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"How to Protect from Nuclear Radiation"

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Abstract: Nuclear radiation protection is a crucial for future development in the field of Nuclear energy generation. This work categorizes the various types of radiation protections. It is comprehensive review of nuclear radiation protection.

Introduction

Nuclear radiation is defined as the release of elementary particles or energy as a result of atom decay. It is frequently confused with nuclear fission, in which a larger atomic nucleus is split into two smaller nuclei of similar size [1]. These kinds of processes do involve nuclear radiation. The purpose of this paper is to examine the various types of radiation, such as alpha, beta, gamma, and neutron radiation, as well as how to protect yourself from them. These forms of radiation were discovered around the turn of the century. Both alpha particles, which are massive and positively charged, and beta radiation, which consists of lighter negatively charged particles, were discovered by Ernest Rutherford, a prominent scientist. Paul Villard, a French physicist, was the first to discover the third form of radiation. Villard discovered the massless gamma rays, which have no charge at all. They're high-intensity lights. Henri Becquerel discovered radiation, as defined above, in 1896 when he discovered that Uranium could fog a piece of film [2]. What is radiation, exactly? The emission of energy by a substance is known as radiation. The two types of radiation are electromagnetic and nuclear. These words are all recognized, but they are not synonymous with the phrase "radiation."

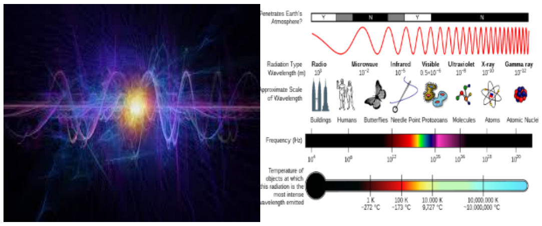

Figure 1. EM radiation spectrum

When people talk about radiation, they mostly mean nuclear radiation, which is when subatomic particles are emitted from the nucleus of atoms. Nuclear radiation is also called ionizing radiation, as it is energetic enough to knock electrons off the atoms. It is referred to as nuclear radiation in this work to remind you of the radiation's origin.

Types of Nuclear Radiation

There are at least four distinct kinds of nuclear radiation. These radiations are; Alpha radiation, Beta radiation, Gamma radiation, and Neutron radiation. Each of these types of radiation have a distinct characteristic.

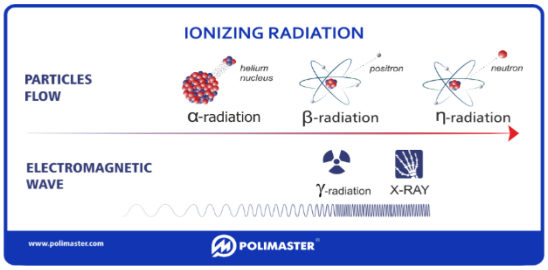

Figure 2. Ionization radiation of particles flow and EM wave

Alpha radiation

Alpha radiation occurs whenever an atomic nucleus shoots out an alpha particle, which consists of two protons and two neutrons. Alpha radiation is when the radioactive element shoots out a helium atom. The diagram below shows the radiation of an alpha particle. Alpha particles are high-energy helium-4 (4 He) atoms that are emitted from the nucleus of a radionuclide and consist of two protons with a +2 charge and two neutrons coupled together with an atomic mass of four. Alpha -particles have an energy range of 4 to 8 MeV, with the energy increasing with the mass of the parent nucleus that emitted them. As a result, any radionuclide's emissions are mono-energetic and have a distinctive energy. On an atomic scale, the energy and mass of alpha-particle are significant, therefore its emission causes the parent/daughter nucleus to recoil. This alpha-recoil effect accounts for a modest but significant portion of the overall energy lost during decay (2%). Alpha particles lose energy quickly and pick up electrons from their surroundings, becoming inert Helium-4 (their typical lifetime is a few picoseconds).

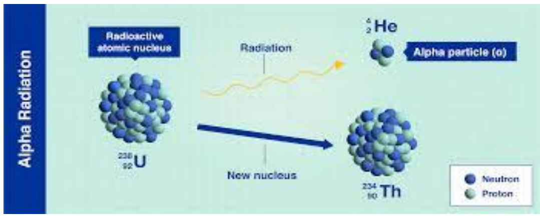

Figure 3. Emission of Alpha radiation (Alpha particle)

Beta radiation

Beta radiation is caused when an atomic nucleus shoots out an electron. We can call it electron radiation, but the name was invented before the emitted particle was identified as an electron. It occurs when a neutron in an atomic nucleus turns into a proton and electron. The proton is kept inside the nucleus and the electron escapes. Beta particles are electrons or anti-electrons that are emitted from the nucleus of a radionuclide. These electrons have a mass of around 0.00055 of an atomic mass unit. The conversion of a neutron into a proton result in the emission of a negatively charged electron, which is known as beta-(negatron) radiation. A proton is changed to a neutron and an antielectron, the positively charged equivalent of an electron, known as a positron, is ejected as a result of the opposite conversion. The formation of a third body, in addition to the daughter nuclide and electron/positron, is a result of beta radiation. In the case of Beta- emission, the third body is an anti-neutrino, while in the case of beta+ emission, it is a neutrino. The energy of beta-particles varies because the energy from radiation is shared between the emitted particle and the third body, even when the source radionuclide is the same (their energy is not characteristic). A Beta particle's energy ranges from zero to the maximum accessible energy from the parent's transmutation into the daughter (the reaction energy 'Q,' typically around 1 MeV). Many emitters also produce gamma-rays; those that do not are referred to be 'pure' beta emitters. Bremsstrahlung is caused by high-energy beta particles. Emitted beta- particles lose their extra energy quickly (in a few tens of picoseconds) and become indistinguishable from other electrons in the surroundings. Because positrons are antielectrons, they are generally quickly annihilated after colliding with electrons in the surrounding environment, which are also annihilated. Two 0.511 MeV gamma-rays are emitted as a result of the released energy. Beta particles will now be referred to as beta-particles, while beta+ particles will be referred to as positrons.

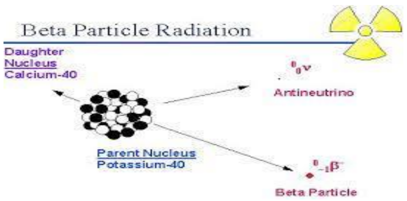

Figure 4. Emission of Beta radiation (Beta particle)

Gamma radiation

Gamma radiation is when an extremely high energy photon escapes the nucleus. In a better sense, this is not much different than a nucleus emitting ordinary light, but the much higher energy can damage surrounding material. X-rays are like gamma radiation in many ways, but less energetic. They are like gamma radiation younger and less successful sibling.

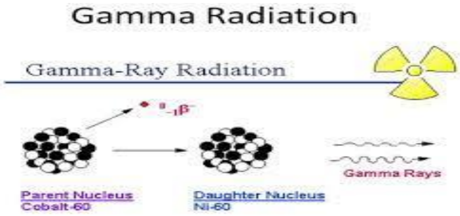

Figure 5. Emission of Gamma-rays

What are X-rays?

The X-ray is an example of ionizing radiation. Ionizing radiation creates positively and negatively charged particles when it passes through materials (ions). The event that may cause harm to human tissue is the formation of these particles. In human cells, ionization leads to the formation of unstable atoms, free electrons, lower energy x-ray photons, reactive free radicals capable of producing substances toxic to the cell, the production of new biologic molecules that are hazardous to the live cell, and cell injury manifested as aberrant function or lack of function are all examples of cell injury [4,5].

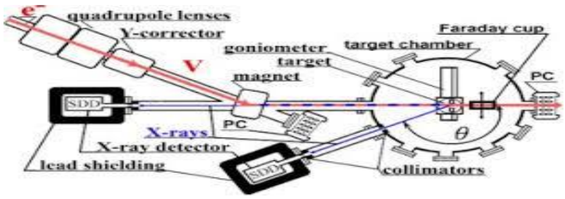

Figure 6. Ionization radiation (X-rays)

Neutron radiation

In 1999, an IARC Working Group looked into neutrons. (2000, IARC). New information has been available since then, which has been added into the Monograph and considered in the present evaluation. Neutron radiation is just the emission of a neutron. This is the most dangerous type of radiation, but, as we will see that it is a subjective statement. Neutrons are uncharged particles that make up the nucleus of atoms, together with protons. Neutrons interact with the nucleus of atoms, whereas X- and -rays interact largely with orbital electrons. Neutrons are emitted from nuclei in a variety of ways, including when high-energy cosmic radiation interacts with the Earth's atmosphere and when nuclei fission or fusion. Fission neutrons have energy of several MeV, while fusion neutrons have energies of about ten MeV [1,2,3]. The collision of highly charged particles (e.g. -particles, ions from an accelerator) with a suitable target material can also yield neutrons. Radiography and radiotherapy employ the neutrons emitted. The mean free path of neutrons in tissues varies depending on their energy from a fraction of a millimeter to several tens of centimeters. In tissue, neutrons interact with hydrogen nuclei. The low-energy proton (reacting nuclei) produces densely ionizing tracks with a high linear energy transfer (LET), which might damage cells. As a result, for the same tissue dose, the ICRP (2007) devised radiation weighting factors for calculating the risks associated with neutron exposure, which are higher than those associated with X- or -rays. Neutrons with energies greater than 50 MeV interact mostly with nuclei such as C, N, O, and Ca in tissue, resulting in a large number of lower energy particles such as -particles, protons, and other neutrons with a wide LET distribution. High-energy neutron exposure is so distinct from low-energy neutron exposure. Gamma rays are produced when neutrons interact with matter [3].

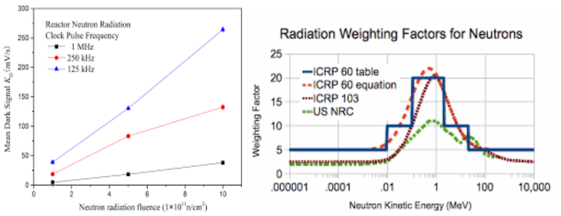

Figure 7. (a) Frequencies level of Reactor Neutron Radiation (b) Weight factor vs neutron KE (MeV)

How to protect yourself from radiation?

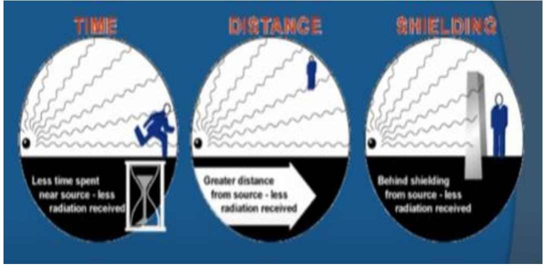

Figure 8. Source: https://www.nde-ed.org

Obviously, the easiest thing to do is to get far away from radiation. Just like a fire seems cooler, the further you get away from it. Therefore, distance is the easiest way to reduce your exposure to radiation. However, that is not always possible. We live in a radioactive world. Bananas are radioactive, as Brazil nuts, and most interestingly, the human body is radioactive. Low-energy radiation, such as low-energy X-rays, can be protected in a number of ways. By wearing lead aprons, patients and clinicians can be protected from the potentially harmful radiation consequences of routine medical tests. Because only a small amount of shielding material is required to give the desired protection, protecting substantial regions of the body from lower-energy radiation is highly practical. Copper shielding is significantly more effective than lead, according to recent studies, and is expected to replace lead as the standard material for radiation shielding. It is important to know the ways in which we can shield ourselves from various kinds of radiation.

- Alpha (α) radiation consists of heavy and slowly moving particles with a lot of electrical charge. These properties combine to make it easy to stop. You can stop alpha particles by using a single sheet of paper.
- Beta (β) radiation consists of light and fast-moving particles with electric charges. This means that they can be stopped by thin metal plates.
- Gamma radiation consists of fast-moving particles with no electric charge. This means that they can emit no electric field to interact with matter. They are therefore much harder to stop. To stop gamma rays, you need a heftier chunk of dense material like lead. This is also true for x-rays, which is the reason they put a lead apron on you when you are getting dental x-rays.
- Neutron (n) radiation consists of heavy particles with no electric charge. Since they do not interact with atomic electrons, they can travel long distances, hundreds or even thousands of meters in air. The way to slow neutron radiation down is not so intuitive. You must use something

with a lot of hydrogen in it, like water or plastic. The neutrons hit the protons in the hydrogen nuclei and knock them out. This stops the neutrons and then the charged protons stop quickly much like alpha particles [4,5,6].

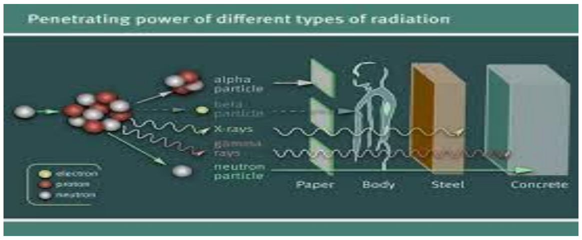

Figure 9. Shows how to shield the various kinds of radiation

Radiation Safety in Nuclear Medicine

In this section, we'll talk about how to optimize radiation protection, what's new in terms of safety, and what's new in terms of radioactive waste, dose management, and maximum exposure. Over the last few decades, the development of new radiopharmaceuticals, notably those for radionuclide therapy, has fueled significant advances in nuclear medical procedures (RNT). Large doses for even diagnostic studies are becoming more popular, thanks to the rising use of 99mTc base radiopharmaceuticals for perfusion imaging of the myocardial and brain imaging lesions with peptides and proteins. As a result, practices in nuclear medicine departments, particularly in the hospital radio-pharmacy wing, must be carefully designed, implemented, and monitored in order to protect workers, the public, and the environment from radiation [1].

^{99m}Tc-Product

The recent generation of ^{99m}Tc products include compounds for;

I. Imaging blood flow to myocardium and brain
II. Imaging lesion such as infection/inflammation
III. Tumor and Thrombus formation.

Proper care and safety protocols should be followed at all phases of preparation, handling, injection, and imaging. The amount of activity retained in the organ of interest could be a fraction of the injected dose, with the majority of the injected activity eliminated in urine over a few hours. As a result, there is not only a concern for occupational employees and nearby personnel, but also a potential contamination risk.

Cyclotron Products-SPECT product

1. ^{111}In products are mainly useful in cases of delay imaging needs. Amongst the more important ^{111}In products, special mention can be made of the ^{111}In labeled-peptide and ^{111}In labeled-octreotide, for imaging tumors of neuro-endocrine origin.
2. ^{123}I-metaiodobenzylguanidine (^{123}I-MIBG) is a particularly good maker for myocardial imaging but due to its planning problems of accessibility to pure ^{123}I have precluded wide use of these products, despite their importance in clinical practice.

PET Product

1. PET product in Neurology: ^{18}FDG was originally proposed for estimating regional cerebral blood flow and shown as a good activity during variety of metal functions, since glucose is the source energy for brain. Similarly, ^{15}O and ^{11}C labeled receptor radiopharmaceuticals are used for investigation in patients for neurological disorder.

2. FDG in Cardiology: This isotope is a useful tool for myocardial viability studies.

3. FDG in Oncology: The role of FDG tumor metabolism as a better grading or staging indicator of tumor prognosis.

Spectrum of major Therapeutic Application

- Radioiodine in thyroid disorders including thyroid carcinoma.
- ^{131}I-MIBG in tumor derived from neural crest.
- Intra-arterial therapy, e.g., radiolabeled lipiodol for hepatocellular carcinoma (up to 120 mCi used).
- Intra-cavitary therapy (Intrapleural, Intraperitoneal, Intrapericardial, Intrathecal, and Intracystic).
- Radioimmunotherapy.
- Radionuclide therapy for benign disorders, e.g., ^{198}Au colloids and ^{90}Y colloids in rheumatoid arthritis and other inflammatory joint diseases.
- Intravascular radionuclide therapy for prevention of re-stenosis.
- Labeled hormone therapy and
- Radiopeptide therapy.

Radionuclide Therapy

The half-life, energy of the emissions, volume to be irradiated, type of alpha emitters, auger or conversion electron emitters, hard beta emitters, and soft beta emitters all influence the therapeutic radionuclide selection. Also, production and organization are simplified.

Tritium-Nuclear weapons production: Because the amount of ^{3}H required for nuclear bombs is so little, the facilities used to generate it are typically far smaller than those used to produce plutonium, resulting in a lesser number of employees exposed to ^{3}H. Because of the secrecy of military ^{3}H production, there are only a few ^{3}H worker cohorts identified from this activity. In the last ten years, the UK has relaxed the secrecy around military ^{3}H production, resulting in the discovery of several hundred people who may have been exposed to ^{3}H at the Capenhurst and Chapelcross sites (HPA, 2007).

Tritium-Nuclear power production: ^{3}H exposures often account for the majority of the employees' dose in heavy-water moderated reactors like the CANDU type. ^{3}H has also been used to make self-illuminating devices (in which the -particle emissions are employed to promote light generation in a suitable phosphorescent material) that have been used in a variety of applications such as timepieces, rifle sights, and signs. During the years 1983–2002, roughly 100000 self-illuminating exit signs were made per year in the United States (PSI, 2003), carrying around 100 PBq (petabecquerel, 1015 becquerel) of ^{3}H.

Phosphorus-32

Medical use: Polycythaemia vera has been treated with 32P in the form of 32PO4 since 1939. This has been the radioisotope's primary medical application, accounting for 5% of overall radionuclide therapeutic use in a survey of 17 European countries (Hoefnagel et al., 1999), but just 1% globally (UNSCEAR, 2000a). Individual treatments usually consist of 150–170 MBq of 32PO4 given orally or intravenously. ^{32}P has also been utilized as a radioactive tracer for a variety of applications, including tumor identification and surgical removal. ^{32}P has also been used to treat leukemia in the past (both chronic myelocytic leukaemia and chronic lymphocytic leukaemia).

Strontium-90

As exposure to ^{90}Sr is mostly in conjunction with other fission products, further information on exposures is given in the mixed fission products section below.

Iodine-131

Because ^{131}I is frequently combined with other fission products, the mixed fission products section below includes further information on exposures.

Medical use: For more than 50 years, radioiodine has been used to treat hyperthyroidism and thyroid cancer, and it is by far the most common internal emitter used for therapeutic purposes. It's also worth noting that radioiodine treatment can cause external exposure to others, and it's the primary source of public and family exposure from patients who have received unsealed radionuclides (ICRP, 2004).

Caesium-137

Because ^{137}Cs is commonly used in conjunction with other fission products, the mixed fission products section below has more information on exposures.

Radon

Natural sources: The isotopes in the ^{232}Th and ^{238}U decay chains, particularly ^{222}Rn and its progeny, dominate internal exposures from Naturally Occurring Radioactive Materials (NORM). ^{222}Rn contributes by far the most to average individual internal public exposures from natural sources. Building 222Rn concentrations range from less than 10 Bq/m^3 to more than 100 Bq/m^3 (UNSCEAR, 2006), depending on factors such local geology and air circulation (restricted ventilation in places such as caves can lead to much greater ^{222}Rn concentrations). Residential ^{222}Rn concentrations vary significantly depending on where you live, with basement ^{222}Rn concentrations approximately 50 percent greater than ground-floor concentrations (Field et al., 2000, 2006). Because of subtle characteristics of building structure, such as fractures and fissures in the foundation, and home ventilation, ^{222}Rn concentrations within homes in the same neighborhood can vary significantly (Radford, 1985). Residential ^{222}Rn concentrations also exhibit seasonal variation, both within and between years (Pinel et al., 1995; Krewski et al., 2005). One other source of ^{222}Rn can be from domestic water supplies. Seasonal variations in residential ^{222}Rn concentrations can be found both within and between years (Pinel et al., 1995; Krewski et al., 2005). Domestic water supplies can also be a source of ^{222}Rn.

Occupational exposure: Because ^{222}Rn is created by the radioactive disintegration of ^{238}U, which is prevalent throughout the Earth's crust, large quantities of ^{222}Rn gas have been observed in deep mines in the past (Committee on Health Risks of Radon Exposure (BEIR VI, 1999). 222Rn concentrations in mines have been considerably lowered in the interest of industrial hygiene since the discovery of lung disease in underground miners exposed to high levels of ^{222}Rn in the 19th century, which was later confirmed to be lung cancer in the 20th century. ^{222}Rn concentrations in underground mines are currently seen in ventilated mines, the current occupational exposure guideline of 2 working-level month/year (WLM/yr) is generally well below the current occupational exposure guideline of 130000 MeV of potential energy released by the short-lived progeny in equilibrium with 100 pCi of ^{222}Rn in one litre of air (3.7 kBq/m^3). The cumulative intake of 1 WLM is 0.755 MBq, assuming a breathing rate of 1.2 m^3 /h [6]. Although previous underground mine exposures have outnumbered residential exposures by a factor of 1000 or more, this disparity has narrowed to a factor of 20–30 in recent years.

Radium

Occupational exposure: Just before World War I, the technique of coating clock dials with radium-based paint to make them luminous was introduced. The manufacture and application of luminous paint quickly became a business, notably in the United

States. Because of the precision required to apply these radium-based paints, 'Dial painters' or 'Luminisers' (as they were known) frequently 'tipped' their brushes with their tongues, ingesting some of the paint and the radium it contained. Radium-based paints have also been used in Germany, the United Kingdom, and a number of other countries across the world (IARC, 2001).

Thorium-232

Medical use: In the 1920s, thorium dioxide (ThO_2) was originally employed as an X-ray contrast medium for splenography, and from 1931, a commercial preparation containing it was offered as a general vascular contrast medium under the brand name 'Thorotrast.' Thorotrast was widely used over the world and was given by instillation or injection. Before it was superseded by other contrast media in the 1950s, it is estimated that as many as 2.5 million people were exposed to it (IARC, 2001).

Uranium

Natural source: Uranium is found in minute levels practically everywhere in nature, including soil, rock, well water, and groundwater. Natural uranium ores contain higher amounts.

Occupational exposure: Uranium is pervasive in the nuclear fuel cycle, from mining and initial processing to enrichment and/or fuel manufacturing, power production, and reprocessing, as it is the source material for most nuclear power generating. Natural, depleted, and/or enriched uranium, in a variety of chemical states, can be exposed (IARC, 2001).

Plutonium

Nuclear weapons production and testing: The United States was the first country to seek plutonium manufacture as a way of building a nuclear bomb, however exposed persons are often compartmentalized and/or scattered. The two largest continuous populations of employees exposed to plutonium are at the Mayak Production Association in the Russian Federation's southern Urals and the Sellafield (formerly Windscale) factory in the United Kingdom. Both factories have around 10,000 plutonium worker cohorts, with exposure dates ranging from the late 1940s to the early 1950s (Mayak) (Sellafield). During and after WWII, political pressure to develop nuclear weapons as rapidly as possible resulted in severe internal exposure, notably to plutonium. Unfortunately, this is usually when monitoring data is scarcest, particularly in Mayak, when exposures were at their highest and many persons had no monitoring data at all.

Occupational exposure: Exposure to plutonium can occur during the reprocessing of irradiated nuclear fuel and, to a lesser extent, during the manufacturing of mixed oxide 'MOX' fuel assemblies.

Mixed fission products

Above is information on three of the most important fission products (^{90}Sr, ^{131}I, and ^{137}Cs). However, because fission products are always created in mixtures due to the stochastic nature of their synthesis, exposures to mixtures of fission products are common. Environmental transport models are widely used to estimate dosages from mixed fission products that have been released into the environment.

Southern urals: As previously noted, Mayak, the former Soviet Union's major weapons-grade plutonium production site, was established in the 1940s near Ozersk in the Russian Federation's southern urals. The facility's operations produced in a number of substantial and ongoing minor releases of activity into the surrounding environment, particularly the Techa River and its environs (IARC, 2001).

Techa river: 100 PBq (100 1015 Bq) of activity was discharged into the Techa–Isset–

Tobol-river system between 1949 and 1956. Around 7500 individuals were evacuated between 1953 and 1960 due to their exposure to radionuclides in communities around the Techa river, out of a total population of approximately 28000. (UNSCEAR, 2000a).

Kyshtym accident: 74 PBq of radionuclides were emitted in the Kyshtym accident. Around 273000 people lived in the territory contaminated by the accident, and around 11000 of them had to be moved, including 1500 who had previously been resettled from the Techa River area (UNSCEAR, 2000a).

Lake Karachay: The Karachay lake disaster released 0.022 PBq of radionuclides into the environment, which distributed worldwide (UNSCEAR, 2000a).

Chernobyl: The Chernobyl disaster unleashed large quantities of radionuclides into the environment, notably ^{131}I (1760 PBq) and ^{137}Cs (85 PBq), which were distributed over large areas. Individuals working on recovery activities (also known as liquidators) at the nuclear site and members of the general public living in the area were the two primary groups exposed. Following the catastrophe, 116000 people were evacuated from a 30-kilometer radius around the Chernobyl site, while 226000 recovery workers worked at the site or in the evacuated zone for the next year.

Therapeutic Radiopharmaceuticals

Patient preparation and precautions for safe radiation release must be done with the radiopharmaceutical due to the route of excretion. Samarium-153, Phosphorus-32, Yttrium-90, Dysprosium-165, Holmium-166, Rhenium-186, and Gold-198 are the products used in radiation synovectomy.

What impact do these types of radiation have on human tissue?

Varied forms of radiation, it turns out, have very different biological effects. To determine this out, scientists used several types of radiation and directed it at different organs, measuring the amount of cellular damage that resulted. They then come up with a number to account for the various levels of damage observed. A Quality factor, or simply Q, is the name given to this figure. There is no adjustment if Q is one or Q =1. If Q is more than 1, this form of radiation is more physiologically hazardous than others.

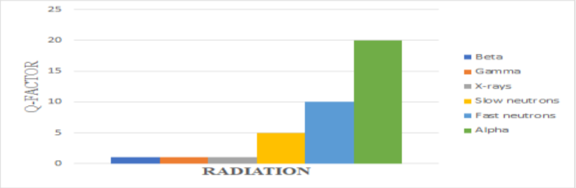

Figure 10. Q-factor of various nuclear radiation

We can see that gamma, beta, and X-rays all have a Q-factor of 1, indicating that they are not capable of doing further damage. Because slow neutrons have a Q-factor of 5, they cause more biological harm for the same amount of absorbed radiation. Because fast neutrons have a Q of 10 and alpha particles have a Q of 20, they cause greater biological damage than other types of radiation. Although alpha particles are easily stopped, they cause more damage to live cells. This makes sense because when an alpha particle comes to a complete stop, it does so abruptly and deposits all of its energy in one location. This means that when it impacts a cell, it causes substantial local damage. This is especially true if you are unlucky enough to inhale alpha emitting radioactive dust-which is extremely dangerous.

Exposure to Radiation

X-rays, γ-rays and neutrons: NCRP contains extensive information on current and historical external radiation measurement procedures, as well as the accompanying uncertainty (2007). Because excellent personal neutron dosimetry is difficult to obtain over all energy ranges (energies of interest span > 10^9 eV) and detection thresholds are often large, estimations of neutron dosage are suspect, especially in the early stages of monitoring.

Accidents: Several nuclear weapons manufacture and transit incidents have occurred. The Mayak complex at Kyshtym in the Russian Federation (previously the Soviet Union) and the Windscale plant at Sellafield in the United Kingdom were the two most serious nuclear weapons production mishaps. Chernobyl, Ukraine, experienced a severe nuclear power plant accident.

Southern urals

Mayak, the former Soviet Union's major weapons-grade plutonium production plant, was developed in the 1940s near Ozersk in the Russian Federation's southern Urals. The facility's operations resulted in a number of substantial and continuous minor unplanned discharges of activity into the surrounding environment, particularly the Techa river. A Mayak waste storage facility near Kyshtym burst in 1957 as a result of a chemical reaction; this event is known as the Kyshtym accident. Around 273000 individuals lived in the territory contaminated by the accident, and around 11000 of them had to be relocated, including 1500 people who had already been resettled from the Techa River area. The overall cumulative effective dose to a population of 273000 in Mayak was 2500 man.Sv (UNSCEAR, 2000a). Workers (see Vasilenko et al., 2007) and the nearby community received significant doses from this and other plant emissions (both routine and accidental) (Degteva et al., 2006). Karachay Lake, which had been utilized as an open repository for liquid radioactive waste from Mayak, dried up as a result of a drought in 1967.

Windscale fire

A nuclear reactor used to generate plutonium for bombs caught fire in October 1957 at the Windscale Works, now part of the Sellafield facility in the United Kingdom. The radioactive fuel in the reactor was damaged before it could be extinguished, and radionuclides were released into the environment. Mostly gaseous and volatile radioisotopes escaped due to the reactor's design, which included filtering of expelled coolant air. Internal ingestion was the primary cause of dosage in the Windscale accident.

Three Mile Island

Failure to keep coolant fluid in a commercial light-water reactor at Three Mile Island in the United States resulted in the reactor core being exposed to the air, causing a partial meltdown of the fuel load.

Chernobyl

A Russian reactor, Bolshoy Moschnosti Kanalniy (RMBK), became uncontrollable in the Chernobyl catastrophe in Ukraine in April 1986, resulting in a steam explosion and subsequent fire, which resulted in a loss of containment and ultimately the entire destruction of the reactor. The greatest contributor to the dosage from external irradiation in the Chernobyl accident was ^{137}Cs. Individual dosages ranged greatly over the northern hemisphere, with some employees and rescue workers on duty at the time of the disaster getting fatal doses of > 4 Sv (Savkin et al., 1996). During 1986–89, annual averaged exposures to operation recovery employees in Belarus, Russia, and Ukraine were in the range of 20–185 mGy (UNSCEAR, 2008a).

External Exposure

Natural sources: External radiation accounts for around 40% of the average global natural radiation dosage, with the balance coming from internal sources, primarily ^{222}Rn. The majority of natural X- and -ray exposure comes from terrestrial sources and is determined by the concentration of (natural) radioactive elements in the soil and construction materials. Cosmic rays account for a significant portion of the effective dosage and are the only natural source of neutron exposure. Muons, electrons, and photons account for the majority of cosmic ray radiation at sea level, with neutron interactions accounting for roughly 8% of the effective dosage [9]. At a height of roughly 4000 m, the neutron percentage reaches a peak of about 40%. The dose of cosmic rays rises with height and is also larger at higher latitudes. UNSCEAR (2000a) provides thorough information on exposure in different parts of the world. The average outdoor external radiation rates for various countries range from 18 to 93 nGy/h. 59 nGy/h is the population-weighted average (0.52 mSv per year). Various sites across the world have reported areas with exceptionally high radiation rates exceeding 100000 nGy/h. UNSCEAR calculated the population-weighted average effective dosage of neutrons to be 100 Sv per year (2000a).

Medical uses

Radiation is used in medicine for diagnostic and therapeutic purposes. Radiotherapy is designed to deliver large doses of tens of Gy to specific organs (UNSCEAR, 2000a). In some circumstances, assessing the risk to non-target organs is necessary. The dose per medical diagnostic examination ranges between 0.1 and 20 mGy. Diagnostic examinations are the principal source of radiation from medical use, but at lower levels than doses from radiotherapy. The use of X- and -rays for medicinal reasons is highly unevenly spread over the globe. According to UNSCEAR (2000a), the overall frequency of diagnostic X-ray exams has increased, although the frequency has remained stable or has decreased in several countries. The bulk of the world's population is not exposed to X- and -irradiation in medical diagnosis in any given year, but the effective dose for a tiny number of people can be up to 100 mSv. As technology advances, doses from diagnostic X-rays are rapidly changing (NCRP, 2009). In developed countries, average levels of radiation exposure from medical uses of radiation have been rising, owing to increased use of computed tomography (CT), angiography, and interventional procedures. In 1991–96, the projected global annual effective dose from all diagnostic uses of radiation was 1.2 mSv per person, up from 1.0 mSv in 1985–90. In 2006, Americans received a 7.3-fold higher effective dose from medical treatments than they did in the early 1980s (NCRP, 2009). Doses for the same examination can vary by an order of magnitude, and lowering the highest doses can lower the overall dose without reducing diagnostic information (Watson et al., 2005). The bulk of radiographic examinations are conventional radiographs, which have dosages ranging from less than 0.01 up to 10mSv per procedure.

Occupational Exposure

Nuclear power generation and fuel recycling, military activities, industrial operations, flying, and medical procedures all expose workers to radiation. Occupational workers' average yearly effective dosage has decreased from 1.9 mSv in 1975–79 to 0.6 mSv in 1990–94. In the United States, mean exposures to medical radiation technologists have decreased from 100 mSv per year before 1940 to 2.3 mSv per year between 1977 and 1984. (Simon et al., 2006). Global yearly doses have also been lowered in recent years, from 0.6 mSv in 1980–84 to 0.33 mSv in 1990–94. (UNSCEAR, 1993, 2000a). Occupational neutron exposure accounts for a minor portion of the total effective dose and is primarily found in the nuclear industry. The top limit of the neutron component was calculated to be 3% of the overall exposure in a United Kingdom compilation of dosage to nuclear employees (Carpenter et al., 1994). More than 10,000 nuclear employees in the

United States receive detectable neutron doses each year (NCRP, 1987). The search for gas and oil deposits uses neutron sources to track development. In one study (Fujimoto et al., 1985), dosages of 1–2 mSv per year were observed, whereas in another (Inskip et al., 1991), only seven of 1344 workers received above-threshold (0.02 mGy) doses. At an altitude of 10 km, secondary neutrons from galactic cosmic rays contribute around 10–15 percent of the dose to commercial aircraft crews, depending on the flight route and the number of flight hours [8,10].

How can humans safely control the use of "Radiant Energy"?

- The use of knowledge of radiation-induced hazards that have been gained over many years,
- Employing the necessary and effective methods to cut those hazards,
- Control radiation tools from X-rays tube, Nuclear Power Plant, and nuclear research centers and ensure safety measures during and after operations,

Increased distance reduces dose according to the inverse square law. Using forceps instead than fingertips to handle a source can lessen distance. Move away from the patient if a problem emerges during a fluoroscopic operation, for example. Radiation sources can be shielded by solid or liquid material that absorbs the energy of the radiation. The term "biological shield" refers to material that is placed around a nuclear reactor or other source of radiation to absorb radiation and lower it to a safe level for people. Shielding materials include concrete with a 0.25 mm thick lead shield for secondary radiation and a 0.5 mm thick lead shield for primary radiation. We also evaluate x-ray beam restriction, picture receptor speed, filtration, and the best exposure strategy choice in

- Limiting the energy deposited in living tissues by radiation during the operations of X-rays can also reduce the potential for unfavorable effects,
- Ensure that Physicians, Technologists, and Therapists are educated in the safe operation of producing equipment,
- Use protective devices whenever possible,
- Follow established procedures and
- Select technical exposure factors that significantly reduce radiation exposure to the environment.

Conclusion

The cardinal rules of protection of radiation are **Time**, **Distance** and **Shielding**. A combination of these factors can reduce radiation exposure. Reduce the exposure time to reduce the effective dose correspondingly. Improving operator training to shorten the time it takes to handle a radioactive source is an example of minimizing radiation doses through reducing exposure time.

medical applications. Radiation has enough energy to induce electrons to be injected into atoms. Ionization occurs when electrons are lost. Ionization has biological consequences. Benefits must outweigh the risks of any x-ray diagnostic study. The benefit of these good practices will minimize the possibility of causing damage to humans and the environment.

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