Radioactive Pollution

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Introduction

We live in a radioactive world and human beings have been exposed to radiation from natural sources from the time of their appearance on this planet. These sources of radiation include natural radioactive materials in our surroundings, natural radioactive materials in our bodies and the cosmic radiation that enter our earth's atmosphere from outer space. Since the discovery of radioactivity by a French scientist by the name of Henri Becquerel in 1896, and the development of the uses of nuclear technology that followed, human beings have been also exposed to radiation from manmade sources. On a global scale, exposure to natural sources of radiation is greater than the exposure to manmade sources of radiation.

This article describes what radioactive materials are, the health effects of exposure to radiation, measures taken to control such exposure, and the sources of radioactive pollutants.

Radioactive materials and radiation

As we know, everything on this earth is made of atoms. A material that has only one type of atom is called an element. For example, carbon, oxygen and hydrogen are elements. An atom consists of a nucleus surrounded by moving electrons, as shown in Fig.1. The nucleus contains two types of particles known as protons and neutrons. The element to which an atom belongs depends on the number of protons. For example, all carbon atoms have 6 protons, oxygen atoms 8 protons and hydrogen atoms 1 proton. The atoms of a given element can have different numbers of neutrons. For example, carbon atoms can have 6, 7 or 8 neutrons in the nucleus, in addition to 6 protons. Atoms of the same element with different numbers of neutrons are known as isotopes.

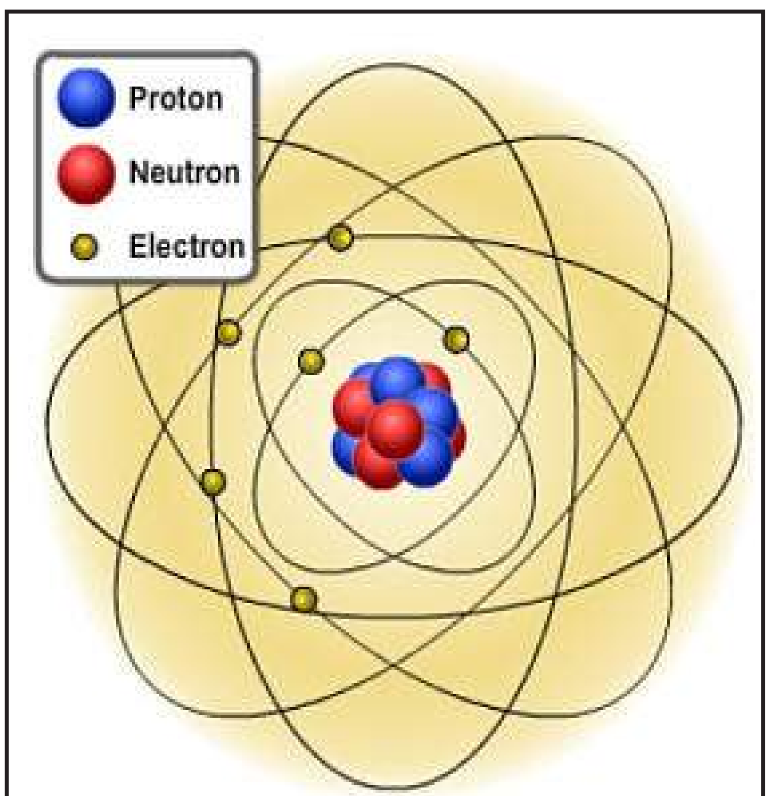

Figure 01 : Structure of anatom

Some of these isotopes are stable, but some are not. Isotopes with too many neurons or too few neutrons compared to the number of protons are unstable. For example, carbon atoms with 6 or 7 neutrons (Carbon -12 and Carbon 13) are stable but carbon atoms with 8 neutrons (Carbon-14) are not. Unstable atoms try to become stable by emitting particles, usually accompanied by emission of energy in the form of waves. (Electromagnetic waves). The particles emitted are of two different types called alpha and beta and the waves are known as gamma radiation. The isotopes that behave in this manner are called radioactive isotopes or radioisotopes and the particles and electromagnetic waves emitted are collectively called radiation or more correctly, ionizing radiation. This is to distinguish it from other types of radiation such as radio waves and microwaves that do not have enough energy to produce ionizations (i.e. removal of electrons from the influence of the nucleus of an atom).

The presence of radioactive materials can be easily detected by using devices that detect the radiation emitted (i.e. alpha and beta particles and gamma radiation). It is possible to identify the presence of radioactive materials in extremely small concentrations, which could be as low as 1 part in 10^9.

Exposure to radiation and its effects

The health effects due to exposure to ionizing radiation depend on the amount of energy absorbed by the cells in our bodies from radiation. The amount of energy absorbed by a unit mass of body tissue is called the radiation dose. Radiation dose is measured using a unit called Grays (Gy). The dose with a correction factor to account for different types of radiation is called the dose equivalent and is measured using a unit called the Sievert (Sv). Persons exposed to extremely high doses in the range of 3-5 Gy could experience severe health effects and could die within a few days. Many of the Japanese atomic bomb victims received such high radiation doses. These effects are known as acute effects of radiation and are deterministic, i.e. the effects are seen in all those who are exposed.

There would not be immediate health effects in those who are exposed to lower doses of radiation, but could experience cancer and leukemia several years after the exposure. These are called chronic effects. Chronic effects unlike acute effects are stochastic, i.e. all those who are exposed will not be affected, but an average increase in the above mentioned diseases could be seen in a large population. An international organization known as the United Nations Scientific Committee on Effects of Atomic Radiation (UNSCEAR) had been engaged in studying the effects of ionizing radiation on human beings since its inception in 1955. Based on the studies conducted on the Japanese bomb victims who were exposed to lower levels of radiation and survived, cancer patients who had received radiotherapy and other sources, UNSCEAR had estimated that the additional chance of dying of cancer due to radiation exposure above 100 mSvto be about 0.3 to 0.5 in a hundred per 100 mSv. In other words the chances of getting cancer as a result of being exposed to a dose equivalence of 1 mSv are about 1 in 20,000 to 1 in 33,000. Exposure of pregnant mothers to radiation could have an effect on the embryo. UNSCEAR had estimated that no more than two out of every 1 000 live-born children who have been exposed to a dose equivalent of a hundredth of a Sievert in the womb might be affected—compared with the 6 per cent who develop the same effects naturally.

Sources of Radiation

As mentioned earlier, all human beings are continuously exposed to radiation from natural sources. The dose equivalent rate from natural sources varies depending on the location on the earth, and has a range of 1.0 mSv per year to 12.4 mSv per year. (1Sv=1000 mSv). The global average is 2.4 mSv per year.

We are also exposed to radiation from a number of manmade sources. The highest doses received from manmade sources are due to use of radiation for medical diagnostics and therapy. A typical X-ray examination will expose a person to about 0.1 mSv. The CT scan of the abdomen will give a dose equivalent of about 10 mSv. Nuclear power plants expose the population living in their vicinity to a very small dose during normal operation. United Nations Environmental Programme had estimated the average dose equivalent received by a person living in the vicinity of a nuclear power plant to be about 0.0001 mSv per year. (Exposure during accidents are described under sources of radioactive pollutants) A summary of the dose equivalents from natural and manmade sources is given in Table 1.

Measures taken to regulate exposure to radiation

Since the discovery of the harmful nature of ionizing radiation, action had been taken to regulate human exposure to radiation. This is done through a regime of standards, laws, rules, regulations and codes of practices. The current international standard used is known as "International Basic Safety for Protection against Ionizing Radiation and for the Safety of Radiation Sources". This is a standard jointly adopted by the International Atomic Energy Agency (IAEA), World Health Organization (WHO), International Labor Organization (ILO), and Food and Agriculture Organization (FAO) of the United Nations and the Nuclear Energy Agency of the Organization for Economic Cooperation and Development (OECD/NEA).

Within the framework of this standard, all countries that use nuclear technology for power generation and for a number of other purposes mainly in the medical, industrial and agricultural sectors, have promulgated their own laws and regulations and have established regulatory bodies to implement them. In Sri Lanka, the national body responsible for regulating the uses of radiation and radioisotopes is the Atomic Energy Regulatory Council, which functions under the Ministry of Power and Energy.

According to national regulations it is mandatory for all users of radiation and radioisotopes to obtain a license from the Regulatory Council. All activities connected with the use of radiation and radioisotopes should be carried out according to the conditions stipulated in the licenses. Inspectors of the regulatory authority periodically inspect the facilities to ensure safety. No activity that will expose the general public to a dose equivalence of more than 1 mSv per year is allowed.

The regulations also specify the maximum permissible levels of radioactive contaminants allowed in water, food and air in order to limit the radiation dose equivalence levels to the public to 1 mSv per year. The regulations also stipulate the measures to be taken in handling and storing radioactive materials and managing radioactive waste. It is beyond the scope of this article to provide a comprehensive description of all regulatory measures. More details can be obtained from the web-site of the Atomic Energy Regulatory Council; *www.aerc.gov.lk*.

Radioactive Pollutants

Radioactive materials released to the environment above limits allowed by radiation protection regulations can be considered as radioactive pollutants. The main sources of radioactive pollutants include, the tests that had been carried out on nuclear weapons in the past, accidents at nuclear power plants, accidents at other nuclear facilities, improper management of radioactive waste and mining and mineral processing operations.

Over 500 of nuclear weapons had been tested up to 1980 with a total explosive power of 430 MT of TNT equivalent. These tests released radioactive materials produced in the nuclear explosions to the atmosphere. Testing of nuclear weapons is now prohibited

Table 1 : Average Public Exposure by Radiation Source

Natural Sources		Manmade Sources	
Source	Annual Dose Equivalent (mSV)	Source	Annual Dose Equivalent (mSV)
Food	0.29	Nuclear power plants	0.0002
Cosmic radiation	0.39	Chernobyl accident	0.002
Soil	0.48	Fallout from weapons testing	0.005
Radon	1.3	Nuclear medicine	0.03
		Radiology	0.62
Total	2.4	Total	0.65

under an international treaty known as the Comprehensive Test Ban Treaty (CTBT). The radioactive fallout from these tests produced an average dose equivalent of about 0.11 mSv per year in 1963 around the peak of nuclear weapons testing. The current dose equivalent is about 0.005 mSv per year.

There had been 35 severe radiation accidents in nuclear facilities since 1945, which resulted in deaths or serious injuries to the employers of these facilities. They also released radioactive material to the environment, exposing populations living close by to detectable levels of radiation.

There had been three major accidents in nuclear power plants. The first accident occurred at the Three Mile Island nuclear power plant in the USA, on 28th March 1979. A series of events, compounded by faulty response of the plant operators caused a partial meltdown of the reactor core, which contains reactor fuel and the radioactive material produced during the operation of the plant. The accident released a large amount of radioactive material to the containment building of the plant (the concrete structure that surrounds the reactor), but the release of radioactive material to the environment was very low. The most severe accident at a nuclear power plant occurred in the Chernobyl nuclear power plant in Ukraine on the 26th of April 1986. An attempt by the operators to conduct an experiment on the reactor after disabling a number of safety systems grossly overheated the reactor core. This particular type of reactors (unlike most reactors in operation at present) had a core made of graphite and uranium fuel. The high temperatures made the graphite core catch fire and produce combustible gases in chemical reactions with cooling water, resulting in a chemical explosion. The radioactive material released from the accident spread over a number of European countries. About 30 fire fighters who responded to the emergency were exposed to very high levels of radiation (acute exposure) and died within a few days.
The radioactive contamination of milk (by radioactive iodine) produced thyroid cancer among 6000 children, with 15 fatalities. International experts had concluded that the accident had caused 4000 additional cancers among those who were exposed to higher levels of radiation, i.e. emergency workers, evacuees and residents of the most contaminated areas.
An earthquake of magnitude 9.0 on the 11th of March 2011, followed by a tsunami disabled the cooling systems of the Daiichi-Fukushima nuclear power plant in Japan and caused a partial meltdown of the reactor cores of 4 units of the plant in operation at the time of the accident. About 85,000 residents living within 20 km from the power plant were evacuated to reduce their exposure to radiation. A study conducted by UNSCEAR had estimated the dose equivalent to persons in the evacuated areas of Fukushima prefecture during the first year after the accident to be between 1 mSv and 10 mSv.
Improper disposal of low and intermediate level radioactive waste in the sea in the past had also produced radioactive pollution. This practice is no longer permitted. Low level and intermediate level wastes are currently disposed of in specially designed facilities, and high level waste that are produced in nuclear power plants are presently stored in storage ponds inside the reactor buildings of the power plants. They should be eventually disposed of in a manner that will not expose the public to radiation.

Mining and processing of materials that contain naturally occurring radioactive material (NORM) such as uranium and thorium also cause radioactive pollution. Examples are mining and smelting of metals, production of phosphates, coal mining, rare earth and titanium oxide industries.

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