industrial, prospecting, scientific and service instruments may be utilised for detecting radioactivity in a very wide range of sensitivities. The hazard depends upon particular isotopes. Cs^{137} is retained in the body for such a short time that it is unimportant in relation to Sr^{90}. Although it is easy to detect radioactivity in the fields, yet it is difficult to identify the radioisotopes responsible for the cause of radioactivity.

Advantage can be taken of the fact that several harmful radioisotopes including Sr^{90} are beta-ray emitters. A simple equipment can detect beta radiation in water in the field. Furthermore, the important elements can be separated and concentrated by chemical processes. Although these methods are too complicated, they could be carried out in a mobile laboratory.

Protection

There are many radioactive characteristics of physical and biological nature which in many cases make absolute protection from the radiation effects impracticable, if not impossible. However, certain means have been adopted to protect from radiations of contaminated water. The first step