

# Nuclear Energy in Everyday Life



**energy**

Department:  
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## Understanding Radioactivity and Radiation in our Everyday Lives

Radioactivity is part of our earth – it has existed all along. Naturally occurring radioactive materials are present in the earth's crust, the floors and walls of our homes, schools, and offices and in the food we eat and drink. Our own bodies- muscles, bones and tissues, contain naturally occurring radioactive elements.

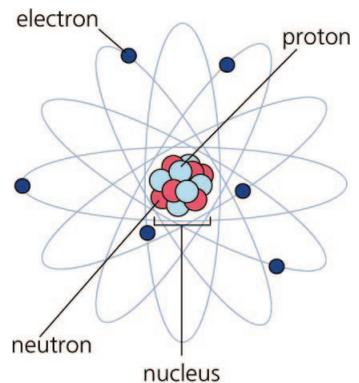
Man has always been exposed to natural radiation arising from earth as well as from outside. Most people, upon hearing the word radioactivity, think only about something harmful or even deadly; especially events such as the atomic bombs that were dropped on Hiroshima and Nagasaki in 1945, or the Chernobyl Disaster of 1986. However, upon understanding radiation, people will learn to appreciate that radiation has peaceful and beneficial applications to our everyday lives.

### What are atoms?

Knowledge of atoms is essential to understanding the origins of radiation, and the impact it could have on the human body and the environment around us. All materials in the universe are composed of combination of basic substances called chemical elements. There are 92 different chemical elements in nature. The smallest particles, into which an element can be divided without losing its properties, are called atoms, which are unique to a particular element.

An atom consists of two main parts namely a nucleus with a circling electron cloud. The nucleus consists of subatomic particles called protons and neutrons. Atoms vary in size from the simple hydrogen atom, which has one proton and one electron, to large atoms such as uranium, which has 92 protons, 92 electrons.

Radioactive elements are those in which the atoms are unstable and breakdown to form atoms of another element. This decay is accompanied by the



**Figure 1:** Diagram illustrating the structure of an atom

release of radiation in the form of invisible small particles and high energy waves. Uranium, thorium and potassium are examples of naturally occurring elements that are slightly radioactive.

## What is Radiation?

Radiation is energy that travels through space, in the form of particles or electromagnetic waves. The word “radiation” refers to many forms of energy such as radio, microwaves, infra-red, visible light, ultra-violet, X-rays and Gamma-rays, alpha particles, etc. Radiation can be broken down in two major classes, based on their energy and penetrating capabilities, these are ionizing and non-ionizing radiation. **Non-ionizing** radiation is unable to directly alter the chemical structure of materials, and includes radio, microwaves, infra-red, and visible light.

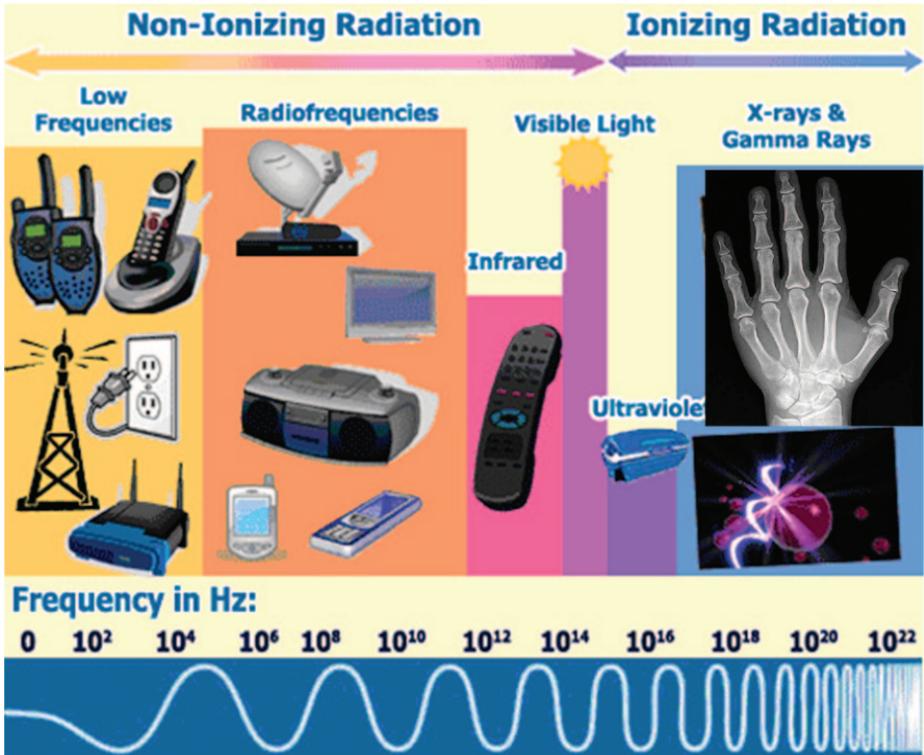
**Ionizing radiation** enough energy to remove electrons from atoms in the materials they penetrate, e.g. our bodies. Its ability to ionize is what makes ionization radiation potentially harmful to life. Ionization causes chemical bonds to break up; it can therefore harm the human body because it changes chemical bonds in the body. Ionizing radiation cannot be felt, smelt, tasted, seen or heard.

The principal kinds of ionizing radiation are:

**Alpha particles:** are heavy, positively charged particles which do not travel very far in air. They cannot penetrate the skin and can only be harmful if emitted inside the body, i.e. if ingested or inhaled.

**Neutrons:** are subatomic (make up parts of an atom) particles which can have a varying degree of energy. Low-energy or slow neutrons have the ability to transform elements, but are not very penetrating. However, fast neutrons can be destructive to human tissue.

**Beta particles:** are fast moving, negatively charged particles and can travel much further through air than alpha particles. They are more penetrating (i.e. can penetrate the skin) but can easily be shielded, for example by a sheet of plastic. They are more harmful if ingested or inhaled.



*Figure 2: The spectrum of electromagnetic radiation*

**Gamma rays:** are waves of energy similar to light, but they have much higher energy and can travel great distance through air. They are very penetrating and require shielding of concrete or lead plating to stop them. Unshielded Gamma rays are harmful inside and outside the body.

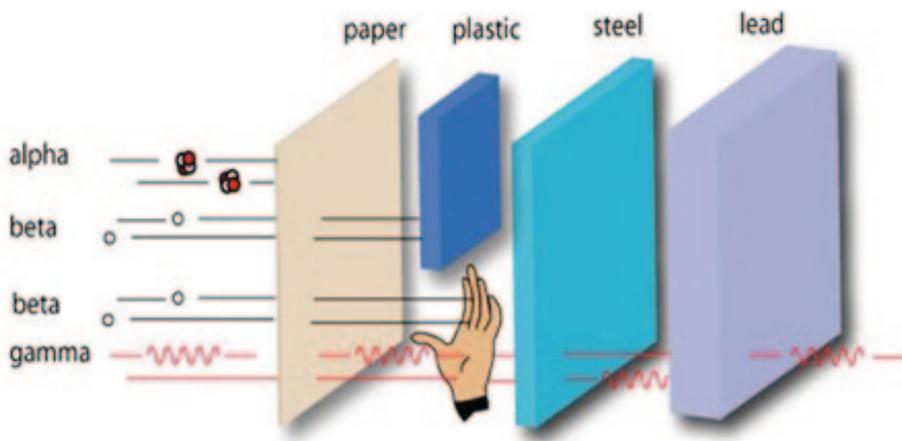
**X-rays:** are lower energy Gamma Rays similar in nature to light. X-rays can more easily penetrate the skin than the bones, and X-ray photographs work on this principle.

### Sources of Ionizing Radiation

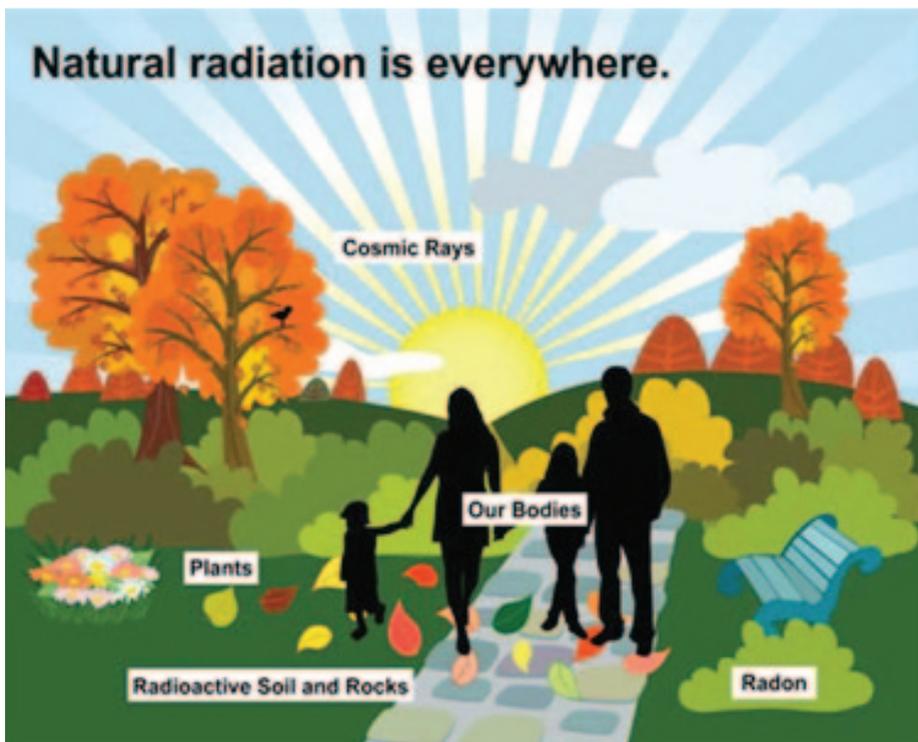
Depending on their origin, primary sources of radiation can be broken down into two classes, namely, natural or man made radiation.

We are all exposed to **natural radiation** to a greater or lesser extent, and for most

people it is the major source of radiation exposure. Background radiation is that which is naturally and inevitably present in our environment.



**Figure 3:** Penetrating Power of Radiation



**Figure 4:** Sources of natural radiation

## *There are three sources of natural background radiation:*

**Cosmic Radiation:** The sun and stars send a constant stream of cosmic radiation to earth, much like a steady drizzle of rain. Differences in elevation, atmospheric conditions, and the earth's magnetic field can change the amount (or dose) of cosmic radiation that we receive.

**Terrestrial radiation:** The earth itself is a source of terrestrial radiation. Radioactive materials (including uranium, thorium, and radium) exist naturally in soil, water and rock. Essentially all air contains radon, which is responsible for most of the dose that people receive each year from natural background sources, and all organic matter (both plant and animal) contains radioactive carbon and potassium. The dose from terrestrial sources varies in different parts of the world, but locations with higher soil concentrations of uranium and thorium generally have higher doses.

**Internal Radiation:** All people have internal radiation, mainly from radioactive potassium-40 and carbon-14 inside their bodies from birth until death. The variation in dose from one person to another is not as great as that associated with cosmic and terrestrial sources.

Although all people are exposed to natural sources of radiation, two distinct groups are exposed to man-made radiation sources, namely the general public and radiation workers

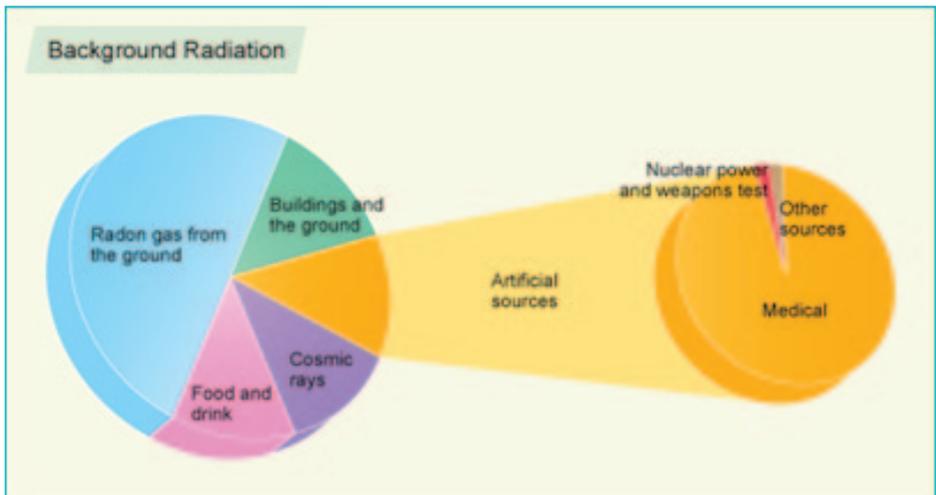
### General Public

The use of radiation in medical procedures, such as diagnostic x-rays, nuclear medicine, and radiation therapy, is by far the most significant source of man-made radiation exposure. In addition members of the public are exposed to radiation from consumer products, such as building materials, combustible fuels (gas and coal), television, cellphones etc.

Individuals who fly frequently wonder about the extra cosmic radiation exposure they receive at higher altitudes. That depends on several things, including

how long the flight lasts, how high the plane flies and, of course, how often a person flies.

Of lesser magnitude, the public is exposed to radiation from nuclear sites. Radioactive discharges from nuclear sites account for less than 0.01% per year of the average dose. The final sources of exposure to the public would be shipment of radioactive materials and residual fallout from nuclear weapons testing's and accidents like Chernobyl.



**Figure 5:** Various contributors to the total public radiation dose

## Radiation Workers

Radiation workers, or occupationally exposed individuals, on the other hand, are exposed according to their occupations, and to the sources with which they work. Occupationally exposed individuals, however, are monitored for radiation exposure with dosimeters to ensure that they do not exceed the prescribed dose limits. Radiation workers usually work in environments of the nuclear fuel cycle, radiography, nuclear power plants, and nuclear medicine.

## Biological Effects of Radiation

Radiation can be either harmful or beneficial, depending on its application, duration and extent of exposure. To understand the dangers of radiation in the correct perspective, people should be well informed on the effects that radiation may have on their body. Since we are already subject to background radiation, we should not unnecessarily increase our exposure to additional radiation, as it is known that exposure to radiation carries a risk.

Risk is something we live with daily. Whenever we drive a vehicle, there is a risk of accidents and possible injury or death. Most of us consider the risk acceptable because the benefit outweighs the risk. The same argument can be applied to the use of radiation. If the benefits outweigh the risk and the risks are acceptably small, there is a justified reason for its use.

When ionizing radiation interacts with cells, it may or may not strike a critical part of the cell. Chromosomes are considered to be the most critical part of the cell since they contain the genetic information and instructions required for the cell to perform its function and to replicate itself. Also, there are very effective repair mechanisms at work constantly to repair cellular damage - including chromosome damage. Depending on the extent of radiation, four primary categories of damage are possible:

### Cells Damaged, No Repair

Ionization may form chemically active substances which in some cases alter the structure of the cells. These alterations may be the same as those changes that occur naturally in the cell and may have no negative effect on the operation of the cell.

### Cells Damaged, Repaired, and Function Normally

Some ionizing events can produce substances 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.

Other events can damage the chromosomal structure, which is usually repaired. Many thousands of chromosome aberrations (changes) occur constantly in our bodies. We have effective mechanisms to repair these changes.

## Cells Damaged, Repaired, and Function Abnormally

If a damaged cell needs to perform a function before it has had time to repair itself, it will either be unable to perform the repair function or perform the function incorrectly. The result may be cells that cannot perform their normal functions that now cause damage to other cells. These altered cells may be unable to reproduce or may reproduce at an uncontrolled rate. Such cells can be the underlying cause of cancer.

## Cells Damaged, and Die

If a cell is extensively damaged by radiation, or damaged in such a way that reproduction is affected, the cell may die. Radiation damage to cells may depend on how sensitive the cells are to radiation. The destruction of cells by radiation is also used to treat some types of cancer.

## Effects of Radiation on Unborn Babies

An embryo/foetus is very sensitive to radiation, because an embryo/foetus' cells are rapidly dividing. Protection of the embryo/foetus is important because the embryo/foetus is considered to be at the most radiation sensitive stage of human development, particularly in the first 20 weeks of pregnancy.

Limits are established to protect the embryo/foetus from any potential effects which may occur from a significant amount of radiation. This radiation exposure may be the result of exposure to external and internal sources of radiation. Special considerations are given to pregnant radiation workers.

Potential effects associated with prenatal radiation doses include:

- Growth retardation
- Small head/brain size
- Mental retardation
- Childhood cancer

## Uses of Radiation

Radiation can be used to improve the quality of life in many more ways than people realize. Nuclear energy, which uses radioactive materials, has a variety of important uses in electricity generation, medicine, industry, agriculture, as well as in our homes. Whenever or wherever it is used, it is incumbent on qualified individuals and responsible organizations to ensure that the radioactive material is prepared, used and disposed of in a safe manner.

### Electricity Generation

The demand for energy increases with the world's booming population and expanding economy. Nuclear energy is one of the solutions to meet this ever increasing demand of energy and generates electricity in an environmentally responsible manner. Koeberg Nuclear Power Station is contributing approximately 6% of South Africa's electricity generation. This nuclear power plant is situated in the Western Cape and it has been operating for more than 25 years.



**Figure 6:** Koeberg Nuclear Power Station

## Medical applications

There are many applications of radiation in the medical field, ranging from diagnostics, to treatment and disease management. Many of these use radioactive elements (more specifically radio isotopes) produced from either reactors or cyclotrons.

Necsa through NTP is one of the world's leading supplier of radioactive elements and is playing the leading role in supporting the practice of nuclear medicine globally. iThemba Laboratory for Accelerator Based Sciences also provides facilities for treatment of cancers using neutron and proton therapy.

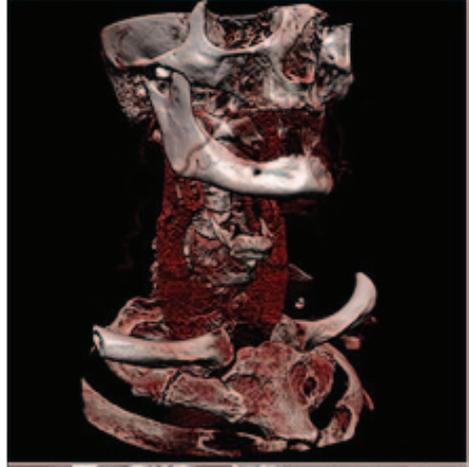


*Figure 7: Patient undergoing radiotherapy treatment*

Radiology is the broad area of using images produced through radiation, to diagnose and treat disease. The most well known technique is X-rays, which is normally used to examine whether bones are broken. However, radiology includes specialised techniques such as mammography, computed tomography (CT) and nuclear medicine (where radioactive material is usually injected into the patient). With advanced imaging computing technologies, a three dimensional picture of the inside of a patient can be generated.



**Figure 8:** X-ray image, and 3 dimensional CT scan



## Industrial Applications

Industries around the world use radioactive materials in a variety of ways to improve productivity and safety, and to obtain information that could not be obtained in other ways. The applications include fields such as civil engineering, materials analysis, measuring devices, process control in factories, oil and mineral exploration, and checking oil and gas pipelines for leaks and weaknesses. These uses directly and indirectly influence our everyday lives.

For example, measuring devices containing radioactive materials are used in tasks such as:

- testing the moisture content of soil during road construction,
- measuring the thickness of paper and plastics during manufacturing,
- checking the height of fluid when filling bottles in factories.

Radioactive materials are even used in devices designed to detect explosives. Radioisotopes are employed in smoke detectors, and as lasting, fail-safe light sources for emergency signs in aircraft and public buildings.



**Figure 9:** Self luminous light source based on radioactive element Tritium

## Agricultural Applications

In agriculture, radioactive materials are used to improve food crops, preserve food, and control insect pests. They are also used to measure soil moisture content, erosion rate and the efficiency of fertilizer uptake.

### Food irradiation

The use of gamma rays and electron beams in irradiating foods to control disease causing micro-organisms and to extend shelf life of food products is growing through out the world.

### Insect control

Radioisotopes assist in enhancing food production. One method is the control of insects, including the control of screw worms, fruit flies and tsetse flies, is through the Sterile Insect Technique. The tsetse fly causes the transmission of a parasitic disease, trypanosomiasis, which slowly destroys livestock herds in sub Saharan Africa. It also causes the spread of the human form of the disease, known as sleeping sickness. Diseases transmitted by tsetse flies kill over 250,000 people per year.

## Archaeological Applications

Archaeological findings can be dated by measuring their natural radioactivity using a technique called carbon dating, which is based on measuring the radiation release profile of the materials. This is a useful tool in geological, anthropological and archaeological research.

## Applications in Consumer Products

One of the most common uses of radioactive materials in the home is in smoke detectors. These devices contain tiny amounts of radioactive material which make the detectors sensitive to smoke.

## Environmental Applications

Radioactive materials are used as tracers to measure environmental processes, in-

cluding the monitoring of silt, water and pollutants. They are used to measure and map effluent and pollution discharges from factories and sewerage plants, and the movement of sand around harbours, rivers and bays. Radioactive material used for such purposes have short half-lives and decay to background levels within days.

## Transportation of Radioactive Material

The transportation of radioactive material in South Africa is subject to strict international regulatory guidelines to ensure the safety of workers and members of the public. Generally, material destined for transport on public routes is packaged in a manner that even if the public or workers were to come into contact with it, there would be no risk to their health.



*Figure 10: Radioactive material packages before transportation*

## Nuclear Waste

Radioactive waste is defined as material that contains radioactive elements at levels greater than the clearance level established by the regulator, and is therefore unsafe for public use. Radioactive waste, like any other waste is managed to protect people and the environment.

## Radiation Safety in South Africa

The National Nuclear Regulator is responsible for exercising regulatory control over the safety of nuclear installations, certain types of radioactive waste, and the mining and processing of radioactive material. It is also responsible for the protection of persons (workers and members of the public), environment and property from the harmful effects arising from ionizing radiation.



*Figure 11: Drummed nuclear waste storage*



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