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Review Article

Benefits and Biological Effects of Ionizing Radiation

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Abstract: The benefits of radiation were first recognized in the use of X-rays for medical diagnosis, then later with the discoveries of radiation and radioactivity. The rush in exploiting the medical benefits led fairly to the recognition of the risks and induced harm associated with it. In those early days, only the most obvious harm resulting from high doses of radiation, such as radiation burns were observed and protection efforts were focused on their prevention, mainly for practitioners rather than patients. Although the issue was narrow, this lead to the origin of radiation protection as a discipline. Subsequently, it was gradually recognized that there were other, less obvious, harmful radiation effects such as radiation-induced cancer, for which there is a certain risk even at low doses of radiation. This risk cannot be completely prevented but can only be minimized. Therefore, the balancing of benefits from nuclear and radiation practices against radiation risk and efforts to reduce the residual risk has become a major feature of radiation protection. In this paper, we shall be looking at the precautionary measures for protecting life, properties and environment against ionizing radiation.
Keywords: Radiation, Alpha particles, Beta particles, Gamma rays, X-rays, Radionuclide's

INTRODUCTION

Radiation is naturally present in our environment and has been there since the birth of the planet. Consequently, life has evolved in an environment which has significant levels of ionizing radiation. It comes from outer space (cosmic), the ground (terrestrial), and even from within our own bodies (Internal). It is present in the air we breathe, the food we eat, the water we drink [1, 2] and in the construction materials used to build our homes. Brick and stone homes have higher natural radiation levels than homes made of wood. The levels of natural or background radiation can vary greatly from one location to another. The radioactivity is part of our earth – it has existed all along. Naturally occurring radioactive materials (NORM) 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 [3, 4]. Man has always been exposed to natural radiation arising from earth as well as from outside. Most people, upon hearing the word radioactivity, only think about something harmful or deadly; especially events such as the atomic bombs that was dropped at 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. According to ref [5], new challenges as regards to global levels of radiation exposure continue to arise and new biological information on the effects of radiation exposure is becoming available. For example, large amounts of radioactive waste have built up as a result of both peaceful uses of nuclear energy and military nuclear operations, and radiation sources used in military and peaceful operations have been abandoned, creating a situation that is prone to illicit trafficking and other criminal activities. Moreover, the potential risks from low-level radiation exposure, that is, exposure to radiation comparable with natural background radiation, are the cause of lively debate and controversy.

ELECTROMAGNETIC RADIATION

Electromagnetic radiation is transmitted through empty space at 3.0 X 10^8 meters per second – 300, 000 kilometers per second [6]. The electromagnetic spectrum includes radio waves, microwaves, infrared rays, light rays, ultra violet rays, X-rays and gamma rays as shown in Fig. 1:

Fig. 1: Electromagnetic Spectrum [6, 7, 8]

They are distinguished from each other by their wavelength and the amount of energy they transfer. These properties also determine their ability to travel through objects, their heating effects and their effect on living tissue. According to the quantum theory model, electromagnetic radiation consists of bundles of energy called photons, which travel at the speed of light. Gamma rays and X-rays are identical, both are photons but differ in origin. Gamma rays result from transformations that take place in the nucleus of an atom, and X-rays are formed by interactions outside the nucleus [9].

Ionizing Radiation

The radiation that has enough energy to remove tightly bound electrons from atoms, thus creating ions is referred to as ionizing radiation [8, 10]. This is the type of radiation which we leverage on its benefits to generate electric power, to kill cancer cells, and in many manufacturing processes. According to ref [11] radiation is the type of energy released by atoms that travels in the form of electromagnetic waves (gamma or X-rays) or particles (neutrons, beta or alpha). This spontaneous disintegration of atoms is called radioactivity, and the excess energy emitted is a form of ionizing radiation. Consequently, people are exposed to natural sources of ionizing radiation, such as in soil, water, vegetation, and in human-made sources, such as x-rays and medical devices. Though; ionizing radiation has many beneficial applications, including uses in medicine, industry, agriculture and research, so does the potential for health hazards if not properly used or contained.

Types of Ionizing

According to ref [3, 4, 7, 8, and 10], there are three main types of ionizing radiation as shown in Fig. 2:

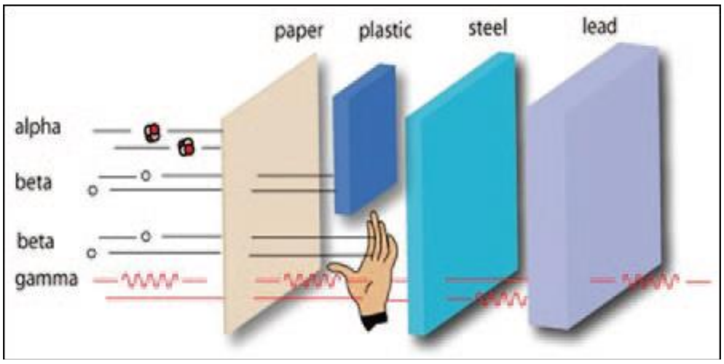

Fig. 2: Penetrating Power of Radiation [3, 4, 8, 10]

Alpha (α) particles, which include two protons and two neutrons are heavy and positively charged particles which do not travel very far in the air and cannot penetrate the skin. But if ingested or inhaled, it can be harmful. Accordingly, alpha particles are easily stopped by a thin sheet of paper or the human body skin. However, if alpha emission enters the body, it poses risk to sensitive body organs such as the lungs and the bones. But this risk can be reduced by ensuring that the inhalation or ingestion of emitted alpha particles is kept at minimum level by either installing dust controls or by the appropriate use of respiratory protection devices such as dust masks.

Beta (β) which are essentially electrons are fast moving and negatively charged particles that can travel much further through air than alpha particles. Quite penetrating even through the skin but can easily be shielded with a sheet of plastic. They are more harmful if ingested or inhaled.

Gamma (Y) and X-Ray which are pure energy (photons). Gamma rays are waves of energy similar to light and they have much higher energy and can travel great distance through air. Therefore, 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 while X-ray has lower energy Gamma rays similar in nature to light. They can easily penetrate the skin than the bones. Details are as shown in Fig. 2 and similarly on Table 2 below – are the physical characteristics of ionizing radiation.

Table 2: Physical Characteristics of the major types of Radiation [13]

Radiation	Mass	Electric Charge	Velocity
Alpha Particles	relatively heavy	double positive	relatively slow
Beta Particles	about 8,000 times lighter	negative	less than the velocity of light
Gamma Rays	None	None	3×10^8 m/s in free space

Non-Ionizing Radiation

Non-ionizing radiation is the radiation that has enough energy to move atoms in a molecule around or cause them to vibrate, but not enough to remove electrons. Examples of this kind of radiation are sound waves, visible light, and microwaves as shown in Fig.1 above. It has extremely low frequency radiation with very long wave lengths (on the order of a million meters or more) and frequencies in the range of 100 Hertz or cycles per second or less. The following are the properties and benefits of non-ionizing radiation [10]:

- Microwave radiation with wavelengths that are about 1 hundredth of a meter long and have frequencies of about 2.5 billion Hertz is commonly use for telecommunications and heating food.
- Infrared radiation is used for warming food in the restaurants
- Radio waves are used for broadcasting and have wave lengths between 1 and 100 meters and frequencies in the range of 1 million to 100 million Hertz.

SOURCES OF RADIATION

Radiation is the energy that travels through space, in the form of particles or electromagnetic waves such as radio, microwaves, infra-red, visible light, ultra-violet, alpha particles, X-rays and Gamma-rays etc [4, 9]. According to ref [14, 15], these sources of ionizing radiation could be from natural background radiation such as radon and thoron, cosmic and terrestrial radiation, or man-made radiation such as those from x-ray or nuclear medicine (NM) procedures. The details (See Fig. 3) as illustrated:

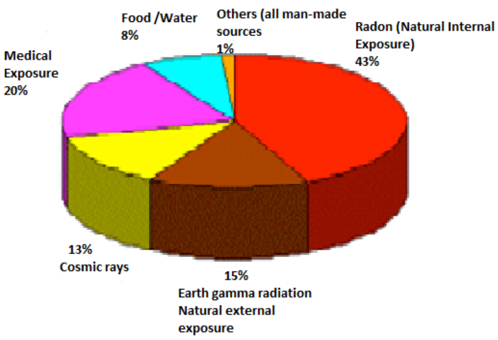

Fig. 3: Sources of Radiation [8]

Natural Radiation

In the literature, there are three sources of natural background radiation; Cosmic Radiation, Terrestrial Radiation and Internal Radiation [3, 10, 12, 16].

Cosmic Radiation:

This is simply the radiation from the sun and stars. Flying based at high altitudes much frequently and for long duration will attract extra cosmic radiation exposure.

Terrestrial Radiation:

This is the radiation due to the presence of radioactive materials such as uranium, thorium, and radium that exist naturally in soil, water and rocks. Essentially air contains radon, which is responsible for the dose from natural background sources, and all organic matter (plant and animal) also contains radioactive carbon and potassium. However, the dose from these sources varies in different parts of the world, but locations with higher soil concentrations of uranium and thorium generally have higher doses. Therefore, the background radiation levels vary in certain areas due to geological differences and sometimes the exposure can be more than 200 times higher than the global average. The highest known level of background radiation affecting a substantial population is in Kerala and Madras States in India where some 140,000 people receive doses which average over 15 mSv per year from gamma radiation in addition to a similar dose from radon for a total of 30 mSv. Similarly, comparable levels occur in Brazil and Sudan, with average of 40 mSv/yr exposures to many people [4, 7, 12, 17, and 18].

Internal Radiation:

This type of radiation is due to the internal composition of human bodies such as radioactive potassium-40 and carbon-14 from birth till death.

Artificial (Man-made) Radiation

According to ref [3, 10, 12, and 16], man-made radiation involves the following:

i. Radiation due to medical procedures, such as diagnostic x-rays, nuclear medicine, and radiation therapy. In this group also is radiation from consumer products, such as building materials, combustible fuels (gas and coal), television, cell phones etc

ii. Radiation from nuclear sites which account for less than 0.01% per year of the average dose and the exposure from shipment of radioactive materials and residual fallout from nuclear weapons testing and accidents like Chernobyl.

HEALTH EFFECTS OF IONIZING RADIATION

Ionizing radiation transfers energy into the body tissue and may thereby interfere in the structure of molecules. In living organisms, this energy transfer may disturb or destroy cellular functions (somatic effect-fatal and nonfatal cancer) or it may change the genetic code of cells (hereditary effect). However, concerning the probability of cell changes, two types can be distinguished either deterministic or stochastic effects [19]. For deterministic, the severity of the effects is proportional to the dose (with threshold) and for stochastic effects the probability but not the severity is proportional to the dose [2, 4, 5, 20]. Accordingly deterministic (acute) effects will occur only if the radiation dose is substantial, such as in accidents. Stochastic effects (cancer and hereditary effects) may be caused by damage in a single cell. As the dose to the tissue increases from a low level, more and more cells are damaged and the probability of stochastic effects occurring increases [5]. Radiobiological and clinical studies have shown that deterministic effects (acute effects, cataracts, malformations) only occur above threshold doses with dose limits and reference values used in radiological protection which are above 100 mSv. However, for low dose range of less than 100 mSv, only genetic and carcinogenic effects are expected. Even though epidemiology may not have probably clarified the connection between cancer induction and radiation in the low dose range [21]. But other health effects may occur in infants as a result of exposure of the embryo or foetus to radiation. These effects include a greater likelihood of leukaemia and for exposure above various threshold doses during certain periods of pregnancy, severe mental retardation and congenital malformations may arise [19, 22]. According to ref [23], an exposure to high levels of radiation is known to cause cancer. But the effects on human health from very low doses of radiation such as the doses from background radiation are very hard to determine because there are so many other factors that can mask or distort the effects of radiation. For example, among people exposed to high radon levels, cigarette smokers are much more likely to get lung cancer than non-smokers. Lifestyle choices, geographic locations, and individual sensitivities are difficult to account for when trying to understand the health effects of radiation. Ref [4] highlighted that studies have shown that the effect of radiation is dependent on many factors including:

i. The type of radiation (alpha, beta or gamma)
ii. The amount received
iii. The rate at which it is received
iv. Which part of the body is exposed
v. Whether the exposure is chronic (regular, low doses) or acute (short time, high dose)
vi. The age of the irradiated person.

Biological effects of radiation are typically classified into two categories [24]: The first category consists of exposure to high doses of radiation over short periods of time producing acute or short term effects (Deterministic) while the second category represents exposure to low doses of radiation over an extended period of time producing chronic or long term effects (Stochastic). The high doses tend to kill cells, while low doses tend to damage or change them. High doses can kill so many cells that will lead to damage of tissues and organs. This may result to a rapid whole body response often called the Acute Radiation Syndrome (ARS).

RADIATION EXPOSURE

Generally radiation exposures can be divided into three categories namely high level, medium and low level exposure:

High-level: Radiation exposure such as the one from atomic weapons that cause massive damage to the body and cannot repair the affected cells fast enough with a dose that may quickly kill the exposed person. However, high level of exposure in some cases within a controlled situation can be beneficial. Such as cancer therapy where concentrated beams of radiation are directed to affected areas of the body to destroy cancer cells. High level radiation doses are doses of more than 1000 mSv. According to ref [1], high radiation doses tend to kill cells, while low doses tend to damage or alter the genetic code DNA (deoxyribonucleic acid) of irradiated cells. High doses can kill so many cells that will make tissues and organs to be damaged immediately. This in turn may cause a rapid body response often called ARS. The higher the radiation dose, the sooner will be the appearance of the radiation effects and the higher the probability of death. This syndrome was observed in many atomic bomb survivors in 1945 and emergency workers responding to the 1986 Chernobyl nuclear power plant accident. Approximately 134 plant workers and fire-fighters battling the fire at the Chernobyl power plant received high radiation doses – 800 to 16,000 mSv and suffered from acute radiation sickness. Out of these, 28 died within the first three months from their radiation injuries. Two more patients died during the first days as a result of combined injuries from the fire and radiation.

Medium-Level radiation exposure: This type does not kill the exposed person, but may cause damage to reproductive cells or other body cells. Cells which have been permanently damaged or changed may go on to produce abnormal cells when they divide. Under such circumstances, these cells may become cancerous.

However, the cancer may take many years to appear. Medium level radiation doses are of the order of hundreds of mSv. Ref [25] noted that there is no direct evidence of negative influence of low radiation doses on heredity and that all human investigations in populations from regions with high radiation background have revealed no genetic effects and no harmful consequences for health and lifespan. But according to ref [5], radiation exposures has the potential to cause hereditary effects in the offspring of persons exposed to radiation and such effects were once thought to threaten the future of the human race by increasing the rate of natural mutation to an inappropriate degree. However, radiation induced hereditary effects have yet to be detected in human populations exposed to radiation, although they are known to occur in other species.

Low-level radiation exposure: This is as a result of natural background radiation or radiation at mines where radioactive ores are dealt with. It may also result in damage to reproductive cells or cancer. Low-level radiation doses are in the tens of mSv. They spread out over long periods of time but do not cause an immediate problem to the organ. The effects of low radiation doses to the cell may not be observed for many years. According to ref [26], ionizing radiation has long been recognized as a human carcinogen. However, it is thought that very low radiation exposure may stimulate DNA repair along with enzymes that destroy free radicals and protects against certain cancers.

THE ASSOCIATED HEALTH EFFECTS OF RADIATION

The long-term effects of radiation are those which may manifest themselves years after the original exposure [27]. It is emphasized that there is no unique disease associated with the long-term effects of radiation. But it is necessary to observe large populations of irradiated persons in order to measure this kind of increase and employ bio statistical and epidemiologic methodology. In addition, the situation is further complicated by the incubation period of radiation-induced disease which may go unrecorded unless the study continues for many years. Despite the above difficulties, many epidemiologic investigations of irradiated human beings have provided convincing evidence that ionizing radiation may indeed result in an increased risk of certain diseases long after the initial exposure. These effects however observed were somatic damage, which may result in an increased incidence of cancer, embryological defects, cataracts, life span shortening, genetic mutations and may have an adverse effect for generations after the original radiation damage. This information was supplemented from animal experimentation which demonstrates these same effects. For low levels of radiation exposure, the biological effects are so small that they may not be detected. The body has repair mechanisms against damage induced by radiation as well as by chemical carcinogens [1, 7]. However, biological effects of radiation on living cells may result in three outcomes:

i. Injured or damaged cells repair themselves, resulting in no residual damage.
ii. Cells die, much like millions of body cells do every day, being replaced through normal biological processes.
iii. Cells incorrectly repair themselves resulting in a biophysical change.

Dose Limits

The purpose of a system of dose limits is to ensure that the radiation dose received by any person other than an accidental exposure or a deliberate exposure as in medical diagnosis is below threshold for any deterministic effect and the probability of any stochastic effect is small enough and acceptable to the individual and to the society [28]. However, the system of radiation dose limits in use in most countries is based on the recommendations of the International Commission on Radiological Protection (ICRP).

Radiation Exposure

Radiation exposure may be classified into either internal or external [11].

Internal exposure

This type of exposure occur when a radionuclide is inhaled, ingested or otherwise enters into the bloodstream through injection or wounds. This type of exposure is eliminated from the body either through treatment or spontaneously through excreta [1]. According to ref [3], the following precautions can be taken to reduce exposure to internal radiation:

- Minimizing dust in the work place by proper watering, washing down and by good ventilation.
- Wearing appropriate respiratory protection devices in areas where dust is inevitable.
- Ventilation of areas where radon or Thoron (isotope of radon- radon 220) may build up. This does not normally apply in open cut mines where even a slight wind will disperse the radon.
- Keeping work areas clean. Surface contamination is the start of a pathway that can lead to radioactive materials being re-suspended in the air and inhaled, or transferred from dusty or unclean surfaces to the mouth or by ingestion.

External exposure

This can either be due to contamination or irradiation. The external contamination occurs when airborne radioactive material such as dust, liquid, aerosols is deposited on the skin or clothes while irradiation such as X-ray. According to ref [4], it is the radiation that comes from a radioactive source that is outside the body. Since alpha particles and beta particles do not travel very far in air, external radiation usually refers to gamma rays.

Occupational Exposure

This is the exposures incurred at work [29, 30] as the result of situations that can reasonably be regarded as being the responsibility of the operating management. The maximum permissible dose for **occupational** exposure should be 20 mSv per year averaged over five years (100 mSv in 5 years) with a maximum of 50 mSv in any one year [1, 12, 14, 28, 31, 32, 33]. According to ref [12], the average dose overall to occupationally exposed workers from artificial sources is less than 1mSv in a year. Similarly, the average in the nuclear industry tends to be little higher than this, but for the medical staff is slightly less.

Public Exposure

For **public** exposure, 1 mSv per year averaged over five years. In both categories, the figures are over and above background levels, and exclude medical exposure [12, 14, 28, 32, and 33]. According to ref [33], in the case of prospective situations that are expected to affect members of the public, what is controlled is the additional dose to the background dose that the public is expected to receive as a result of the introduction of a new activity.

RADIATION PROTECTION

Radiation protection has its origins early in the twentieth century. It is the term applied to concepts, requirements, technologies and operations related to protection of people such as radiation workers, members of the public, and patients undergoing radiation diagnosis and therapy against the harmful effects of ionizing radiation [22]. According to ref [34], the purpose of radiation protection is to provide an appropriate level of protection in preventing occurrence of harmful deterministic effects and stochastic effects such as cancer and hereditary effects to humans without unduly limiting the beneficial actions giving rise to the radiation exposure. Ref [14] however noted that radiation protection program elements include signage and posting; dose limits for the general public; occupational dose program; area surveys; sealed source inventory and leak testing; ordering, receiving, and opening of packages; patient dosage determination and preparation; minimization of contamination and spills; waste decay in storage and disposal; reporting; record keeping and audits of the radiation protection program. Radiation protection standards in any country are set by government authorities and in the Republic of South Africa, The National Nuclear Regulator is mandated with that responsibilities which generally is in line with recommendations by the International Commission on Radiological Protection (ICRP), taking into account social and economic factors with the requirement to keep exposure as low as reasonably achievable (ALARA) [7]. The authority of the ICRP comes from the scientific standing of its members and the merit of its recommendations. Therefore, radiation protection for practices is founded on a conceptual framework, which was proposed by the International Commission on Radiation Protection (ICRP) and involves three principles: justification, optimization and limitation [22, 29, 30, 35, and 36].

ALARA

ALARA is a concept for radiation protection that urges licensees to make a reasonable effort to maintain individual and collective radiation exposure as low as possible. This means that the institutional operational dose limit for any radiological activity needs to be more restrictive, if possible, than the occupational dose limit. ALARA can be achieved by designing processes, implementing procedures, and using engineering controls to minimize radiation exposure [14]. According to ref [15], the aim of Radiation Protection is to establish an appropriate level of protection for people and the environment against detrimental effects of radiation exposure without unduly limiting the desirable human actions that may be associated with such exposure.

Precautionary Measures of Radiation Protection

The three precautionary measures against external radiation sources are time, distance and shielding [7, 9, 32, 37].

Time

By decreasing the amount of time spent near a source of radiation, the less the amount of radiation exposure received [32, 38]. Accordingly, the longer time exposed to a radioactive source, the greater the dose that will be received (radiation dosages are cumulative). Therefore, it is recommended to spend as much short time as possible in a radioactive environment.

Distance

Radiation intensity decreases sharply with distance, according to an inverse square law [9, 13, 32, 36, 38, 39, and 40]. The farther away from a radiation source, the less exposure received. Therefore, the closer it is to the source, the greater chances of bodily damage.

Shielding

This is the method of placing some material such as concrete or lead in-between radiation source [7]. Shielding decreases exposure. However, proper shielding can result in an exponential reduction of dose for gamma emitters and a near-total reduction for beta emitters. Consequently, shielding design may be simple or may involve complex calculations but all depends on the type of radiation, the energy and frequency of emission, the configurations of source and room, and the occupancy factors [9]. Therefore, in planning stages of any experiment or clinical procedure the selection of appropriate shielding materials is highly recommended.

Ref [41] noted that shielding design and shielding analysis are complementary activities.

Shielding Materials

Radiation control and the prevention from causing physical harm to workers or their surroundings is an important part of operating equipment that emits potentially hazardous rays. Preserving both human safety and structural material that may be compromised from radiation exposure are vital concerns, as well as shielding sensitive materials, such as electronic devices and photographic film. However, the process of regulating the effects and degree of penetration of radioactive rays varies according to the type of radiation involved. Indirectly ionizing radiation, which includes neutrons, gamma rays and x-rays, is categorized separately from directly ionizing radiation, which involves charged particles [42]. Different materials are better suited for certain types of radiation than others, as determined by the interaction between specific particles and the elemental properties of the shielding material.

Gamma and X-ray Shielding

Gamma rays have a finite probability of passing all the way through a medium through which it is travelling [32]. However, the probability that a gamma ray will penetrate through a medium depends on many factors, which includes: the energy of the gamma ray, the composition of the medium and the thickness. If the medium is dense and thick enough, the probability of penetration may be practically zero. With a medium of the size and density of the human body, however, most radionuclide's have a good chance of emerging and being detected outside the body. Therefore, for this reason, suitable gamma-ray emitters are powerful tools for studying body function. Ref [42] noted that high-density materials are more effective than low-density alternatives for blocking or reducing the intensity of radiation. However, low-density materials can compensate for the disparity with increased thickness, which is as significant as density in shielding applications. Lead is particularly well-suited for lessening the effect of gamma rays and x-rays due to its high atomic number. This number refers to the amount of protons within an atom, so a lead atom has a relatively high number of protons along with a corresponding number of electrons. These electrons block many of the gamma and x-ray particles that try to pass through a lead barrier and the degree of protection can be compounded with thicker shielding barriers. However, it is important to remember that there is still potential for some rays making it through the shielding, and that an absolute barrier may not be possible in many situations. According to ref [40], three groups of people are considered for protection in the use of x-rays: the patient, workers who perform examinations and members of the public, most of whom can be presumed to be only occasionally exposed when attending patients. However, shielding is placed around x-ray units and x-ray rooms to maintain exposures of workers and members of the public below prescribed limits of ALARA. The other elements for patient protection from medical x-rays are based on good practices, some of which are [32, 40]:

i. To confine the field size to the regions being examined through proper collimation and shielding, especially for the reproductive regions.
ii. Using the maximum distance practicable between the x-ray source and the patient.
iii. Using the highest x-ray tube voltage practicable and proper filtration of the x-ray beam to give the minimum absorbed dose consistent with producing a satisfactory radiograph.
iv. Paying particular attention to the film processor, especially ensuring accurate processing temperature and the quality and strengths of process chemicals.
v. Using fast film/screen combinations and short exposure times.
vi. Planning of all exposures carefully to minimize retakes.

Alpha and Beta Shielding

While density remains an important characteristic for blocking alpha and beta radiation, thickness is less of a concern. A single centimeter of plastic is sufficient for shielding against alpha particles, as in a half-inch of paper. In some cases, lead is ineffective in stopping beta particles because they can produce secondary radiation when passing through elements with a high atomic number and density. Instead, plastic can be used to form an efficient barrier for dealing with high-energy beta radiation [9, 42]. When negatively charged beta particles hit a high-density material, such as tungsten, the electrons are blocked, but the target which the barrier is intended to protect can actually become irradiated.

Neutron Shielding

Accordingly, lead is quite ineffective for blocking neutron radiation, as neutrons are uncharged and can simply pass through dense materials. Materials composed of low atomic number elements are preferable for stopping this type of radiation because they have a higher probability of forming cross-sections that will interact with the neutrons. Hydrogen and hydrogen-based materials are well-suited for this task. Compounds with a high concentration of hydrogen atoms, such as water, form efficient neutron barriers in addition to being relatively inexpensive shielding substances. However, low density materials can emit gamma rays when blocking neutrons, meaning that neutron radiation shielding is most effective when it incorporates both high and low atomic number elements. The low-density material can disperse the neutrons through elastic scattering, while the high-density segments block the subsequent gamma rays with inelastic scattering.

CONCLUSION

Long term epidemiological studies of populations exposed to radiation, have demonstrated that exposure to radiation have potential for the delayed induction of malignancies. It is therefore essential that activities involving radiation exposure, such as the production and use of radiation sources and radioactive materials, and the operation of nuclear installations, including the management of radioactive waste, be subjected to certain standards of safety in order to protect those individuals exposed to radiation. However, radiation and radioactive substances are natural and permanent features of the environment, and thus the risks associated with radiation exposure can only be restricted, not eliminated entirely. Furthermore, the use of human made radiation is widespread. Sources of radiation are essential to modern health care especially disposable medical supplies sterilized by intense radiation have been central to combating disease, radiology is a vital diagnostic tool and radiotherapy is commonly part of the treatment of malignancies. Whereas the use of nuclear energy and applications of its by-products for radiation and radioactive substances, continue to increase around the world, similarly, nuclear techniques are in growing use in industry, agriculture, medicine and many fields of research, benefiting hundreds of millions of people and giving employment to millions of people in the related occupations. Irradiation is likewise used around the world to preserve foodstuffs and reduce wastage while sterilization techniques have been used to eradicate disease carrying insects and pests. To examine welds and detect cracks and help prevent the failure of engineered structures, industrial radiography is still not left out. Therefore, the acceptance by society of risks associated with radiation is conditional on the benefits to be gained from it. Hence, the risks must be restricted and protected against by the application of radiation safety standards which provides desirable international consensus. The outcome of these standards was from extensive research and development work by scientific and engineering organizations, at national and international levels, which was based on experiences in many countries in the use of radiation and nuclear techniques, the health effects of radiation, techniques for the safe design and operation of radiation sources.

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