# 36

# RADIOACTIVE POLLUTION

In the previous lesson we have discussed the harmful effects of some heavy metals and how to reduce these effects. In this lesson we will discuss about the radiations which are the cause of radioactive pollution. These radiations are emitted by radioactive decay of unstable heavy atoms nuclei. Exposure of these radiations can cause damage to living cells and environment.

Concern for radioactive pollution increased after the discovery of artificial radioactivity, development of nuclear weapons and installation of nuclear reactors for generating electricity. In this lesson, we shall discuss the possible threat to human health and environment due to nuclear radiations both from natural and anthropogenic (man-made) sources. Methods for the safe disposal of nuclear waste materials will also be discussed.

## Objectives

After reading this lesson, you will be able to :

- list various radioactive sources;
- account for the release of radioactive products resulting from nuclear waste and nuclear accidents;
- enumerate the ill-effects of radioactive radiation on human body;
- list the various preventive measures of radioactive pollution and
- list the various regulations regarding safety measures for radiation exposure.

## 36.1 Radiations and Radioactivity decay

Radiation is energy travelling through space. Energy can be transported either in form of electromagnetic waves (radiations) or a stream of energetic particles, which can be electrically charged or neutral.

These radiations are of two types :

(1) Non-ionizing radiations

(2) Ionizing radiations

**Non-ionizing radiations** are the electromagnetic waves of longer wavelength from near ultraviolet rays to radiowaves. These waves have energies enough to excite the atoms and molecules of the medium through which they are moving, causing them to vibrate faster. These do not have enough energy to ionize them.

**Ionizing radiations** are the electromagnetic radiations having high energy, such as short wavelength ultra violet radiations, *x*-rays and gamma rays. The energetic rays like ($\alpha$, $\beta$ and $\gamma$ etc.) produced in radiocative decay can cause ionization of atoms and molecules of the medium through which they pass and convert them into charged ions.

For example in water molecule, it can induce reaction that can break bonds in proteins, DNA and or other importants molecules.

Alpha ($\alpha$), beta ($\beta$) and gamma ($\gamma$) radiations are produced by the process called **radioactive decay.** The unstable nuclei decay spontaneously and emit these radiations. These rays (radiations) can affect some other non-radioactive atoms to become radioactive (unstable) and give out radioactive radiations.

## 36.2 Radioactive Pollution and their Sources

Living organisms are continuously exposed to a variety of radiations called background radiations. If the level of the radioactive radiations increases above a certain limit it causes harmful effects to living beings. This harmful level of radiations emitted by radioactive elements is called **radioactive pollution**.

There are two sources of radiation pollution, namely natural sources and arthropogenic sources.

### 36.2.1 Natural Sources of Radiation

(i) Atomic radioactive minerals are one of natural sources of radioactive pollution. During mining of uranium, radon gas is constantly released into the air. The parent of radon-222 ($t_{½}$ = 3.82 days) is radium 226 which has a half-life of 1602 years. Radium-226 is widely distributed in rocks, sediments and soils along with isotopes of uranium. Radioactive radiations from these natural sources are known as natural or background radiation.

(ii) Cosmic rays are high energy ionizing electromagnetic radiation. The cosmic rays originate from the stars in our galaxy by virtue of nuclear reactions primarily in their cores. The cosmic rays are constantly reaching the earth from outer space.

(iii) Naturally occurring radioisotopes such as radon-222 found in soil in small quantity is another source of radioactive radiations.

(iv) Radioactive elements which like uranium, thorium, radium, isotopes of potassium (K-40) and carbon (C-40) occur in the lithosphere.Potassium-40 contributes radioactivity to all potassium containing systems in the soil. Crops grown on such soil contain radioactive elements like carbon-14 and potassium-40. Water gets contaminated with various radionuclides when it runs through soils and rocks containing radioactive minerals.

We live in an environment of natural radiations there is a certain amount of radioactive radiations almost everywhere on the earth. These are only rarely harmful as the radiation level is generally quite low. This small level of radioactive radiation which is present everywhere is called the background radiation.

### 36.2.2 Anthropogenic Sources of Radiation

The following human activites add to the source of radioactive pollution:

(i) **Diagnostic medical applications :** Radiations are employed for diagnostic and therapeutic applications. *X*-rays are used in general radiology and CT scan. Gamma rays are used in treatment of cancer. In all these procedures we are exposed to varying doses of radiations.

(ii) **Nuclear Tests :** Nuclear explosion tests especially when carried out in the atmosphere are a major cause of radiation pollution. It is responsible for increasing the background level of radiation throughout the world. During atmospheric nuclear explosion tests, a number of long-lived radionuclides are released into the atmosphere. This **radioactive dust** (also known as **radioactive fall out**) gets suspended in air at a height of 6 to 7 km above the earth's surface and is dispersed over long distances by winds from the test site. These radionuclides often settle down by rain and get mixed with soil and water. From there they can easily enter the food chain and finally get deposited in the human body where they cause serious health hazards. Some of the radioactive isotopes given off during nuclear test affect the human body.

India exploded its nuclear device (equivalent to 12 kilotons of Tri Nitro Toluene) in an underground tunnel at a depth of 107 meters in the Thar desert near Pokharan in 1974. No radioactivity is said to have been released into the surroundings. Again in May, 1998 India conducted nuclear tests without any fall out of radioactivity into the surroundings.

(iii) **Nuclear Reactors :** Radiations may leak from nuclear reactors and other nuclear facilities even when they are operating normally. It is often feared that even with the best design, proper handling and techniques, some radioactivity is routinely released into the air and water.

However, dangers of radiation leakage are from possibility of accidents that could result in the release of radioactive material which raises the level of radioactive (ionizing) radiations. Such accidents took place at the 'Chernobyl nuclear power plant' in USSR in 1986 and at the 'Three Mile Island Power Plant' in USA in 1979.

The accidents of 'Three Mile Island' plant in Middletown (U.S.A.) in 1979 and at Chernobyl nuclear power plant (U.S.S.R.) in 1986 were the worst disasters in the history of nuclear power industry. In both incidents, a series of mishaps and errors resulted in the overheating of the nuclear core. In both cases radiation was released in the atmosphere. The leakage from the 'Three Mile Island' nuclear reactor has been claimed to be very low with no immediate injuries to workers or people. But the leakage at Chernobyl was very heavy causing death to many workers and radiation was spread over large areas spread all over Europe.

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Nuclear fission converts some tadioactive fuel in the reactors to some other radioactive fragments. These reactions produce a lot of heat and therefore the core of the reactor containing fuel rods cooled by water circulation to avoid a meltdown of the fuel rods. If a meltdown happens by accident, it will release a large quantities of highly dangerous radioactive materials into the environment. In order to avoid this type of very serious mishap nuclear reactors are designed to have a number of safety features and it is very unlikely that a reactor would blow up.

Although a core meltdown is highly unlikely, but it is possible. For example, the loss of coolant due to some material failure, would allow the reactor core to overheat and eventually meltdown the fuel rods. Another possibility is the build up of some gas or steam inside the reactor vessel which would blow off the top and release large clouds of radioactive materials in the atmosphere resulting in death and injury to thousands of people.

(iv) **Nuclear explosions :** Nuclear explosions are a serious source of radiations hazard. The effects of atomic explosions in Nagasaki and Hiroshima are still not forgotten.

(v) **Nuclear Wastes**

When uranium-235 nuclei split in a nuclear reactor, they break into fission products

$$^{235}_{92}\mathrm{U} + {}^{1}_{0}\mathrm{n} \longrightarrow {}^{141}_{56}\mathrm{Ba} + {}^{92}_{36}\mathrm{Kr} + 3{}^{1}_{0}\mathrm{n} + \mathrm{Energy}$$

which are also highly radioactive. Since one uranium atom splits into two radioactive products, there is a doubling of the number of radioactive atoms on the earth. Furthermore. uranium-235 has a half-life of more than 700 million years. Some of its fission products have shorter half-lives and decompose much faster than uranium and emit higher levels of radiations. There is no method by which we can increase or decrease the rate of decay of these products. The wastes of nuclear reactor emit dangerous radiations for thousands and thousands of years. Since it is not possible to destroy these radionuclides, they must be stored somewhere on this earth in order to ensure least harm to humans.

Plutonium-239 is another nuclear waste. The plutonium-239 isotope is produced as a by-product during uranium fission. It is an alpha particle emitter and has a long half-life of 24000 years. After about 1000 years or more, the main radioactivity from fuel rods of the nuclear reactors will be from plutonium and other such heavy elements, since by then most of the other nuclides produced in fission and having much shorter half-life will have decayed to a large extent. Plutonium is one of the deadliest poisons known. Plutonium does not occur naturally on earth. This element is produced either in nuclear reactors or in nuclear weapons programme. The plutonium produced today will have to be taken care of for thousands of years by future generations. The general approach in dealing with radioactive wastes is to concentrate and contain as much radioactivity as possible. Effluents containing only very low level of radioactivity are allowed to be discharged into the environment.

Radon can diffuse through rocks and soils into the atmosphere. Once the radon reaches the atmosphere it can be breathed in. The transformation into lead is very significant because the solid radioactive particles are trapped in the lungs and are acutely harmful.

(vi) Nuclear material processing. Many radioactive minerals are processed to extract radioactive metals. Several compounds of radioactive elements are also produced and processed, for various uses. All those who handle these materials are at a greater risk of man-made radioactive pollution.

Notes

## Intext Questions 36.1

1. What are ionizing radiations?

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2. Name any of the two sources of radioactive pollution in nature.

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3. Name three man-made or anthropogenic sources of radioactive pollution.

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4. What were the two accidents in the past which led to high radioactive leakage.

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5. What happens when a neutron strikes uranium-235?

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## 36.3 Biological Effects of Ionizing Radiation on the Human Body

In the last few decades, number of people being exposed to ionizing radiation has increased tremendously, especially people involved in the mining of uranium ores, patients treated with $\gamma$-radiations and technical people using *X*-rays and other radioactive isotopes. Before the dangers of radiation on human body were known, workers dealing with radioactive materials were careless and suffered from various types of cancer. Early workers who used phosphorescent radium paint on the dials of watches suffered from bone tumors in 1920s.

Exposure to any type of ionizing radiation (~ and  particles, ¥-rays and *X*-rays) can prove harmful and even lethal. The two types of effects are :

(i) **genetic** and

(ii) **nongenetic** or **body damage.**

In **genetic damage,** genes and chromosomes get altered. Its effect may become visible as deformations in the offsprings (children or grandchildren). Alterations or breaks in the genetic material, that is DNA (deoxyribonucleic acid)- the molecule containing genetic information, is called **mutation**. In **nongenetic effects**, the harm is visible immediately in the form of birth defects, burns, some type of leukemia, miscarriages, tumors, cancer of one or more organs and fertility problems.

**Table 36.1 : Effects of radioactive radiation on living beings**

| Type of radiation | Effect on the body |
|---|---|
| $\alpha$-particles | Generally they cannot penetrate the skin. But if their sources is inside the body, they can cause damage to bones or lungs. |
| $\beta$-particles | Can penetrate the skin but cannot damage the tissues. They can cause damage to skin and eyes (cataract). |
| $\gamma$-radiation | Can easily penetrate the body and pass through it. They cause damage to cell structure. |
| X-rays | Can travel very far and pass through the body tissues except bones. They can cause damage to the cells. |

## 36.4 Radiation Doses and Radiation Effects

The biological damage caused by the radiation depends upon the following factors :

(i) the time of exposure

(ii) the intensity of radiation

(iii) the type of ionizing radiation (i.e. its penetration power)

(iv) whether the radiation is emanating from outside or inside the human body.

On account of these factors the absorbed (or simply doses dose) designated as D, of the radiation to be the amount of energy deposited into a region of the body divided by the mass of the portion of the body that absorbed the radiation.

The MKS unit of absorbed dose is ‘gray’ (Gy), thus one gray is one joule of energy deposited per kg of mass. More traditional unit of absorbed doses is **radiation absorbed dose** (rad). One rad is equivalent to 0.01 Gy. Biological damage caused by a particle depends not only on the total energy deposited but also on the rate of energy loss per unit distance traversed by the particle. For example, alpha particles do much more damage per unit energy deposited than do electron ($\beta$-particles). This effect is represented by the quality factor Q taken 0 for electron and 20 for alpha particle.

The biological impact is specified by the human equivalent dose H, which is the product of the absorbed dose D and the quality factor Q : H = QD. The MKS unit of the human equivalent dose is called the sievert, Sv.

A traditional unit of human equivalent dose is the rem, which stands for radiation equivalent in man, 1 rem = 0.01 Sv.

At low doses such as what we receive every day from background radiation (< 1m rem), the cells repairs the damage rapidly, At higher doses (upto 100 rem), the cell might not be able to repair the damage, the cell may either be changed permanently or die. Cells changed permanently may go on produce abnormal cells when they divide and may become canerous.

Table 36.1 shows the effects of different radiations on the body. These radiations reach human system from natural and anthropogenic sources.

Alpha ($\alpha$) and beta ($\beta$) particles can cause burns to skin on high level of exposure from outside but they cannot penetrate the skin to cause internal damage. However, if a radioactive isotope which can emit alpha or beta particles is inhaled or ingested in the body the particles can then cause serious damage to nearby tissues. They may affect the replication of cells and induce tumor formation. The damage inside the body from beta particles is lower than that from the alpha particles of the same energy. Gamma ($\gamma$) rays and high energy neutrons are so much penetrating that they pass through the body easily and can cause cellular damage both from outside or inside the body.

Rapidly growing tissues of embryo are very sensitive and therefore pregnant women should avoid exposure to radioactivity and *X*-rays unless they are very essential. Although the medical use of *X*-rays may involve very low levels of radiation but even such exposures if carried out frequently can result in a significant increase in the dose of ionizing radiation and involves definite risks. The use of radio-isotopes and gamma ray irradiation for cancer treatment can lead to fairly high dosages of radioactivity.

An increase in the altitude, where an individual lives determines the dose received from cosmic radiation. For example, an increase in an altitude of 2000 meters doubles the dose of radiation due to cosmic rays from outer space. The effect of radiation may be immediate or delayed.

## Intext Questions 36.2

1. What is radiation absorbed dose (rad)?

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2. What as the effect of radiations on human body?

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3. What are the factors or which the biological damage by radioactive radiations depends?

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## 36.5 Preventive Measures from Nuclear Radiation

The following preventive measures my be adopted to reduce the effects due to both natural and artificial radiations:

(i) Atomic explosions should not be carried out in the atmosphere.

(ii) In nuclear reactors, closed cycle coolant system may be employed, so that no radiation leakage through coolant can take place.

(iii) Radioactive wastes generated by nuclear reactors or from nuclear weapons programme must be disposed in a manner that they will do the least harm. First, the wastes may be stored at some place temporarily to allow for the initial, very intense, radioactivity to die down by natural decay. Nuclear wastes should always be sealed in double-walled tanks so that no leaks may take place. In the second stage, some useful isotopes generated during fission in the reactors may be recycled in reprocessing plants. Finally, a permanent storage space for the wastes in geologically stable underground deep mines should be established It has been suggested that these wastes may be stored till the wastes are reduced to the same radioactivity level as that of a natural uranium mine.

(iv) Production and use of radioisotopes should be minimum and only for very essential use because radioisotopes once produced cannot be destroyed by any means except by the passage of time.

(v) The number of nuclear installations should be minimised so as to limit the emission of radio-pollutants.

(vi) Fission reactions should be minimized.

(vii) In nuclear mines, wet drilling may be used and tailings properly sealed and protected for radiation leakage.

(viii) Industrial wastes contaminated with radionuclides be disposed off carefully in specially built tanks.

(ix) Working places where radioactive emissions are possible should have high chimneys and good ventillation system.

(x) In areas where there is a risk of radon leakage from underground. radon concentrations be monitored and protection measures be installed in buildings and homes.

## 36.6 Regulations Regarding Safety Measures

The executive agency for all activities related to atomic anergy is Department of Atomic Energy (DAE) which was established in 1954. The sites for nuclear installations are chosen with safety parameters in view. A number of physical barriers are designed which checks any significant escape of radiation from the reactor. The radiation dosage received by workers are monitored on a monthly basis. The Atomic Energy Regulatory Board (AERB) has fixed the dose limit to 30 millisievert (mSv) for workers. This is in agreement with the limit set up by International Commission on Radiological Protection (ICRP).

The atomic Energy Regulatory Board, an autonomous body of Atomic Energy Commission, carries out all regulatory and safety functions as envisaged under the Atomic Energy Act, 1962 covering all establishments of Department of Atomic Energy. It is also empowered to take decision with regard to site selection, design, construction and commissioning, operation, etc. of all nuclear installations.

### Intext Questions 36.3

1. How the radioactive waste management should be done?

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2. How can we safeguard ourselves from radiation originating from tailings?

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3. What the dose limit is fixed for the workers of nuclear installations?

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Notes

## What You Have Learnt

- Nuclear radiations are emitted in the atmosphere through natural sources and man made sources.
- Radiations due to natural sources are due to uranium and other radioactive elements which occur in nature and on disintegration may yield other radioactive isotopes. The prominent amongst them is radon-222 gas.
- Man-made sources of radiation include :
  (i) medical diagnostic tests using radioisotopes
  (ii) nuclear tests conducted in the atmosphere
  (iii) nuclear reactors for research and power
  (iv) nuclear accidents
  (v) nuclear explosion
  (vi) nuclear waste
  (vii) production and handling of nuclear material.
- Ionising radiations can cause mild to very serious effects on the health of humans on exposure and may even lead to death. Some ill effects continue to pass on to future generations.
- Various steps have been suggested by which radiation leakage can be minimized.

## Terminal Exercise

1. Do the cosmic rays act as radioactive pollutant?
2. Which type of radiations are damaging for human health?
3. Define the term 'Background Radiation'?
4. What are the different man-made sources of radiation pollution?
5. What are the effects of ionizing radiation on human health?
6. What are the preventive measures for radiations?

## Answers to Intext Questions

### 36.1

1. These are the electromagnetic radiations of short wavelength or charged particles (like $\alpha$ and $\beta$-particles) which can cause ionization of atoms or molecules.
2. Weathering of minerals, cosmic rays from outer space, radioactive elements occurring in nature. (Any two)
3. Nuclear waste, nuclear reactors, nuclear accidents.
4. The accident of 'three mile Island' in Middle Town (U.S.A) in 1979 and at Chernobyl nuclear power plant (U.S.S.R) in 1986.

Notes

5. Uranium-235 splits into two fission products with the production of three neutrons and lot of energy. The split products are also radioactive. The reaction is known as a nuclear fission reaction.

$$^{235}_{92}U + {}^{1}_{0}n \longrightarrow {}^{141}_{56}Ba + {}^{92}_{36}Kr + 3{}^{1}_{0}n + \text{Energy}$$

## 36.2

1. Radiation absorbed dose (rad) is the unit of adsorbed dose. It is defined as the amount of energy deposited into a region of the body divided by the mass of the portion of the body that absorbed the radiations.

2. Both the effects are observed on human body : (i) gentic and (ii) non-genetic (body damgage). In genertic effects are observed in offsprings. In non-genetic effects harms are visible as burns, miscarriages, leukemia, cancer, etc.

3. Biological damage by radiatins depends upon :
(i) the time of exposure;
(ii) the intensity of radiation;
(iii) the type of ionizing radiations and
(iv) radiations emanating from outside or inside of body.

## 36.3

1. Radioactive waste should be disposed of properly and storing should be done carefully in double walled tanks, storing of these waste should be done till it comes to its natural level of radioactivity.

2. Refer to section 36.5.

3. Dose limit fixed for workers is 30 m Sv.