

UNDERSTANDING THE BIOLOGICAL EFFECTS OF IONIZING RADIATION

INTRODUCTION

Ionizing radiation is widely used in medicine, industry, agriculture, research, education, and security applications. These technologies provide significant benefits to society, including disease diagnosis and treatment, non-destructive testing, food preservation, and scientific research. However, like many technologies, ionizing radiation must be used safely because excessive or uncontrolled exposure can have adverse effects on human health.

Atomic Energy Council (AEC), as the national regulatory body for radiation safety and nuclear security in Uganda, is committed to ensuring that ionizing radiation is used safely and securely. An understanding of the biological effects of ionizing radiation is essential for radiation workers, facility operators, decision-makers, and the general public.



Figure 1: A fixed X-ray machine used in diagnosis

What is Ionizing Radiation?

Ionizing radiation is a form of energy that has sufficient strength to remove electrons from atoms and molecules, creating ions. Common forms of ionizing radiation include alpha particles, beta particles, gamma rays, X-rays, and neutrons.

When ionizing radiation interacts with human tissue, it can transfer energy to cells and biological molecules, potentially causing changes that may affect normal cellular functions.

How Radiation Affects the Human Body

The human body is made up of billions of tiny building blocks called cells. When a person is exposed to ionizing radiation, the radiation can pass through the body and affect these cells, especially the parts that control how cells work and grow.

In many cases, the body can repair this damage naturally. However, if the damage is too serious or the body is unable to repair it properly, it may lead to effects such as damaged tissues, cell death, or health problems that may appear later.

The effect of radiation on the body depends on several factors, including:

- a) The amount of radiation received; higher amounts of radiation are more likely to cause harm.
- b) How quickly the radiation is received; receiving a large amount in a short time can have greater effects.
- c) The type of radiation involved; different types of radiation (alpha, beta and gamma) affect the body differently.
- d) The part of the body exposed; some organs (e.g. thyroid, gonads) are more sensitive to radiation than others.
- e) The age and general health of the person; children and some individuals may be more sensitive.
- f) How the radiation enters the body; exposure can happen from outside the body or from radioactive materials taken into the body.

Categories of Biological Effects

The biological effects of ionizing radiation are generally classified into two categories:

1. Short term Effects

These are also known as deterministic effects, which occur when radiation exposure exceeds a certain threshold dose. Once this threshold is exceeded, the severity of the effect increases with increasing radiation dose.

Examples include:

- Skin reddening (erythema)



- Hair loss



- Radiation burns



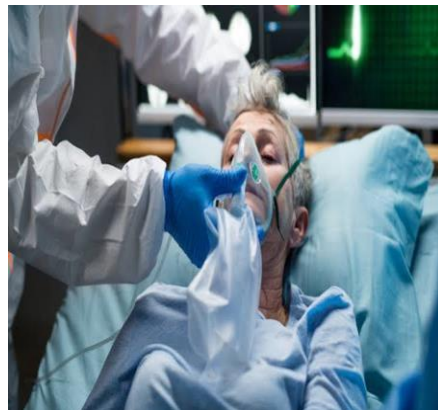
- Cataracts



- Temporary or permanent infertility



Radiation sickness



- Damage to organs and tissues



These effects are generally associated with high radiation doses received over a short period. They are uncommon under normal occupational or public exposure conditions when proper safety measures are in place and being followed.

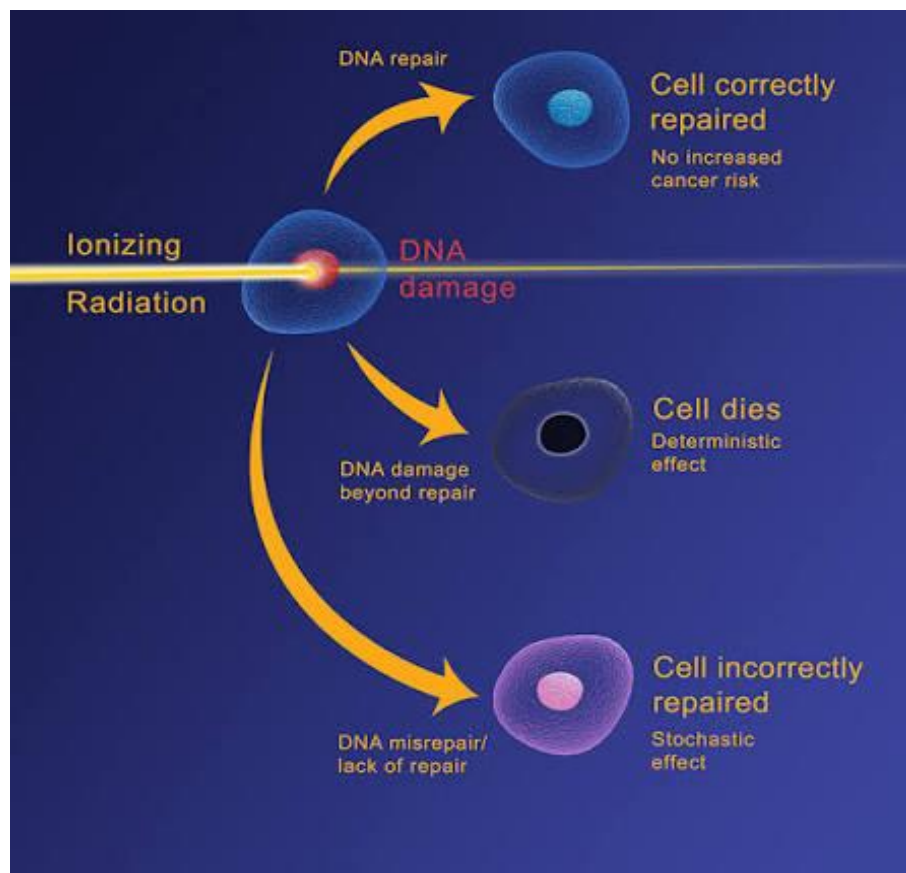


Figure 2: How radiation affects the cell

2. Long term Effects

These are also known as stochastic effects which may occur even at relatively low radiation doses, although the probability of occurrence increases with increasing dose. Unlike deterministic effects, there is no known threshold below which the risk is completely absent.

The main stochastic effects are:

- Cancer
- Hereditary genetic effects

In this case, radiation does not necessarily cause immediate illness but may increase the likelihood of developing cancer many years after exposure.

Long-term exposure to elevated levels of radiation may increase the risk of certain health effects, including:

Cancer

Cancer is the most significant long-term health effect associated with radiation exposure. Scientific studies of exposed populations have shown that radiation can increase the likelihood of developing cancers such as leukemia, thyroid cancer, lung cancer, and other solid tumors.

Cataracts

Prolonged exposure of the eyes to radiation may increase the risk of developing cataracts, particularly among workers who are not adequately protected.

Cardiovascular and Tissue Effects

At relatively high doses, radiation may contribute to damage of certain tissues and organs, including the cardiovascular system.

Effects on the Unborn Child

Pregnant women require special consideration because the developing fetus is more sensitive to radiation.

Depending on the stage of pregnancy and the radiation dose received, excessive exposure may result in:

- Developmental abnormalities
- Growth retardation
- Impaired brain development
- Increased risk of childhood cancer

For this reason, medical practitioners are encouraged to establish the pregnancy status before conducting certain radiological procedures, and pregnant radiation workers should notify their employers in accordance with applicable safety requirements.

Acute Radiation Exposure

Acute radiation exposure occurs when a person receives a large radiation dose within a short period of time.

Symptoms may include:

- Nausea and vomiting
- Fatigue and weakness
- Loss of appetite
- Skin injuries
- Hair loss
- Reduced blood cell production

Very high doses can result in Acute Radiation Syndrome (ARS), a serious medical condition requiring urgent treatment. Such incidents are extremely rare and are generally associated with major radiation accidents or severe failures in radiation protection measures.

Protecting People from Harmful Radiation Effects

Radiation protection refers to the measures taken to reduce unnecessary radiation exposure with a goal to minimize the harmful effects of ionizing radiation.

Key protection measures include:

a) Justification

No practice involving radiation should be adopted unless it produces a net benefit to individuals or society compared to the associated risk.

b) Optimization

Radiation exposures should be kept As Low As Reasonably Achievable (ALARA), taking into account social and economic factors.

The three radiation protection principles of ALARA are;

- i. Time:** Dose is directly proportional to exposure time. Reducing the duration spent in the vicinity of a radiation source directly limits your total accumulated dose.
- ii. Distance:** Radiation intensity decreases as you move away from the source. Increasing the distance between yourself and a radiation source greatly reduces the amount of radiation reaching your body.
- iii. Shielding:** Placing absorbing materials between you and the source blocks or attenuates penetrating radiation. Common shielding materials include lead for X-rays, concrete for gamma rays, and even water or special plastics for neutrons.

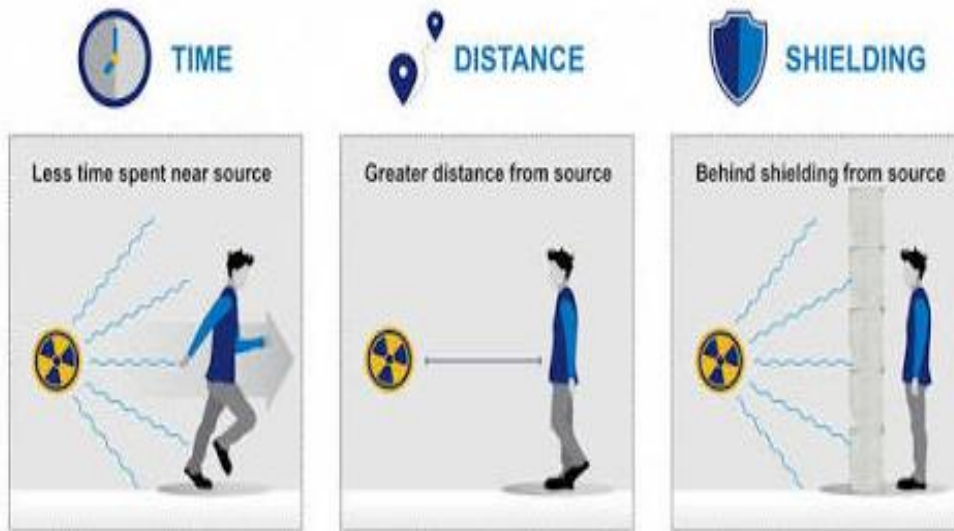


Figure 3: An illustration of the Time, Distance and Shielding principles

c) Dose Limitation

Occupational and public exposures are controlled through setting regulatory dose limits which must not be exceeded to ensure safety.

Role of the Atomic Energy Council

The Atomic Energy Council regulates the peaceful applications of ionizing radiation in Uganda to ensure the protection of workers, patients, the public, and the environment.

AEC achieves this through:

- i. Development of Regulations and guides on radiation protection and safety
- ii. Authorization of radiation facilities and activities.
- iii. Inspection and enforcement of radiation safety requirements.
- iv. Monitoring compliance with regulations.
- v. Providing assistance in emergency preparedness and response.
- vi. Public awareness and stakeholder engagement.



Figure 4: An AEC Inspector conducting an inspection on a CT Machine

Conclusion

Ionizing radiation is a valuable tool that contributes significantly to healthcare, industry, agriculture, research, and national development. While exposure to excessive radiation can lead to harmful biological effects, these risks can be effectively controlled through proper regulation, safe operating practices, and adherence to radiation protection principles.

By understanding the biological effects of ionizing radiation and following established safety requirements, workers, facility operators, and members of the public can continue to benefit from radiation technologies while maintaining the highest standards of health, safety, and environmental protection.