LAPORAN PENELITIAN

LITERATURE REVIEW

Ionizing Radiation

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UNIVERSITAS TARUMANAGARA
JAKARTA

2024

Ionizing Radiation

Background

Energy that is generated by a source and moves through space or another material is called radiation.[1] It is well recognized that there are primarily two types of radiation sources: artificial or man-made radiation and natural or background radiation. Radiation can be further divided into two categories: ionizing and nonionizing radiation.[2]

The term "ionizing radiation" refers to radiation with enough energy to remove electrons from molecules.[1,3] On the other hand, nonionizing radiation is a kind of electromagnetic radiation that lacks the energy necessary to ionize an atom.[2] Since ionizing radiation contains higher energy, the free electrons that was displaced in ionizing radiation process is sufficient to alter chemicals and harm cells and tissues in the body.[2,3]

Every day, people are exposed to radiation from both man-made and natural sources as stated above. There are several sources of naturally occurring radioactive elements, for example found in soil, water, and air. Conversely, man-made sources are found in nuclear power and the use of radiation in medicine for diagnosis or treatment.[4]

The greatest man-made source of ionizing radiation exposure is still medical exposure, which is growing at an astounding rate due to breakthrough in technology and healthcare. These medical instruments such as CT scan and x-ray machines are the most common ones found in daily practices. With medical exposures making up 98% of the man-made source contribution, they are currently the second largest contributor to the population dose globally, contributing around 20% of the total. Over 4.2 billion diagnostic radiological exams, 40 million nuclear medicine operations, and 8.5 million radiation treatments are done globally each year.[2,4,5]

Based on the data released by Nuclear Energy Regulatory Agency[6] in Indonesia, there are a total of more than 31000 ionizing radiation sources found all over Indonesia in 2022. Due to the magnitude of these numbers, it is important for us to understand the effects that ionizing radiation have on the body.

Radiation

The release of energy in the form of moving subatomic particles or electromagnetic waves is known as radiation. People consume and inhale radiation on a daily basis from food, water, and the air. Radiation exposure can come from unintentional events, deliberate circumstances (such as medical or work-related ones), or natural sources (such as radon in homes). Exposure can occur internally (by ingestion, inhalation, or contact with a contaminated wound), externally (via contamination of skin, hair, or clothing), or both. [6]

There are various types and sources of radiation. Certain radiation types cause damage to biological tissue, while other radiation types do not. Since certain radiation sources are constantly present in the environment, they are regarded as natural sources. Other sources, though, are human-made and serve certain functions. [7]

Radiation sources created by humans are frequently employed in industry, research, and medicine. The two different categories of radiation are ionizing and nonionizing radiation.[8] The radiation dosage, or amount of radiation, is the most important consideration for assessing health implications. Genetic material, or DNA, is the primary target.[9] Radiation can harm live tissue by altering cellular structure and destroying an organism's DNA. The level of damage is determined by several factors, including the type and quantity of radiation received, as well as its energy. [10]

Radiation can interact with DNA directly, causing damage by breaking links, or indirectly, by disrupting water molecules that surround the DNA. When these water molecules are broken down, they form free radicals, which are unstable oxygen molecules that can harm cells and organs. There are three possible outcomes when a cell is injured. The first is the cell fixes itself The second is if the cell damage is not fixed or is repaired improperly, the cell is replaced. Last, if the cell sustains too much damage, it dies.[9]

Due to the cellular nature of radiation damage, it can be challenging to detect the effects of even small to moderate exposure because the body is often capable of effectively repairing such damage. However, specific cell types exhibit greater susceptibility to radiation-induced damage compared to others. Furthermore, higher levels of radiation exposure might hinder cellular repair, potentially leading to the development of cancer. Radiation has the ability to cause cell death and also harm the DNA within cells. This clearly poses a risk, but it also presents possibilities for medical intervention, provided that cellular apoptosis can be accurately focused (for instance, in the context of radiation therapy for cancer). [10]

Approximately 50% of the radiation we encounter originates from our surrounding environment. Several elements present in the earth's crust release radioactivity, such as uranium, radium, polonium, thorium, and potassium. The extent of exposure will be contingent upon the composition of the indigenous soil and rocks. Radon, an odorless and colorless gas, is a significant source of natural radiation and is responsible for around 20,000 occurrences of lung cancer annually, making it the second leading cause of lung cancer mortality after smoking. Individuals who smoke and reside in a household with elevated levels of radon are especially susceptible to harm. [10]

Ionizing Radiation

Definition of Ionizing Radiation

As stated above, there are two forms of radiation, which are ionizing and non-ionizing radiation.[8] Nonionizing radiation is a type of electromagnetic radiation that does not possess sufficient energy to ionize atoms. On the other hand, ionizing radiation is radiation that possesses sufficient energy to extract electrons from atoms, hence causing the atom to become charged or ionized. [2] The ionizing radiation can be transmitted in the form of electromagnetic waves (such as gamma or X-rays) or particles (such as neutrons, beta, or alpha).[4]

Ionizing radiation is typically defined by its capacity to stimulate and ionize atoms of materials it comes into contact with. For radiation to be considered 'ionizing', it must possess kinetic or quantum energies greater than the range of 4 eV–25 eV, which is the energy required to free a valence electron from an atom. [11]

Types of Ionizing Radiation

Among the various types of electromagnetic radiation in the electromagnetic spectrum, only certain radiations are categorized as ionizing radiations, which are x-rays, gamma rays, and high-energy UV light (with energy more than 10 electron volts). Other research stated that ionizing radiation can be classified into four distinct types: alpha particles, beta particles, gamma rays, and X-rays. [2]

Doses of Ionizing Radiation

There are distinctly different dose magnitudes of radiation (either measured or computed) that are significant. The terms are *"absorbed dose", "equivalent dose",* and *"effective dose"*. Currently, there are two commonly used systems of radiation units worldwide. The units of rad/rem/curie are considered conventional or traditional, while the units of gray/sievert/becquerel are part of the newer System Internationale (SI).

The extent of tissue and/or organ damage caused by radiation is directly influenced by the dose of radiation exposure. The phrase "absorbed radiation dose" refers to the quantity of energy that is absorbed from ionizing radiation by a specific mass of material. The quantity is measured in joules per kilogram, which is referred to as gray (Gy). One gray is equal to 1000 milligray (mGy). [4]

Using variables that account for the various radiation kinds and their delivery rates, the *"equivalent"* dosage is calculated from the absorbed dose. The equivalent dosage and absorbed dose of x-rays are the same. Sieverts (Sv) or rem are used to measure the equivalent dose.[12]

In order to ensure radiation protection, the absorbed dosage is adjusted to consider the varying effectiveness of different types of radiation and the sensitivity of different organs and tissues. The resulting quantity is referred to as the *“effective dosage”,* measured in sieverts (Sv) [1 Sv = 1000 millisieverts (mSv)]. Sv is a measurement unit of quantifying ionizing radiation based on its capacity to cause harm. For photons in the intermediate energy range, 1 milligray (mGy) is approximately equivalent to 1 millisievert (mSv). The dose rate, measured in microsieverts per hour (μSv/hour) or millisieverts per year (mSv/year), is a crucial metric alongside the dose of radiation. [4,13]

The term *"low radiation dose"* refers to a radiation dose that is below specified levels. It is occasionally used informally to describe a low dose rate, which means a low dose per unit of time. Within specialized radiobiological forums, the term "low radiation dose" (including dose rate) is used to describe exposures where it is highly improbable for more than one instance of energy absorption from radiation to occur in the critical components of a cell, causing damage, within the timeframe in which the cell's repair mechanisms can function. [13]

Utilizing radioactive sources has hazards associated with exposure to radiation. Individuals may encounter ionizing radiation in several settings, including their residences or public areas (public exposures), their jobs (occupational exposures), or during medical procedures (medical exposures). Various professions include exposure to ionizing radiation. Artificial sources of radiation are frequently employed in various sectors such as manufacturing, service industries, defence industries, research institutes, universities, and the nuclear power industry. Physicians and health professionals rely heavily on them for diagnosing and treating disorders.[4,14]

Radiation exposure can happen through internal or external routes. Internal exposure to ionizing radiation occurs when a radionuclide is taken into the body through inhalation, ingestion, or other means, and then enters the bloodstream, such as through injection or wounds. Internal exposure ceases when the radionuclide is expelled from the body, either naturally (such as through bodily waste) or due to a medical intervention. [4]

External exposure can happen when radioactive material in the form of dust, liquid, or aerosols settles on the skin or clothing. Typically, this variety of radioactive substance can be eliminated from the body by the process of washing. Ionizing radiation exposure can also occur due to irradiation from an external source, such as medical radiation exposure via x-rays. External irradiation ceases when the radiation source is adequately protected or when the individual exits the area affected by the radiation. [4]

For the purpose of radiation protection, exposure to ionizing radiation can be categorized into three situations: planned, existent, and emergency. Planned exposure circumstances occur when radiation sources are intentionally introduced and operated for certain goals, such as using radiation for medical diagnosis or treatment, or for industrial or research purposes. Existing exposure refers to situations when radiation is already present and requires a decision on how to limit it. This includes exposure to radon in homes or workplaces, as well as exposure to natural background radiation from the environment. Emergency exposure circumstances arise from unforeseen incidents that demand immediate action, such as nuclear accidents or deliberate acts of harm. [4]

Certain workers are also subjected to natural sources of radiation. This is especially accurate when it comes to being exposed to radon in mines and regular workplaces located in regions with elevated radon levels. The prescribed thresholds for radiation exposure are 20 mSv/year for individuals involved in radiation-related tasks and 1 mSv/year for the general population.[14]

In recent times, radioactive sources have been employed for a wide range of advantageous reasons in numerous sectors, including industry, agriculture, research, education, and medicine. An aging population and better health services have led to a rise in the use of radiation and radionuclides in diagnosis and therapy. The majority of exposure to low radiation doses comes from medical and occupational exposure to ionizing radiation. Medical personnel are among the workers who are most frequently exposed to radiation because they may perform X-ray imaging or other procedures that expose them to ionizing radiation. The medical application of radiation is responsible for 98% of the radiation dose that the public receives from all man- made sources. Although doses in the medical, dental, and veterinary fields are typically minimal, certain diagnostic radiology procedures may put physicians at risk of significant exposure due to their close proximity to the patient.[4,14]

Health Effects of Ionizing Radiation

There are two types of radiation effects: *stochastic* and *deterministic.* Once a threshold dose is reached, the frequency and severity of *deterministic effects* increase with increasing dose. Skin reddening and infertility at estimated thresholds of roughly 2.5 and 6 Gy, respectively, are examples of *deterministic effects*. The doses at which these effects happen are usually not reached by diagnostic radiological methods. On the other hand, there is no starting point for *stochastic effects*. Rather, increasing lifetime accumulation of radiation exposure raises the likelihood of occurrence but not its severity. An example of a stochastic effect is carcinogenesis.[12]

Over specific thresholds, radiation can cause acute symptoms including skin redness, hair loss, radiation burns, or acute radiation sickness, as well as disrupt the functioning of tissues and/or organs. At greater doses and dose rates, these effects become more severe. For example, the acute radiation sickness dose threshold is around 1 Sv (1000 mSv). [4]

The risk is significantly reduced when the radiation dose is modest and/or is administered slowly (low dose rate), as there is a higher chance that the damage will be repaired. However, there's still a chance of long-term consequences like cataracts or cancer, which could manifest years or even decades later. Although these kinds of effects are not certain, their probability increases with radiation exposure. Since children and teenagers are considerably more sensitive to radiation exposure than adults, they are at a higher risk. [4]

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