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Radiation Safety

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Dedication

This project is dedicated to our family and Sudan University of Science and Technology who have been strongly supporting us during this work. They taught us the value of life and faithful love. Most of all, we cannot fully express in words for priceless love and encouragement that our parents brought in our life.

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Abstract

In Sudan there is only one radiation safety center, located in Khartoum. In other towns there is no inspection in hospitals. The public and the workers are exposed to radiation.

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Chapter(1)

Introduction

1.1 Background

Radiation comes from environmental sources including the earth's crust, the atmosphere, cosmic rays, and radioisotopes. Natural sources of radiation account for the largest amount of radiation exposure received by most people each year with medical and occupational sources accounting for only a fraction of that exposure. It is currently believed that radon, a gas produced by radium decay within rock, constitutes the major source of background radiation throughout many parts of the US. The buildup of radon in inadequately ventilated homes may pose a long-term health hazard. The deleterious effects of background radiation, estimated as causing 1-6% of spontaneous genetic mutation, rise with dose.

1.2 Discovery

Electromagnetic radiation of wavelengths other than light were discovered in the early 19th century. The discovery of infrared radiation is ascribed to William Herschel, the astronomer. Herschel published his results in 1800 before the Royal Society of London. Herschel, like Ritter, used a prism to refract light from the Sun and detected the infrared (beyond the red part of the spectrum), through an increase in the temperature recorded by a thermometer.

In 1801, the German physicist Johann Wilhelm Ritter made the discovery of ultraviolet by noting that the rays from a prism darkened silver chloride preparations more quickly than violet light. Ritter's experiments were an early precursor to what would become photography. Ritter noted that the UV rays were capable of causing chemical reactions.

The first radio waves detected were not from a natural source, but were produced deliberately and artificially by the German scientist Heinrich Hertz in 1887, using electrical circuits calculated to produce oscillations in the radio frequency range, following formulas suggested by the equations of James Clerk Maxwell .

Wilhelm Röntgen discovered and named X-rays. While experimenting with high voltages applied to an evacuated tube on 8 November 1895, he noticed fluorescence on a nearby plate of coated glass. Within a month, he discovered the main properties of X-rays that we understand to this day.

In 1896, Henri Becquerel found that rays emanating from certain minerals penetrated black paper and caused fogging of an unexposed photographic plate. His doctoral student Marie Curie discovered that only certain chemical elements gave off these rays of energy. She named this behavior radioactivity.

Alpha rays (alpha particles) and beta rays (beta particles) were differentiated by Ernest Rutherford through simple experimentation in 1899. Rutherford used a generic pitchblende radioactive source and determined that the rays produced by the source had differing penetrations in materials. One type had short penetration (it was stopped by paper) and a positive charge, which Rutherford named *alpha rays*. The other was more penetrating (able to expose film through paper but not metal) and had a negative charge, and this type Rutherford named *beta*.[3] This was the radiation that had been first detected by Becquerel from uranium salts. In 1900, the French scientist Paul Villard discovered a third neutrally charged and especially penetrating type of radiation from radium, and after he described it, Rutherford realized it must be yet a third type of radiation, which in 1903 Rutherford named gamma rays.

Henri Becquerel himself proved that beta rays are fast electrons, while Rutherford and Thomas Royds proved in 1909 that alpha particles are ionized helium. Rutherford and Edward Andrade proved in 1914 that gamma rays are like X-rays, but with shorter wavelengths.

Cosmic ray radiations striking the Earth from outer space were finally definitively recognized and proven to exist in 1912, as the scientist Victor Hess carried an electrometer to various altitudes in a free balloon flight. The nature of these radiations was only gradually understood in later years.

Neutron radiation was discovered with the neutron by Chadwick, in 1932. A number of other high energy particulate radiations such as positrons, muons, and pions were discovered by cloud chamber examination of cosmic ray reactions shortly thereafter, and others types of particle radiation were produced artificially in particle accelerators, through the last half of the twentieth century.

1.3 Radiation

Illustration of the relative abilities of three different types of ionizing radiation to penetrate solid matter. Typical alpha particles (α) are stopped by a sheet of paper, while beta particles (β) are stopped by an aluminium plate. Gamma radiation (γ) is damped when it penetrates lead. Note caveats in the text about this simplified diagram.

In electromagnetic radiation (such as microwaves from an antenna, shown here) the term "radiation" applies only to the parts of the electromagnetic field that radiate into infinite space and decrease in intensity by an inverse-square law of power so that the total radiation energy that crosses through an imaginary spherical surface is the same, no matter how far away from the antenna the spherical surface is drawn. Electromagnetic radiation includes the far field part of the electromagnetic field around a transmitter. A part of the "near-field" close to the transmitter, is part of the changing electromagnetic field, but does not count as electromagnetic radiation.

In physics, radiation is a process in which electromagnetic waves (EMR) travel through a vacuum or through matter-containing media; the existence of a medium to propagate the waves is not required. A different but related definition says **radiation** is a subset of these electromagnetic waves combined with a class of energetic subatomic particles with very high kinetic energies; these are called **ionizing radiation**, and the particles are termed particle radiation. Other sorts of waves, such as acoustic, seismic, hydraulic and so on are not usually considered to be forms of "radiation" in either sense. We will consider the first definition, and return to the second later.

The word arises from the phenomenon of waves *radiating* (i.e., travel outward in all directions) from a source. This aspect leads to a system of measurements and physical units that are applicable to all types of radiation. Because such radiation expands as it passes through space, and as its energy is conserved (in vacuum), the power of all types of radiation radiating from a point source follows an inverse-square law in relation to the distance from its source. While it is most common that radiation may be emitted radially from a point source, such as a light-bulb filament or a microwave antenna, there are other modes of radiation. Some examples are radiation from a phosphorescent panel (chaotic), a laser beam (coherent), and emitted from a parabolic mirror (parallel), in which cases adherence to the inverse-square law is violated.

EMR is energy transferred by waves of combined electric charge and magnetic monopole, capable of traveling through a vacuum and traveling at the universal speed of light in whatever media it is passing through; the speed is dependent on the media, and is fastest in vacuum. In quantum mechanics these waves have been shown to have particle structure as well as wave structure; these particles are called photons. EMR includes radio and microwave signals, infrared (radiant heat), visible light and ultraviolet, and x-rays and gamma rays. These are differentiated from one another by the frequency of the waves, which directly correlates with the energy carried in each type's photons. This is the first definition of radiation stated in the opening paragraph.

Notice that the differentiation of radiation into the classes above is somewhat arbitrary. The classes overlap at the meeting points, and the distinctions are strictly man-made, not directly apparent in the physics of the waves under study. There is, for example, no difference between an X-ray and a gamma ray except a relative difference in frequency, and thus energy.

This spectrum of radiant energy can be divided into ionizing and non-ionizing, according to whether it ionizes or does not ionize the atoms in ordinary chemical matter. Ionization is the removing of electrons from atoms, and it may be partial, in which the weaker held outer electrons are removed, grading upwards to removal of all electrons from an atom. The energy required to do this varies with the kinds of atoms and their physical state, such as temperature, chemical binding and so on. Some overlap of ionizing and non-ionizing radiation exists in the domain of ultraviolet where materials experience first simple thermal heating in the infrared and visible light, then excitation of electrons in "softer" UV, and then partial-to-total ionization as the energy increases with frequency.

The second definition of *radiation* in the opening paragraph is used in reference to ionizing radiation in hard UV, x-rays, and gamma rays.

Both ionizing and non-ionizing radiation can be harmful to organisms and can result in changes to the natural environment. In general, however, ionizing radiation is far more harmful to living organisms per unit of energy deposited than non-ionizing radiation, since the ions that are produced, even at low radiation powers, leave behind atoms which, due to charge imbalance, are eager to combine in semi-random ways with other atoms in the environment; these are called free radicals. Such random chemical action in a cell may result in anything from harmless reactions, to degradation of important structures in the cell, to killing it outright or triggering suicide (apoptosis), or modifying the DNA in harmful, but yet temporarily viable ways. By contrast, most non-ionizing radiation is harmful to organisms only in proportion to the thermal energy deposited (a prime example is microwaves generated in a microwave oven), and is conventionally considered harmless at low powers that do not produce a significant temperature rise. Ultraviolet radiation in some aspects occupies the overlap in a middle ground, as it has some features of both ionizing and non-ionizing radiation. Although nearly all of the ultraviolet spectrum that penetrates the Earth's atmosphere is non-ionizing, this radiation does far more damage to many molecules in biological systems than can be accounted for by heating effects, such as sunburn). These properties derive from ultraviolet's power to alter chemical bonds, even without having quite enough energy to ionize atoms.

The question of harm to biological systems due to low-power ionizing and non-ionizing radiation is not settled. Controversy continues about possible non-heating effects of low-power non-ionizing radiation, such as non-heating microwave and radio wave exposure. Non-ionizing radiation is usually considered to have a safe lower limit, especially as thermal radiation is unavoidable and ubiquitous. By contrast, ionizing radiation is currently conservatively considered to have no completely safe lower limit, although at some energy levels, new exposures do not add appreciably to background radiation. The evidence that small amounts of some types of ionizing radiation might confer a net health benefit in some situations is called radiation hormesis.

1.4 Types of Radiation

1.4.1 Ionizing Radiation

Radiation with sufficiently high energy can ionize atoms; that is to say it can knock electrons off atoms and create ions, as well as lower-energy damage such as breaking chemical bonds within molecules. Ionization occurs when an electron is stripped (or "knocked out") from an electron shell of the atom, which leaves the atom with a net positive charge.

Because living cells and, more importantly, the DNA in those cells can be damaged by this ionization, exposure to ionizing radiation is considered to result in an increased chance of cancer. Thus "ionizing radiation" is somewhat artificially separated from particle radiation and electromagnetic radiation, simply due to its great potential for biological damage. While an individual cell is made of trillions of atoms, only a small fraction of those will be ionized at low to moderate radiation powers. The probability of ionizing radiation causing cancer is dependent upon the absorbed dose of the radiation, and is a function of the damaging tendency of the type of radiation (equivalent dose) and the sensitivity of the irradiated organism or tissues (effective dose).

If the source of the ionizing radiation is a radioactive material or a nuclear process such as fission or fusion, there is also particle radiation to consider. Particle radiation is quantities of subatomic particles accelerated to relativistic speeds by nuclear reactions. Because of their momenta they are also quite capable of knocking out electrons and ionizing materials, but since most have an electrical charge, they don't have the penetrating power of ionizing radiation. The exception is neutron particles; see below. There are several different kinds of these particles, but the majority are alpha particles, beta particles, neutrons, and protons.

Roughly speaking, EM photons and particles with energies above about 10 electron volts (eV) are ionizing, and that includes most cases for all these particles.

Ionizing radiation originates from radioactive materials, X-ray tubes, particle accelerators, nuclear weapons, nuclear reactors, space (cosmic rays) and is naturally present in the environment, since most rock and soil has small concentrations of radioactive materials. The radiation is invisible and not directly detectable by human senses; as a result, instruments such as Geiger counters are usually required to detect its presence. In some cases, it may lead to secondary emission of visible light upon its interaction with matter, as in the case of Cherenkov radiation and radio-luminescence. Ionizing radiation has many practical uses in medicine, research and construction, but presents a health hazard if used improperly. Exposure to radiation causes damage to living tissue; high doses result in Acute radiation syndrome (ARS), with skin burns, hair loss, internal organ failure and death, while any dose may result in an increased chance of cancer and genetic damage; a particular form of cancer, thyroid cancer, often occurs when nuclear weapons and reactors are the radiation source because of the biological proclivities of the radioactive iodine fission product, I=131. However, calculating exact risk and chance of cancer forming in cells caused by ionizing radiation is still not well understood and currently estimates are loosely determined by population based on data from the atomic bombing in Japan and from reactor accident follow-up, such as with the Chernobyl disaster.

The International Commission on Radiological Protection states that "The Commission is aware of uncertainties and lack of precision of the models and parameter values", "Collective effective dose is not intended as a tool for epidemiological risk assessment, and it is inappropriate to use it in risk projections" and "in particular, the calculation of the number of cancer deaths based on collective effective doses from trivial individual doses should be avoided.

1.4.2Types of Ionizing Radiation

1.4.2.1Ultraviolet Radiation

Ultraviolet of wavelengths from 10 nm to 125 nm ionizes air molecules, and this interaction causes it to be strongly absorbed by air, ozone (O_3) in particular. Ionizing UV therefore does not penetrate Earth's atmosphere to a significant degree, and is sometimes referred to as vacuum ultraviolet.

There is a zone of the atmosphere in which ozone absorbs some 98% of UV, starting about 20 miles (32 km) high and extending upward. Although present in space, this part of the UV spectrum is not of biological importance, because it does not reach living organisms on Earth, thanks to this ozone layer.

Some of the ultraviolet spectrum that does reach the ground (the part that begins above energies of 3.1 eV, or wavelength less than 400 nm) is non-ionizing, but is still biologically hazardous due to the ability of single photons of this energy to cause electronic excitation in biological molecules, and thus damage them by means of unwanted reactions. An example is the formation of pyrimidine dimers in DNA, which begins at wavelengths below 365 nm (3.4 eV), which is well below ionization energy. This property gives the ultraviolet spectrum some of the dangers of ionizing radiation in biological systems without actual ionization occurring. In contrast, visible light and longer-wavelength electromagnetic radiation, such as infrared, microwaves, and radio waves, consists of photons with too little energy to cause damaging molecular excitation, and thus this radiation is far less hazardous per unit of energy.

1.4.2.2 X-ray

X-rays are electromagnetic waves with a wavelength less than about 10^{-9} m (greater than $3x10^{17}$ Hz and 1,240 eV). A smaller wavelength corresponds to a higher energy according to the equation $E=hc/\lambda$. ("E" is Energy; "h" is Planck's constant; "c" is the speed of light; "λ" is wavelength.) When an X-ray photon collides with an atom, the atom may absorb the energy of the photon and boost an electron to a higher orbital level or if the photon is very energetic, it may knock an electron from the atom altogether, causing the atom to ionize. Generally, larger atoms are more likely to absorb an X-ray photon since they have greater energy differences between orbital electrons. Soft tissue in the human body is composed of smaller atoms than the calcium atoms that make up bone, hence there is a contrast in the absorption of X-rays. X-ray machines are specifically designed to take advantage of the absorption difference between bone and soft tissue, allowing physicians to examine structure in the human body.

X-rays are also totally absorbed by the thickness of the earth's atmosphere, resulting in the prevention of the X-ray output of the sun, smaller in quantity than that of UV but nonetheless powerful, from reaching the surface.

1.4.2.3 Alpha Radiation

Alpha particles are helium-4 nuclei (two protons and two neutrons).

They interact with matter strongly due to their charges and combined mass, and at their usual velocities only penetrate only a few centimeters of air, or a few millimeters of low density material (such as the thin mica material which is specially placed in some Geiger counter tubes to allow alpha particles in). This means that alpha particles from ordinary alpha decay do not penetrate the outer layers of dead skin cells and cause no damage to the live tissues below. Some very high energy alpha particles compose about 10% of cosmic rays, and these are capable of penetrating the body and even thin metal plates. However, they are of danger only to astronauts, since they are deflected by the Earth's magnetic field and then stopped by its atmosphere.

Alpha radiation is dangerous when alpha-emitting radioisotopes are ingested (breathed or swallowed). This brings the radioisotope close enough to sensitive live tissue for the alpha radiation to damage cells. Per unit of energy, alpha particles are at least 20 times more effective at cell-damage as gamma rays and X-rays. See relative biological effectiveness for a discussion of this. Examples of highly poisonous alpha-emitters are all isotopes of radium, radon, and polonium, due to the amount of decay that occur in these short half-life materials.

1.4.2.4 Beta Radiation

Beta-minus (β^-) radiation consists of an energetic electron. It is more penetrating than alpha radiation, but less than gamma. Beta radiation from radioactive decay can be stopped with a few centimeters of plastic or a few millimeters of metal. It occurs when a neutron decays into a proton in a nucleus, releasing the beta particle and an antineutrino. Beta radiation from linac accelerators is far more energetic and penetrating than natural beta radiation. It is sometimes used therapeutically in radiotherapy to treat superficial tumors.

Beta-plus (β^+) radiation is the emission of positrons, which are the antimatter form of electrons. When a positron slows down to speeds similar to those of electrons in the material, the positron will annihilate an electron, releasing two gamma photons of 511 keV in the process. Those two gamma photons will be traveling in (approximately) opposite direction. The gamma radiation from positron annihilation consists of high energy photons, and is also ionizing.

1.4.2.5 Gamma Radiation

Gamma (γ) radiation consists of photons with a wavelength less than 3x10,$^{-11}$ meters (greater than 10^{19} Hz and 41.4 keV). Gamma radiation emission is a nuclear process that occurs to rid an unstable nucleus of excess energy after most nuclear reactions. Both alpha and beta particles have an electric charge and mass, and thus are quite likely to interact with other atoms in their path. Gamma radiation, however, is composed of photons, which have neither mass nor electric charge and, as a result, penetrates much further through matter than either alpha or beta radiation.

Gamma rays can be stopped by a sufficiently thick or dense layer of material, where the stopping power of the material per given area depends mostly (but not entirely) on the total mass along the path of the radiation, regardless of whether the material is of high or low density. However, as is the case with X-rays, materials with high atomic number such as lead or depleted uranium add a modest (typically 20% to 30%) amount of stopping power over an equal mass of less dense and lower atomic weight materials (such as water or concrete). The atmosphere absorbs all gamma rays approaching Earth from space. Even air is capable of absorbing gamma rays, halving the energy of such waves by passing through, on the average, 500 ft (150 m).

1.4.2.6 Neutron Radiation

Neutron radiation and Neutron temperature

Neutrons are categorized according to their speed/energy. Neutron radiation consists of free neutrons. These neutrons may be emitted during either spontaneous or induced nuclear fission. Neutrons are rare radiation particles; they result in large amounts only where chain reaction fission or fusion reactions are active; this happens for about 10 microseconds in a thermonuclear explosion, or continuously inside an operating nuclear reactor; the neutrons stop almost immediately in the reactor when it goes non-critical.

Neutrons are the only type of ionizing radiation that can make other objects, or material, radioactive. This process, called neutron activation, is the primary method used to produce radioactive sources for use in medical, academic, and industrial applications. Even comparatively low speed thermal neutrons, will cause neutron activation (in fact, they cause it more efficiently). Neutrons do not ionize atoms in the same way that charged particles such as protons and electrons do (by the excitation of an electron), because neutrons have no charge. It is through their absorption by and the creation of unstable nuclei that they cause ionization. Such neutrons are "indirectly ionizing." Even neutrons without significant kinetic energy are indirectly ionizing, and are thus a significant radiation hazard. Not all materials are capable of neutron activation; in water, for example, both of the normal atoms present will capture neutrons and become heavier but still stable forms of those atoms. Only the absorption of more than one neutron, a statistically rare occurrence, can activate a hydrogen atom, while oxygen requires two additional absorptions. Thus water is only very weakly capable of activation. The sodium in salt (as in sea water), on the other hand, need only absorb a single neutron to become Na-24, a very intense source of beta decay, with half-life of 15 hours.

In addition, high-energy (high-speed) neutrons have the ability to directly ionize atoms. One mechanism by which high energy neutrons ionize atoms is to strike the nucleus of an atom and knock the atom out of a molecule, leaving one or more electrons behind as the chemical bond is broken. This leads to production of chemical free radicals. In addition, very high energy neutrons can cause ionizing radiation by "neutron spallation" or knockout, wherein neutrons cause emission of high-energy protons from atomic nuclei (especially hydrogen nuclei) on impact. The last process imparts most of the neutron's energy to the proton, much like one billiard ball striking another. The charged protons, and other products from such reactions are directly ionizing.

High-energy neutrons are very penetrating and can travel great distances in air (hundreds or even thousands of meters) and moderate distances (several meters) in common solids. They typically require hydrogen rich shielding, such as concrete or water, to block them within distances of less than a meter. A common source of neutron radiation occurs inside a nuclear reactor, where a meters-thick water layer is used as effective shielding.

1.4.2.7 Cosmic Radiation

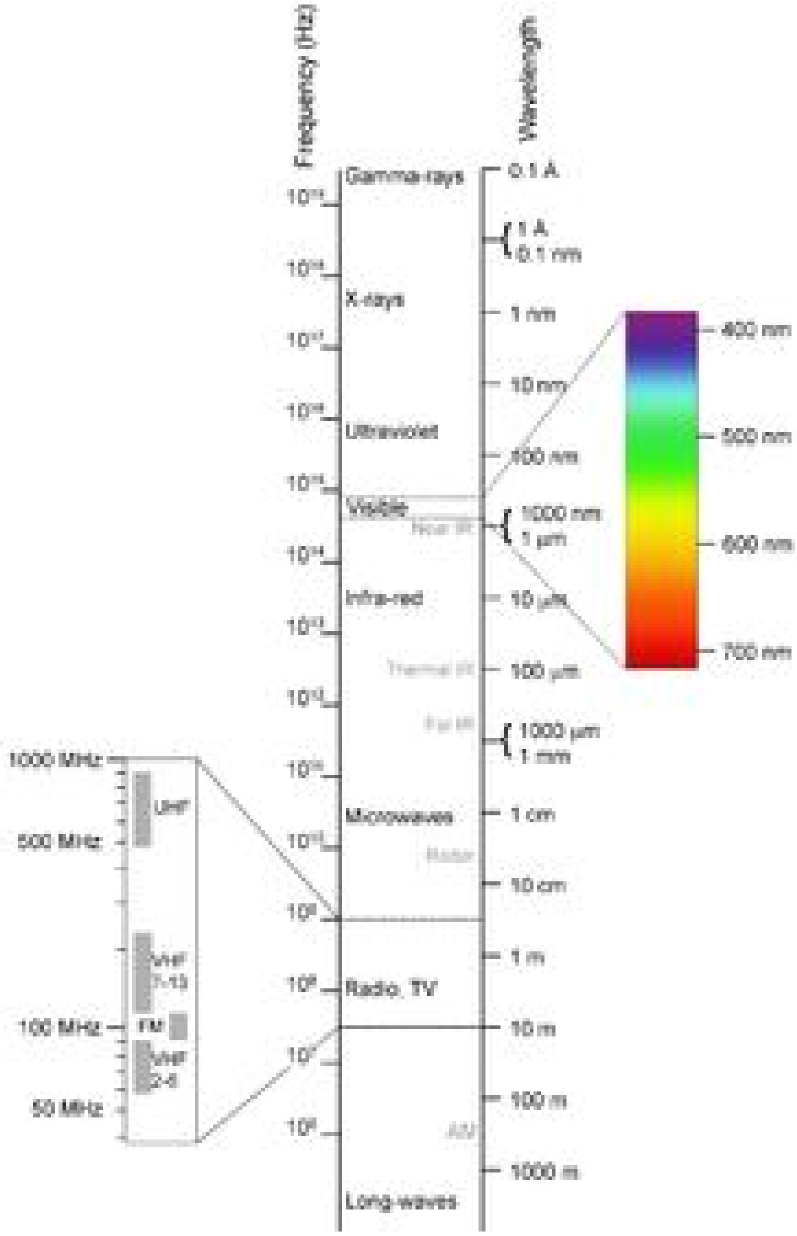
There are two sources of high energy particles entering the Earth's atmosphere from outer space: the sun and deep space. The sun continuously emits particles, primarily free protons, in the solar wind, and occasionally augments the flow hugely with coronal mass ejections (CME). The particles from deep space (inter- and extra-galactic) are much less frequent, but of much higher energies. These particles are not yet well understood, but seem to be remnants of supernovae and especially gamma-ray bursts (GRB), which feature magnetic fields capable of the huge accelerations measured from these particles. They may also be generated by quasars, which are galaxy-wide jet phenomena similar to GRBs but for their much larger size, and which seem to be violent part of the universe's early history.

1.4.3Non-ionizing Radiation

The kinetic energy of particles of non-ionizing radiation is too small to produce charged ions when passing through matter. For non-ionizing electromagnetic radiation (see types below), the associated particles (photons) have only sufficient energy to change the rotational, vibrational or electronic valence configurations of molecules and atoms. The effect of non-ionizing forms of radiation on living tissue has only recently been studied. Nevertheless, different biological effects are observed for different types of non-ionizing radiation.

Even "non-ionizing" radiation is capable of causing thermal-ionization if it deposits enough heat to raise temperatures to ionization energies. These reactions occur at far higher energies than with ionization radiation, which requires only single particles to cause ionization. A familiar example of thermal ionization is the flame-ionization of a common fire, and the browning reactions in common food items induced by infrared radiation, during broiling-type cooking.

1.4.3.1 Non-ionizing Electromagnetic Radiation



1.The electromagnetic spectrum

The electromagnetic spectrum is the range of all possible electromagnetic radiation frequencies, Fig.1. The electromagnetic spectrum (usually just spectrum) of an object is the characteristic distribution of electromagnetic radiation emitted by, or absorbed by, that particular object.

The non-ionizing portion of electromagnetic radiation consists of electromagnetic waves that (as individual quanta or particles, see photon) are not energetic enough to detach electrons from atoms or molecules and hence cause their ionization. These include radio waves, microwaves, infrared, and (sometimes) visible light. The lower frequencies of ultraviolet light may cause chemical changes and molecular damage similar to ionization, but is technically not ionizing. The highest frequencies of ultraviolet light, as well as all X-rays and gamma-rays are ionizing.

The occurrence of ionization depends on the energy of the individual particles or waves, and not on their number. An intense flood of particles or waves will not cause ionization if these particles or waves do not carry enough energy to be ionizing, unless they raise the temperature of a body to a point high enough to ionize small fractions of atoms or molecules by the process of thermal-ionization (this, however, requires relatively extreme radiation intensities).

1.4.3.2 Ultraviolet light

As noted above, the lower part of the spectrum of ultraviolet, called soft UV, from 3 eV to about 10 eV, is non-ionizing. However, the effects of non-ionizing ultraviolet on chemistry and the damage to biological systems exposed to it (including oxidation, mutation, and cancer) are such that even this part of ultraviolet is often compared with ionizing radiation.

1.4.3.3 Visible light

Light, or visible light, is a very narrow range of electromagnetic radiation of a wavelength that is visible to the human eye, or 380–750 nm which equates to a frequency range of 790 to 400 THz respectively. More broadly, physicists use the term "light" to mean electromagnetic radiation of all wavelengths, whether visible or not.

1.4.3.4 Infrared

Infrared (IR) light is electromagnetic radiation with a wavelength between 0.7 and 300 micrometers, which corresponds to a frequency range between 430 to 1 THz respectively. IR wavelengths are longer than that of visible light, but shorter than that of microwaves. Infrared may be detected at a distance from the radiating objects by "feel." Infrared sensing snakes can detect and focus infrared by use of a pinhole lens in their heads, called "pits". Bright sunlight provides an irradiance of just over 1 kilowatt per square meter at sea level. Of this energy, 53% is infrared radiation, 44% is visible light, and 3% is ultraviolet radiation.

1.4.3.5 Microwave

Microwaves are electromagnetic waves with wavelengths ranging from as short as one millimeter to as long as one meter, which equates to a frequency range of 300 GHz to 300 MHz. This broad definition includes both UHF and EHF (millimeter waves), but various sources use different other limits. In all cases, microwaves include the entire super high frequency band (3 to 30 GHz, or 10 to 1 cm) at minimum, with RF engineering often putting the lower boundary at 1 GHz (30 cm), and the upper around 100 GHz (3mm).

1.4.3.6 Radio Waves

Radio waves are a type of electromagnetic radiation with wavelengths in the electromagnetic spectrum longer than infrared light. Like all other electromagnetic waves, they travel at the speed of light. Naturally occurring radio waves are made by lightning, or by certain astronomical objects. Artificially generated radio waves are used for fixed and mobile radio communication, broadcasting, radar and other navigation systems, satellite communication, computer networks and innumerable other applications. In addition, almost any wire carrying alternating current will radiate some of the energy away as radio waves; these are mostly termed interference. Different frequencies of radio waves have different propagation characteristics in the Earth's atmosphere; long waves may bend at the rate of the curvature of the Earth and may cover a part of the Earth very consistently, shorter waves travel around the world by multiple reflections off the ionosphere and the Earth. Much shorter wavelengths bend or reflect very little and travel along the line of sight.

1.4.3.7 Very low Frequency (VLF)

Very low frequency, or VLF, refers to a frequency range of 30 Hz to 3 kHz which corresponds to wavelengths of 100,000 to 10,000 meters respectively. Since there is not much bandwidth in this range of the radio spectrum, only the very simplest signals can be transmitted, such as for radio navigation. Also known as the myriameter band or myriameter wave as the wavelengths range from ten to one myriameter (an obsolete metric unit equal to 10 kilometers).

1.4.3.8 Extremely low Frequency (ELF)

Extremely low frequency (ELF) is radiation frequencies from 3 to 30 Hz (10^8 to 10^7 meters respectively). In atmosphere science, an alternative definition is usually given, from 3 Hz to 3 kHz. In the related magnetosphere science, the lower frequency electromagnetic oscillations (pulsations occurring below ~3 Hz) are considered to lie in the ULF range, which is thus also defined differently from the ITU Radio Bands. A massive military ELF antenna in Michigan radiates very slow messages to otherwise unreachable receivers, such as submerged submarines.

1.4.3.9 Thermal Radiation

Thermal radiation is a common synonym for infrared radiation emitted by objects at temperatures often encountered on Earth. Thermal radiation refers not only to the radiation itself, but also the process by which the surface of an object radiates its thermal energy in the form black body radiation. Infrared or red radiation from a common household radiator or electric heater is an example of thermal radiation, as is the heat emitted by an operating incandescent light bulb. Thermal radiation is generated when energy from the movement of charged particles within atoms is converted to electromagnetic radiation.

As noted above, even low-frequency thermal radiation may cause temperature-ionization whenever it deposits sufficient thermal energy to raises temperatures to a high enough level. Common examples of this are the ionization (plasma) seen in common flames, and the molecular changes caused by the "browning" during food-cooking, which is a chemical process that begins with a large component of ionization.

1.4.3.10 Black-body Radiation

Black-body radiation is an idealized spectrum of radiation emitted by a body that is at a uniform temperature. The shape of the spectrum and the total amount of energy emitted by the body is a function the absolute temperature of the body. The radiation emitted covers the entire electromagnetic spectrum and the intensity of the radiation (power/unit-area) at a given frequency is described by Planck's law of radiation. For a given temperature of a black-body there is some frequency at which the maximum amount of radiation is emitted. That maximum radiation frequency moves toward higher frequencies as the temperature of the body increases. The frequency at which the black body radiation is at maximum is given by Wien's displacement law and is a function of the body's absolute temperature. A black-body is one that emits at any temperature the maximum possible amount of radiation at any given wavelength. A black-body will also absorb the maximum possible incident radiation at any given wavelength. A black-body with a temperature at or below room temperature would thus appear absolutely black, as it would not reflect any incident light nor would it emit enough radiation at visible wavelengths for our eyes to detect. Theoretically, a black-body emits electromagnetic radiation over the entire spectrum from very low frequency radio waves to x-rays, creating a continuum of radiation.

The color of a radiating black-body tells the temperature of its radiating surface. It is responsible for the color of stars, which vary from infrared through red (2,500K), to yellow (5,800K), to white and to blue-white (15,000K) as the peak radiance passes through those points in the visible spectrum. When the peak is below the visible spectrum the body is black, while when it is above the body is blue-white, since all the visible colors are represented from blue decreasing to red.

1.5 Uses of Radiation

Radiation and radioactive substances are used for diagnosis, treatment, and research. X-rays, for example, pass through muscles and other soft tissue but are stopped by dense materials. This property of X-rays enables doctors to find broken bones and to locate cancers that might be growing in the body. Doctors also find certain diseases by injecting a radioactive substance and monitoring the radiation given off as the substance moves through the body. Radiation used for cancer treatment is called ionizing radiation because it forms ions in the cells of the tissues it passes through as it dislodges electrons from atoms. This can kill cells or change genes so the cells cannot grow. Other forms of radiation such as radio waves, microwaves, and light waves are called non-ionizing. They don't have as much energy and are not able to ionize cells.

1.5.1 Uses in Communication

All modern communication systems use forms of electromagnetic radiation. Variations in the intensity of the radiation represent changes in the sound, pictures, or other information being transmitted. For example, a human voice can be sent as a radio wave or microwave by making the wave vary to correspond variations in the voice. Musicians have also experimented with gamma sonification, or using nuclear radiation, to produce sound and music.

1.5.2 Uses in Science

Researchers use radioactive atoms to determine the age of materials were once part of a living organism. The age of such materials can be estimated by measuring the amount of radioactive carbon they contain in a process called radiocarbon dating. Similarly, using other radioactive elements, the age of rocks and other geological features (even some man-made objects) can be determined; this is called Radiometric dating.

Environmental scientists use radioactive atoms, known as tracer atoms, to identify the pathways taken by pollutants through the environment.

Radiation is used to determine the composition of materials in a process called neutron activation analysis. In this process, scientists bombard a sample of a substance with particles called neutrons. Some of the atoms in the sample absorb neutrons and become radioactive. The scientists can identify the elements in the sample by studying the emitted radiation. [1]

1.6 Sources of Radiation

Can be divided into two categories:

Natural background radiation and man-made radiation.

1.6.1 Natural Back Ground Radiation

-Cosmic Radiation

-Terrestrial Radiation

-Internal Radiation

1.6.1.1 Cosmic Radiation

The earth and all living thing on it are constantly bombarded by radiation from outer space, similar to a steady drizzle of rain

Charged particales from the sun and stars interact with the earth's atmosphere and maganetic field to prouduce a shower of radiation.

The amount of cosmic radiation varies in differences in elevation and to the effects of the earth's magnetic field.

1.6.1.2 Terrestrial Radiation

Radioactive material is found throughout nature in soil, water, and vegetation.

Important radioactive elements include uranium and thorium and their radioactive decay products which have been present since the earth was formed billions of years ago.

Some radioactive material is ingested with food and water radon gas, a radioactive decay product of uranium is in haled.

The amount of terrestrial radiation varies in different parts of the world due to different concentrations of uranium in soil.

1.6.1.3 Internal Radiation

People are exposed to radiation from radioactive material inside their bodies.

Besides radon, the most important internal radioactive element is naturally occurring potassium-40 but uranium and thorium are also present.

The amount of radiation from potassium-40 does not vary much from one person to another.

However, exposure from radon varies significantly from place depending on the amount of uranium in the soil.

On average, radon contributes 55% or all radiation exposure from natural and man-made sources.

Another 11% comes from the other radioactive materials the body.

1.6.2 Man-made Radiation Sources

The nuclear regulatory commission and other federal and state agencies regulate exposure from man-made radiation sources. Different regulations apply to two distinct groups:

-Members of the public.

-Occupational workers.

Ranking sources of exposure to members of the public examples of man-made sources of radiation:

-Natural gas.

-Lantern mantles.

-Medical diagnosis.

-Building materials.

-Nuclear power plants.

-Coal power plants.

-Tobacco.

-Phosphate fertilizers. [2]

Chapter (2)

Biological Effects of Radiation

2.1 Biological Effects of Radiation

All living species are exposed to a certain amount of natural radiation in the form of particles and rays. In addition to the sunlight, without which life would be impossible to sustain, all beings experience cosmic radiation from space outside the earth and natural background radiation from materials on the earth. There are rather large variations in the radiation from one place to another, depending on mineral content of the ground and on the elevation above sea level. Man and other species have survived and evolved within such an environment in spite of the fact that radiation has a damaging effect on biological tissue. The situation has changed somewhat by the discovery of the means to generate high-energy radiation, using various devices such as X-ray machines, particle accelerators, and nuclear reactors. In the assessment of the potential hazard of the new man-made radiation, comparison is often made with levels in naturally occurring background radiation.

The principal components of a cell are the nucleus as control center, the cytoplasm containing vital substances, and the surrounding membrane, as a porous cell wall. Within the nucleus are the chromosomes, which are long threads containing hereditary material. The growth process involves a form of cell multiplication called mitosis–in which the chromosomes separate in order to form two new cells identical to the original one. The reproduction process involves a cell division process called meiosis–in which germ cells are produced with only half the necessary complement of chromosomes, such that the union of sperm and egg creates a complete new entity. The laws of heredity are based on this process. The genes are the distinct regions on the chromosomes that are responsible for inheritance of certain body characteristics. They are constructed of a universal molecule called DNA, a very long spiral staircase structure, with the stair steps consisting of paired molecules of four types Duplication of cells in complete detail involves the splitting of the DNA molecule along its length, followed by the accumulation of the necessary materials from the cell to form two new ones. In the case of
man, there are 46 chromosomes, containing about four billion of the DNA molecule steps, in an order that describes each unique person.

2.1.1 Physiological Effects

Now, we are interested in the effects on the medium, which are viewed s “damage” in the sense that disruption of the original structure takes place, usually by *ionization*. Energetic electrons and photons are capable of removing electrons from an atom to create ions; that heavy charged particles slow down in matter by successive ionizing events; that fast neutrons in slowing impart energy to target nuclei, which in turn serve as ionizing agents; and that capture of a slow neutron results in a gamma ray and a new nucleus.

As a good rule of thumb, 32 eV of energy is required on average to create an ion pair. This figure is rather independent of the type of ionizing radiation, its energy, and the medium through which it passes. For instance, a single 4-MeV alpha particle would release about 105 ion pairs before stopping. Part of the energy goes into molecular excitation and the formation of new chemicals. Water in cells can be converted into free radicals such as H, OH, H2O2, and HO2. Since the human body is largely water, much of the effect of radiation can be attributed to the chemical reactions of such products. In addition, direct damage can occur, in which the radiation strikes certain molecules of the cells, especially the DNA that controls all growth and reproduction.

The most important point from the biological standpoint is that the bombarding particles have energy, which can be transferred to atoms and molecules of living cells, with a disruptive effect on their normal function.

Since an organism is composed of very many cells, tissues, and organs, a disturbance of one atom is likely to be imperceptible, but exposure to many particles or rays can alter the function of a group of cells and thus affect the whole system. It is usually assumed that damage is cumulative, even though some accommodation and repair takes place.

The physiological effects of radiation may be classified as *somatic*, which refers to the body and its state of health, and *genetic*, involving the genes that transmit hereditary characteristics. The somatic effects range from temporary skin reddening when the body surface is irradiated, to a life shortening of an exposed individual due to general impairment of the body functions, to the initiation of cancer in the form of tumors in certain organs or as the blood disease, leukemia. The term “radiation sickness” is loosely applied to the immediate effects of exposure to very large amounts of radiation. The genetic effect consists of mutations, in which progeny are significantly different in some respect from their parents, usually in ways that tend to reduce the chance of survival. The effect may extend over many generations.

Although the amount of ionization produced by radiation of a certain energy is rather constant, the biological effect varies greatly with the type of tissue involved. For radiation of low penetrating power such as *a* particles, the outside skin can receive some exposure without serious hazard, but for radiation that penetrates tissue readily such as X-rays, gamma rays, and neutrons, the critical parts of the body are bone marrow as blood-forming tissue, the reproductive organs, and the lenses of the eyes.

The thyroid gland is important because of its affinity for the fission product iodine, while the gastrointestinal tract and lungs are sensitive to radiation from radioactive substances that enter the body through eating or breathing.

If a radioactive substance enters the body, radiation exposure to organs and tissues will occur. However, the foreign substance will not deliver all of its energy to the body because of partial elimination.

2.1.2 Radiation Dose Units

Absorbed dose (D) is the amount of energy in joules imparted to each kilogram of exposed biological tissue, and it appears as excitation or ionization of the molecules or atoms of the tissue. The SI unit of dose is the gray (Gy) which is 1 J/kg.

An older unit of energy absorption is the *rad*, which is 0.01 J/kg, i.e., 1 Gy = 100 rads. The above dose to the GI tract would be 0.003 rads or 3 millirads.

The biological effect of energy deposition may be large or small depending on the type of radiation. For instance a rad dose due to fast neutrons or alpha particles is much more damaging than a rad dose by X-rays or gamma rays. In general, heavy particles create a more serious effect than do photons because of the greater energy loss with distance
and resulting higher concentration of ionization. The dose equivalent (*H*) as the biologically important quantity takes account of those differences by scaling the energy absorption up by a quality factor (QF).
1 sievert (Sv) = 100 rems
10 mSv = 1 rem
1 mSv = 100 mrems
10 μSv = 1 mrem.

2.1.3 Basis for Limits of Exposure

There is a wide variation of annual dose around the world. In countries such as India and Brazil the presence of thorium gives exposures of about 600 mrems/y.

The amounts of energy that result in biological damage are remarkably small.

A gamma dose of 400 rems, which is very large in terms of biological hazard, corresponds to 4 J/kg, which would be insufficient to raise the temperature of a kilogram of water as much as 0.001°C. This fact shows that radiation affects the function of the cells by action on certain molecules, not by a general heating proces.

The occupational dose limits are considerably higher than the average U.S. citizen's background dose of 0.36 rems/y, while those for the public are only a fraction of that dose.

The National Academy of Sciences Committee on the Biological Effects of Ionizing Radiation analyzes new data and prepares occasional reports, such as BEIR V.

In the judgment of that group, the lifetime increase in risk of a radiation induced cancer fatality for workers using the official dose limits is 8 × 10-4 per rem, and the NRC and other organizations assume half of that figure, 4 x 10-4 per rem. However, since the practice of maintaining doses as low assreasonably achievable (ALARA) in nuclear facilities keeps doses well below the limit, the increase in chance of cancer is only a few percent.

Measured dose figures have decreased considerably over the years, as reported by the Institute of Nuclear Power Operations. exposure from nuclear power plants is [3]

Chapter (3)

Applications of Radiation

3.1 Useful Radiation Effects

Radiation in the form of gamma rays, beta particles, and neutrons is being used in science and industry to achieve desirable changes. Radiation doses control offending organisms including cancer cells and harmful bacteria, and sterilize insects. Local energy deposition can also stimulate chemical reactions and modify the structure of plastics and semiconductors.

Neutrons and X-rays are used to investigate basic physical and biological processes.

3.1.1 Medical Treatment

The use of radiation for medical therapy has increased greatly in recent years, with millions of treatments given patients annually. The radiation comes from teletherapy units in which the source is at some distance from the target, or from isotopes in sealed containers implanted in the body, or from ingested solutions of radionuclides.

Doses of radiation are found to be effective in the treatment of diseases such as cancer. In early times, X-rays were used, but they were supplanted by cobalt-60 gamma rays, because the high energy (1.17 and 1.33 MeV) photons penetrated tissue better and could deliver doses deep in the body, with a minimum of skin reaction. In modern nuclear medicine, there is increasing use of accelerator-produced radiation in the range 4-35 MeV for cancer treatment.

Treatment of disease by implantation of a radionuclide is called interstitial brachytherapy ("brachys" is Greek for "short"). A small radioactive capsule or "seed" is imbedded in the organ, producing local gamma irradiation. The radionuclides are chosen to provide the correct dose. In earlier times, the only material available for such implantation was *a*-emitting radium-226 (1599 years). Most frequently used today are iridium-192 (73.8 days), iodine-125 (59.4 days), and palladium-103 (17.0 days). Examples of tumor locations where this method is successful are the head and neck, breast, lung, and prostate gland. Other isotopes sometimes used are cobalt-60, cesium-137, tantalum-182, and gold-198. Intense fast neutron sources are provided by californium-252. For treatment of the prostate, 40-100 "rice-sized" seeds, (4.5 mm long and 0.81 mm diameter) containing a soft-gamma emitter, Pd-103, are implanted with thin hollow needles. Computerized tomography and ultrasound aid in the implantation.

One sophisticated device for administering cancer treatment uses a pneumatically controlled string of cesium-137 impregnated glass beads encapsulated in stainless steel, of only 2.5 mm diameter. Tubes containing the beads are inserted in the bronchus, larynx, and cervix.

Success in treatment of abnormal pituitary glands is obtained by charged particles from an accelerator, and beneficial results have come from slow neutron bombardment of tumors in which a boron solution is injected.

Selective absorption of chemicals makes possible the treatment of cancers of certain types by administering the proper radionuclides. Examples are iodine-125 or iodine-131 for the thyroid gland and phosphorus-32 for the bone. However, there is concern in medical circles that use of iodine-131 to treat hyperthyroidism could cause thyroid carcinoma, especially in children.

Relief from rheumatoid arthritis is obtained by irradiation with beta particles. The radionuclide dysprosium-165 (2.33 hr) is mixed with ferric hydroxide, which serves as a carrier. The radiation from the injected radionuclide reduces the inflammation of the lining of joints.

A promising treatment for cancer is boron neutron capture therapy (BNCT). A boron compound that has an affinity for diseased tissue is injected, and the patient is irradiated with neutrons from a reactor. Boron-10, with abundance 20 percent in natural boron, strongly absorbs thermal neutrons to release lithium-7 and helium-4 ions. An energy of over two MeV is deposited locally because of the short range of the particles.

The technique was pioneered in the 1950s by Brookhaven National Laboratory, but the program was suspended from 1961 to 1994 and terminated in 1999.

Research is continuing at other locations, however (see References). A compound BPA was found that localized boron better and thermal neutrons were replaced by intermediate energy neutrons, with favorable results. A single treatment with BNCT is as effective as many conventional radiation chemotherapy sessions. The method has been found to be effective in treatment of malignancies such as melanoma (skin) and gliobla stoma multi for me (brain). The discovery of monoclonal antibodies opens up new possibilities for large scale use of BNCT.

The mechanism of the effects of radiation is known qualitatively.

Abnormal cells that divide and multiply rapidly are more sensitive to radiation than normal cells. Although both types are damaged by radiation, the abnormal cells recover less effectively. Radiation is more effective if the dosage is fractionated; i.e., split into parts and administered at different times, allowing recovery of normal tissue to proceed.

3.1.2 Radiation Preservation of Food

The ability of radiation treatment to eliminate insects and microorganisms from food has been known for many years. Such application in the U.S. has been slow because of fears related to anything involving radiation.

Spoilage of food before it reaches the table is due to a variety of effects: sprouting as in potatoes, rotting due to bacteria as in fruit, and insect infestation as in wheat and flour. Certain diseases stem from on food irradiation.

Examples are the bacteria Salmonella, found in much of poultry products, and the parasite Trichinae that infest some pork. The National Centers for Disease Control state that food-borne illnesses affect millions of people in the U.S. each year, with thousands of deaths.

Various treatments are conventionally applied to preserve food, including drying, pickling, salting, freezing, canning, pasteurization, sterilization, the use of food additives such as nitrites, and until they were banned, the application of fumigants such as ethylene dibromide (EDB).

Each treatment method has its advantages, but nitrites and EDB are believed to have harmful physiological effects.

On the other hand, research has shown that gamma radiation processing can serve as an economical, safe, and effective substitute and supplement for existing treatments. The shelf-life of certain foods can be extended from days to weeks, allowing adequate time for transportation and distribution. It has been estimated that 20 to 50 percent of the food supplied to certain countries is wasted by spoilage that could be prevented by radiation treatment. The principal sources of ionizing radiation that are suitable for food processing are X-rays, electrons from an accelerator, and gamma rays from a radionuclide. Much experience has been gained from the use of cobalt-60, half-life 5.27 years, with its two gamma rays of energy 1.17 MeV and 1.33 MeV. The largest supplier of cobalt-60 is a Canadian firm, MDS Nordion, formerly part of Atomic Energy of Canada, Ltd. The isotope is prepared by irradiating pure cobalt-59 target pellets with neutrons in the CANDU reactors of Ontario Hydro. The targets are disassembled, and shipped for processing into double layer capsules of about 10 Ci each.

Another attractive isotope is cesium-137, gamma ray 0.662 MeV, because of its longer half-life of 30.2 years, and its potential availability as a fission product. A considerable amount of cesium-137 has been separated at Hanford, Washington, as a part of the radioactive waste management strategy. Arrangements for loans of capsule s from the Department of Energy to industrial firms have been made. Additional cesium-137 could be obtained through limited reprocessing of spent reactor fuel. unique radiolytic products (URP) are small, less than those produced by cooking or canning, and similar to natural food constituents. No indication of health hazard has been found, but scientists recommend continuing monitoring of the process. A third concern is that there would be a loss in nutritional value. Some loss in vitamin content occurs, just as it is in ordinary cooking. Research is continuing on the effects of radiation on nutritional value. It appears that the loss is minor at the low dose levels used. On various food products, there are certain organoleptic effects (taste, smell, color, texture); but these are a matter of personal reaction, not of health. Even these effects can be eliminated by operating the targets at reduced temperatures. The astronauts of the Apollo missions and the space shuttle have dined regularly on treated foods while in orbit.

They were enthusiastic about the irradiated bread and meats. Many years ago, some scientists in India reported that consumption of irradiated wheat caused polyploidy, an increase in cell chromosomes. Extensive studies elsewhere disproved the finding.

Finally, it has been suggested that radiation might induce resistance of organisms, just as with pesticides and antibiotics, but the effect appears not to occur. The difference is attributed to the fact that there is a broad effect on enzymes and compounds. [3]

Chapter (4)

Radiation Protection

4.1 Radiation Protection

Sometimes known as **radiological protection**, is the science and practice of protecting people and the environment from the harmful effects of ionizing radiation.

Ionizing radiation is widely used in industry and medicine, and can present a significant health hazard. It causes microscopic damage to living tissue, which can result in skin burns and radiation sickness at high exposures (known as "tissue effects"), and statistically elevated risks of cancer at low exposures ("stochastic effects").

Fundamental to radiation protection is the reduction of expected dose and the measurement of human dose uptake. For radiation protection and dosimetry assessment the International Committee on Radiation Protection (ICRP) and International Commission on Radiation Units and Measurements (ICRU) have published recommendations and data which is used to calculate the biological effects on the human body, and set regulatory and guidance limits.

4.2 Protection Groups

Radiation protection can be divided into occupational radiation protection, which is the protection of workers, medical radiation protection, which is the protection of patients, and public radiation protection, which is protection of individual members of the public, and of the population as a whole. The types of exposure, as well as government regulations and legal exposure limits are different for each of these groups, so they must be considered separately.

4.3 Factors in Dose Uptake

There are three factors that control the amount, or dose, of radiation received from a source. Radiation exposure can be managed by a combination of these factors:

1-Time: Reducing the time of an exposure reduces the effective dose proportionally. An example of reducing radiation doses by reducing the time of exposures might be improving operator training to reduce the time they take to handle a source.

2-Distance: Increasing distance reduces dose due to the inverse square law. Distance can be as simple as handling a source with forceps rather than fingers.

4.3.1 Particle Radiation

The effectiveness of a material as a biological shield is related to its cross-section for scattering and absorption, and to a first approximation is proportional to the total mass of material per unit area interposed along the line of sight between the radiation source and the region to be protected. Hence, shielding strength or "thickness" is conventionally measured in units of *g/cm 2* . The radiation that manages to get through falls exponentially with the thickness of the shield. In x-ray facilities, walls surrounding the room with the x-ray generator may contain lead sheets, or the plaster may contain barium sulfate. Operators view the target through a leaded glass screen, or if they must remain in the same room as the target, wear lead aprons. Almost any material can act as a shield from gamma or x-rays if used in sufficient amounts.

Practical radiation protection tends to be a job of juggling the three factors to identify the most cost effective solution.

4.3.2 Interaction of Radiation with Shielding

Different types of ionizing radiation interact in different ways with shielding material. The effectiveness of shielding is dependent on the Stopping power of radiation particles, which varies with the type and energy of radiation and the shielding material used. Different shielding techniques are therefore used dependent on the application and the type and energy of the radiation.

Particle radiation consists of a stream of charged or neutral particles, both charged ions and subatomic elementary particles. This includes solar wind, cosmic radiation, and neutron flux in nuclear reactors.

Alpha particles (helium nuclei) are the least penetrating. Even very energetic alpha particles can be stopped by a single sheet of paper. Beta particles (electrons) are more penetrating, but still can be absorbed by a few millimeters of aluminum. However, in cases where high energy beta particles are emitted shielding must be accomplished with low density materials, *e.g.* plastic, wood, water, or acrylic glass (Plexiglas, Lucite).

This is to reduce generation of Bremss trahlung X-rays. In the case of beta+ radiation (positrons), the gamma radiation from the electron-positron annihilation reaction poses additional concern.

Neutron radiation is not as readily absorbed as charged particle radiation, which makes this type highly penetrating. Neutrons are absorbed by nuclei of atoms in a nuclear reaction. This most-often creates a secondary radiation hazard, as the absorbing nuclei transmute to the next-heavier isotope, many of which are unstable.

Cosmic radiation is not a common concern, as the Earth's atmosphere absorbs it and the magnetosphere acts as a shield, but it poses a problem for satellites and astronauts. Frequent fliers are also at a slight risk. Cosmic radiation is extremely high energy, and is very penetrating.

In most countries a national regulatory authority works towards ensuring a secure radiation environment in society by setting dose limitation requirements that are generally based on the recommendations of the International Commission on Radiological Protection (ICRP). These use the following overall principles:

(a) Justification**:** No unnecessary use of radiation is permitted, which means that the advantages must outweigh the disadvantages.
(b) Limitation: Each individual must be protected against risks that are far too large through individual radiation dose limits.
(c) Optimization: Radiation doses should all be kept as low as reasonably achievable. This means that it is not enough to remain under the radiation dose limits. As permit holder, you are responsible for ensuring that radiation doses are as low as reasonably achievable, which means that the actual radiation doses are often much lower than the permitted limit.

4.4 Graded-Z Shielding

It is a laminate of several materials with different Z values (atomic numbers) designed to protect against ionizing radiation. Compared to single-material shielding, the same mass of graded-Z shielding has been shown to reduce electron penetration over 60%. It is commonly used in satellite-based particle detectors, offering several benefits:

Designs vary, but typically involve a gradient from high-Z (usually tantalum) through successively lower-Z elements such as tin, steel, and copper, usually ending with aluminium. Sometimes even lighter materials such as polypropylene or boron carbide are used.

In a typical graded-Z shield, the high-Z layer effectively scatters protons and electrons. It also absorbs gamma rays, which produces X-ray fluorescence. Each subsequent layers absorbs the X-ray fluorescence of the previous material, eventually reducing the energy to a suitable level. Each decrease in energy produces bremsstrahlung and Auger electrons, which are below the detector's energy threshold. Some designs also include an outer layer of aluminium, which may simply be the skin of the satellite.

4.5 Radiation Protection Instruments

Practical radiation measurement using calibrated radiation protection instruments is essential in evaluating the effectiveness of protection measures, and in assessing the radiation dose likely to be received by individuals. The measuring instruments for radiation protection are both "installed" (in a fixed position) and portable (hand-held or transportable).

4.5.1 Installed Instruments

Installed instruments are fixed in positions which are known to be important in assessing the general radiation hazard in an area. Examples are installed "area" radiation monitors, Gamma interlock monitors, personnel exit monitors, and airborne particulate monitors.

The area radiation monitor will measure the ambient radiation, usually X-Ray, Gamma or neutrons; these are radiations which can have significant radiation levels over a range in excess of tens of metres from their source, and thereby cover a wide area.

Gamma radiation "interlock monitors" are used in applications to prevent inadvertent exposure of workers to an excess dose by preventing personnel access to an area when a high radiation level is present. These interlock the process access directly.

Airborne contamination monitors measure the concentration of radioactive particles in the ambient air to guard against radioactive particles being ingested, or deposited in the lungs of personnel. These instruments will normally give a local alarm, but are often connected to an integrated safety system so that areas of plant can be evacuated and personnel are prevented from entering an air of high airborne contamination.

Personnel exit monitors (PEM) are used to monitor workers who are exiting a "contamination controlled" or potentially contaminated area. These can be in the form of hand monitors, clothing frisk probes, or whole body monitors. These monitor the surface of the workers body and clothing to check if any radioactive contamination has been deposited. These generally measure alpha or beta or gamma, or combinations of these.

The UK National Physical Laboratory publishes a good practice guide through its Ionising Radiation Metrology Forum concerning the provision of such equipment and the methodology of calculating the alarm levels to be used.

4.5.2 Portable Instruments

Portable instruments are hand-held or transportable. The hand-held instrument is generally used as a survey meter to check an object or person in detail, or assess an area where no installed instrumentation exists. They can also be used for personnel exit monitoring or personnel contamination checks in the field. These generally measure alpha, beta or gamma, or combinations of these.

Transportable instruments are generally instruments that would have been permanently installed, but are temporarily placed in an area to provide continuous monitoring where it is likely there will be a hazard. Such instruments are often installed on trolleys to allow easy deployment, and are associated with temporary operational situations.

In the United Kingdom the HSE has issued a user guidance note on selecting the correct radiation measurement instrument for the application concerned. This covers all radiation instrument technologies, and is a useful comparative guide.

4.5.3 Instrument Types

A number of commonly used detection instruments are listed below: ionization chambers, proportional counters, Geiger counters, semiconductor detectors, scintillation detectors **and** airborne particulate radioactivity monitoring

The links should be followed for a fuller description of each.

4.5.4 Radiation Dosimeters

Quartz fiber dosimeter , film badge dosimeter , thermoluminescent dosimeter and solid state (MOSFET or silicon diode) dosimeter.

Dosimeters are devices worn by the user or by a patient which measure the absorbed dose the person receives. Common types of wearable dosimeters for ionizing radiation include.

4.6 Early Dangers

The dangers of radioactivity and radiation were not immediately recognized. The discovery of x-rays in 1895 led to widespread experimentation by scientists, physicians, and inventors. Many people began recounting stories of burns, hair loss and worse in technical journals as early as 1896. In February of that year, Professor Daniel and Dr. Dudley of Vanderbilt University performed an experiment involving x-raying Dudley's head that resulted in his hair loss. A report by Dr. H.D. Hawks, a graduate of Columbia College, of his suffering severe hand and chest burns in an x-ray demonstration, was the first of many other reports in Electrical Review.

Many experimenters including Elihu Thomson at Thomas Edison's lab, William J. Morton, and Nikola Tesla also reported burns. Elihu Thomson deliberately exposed a finger to an x-ray tube over a period of time and suffered pain, swelling, and blistering. Other effects, including ultraviolet rays and ozone were sometimes blamed for the damage. Many physicians claimed that there were no effects from x-ray exposure at all. [1]

Chapter (5)

Radiation Safety

5.1 Radiation Safety

Since X-ray and gamma radiation are not detectable by the human senses and the resulting damage to the body is not immediately apparent, a variety of safety controls are used to limit exposure. The two basic types of radiation safety controls used to provide a safe working environment are engineered and administrative controls. Engineered controls include shielding, interlocks, alarms, warning signals, and material containment

Engineered controls such as shielding and door interlocks are used to contain the radiation in a cabinet or a "radiation vault." Fixed shielding materials are commonly high density concrete and/or lead. Door interlocks are used to immediately cut the power to X-ray generating equipment if a door is accidentally opened when X-rays are being produced. Warning lights are used to alert workers and the public that radiation is being used. Sensors and warning alarms are often used to signal that apredetermined amount of radiation is present. Safety controls should never be tampered with or bypassed.

When portable radiography is performed, it is most often not practical to place alarms or warning lights in the exposure area. Ropes and signs are used to block entrance to radiation areas and to alert the public to the presence of radiation. Occasionally radiographers will use battery operated flashing lights to alert the public to the presence of radiation. Portable or temporary shielding devices may fabricated from materials or equipment located in the area of the inspection. Sheets of steel, steel beams, or other equipment may be used for temporary shielding. It is the responsibility of the radiographer to know and understand the absorption value of various materials. More information on absorption values and material properties can be found in the radiography section of this site.

5.2 Administrative Controls

As mentioned above, administrative controls supplement the engineered controls. These controls include postings, procedures, dosimetry, and training. It is commonly required that all areas containing X-ray producing equipment or radioactive materials have signs posted bearing the radiation symbol and a notice explaining the dangers of radiation. Normal operating procedures and emergency procedures must also be prepared and followed. In the US, federal law requires that any individual who is likely to receive more than 10% of any annual occupational dose limit be monitored for radiation exposure. This monitoring is accomplished with the use of dosimeters, which are discussed in the radiation safety. [1]

5.3 Radiation Dose Limits For Public and Workers

A risk-benefit argument was developed for the worker dose, assuming there were indeed a risk (the 0.5 Sv safe level might be in error) that risk would be small. A worker derived benefit (income) from exposure to the risk, but the public did not. A factor of 10 was introduced for the public and the limit set at 5 mSv. This level was reduced to 1 mSv since it was obvious that most public exposures were less than 1 mSv.[1]

5.4 Radiation Safety in Sudan

Response of the director of the Radiation Safety Institute to our questions:

Q1. How is radioactive materials waste disposed?

A1. It is treated in laboratories in Soba. There are plants in Soba where the radioactive waste is stored, Waste is stored according to its shape, size and radioactivity.

Q2. What is the maximum dose for the workers and the public?

A2. The dose is not to exceed 20 msv for the workers during the year and not to exceed 1 msv for the public during the year.

Q3. What is the safety procedure for protection of the workers?

A3. Any worker is provided with a personal dosimeter.

Q4.Are there any periodical visits to the hospitals?

A4. Yes, there are routine visits by the inspectors to the hospitals.

Q5. Is there routine calibration for the devices?

A5. Yes. [4]

5.5 Conclusion

Radiation has useful application, but it requires safety procedures. In Sudan there is only one radiation safety center, located in Khartoum. In other towns there is no inspection in hospitals. The public and the workers are exposed to radiation.

References

[1] en.wikipedia.org/wiki/Radiation.

[2] Laila Hassan Obidalla, Oil and Gas, Ministry of Petroleum (2011) 10-11.

[3] Raymond L. Murray, Nuclear Energy.

[4] Institute of Radiation Safety, personal communication, (2015).