7/Atomic Radiation and its effects

Atom and its particles. Atoms were supposed to be the smallest particles existing in nature but now it has been established that still smaller particles exist. Atom consists of these smaller particles, e.g., electrons, protons, neutrons, positrons, etc. Electrons are very small particles and remain around the nucleus of each atom. The electron particles are negatively charged and can move from one atom to another. The protons exist in the nuclei of the atom. They are positively charged. Electron and proton when get united, neutron is formed. The neutron has got no electrical charge. The positrons are positively charged. Radio-activity is due to disparity between the number of protons and neutrons in the nucleus. When radio-active disintegration occurs fast moving subatomic particles, electrons are emitted. These beams are called beta rays. When a positron strikes an electron there is release of gamma rays. Gamma rays and X-rays are practically of same nature. The term gamma ray is used when the radiations are emitted by radio-active substances and X-rays are called when they are produced in special high voltage equipment. Radio-active atoms like helium on disintegration discharge alpha particles. Helium contains proton and neutron.

Nuclear reactions. In the nuclear reaction there is release of excess amount of energy and nuclear re-arrangement. When the two nuclei are brought into contact by some artificial procedure, at first a large nucleus is formed which undergoes disintegration. There may be fission of the large nucleus, or there may be release of gamma rays, or beta rays, or alpha rays, neutrons, protons or positrons, etc.

Atom bomb. In recent years the atom bomb has become lethal weapon in modern warfare. In making an atom bomb radio-active substances such as uranium^{235} or uranium^{233} and plutonium^{239} are used. In the atom bomb reaction there is nuclear fission, i.e., the nuclei of uranium or plutonium split up and liberate neutrons. Again each of the neutrons helps splitting up of another uranium atom. Ultimately disintegration of the whole mass of uranium occurs. In the atom bomb very small masses of uranium are put together in a suitable container for explosion.

Ionising radiation. Since 1945 when the atomic bomb was dropped on Hiroshima and Nagasaki the concious people of the world became alert about the hazards of atomic radiation. What we mean by 'radiation'? When we use the word *radiation* we commonly refer to 'ionising' radiations. Ionising radiations cause serious damage to living tissues and are so called because they cause each atom they hit to lose an electron, the atom thereby being converted to a positively charged ion. The freed electron is incorporated in another atom which therefore becomes a negatively charged ion. When each electron lost from one atom is gained by another atom, the number of positively charged ions is equal to the number of negatively charged ions.

Ionising radiations include electromagnetic waves of very short wavelength (X-rays and γ-rays), and high energy particles (α-particles, β-particles, and neutrons). X-rays, γ-rays, and neutrons have great penetrating power but α-particles can invade soft tissues to a depth of only a fraction of a millimetre and β-particles only up to a few millimetres in such tissues. Alpha and beta particles are extremely important if they are emitted from a radio-active substance which is actually inside the body.

The amount of radiation received by irradiated tissues is often called the 'dose' of radiation, which is measured in terms of *rads* and *rems*. The rad is a measure of the amount of any ionising radiation which is actually absorbed by the tissues and the rem is a convenient unit for it is a measure of any radiation in terms of X-rays. One rad is equivalent to 100 ergs of energy absorbed per gram of tissue and one rem of radiation is that absorbed dose which produces in a given tissue the same biological effect as one rad of X-rays.

Sources of ionising radiations. Sources of ionising radiations are natural (background) and artificial. The amount of radiation from natural sources has remained the same since life first appeared on this planet. These natural sources of radiation consists of cosmic rays, external radiation from radio-active materials in certain rocks, and internal radiation from radio-active materials in our tissues.

Cosmic rays originate from outer space and consist of high energy particles, mostly protons and small amounts of alpha particles, carbon, nitrogen, oxygen and iron. The effects of cosmic radiation in man are perhaps negligible but in the future the hazards to aircrews who operate at very high altitudes for considerable periods of time may be significant. The effects on persons involved in interplanetary space travel will have to be studied. The intensity of cosmic radiation depends not only on altitude but also on latitude being greater at the poles than at the equator. The dose of radiation is expressed in relation to the amount received by the gonads. The *gonad dose* of radiation is often expressed as the amount received in 30 years. In the case of cosmic radiation the dose to the gonads is about 0·90 rems per 30 years.

A number of natural radio-active elements namely thorium, uranium, radium and an isotope of potassium (^{40}K) are widely distributed over the earth's surface. The amount of radiation received by man from these sources varies considerably in various parts of the world. An average dose to the gonads from radiation from naturally occuring radio-active materials external to the body amounts to about 50 mrems per year or 1·50 rems in 30 years. For example in parts of the state of Kerala in India the average level of radiation is as high as 2800 mrems per year and in the state of Espirito Santo in Brazil it is about 500 mrems per year.

Common natural radio-active materials are constituents of the breathing air, the eating food, and the drinking water. These radio-active materials include minute quantities of uranium, thorium and related substances, and isotopes of potassium (^{40}K), strontium (^{90}Sr), and carbon (^{14}C). The radiation from these elements within the body amounts to about 20 mrems per year.

The hazards and dangers from radio-active fallout resulting from the testing of nuclear weapons has become usually a political issue in many countries. On the average the world population at present is exposed to less radiation from fallout from nuclear explosions than from medical radiology.

When a nuclear device is implied, it releases a tremendous amount of energy in the form of heat, light, ionising radiations, and many radio-active substances. Among the most important of these radio-active substances are isotopes of carbon (^{14}C), iodine (^{131}I), cesium (^{137}Cs), strontium (^{90}Sr). ^{137}Cs and ^{90}Sr are considered most important. Because the 'half-life' of ^{90}Sr is 28 years and that of ^{137}Cs is 30 years. This means that the radio-activity of ^{90}Sr is reduced by a half in 28 years, by three-quarters in 56 years and by seven-eighths in 84 years. The hot gases of a nuclear explosion carry these radio-active substances into the atmosphere and stratosphere where they remain for some time before falling back to the earth (fallout). ^{137}Cs and ^{90}Sr are lodged on water which is later drunk or on vegetation which is either eaten by man or by cattle. The radio-active materials may also be passed on to man in the meat of cattle or in their milk. In man ^{137}Cs is widely distributed throughout the body but is commonly abundant in muscle whereas ^{90}Sr becomes almost solely localised in bone.

Moderately large numbers of workers are engaged in medical radiology and atomic energy projects. The use of X-rays for detecting flaws in castings and for the examination of other commercial products has introduced potential hazards in industry. The use of radio-active isotopes has increased greatly in many spheres of activity from biologists using tritiated thymidine in studies of chromosome replication to engineers interested in the combustion of motor fuels. Obviously persons in technologically advanced countries will be exposed to the greatest amount of radiation from man-made sources.

Effects of radiation. Ionizing radiation acts upon the cells of the body and the sex cells; they have somatic and genetic effects. The immediate somatic effects of accute 'whole' body irradiation were seen in those individuals close to the centre of the atomic explosions in Japan in 1945. Among those who were not killed immediately by the blast, many suffered from the effects of having received an enormous dose of radiation. Some died within 10 days, others were ill for several weeks. Those exposed lost their hair and their bone marrow activity was greatly reduced so that the number of circulating leucocytes was considerably decreased and their resistance to infection was therefore severely impaired. Among those who recovered from the immediate effects some later developed leukaemia. One of the possible hazards of radiotherapy is an increased risk of developing leukaemia or other neoplastic diseases. Experiments on animals have shown that exposure to ionizing radiation leads to a reduction in the life span; but so far there is no proof of this in man. There is good evidence in man that irradiation of the foetus, particularly during the early weeks of pregnancy, is associated with an increased risk of microcephaly and malignant disease in childhood. For this reason it is suggested that X-ray examination of the lower abdomen should be carried out within 10 days following the first day of the last menstrual period when it is most improbable that the woman could be pregnant

The somatic effects of a high dose of radiation to a 'localised' volume of tissue are seen in patients being treated for malignant tumours and in persons involved in accidents with radio-active materials. The result may be local tissue necrosis (radiation burn) and general malaise with some nausea and vomiting (radiation sickness). Sufficient exposure to radiation will result in sterility but since it requires several hundred rads to destroy the sex cells, if this amount of radiation were received by the whole body it would probably be fatal.

The somatic effects of radiation are extremely important to those involved in radiotherapy and the handling of radio-active materials.

In 1927 H. K. Muller demonstrated that exposure of colonies of *Drosophila* to X-rays resulted in an increase in the number of mutations in excess of those occuring spontaneously. He thus showed that X-rays are mutagenic.

In the field of radiation genetic mutations are chromosome aberrations and point mutations. The chromosomes aberrations are gross structural changes of the chromosomes such as deletions and breakages which are caused by high doses of radiation. Point mutations involve such a minute amount of chromosome material that they produce no visible change microscopically. It seems that ionising radiations and other mutagenic agents (exposure to high temperatures, ultra-violet radiation, and certain chemicals have been shown to be mutagenic in animals) bring about their effects by changing the arrangement of the atoms within a localised region of the DNA molecule. Mutations are usually harmful.

Sometimes a new mutation is beneficial. Plant and animal breeders are continually on the lookout for new mutations which have economic importance,. Examples include strains of barley with higher protein contain: varieties of cattle with increased milk yield. There is no doubt that these mutations are beneficial to man, but it is a moot point whether, under natural conditions, such mutations are necessarily of benefit to the organism possessing them. In man a new mutation is much more likely to be recognised if its effect is detrimental rather than if it confers some increased resistance to infection or leads to a slightly longer survival time.

Sequence of events of first atom bomb blasts during the last World War : (a) Release of huge quantity of gamma rays in all directions due to nuclear reaction.

(b) Disintegration of the atom bomb into a gaseous mass having very high temperature. The gaseous mass due to its very high temperature emits electromagnetic radiations, e.g., heat and light rays. These heat rays cause burning of the skin of the body.

(c) Excessive heat produced due to atom bomb blast makes a shock wave which travels at quite a high speed. This shock wave is so powerful that it will destroy all the animate and inanimate objects in its path up to a distance of about 3 kilometres.

(d) Emission of gamma rays which may kill a person even if he may remain about 3 to 5 kilometres away from the place of atom bomb blast.

A person being exposed to atom bomb blast may die due to shock wave or due to burns within a few hours to a few days or due to effects of gamma rays which produce its deleterious effects on the different tissues of the body.

The **effects of gamma rays** on the different systems of the living body are as follows:

(a) *Cell division*—Mitosis is blocked completely or almost completely after exposure to gamma rays or any other ionising radiations. Some cells in the body must be formed anew at different intervals according to their span of life. So if there is blocking in mitosis, the specific functions carried out by these cells will be hampered due to their complete or partial disappearance.

(b) *Blood*—(i) Leucopenia. Both the granulocytes (function against invading organisms) and the lymphocytes (responsible for anti-body formation) are diminished. As a result of leucopenia the body is prone to infection and often there is septicaemia. (ii) Anaemia occurs at a later stage as the life span of red blood corpuscles is approximately 120 days. It is due to inhibitory effects of gamma rays on the bone marrow. As a result of this inhibitory effect production of red blood corpuscles is reduced.

(c) *Digestive system*—Inhibition of secretion of the epithelial and glandular cells of the gastro-intestinal tract. The inhibition of secretion is due to cessation of mitotic division of the cells. As a result of these changes, symptoms like nausea, vomiting, diarrhoea, bleeding, ulceration, etc., appear within a few hours or days.

(d) *Skin*—The germinative layer of the skin is prone to attack by the gamma rays. Mitotic division of the cells of this layer is inhibited. The skin is gradually atrophied and it may be extensively ulcerated within a few days or weeks.

(e) *Eyes*—Cataract in some cases may develop (delayed effect). This is the late effect of gamma rays. The cells of the anterior part of the lens are destroyed.

(f) *Gonads*—The germinal cells of the testes and ovaries are markedly affected. As a result the genes of the sperms and of the ova may become mutated and it is likely that the mutated offspring might be produced.

(g) *Cellular changes*—Due to changes in the genes of some of the cells there is rapid proliferation of these cells and ultimately they may develop into cancer.

(h) *Other organs*—As the various muscles and the nervous tissues do not depend upon rapid mitosis, they are least affected by gamma rays or other ionising radiations. The greatly depressed mitosis may be returned to normal after a few hours or several months which depend upon the degree of exposure. So if the patients can overcome this depressed mitotic condition (i.e., maintain the life process until the mitosis returns to normal), they may return to normal physiological activity after several months.