الأسبوع الرابع

2.4 Effect of radiation on Environment and Life

The effect of radiation on living organisms, including humans, appears mostly at cell level, since ionizing radiation can potentially affect the normal operation of cells. The biological effect of radiation lies in the ionization of atoms and molecules in the tissue.

Ionizing radiation absorbed by human tissue has sufficient energy for ionization of atoms; this may subsequently lead to breaking chemical bonds and thus molecules. This is a basic model for understanding radiation damage. For a deeper understanding of the effect of ionizing radiation on cells, one needs to consider damage to critical parts of the cell, such as chromosomes that contain genetic information and instructions required for the cell to function, as well as to make copies of it for reproduction purposes. On the other hand, the cells have very effective repair mechanisms, which operate permanently and repair cellular damage - including chromosome damage.

Ionization may form chemically active substances that in some cases alter the structure of the cells. These alterations may be similar to those changes that occur naturally in the cell and may have no negative effect. Some ionizing events produce substances (such as amino acids or enzymes) not normally found in the cell. These can lead to a breakdown of the cell structure and its components. Cells can repair the damage if it is limited. Even damage to chromosomes is usually repairable; thousands of chromosome aberrations occur constantly in our bodies and the majorities are repaired spontaneously.

If a damaged cell needs to perform a function but does not have sufficient time to repair itself, it will be either unable to perform the repair function or perform the repair function incorrectly (incompletely). This could be damaging to other cells. These altered cells may become unable to reproduce themselves or may reproduce at an uncontrolled rate. Such cells can be the underlying causes of cancers. The cell may die if a cell is broadly damaged by radiation or if the damaged in such a way that the reproduction is affected.

Radiation damage to cells may depend on the sensitivity of these cells to radiation. Not all cells are equally sensitive to radiation damage. In general, cells that divide rapidly and/or are relatively non-specialized tend to show effects at lower doses of radiation then those which divide less rapidly and are more specialized. Examples of such radiation sensitive cells are those involved in the production of blood, this system (called the hematopoietic system) is the most sensitive biological indicator of radiation exposure. Radiation doses can be grouped into two categories: *acute* and *chronic*. An acute radiation dose is defined as a large dose (10 rad or greater to the whole body) delivered during a short period (about a few days at most). If the dose is large enough, the negative effects may appear within a short period (hours, days, or weeks). Acute doses can cause a pattern of clearly identifiable symptoms (syndromes). These conditions are referred to as Acute Radiation Syndrome. Symptoms of radiation sickness are apparent following the acute doses of more than 100 rad. acute doses of more than 450 rad may result in a statistical expectation of 50% of the exposed population to die within 60 days, without medical attention. As in most illnesses, the specific symptoms, the therapy that a doctor might prescribe, and the prospects for recovery vary from one person to another and are generally dependent on the age and general health of the individual.

The syndrome of bone marrow (blood-forming organ) which normally appears at doses higher than100 rad is characterized by damage to cells that divide at the most rapid pace (such as bone marrow, the spleen, and lymphatic tissue). Symptoms include internal bleeding, fatigue, bacterial infections, and fever.

Central nervous system syndrome at doses higher than 5000 rad is associated with the damage of nerve cells that are not reproducible. Symptoms include loss of coordination, confusion, coma, convulsions, shock, etc.

Other effects from an acute dose include 200 to 300 rad to the skin can result in the reddening of the skin. Similar to mild sunburn, and may result in hair loss due to damage to hair follicles; 600 rad to the ovaries or testicles can result in permanent sterility; and 50 rad to the thyroid gland can result in non-cancerous tumours. The effects caused by acute doses are called deterministic.

Humans and other organisms are continuously exposed to ionizing radiation from natural background sources in the environment, including cosmic radiation and Rn-222, alongside K-40 and C-14. This unavoidable exposure is not without consequences, as ionizing radiation exposure has been known to deliver a variety of injuries to DNA. Unfortunately, natural background is not the only source of ionizing radiation to which organisms are exposed. Numerous sites around the world have been contaminated with radionuclide, because of anthropogenic activity. Human exposure can be minimized by limiting access to contaminated areas, but this is generally not feasible for other species, and resulting exposures can be significantly higher than those from natural background sources. In general, radiation exposure may be internal or external.

Internal exposure comes from eating or drinking contaminated food or water, or from breathing contaminated air. A radioactive substance can also enter the body through cuts in the skin. Alpha- and beta- radiations contribute to internal exposure. External exposure can come from beta, gamma and X- ray; both internal and external radiation exposure can directly harm cells. When the body is exposed to radiation, the following events on the cell-level may occur:-

1- Radiation may pass through the cell without detectable damage.

2- It may damage the cell, but the cell may be able to repair the damage before producing new cells.

3- It may damage the cell in such a way that damage is passed on when new cells are formed.

4- It may kill the cell.

If the radiation passes through the cell without causing damage or the cell repairs itself successfully (number 1 and 2 above), there is no lasting damage or health effect. If the damage is passed on when new cells are formed (number 3 above), there may be a delayed health effect, such as genetic effects. When radiation kills a cell, there will be an acute (immediate) health effect if the dose is high and many cells die. Death may occur within days or weeks from the moment of exposure to radiation. Ionizing radiation acting on living system can result in biological endpoints, including tissue injury, carcinogenesis and death. The initial step in this interaction of radiation with biological material is the deposition of energy into atoms and molecules that results in ionization and excitation. Small quantities of energy from radiation exposure result from the non-uniform deposition of energy and through biochemical processes that amplify damage.

There are two actions of ionization radiation on cell. Firstly, the direct action, when a molecule is ionized and/or excited by the incident of radiation, as has already been stated, the extra portion of energy of the ionizing particle is used to remove an electron from a molecule. The remaining energy excites the molecule and can actually break molecules into smaller units that are identical because many larger molecules are composed of a chain of smaller molecules bonded together chemically. It appears that damage occurs at the same bond.

Direct action occurs within milliseconds of irradiation. This type of action causes a number of physical events that bring about the death of the cell. The radiation risk level depends on several factors, namely 1. The type of radioactive isotopes; 2. The radiation intensity and exposure period. Living organisms are affected differently by high or low levels of radiation sources; while, 3. The period of exposure also has a crucial effect on living cells. The effect of a low level of radiation (particularly with long time exposure) causes changes in DNA structure, which can result in different types of cancer and/or genetic transformations, called indirect action.

Free radicals result from radiation exposure; these are electrically neutral, having an unpaired electron in there outer orbits. Free radicals are formed by radiation when an atom is left with one of its outer orbital electrons unpaired with respect to spin. Free radicals are usually very reactive since they have a great tendency to pair the odd electron with a similar one in another free radical or to eliminate the odd electron by an electron transfer reaction. Free radicals can therefore be electron acceptors (oxidizing species) or electron donors (reducing species).

The simplest free radical is the hydrogen atom, which contains one proton and one electron. The most important radicals that may be involved in disease processes are species that maybe derived from molecular oxygen, and certain oxides of nitrogen, especially nitric oxide. An unpaired electron can be associated with almost any atom, but oxygen and carbon-centered free radicals are of the greatest biological relevance.

Sources of radicals are alcohol, cigarette smoking, stress, strain, anger, air pollution, and solar radiation.