# RADIATION HAZARDS AND SAFETY

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All types of radiation produce changes in the living tissues. The resultant cellular injury causes physiological and pathological changes leading to **"Radiation sickness"**. The radiation effects may be somatic or genetic. Somatic effects are harmful to a person in his lifetime whereas genetic effects affects generations.

Radiation may cause changes in complex molecular systems of living cells, primarily in following two ways-

1. **Direct interactions:** These appear when molecules of the body are modified due to absorption of energy of the incident photons of X-rays or any other radiation.
2. **Indirect interactions:** These appear due to the damage caused by the product of radiation decomposition (Radiolysis) of water and other solutes of the body.

**Direct interactions/effects:** These are brought about by following three important mechanisms-

**1. Thermalization**

This is a process where incident radiations (X-ray photons) agitate the living macromolecules in a non-destructive manner and in the process transfer their kinetic energy and thereby increase the temperature of the molecular system.
*Of course if the temperature of the material becomes too high, complex organic molecules may break apart* (i.e. *the material gets "cooked") resulting in destruction.*

Dr SP Tyagi

**2. Excitation**

This is a process whereby the incident radiation while traversing through the tissue force bound electrons to be "knocked" free from their parent atoms or molecules. These free electrons are then available to interact with other atoms and molecules within the irradiated system. Generally however the free electrons are quickly captured and their energy added to the overall thermal energy of the system with little or no other effect.

**3. Ionization**

This is a process whereby molecules absorb sufficient energy from radiation to break their molecular bonds. This causes the direct modification or destruction of complex molecules.

- ***Covalent bonds*** *and* ***ionic bonds,*** *the bonds between the atoms that form simple inorganic molecules such as sodium chloride (common table salt) have binding energies of about* ***2 to 5eV,*** *about one half the strength of the ionizing energies of individual atoms.*

- *Organic molecules, many of which are important in cell biology, have bond energies of about* ***0.04 to 0.3eV*** *and are typically referred to as "weak bonds".*

## Indirect effects:

The most abundant substance in cells is water. It is estimated that on average 80% of the biological system is water. It is because of this ubiquitous nature of the water in body, that the most of the energy of incident radiation is absorbed by the water molecules. These water molecules may sometimes be broken into highly reactive components particularly when high energy radiation is absorbed. The reactive components of the modified molecule are then available to react with complex organic molecules within the cell and causes damage.

When there is radiolysis of this water, free radicals $H^0$ and $Oh^o$ are produced with in the cells and after a series of reactions they will form hydrogen peroxide ($H_2O_2$) -

$$\mathbf{3(H_2O) + energy \rightarrow 3H^o + 3OH^o \rightarrow (H_2O_2) + 2\ H_20}$$

The $H_2O_2$ is a highly reactive oxidizing compound and can break chemical bonds in macromolecules of the body such as proteins, nucleic acid, lipids and other important molecules which regulate and control vital cellular functions thereby inflicting variable molecular damage. Although the cell is able to repair most molecular damage, excessive molecular damage can lead to cellular death or mutation.

Dr SP Tyagi

- *Many other reactions involving water molecules are known, the formation of hydrogen peroxide is merely one (although important) example.*
- *These biological effects of radiation are enhanced by the presence of oxygen which is always present in the cells.*

**<u>Radio sensitivity of different body cells:</u>** Radiation sensitivity refers to the loss of reproductive capability of the proliferating cells.

Regularly proliferating cells are more sensitive. Therefore, stems cells of haemopoietic systems and cells of the gut, skin & testes are highly radiosensitive whereas, cells of nerve and muscles are relatively radio-resistant.

Different body cells in order of decreasing radio-sensitivity -

Lymphoid cells
Epithelial cells of the small intestine
Haemopoietic cells
Germinal cells
Epithelial cells of the skin
Connective tissue cells
Cartilage and growing bone cells
Cells of the brain and spinal cord
Cells of the skeletal muscles and mature bone ↓

**Early Vs late radiation effects:**

**Early effects-** The intensive irradiation of the entire body severely depletes radiosensitive cells in many organs simultaneously. The combined effect produces "Radiation sickness". These effects appear within days or weeks after exposure.

| **Time after exposure** | **Supra-lethal dose(1000 rad)** | **Medium lethal dose(500rad)** | **Sub-lethal dose(200rad)** |
|---|---|---|---|
| *First day* | Nausea & vomition | | |
| *First and second week* | Nausea, vomition., diarrhoea, fever, throat inflammation, prostrations, dehydration, emaciation leading to death | | |
| *Third week* | | General malaise. Haemorrhage, loss of appetite, pallor, fever, diarrhoea, throat inflammation, emaciation leading to death in 50% of cases | Loss of appetite and hair, inflammation, haemorrhage, diarrhoea |

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**Delayed effects of radiation:** These appear after months or even many years of radiation exposure. These effects include shortening of life span, leukemia, malignant tumors and cataract.

## Measurement of radiation:

- *Unit which measures the energy of an X-ray is called Electron volt (eV).*
- 1000eV = keV(Kilo electron volt)

There are several units used to measure levels of ionizing radiation

1. **Roentgen (R)** - It is the quantity of X-rays or gamma radiation which produces one electrostatic unit ($2.08 X 10^9$ pairs/$cm^3$) in 1c.c. of dry air after its ionization at $0^0$ c and 760 mm Hg. **Not used for particle radiation.**

   This unit(R) does not describe dose to tissue. The unit **rad** (Radiation absorbed dose) is used as a unit of absorbed dose following exposure to any type of ionizing radiation.

2. **Rad:** One rad is equal to the radiation necessary to deposit energy of 100 ergs in 1 gm. of irradiated material (100 ergs/gm.). **Used for all types of ionizing radiation**.

3. **Rem**(Roentgen equivalent man): It is another unit and one rem is equal to rad X quality factor. The quality factor for X-rays and gamma rays is one.

4. A unit called the *dose equivalent* is the mSv (millisievert). It is becoming a commonly used unit to measure equivalent absorbed dose.

   The ***sievert* (Sv)** is an absorbed dose of 1J/kg (as stipulated by the International Commission on Radiological Protection)

   The units of measurement are mSv (1 mSv = 100 mrem).

| Species | Lethal Dose (Sv (sieverts)) | Species | Lethal Dose (Sv (sieverts)) |
|---|---|---|---|
| Dog | 3.50 | Rabbit | 8.00 |
| Guinea Pig | 4.00 | Chicken | 6.00 |
| Hibernating Bat | 200.00 | Sparrow | 8.00 |
| Human | 2.50-4.50(?) | Goldfish | 23.00 |
| Mouse | 5.50 | Frog | 7.00 |
| Monkey | 6.00 | Tortoise | 15.00 |
| Pine Tree | 8.00-15.00 | Snail | 80-200 |
| Rat | 7.50 | Viruses | .50-2000 |

- *The lethal exposure for humans is not well known due to a lack of data and an understandable unwillingness for individuals to volunteer as prospective subjects for such a study.*

Dr SP Tyagi

**Maximum permissible dose (MPD):** It is a level at which any appreciable injury is unlikely to be manifested in the lifetime of an individual.

MPD for veterinarians and radiographic staff---

| Body part | One week | One year |
|---|---|---|
| Whole body, gonads, bone marrow, lens of the eye | 100 m rem | 5000 m rem |
| Hand, forearms and feet | 1500 m rem | 75000 m rem |

## <u>RADIATION PROTECTION</u>

**General principles of radiation safety-**

1. <u>Increase the distance between radiation source and personnel</u>

- Only the minimum required personnel should be present inside X-ray room during exposure.
- The patient should preferably be restrained by chemical methods and not manually.
- A cassette holding device should be used whenever possible.

- The operator should be behind shielding screen or at least 6 feet away from X-ray source.

2. Use of protective barriers

   Protective barriers are necessary to protect oneself from scattered radiation.

- Aprons- Aprons should have a minimum of 0.25 mm lead equivalent for voltage up to 100 kV.
- Gloves and goggles- Lead equivalent should not be less than 0.33 mm for voltage up to 100 kV.
- X-ray room and shielding equipments-
  - The wall of X-ray room should be of at least 22 cms thick concrete.
  - The wall should be painted with radiation absorbent paint.
  - When there is possibility of X-ray beam consistently directed horizontally, the wall should have a lead lining sandwiched between plywood.
  - Whenever possible X-ray operator should be in a lead shielded cabin during exposure.

3. Use of optimal exposure factors and reduction of unnecessary radiography

- Different radiographic accessories which reduce exposure factors (*e.g.* intensifying screens) should be used along with correct exposure factors.
- Radiography should not be done just because of owner's wish; a radiologist should decide its necessity.

Dr SP Tyagi

4. Use of radiation monitoring devices

- The personnel involved in regular radiography should wear a radiographic monitoring device (Radiography badge) so that total exposure to that person can be ascertained and accordingly he/she may be rested from radiological work in case of overexposure than the prescribed limits.
- A busy radiographer should get his badge checked every month; a less busy radiographer may get it checked every three month.

5. Consideration for sex and age of the personnel involved

- Person under 18 years of age should not be involved in radiographic work because of the sensitivity of their growing tissues.
- Similarly due to sensitivity of ova and embryos at certain stage of development, pregnant, potentially pregnant and women during menstrual cycle should avoid X-ray work.