

# Radiation Exposure and Health Effects on the Human Body

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**Abstract:** This study reviewed radiation exposure pathways and their effects on the human body. Radioactive materials are prevalent in many soils and rock formations and consequently in the water that comes in contact with them and as such, extraction and processing of resources that emanate from these sources expose and raise the concentration of naturally occurring radionuclides in the environment. The most common sources to which all individuals are exposed are the ionizing radiation arising from radionuclides in the earth's surroundings and the interaction of cosmic rays on the earth's atmosphere. Radiation exposure is categorized into internal and external exposures. The effects of radiation depend on the type, energy, and location of the radiation source, and the length of exposure. Ionizing radiation includes x-rays, gamma rays, alpha particles, beta particles, neutrons, and a variety of cosmic rays. Ionizing radiation is harmful and potentially lethal and destructive to biological organs in the human body. The health effects of radiation are divided into deterministic and stochastic effects. The sequence of radiation effects on the human body takes this pattern: atoms molecules cells tissues organs the whole body. The severity of the effect increases with the size of the dose. All doses must be kept as low as reasonably achievable (ALARA) with the dose limits recommended by the ICRP to avoid unnecessary exposure causing the biological effects of radiation to radiation workers and the general public. Secondary data sources such as books, journals, online materials, etc are used in this review. The authors recommend among others the employment of inhalation inhibition/reduction gadgets for radiation workers and mine workers and also the reduction of the exposure hours for workers mostly in the tropics that work directly under the sun's radiation.

**Keywords:** Radiation, Exposure, Patterns, Effects, Human Body.

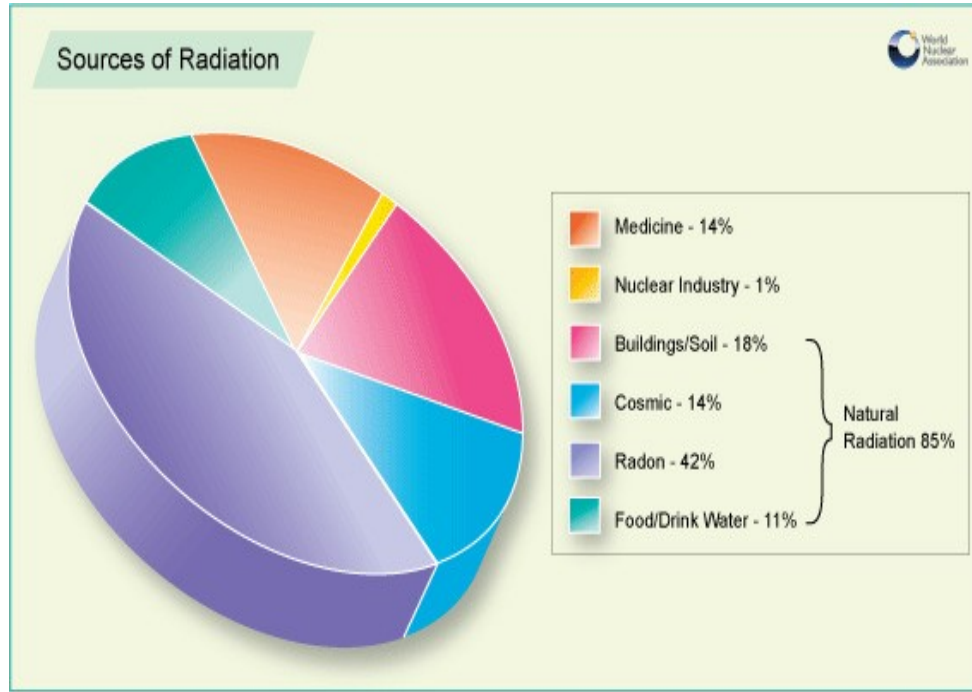
## 1. Introduction

Radioactive materials are prevalent in many soils and rock formations and consequently in the water that comes in contact with them and as such, extraction and processing of resources that emanate from these sources expose and raise the concentration of naturally occurring radionuclides in the environment [7]. For most human activities involving minerals and raw materials, the levels of exposure to these radionuclides are not significantly greater than normal background levels and are not of concern for radiation protection. Nevertheless, some work activities can cause reasonably enhanced exposures that may need to be controlled by regulation. Radioactive materials that occur naturally and where human activities increase the exposure of people to ionizing radiation are known by the acronym 'NORM'. NORM is the acronym for Naturally Occurring Radioactive Material, and this normally includes all radioactive elements found in the environment. Though, the term NORM is used more particularly for all naturally occurring radioactive materials where human activities have increased the potential for exposure in comparison with the unchanged condition. Actual concentrations of radionuclides may or may not have been increased; if they have, the term Technologically-Enhanced (TENORM) may be used. Examples of NORM are long-lived radioactive elements such as uranium, thorium, and potassium and any of their decay products, such as radium and radon. These elements have always been there in the Earth's crust and atmosphere, and are concentrated in some places, such as uranium ore bodies.

When the human body is exposed to any radiation, either from external or internal sources, ionization and excitation of atoms and molecules can be produced [16]. The most common sources to which all individuals are exposed are the ionizing radiation arising from radionuclides in the earth's surroundings and the interaction of cosmic rays on the earth's atmosphere [18][19]. According to the National Council on Radiation Protection and Measurements Report (NCRP, 1975) No.45, the most significant source of radiation exposure to humans is due to natural radiation in the environment.

This exposure to naturally occurring radiation also accounts for up to 85% of annual exposure dose received by the world population, as shown in Figure 1 [21],

NORM emanates from activities such as burning coal, making and using fertilizers, and oil and gas production. Uranium mining exposes those involved to NORM in the uranium ore body. Individual doses to workers exposed to NORM in industry can be reasonable and in many cases, doses are as a result of internal exposure – inhalation of radon and aerosols in workplaces and in dusty conditions respectively. Radon in homes is one occurrence of NORM which may be of great concern and can be put under control through house ventilation.

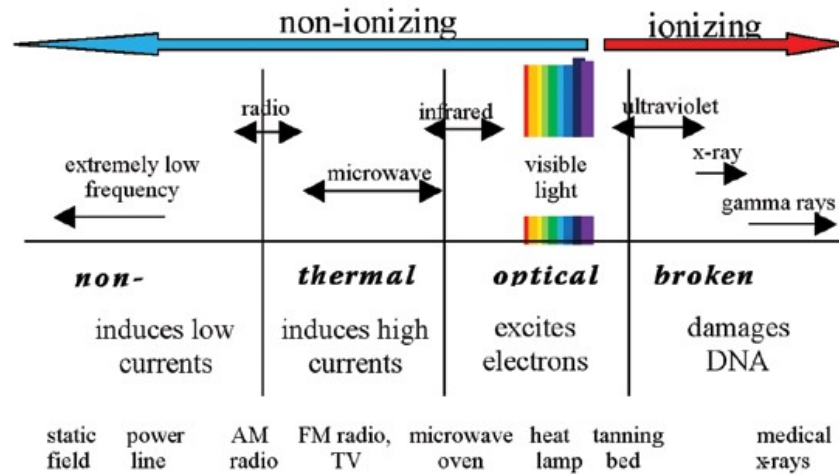


**Fig.1.** Average annual dose to the world population from various sources. [21]

The interaction of radioactive materials with living organisms can lead to the destruction and death of living cells and/or to genetic change. The difference in the biological effects of radiation depends on the types of radiation and its energy which is transferred to the irradiated parts of tissues and organs during the exposure time [11] [6] [14] terms of radiation dosimetry the amount of ionization which occurred and the energy absorbed by particular cells associated with biological effectiveness can be quantified.

### Types of Radiation

Radiation is classified into ionizing and non-ionizing radiation. Ionizing radiation is any radiation consisting of directly or indirectly ionizing particles or a mixture of both [17]. Directly ionizing particles are electrically charged particles having sufficient kinetic energy to produce ionization by collision. These include electrons, protons, alpha particles, beta particles, etc. Indirectly ionizing particles are uncharged particles that can liberate directly ionizing particles or can initiate a nuclear transformation. They include neutrons, gamma rays, x-rays, neutral mesons, etc. Any electromagnetic radiation that does not carry enough energy to ionize an atom is called non-ionizing radiation. Non-ionizing radiation includes ultraviolet light, electric waves, microwaves, infrared rays, visible rays, and radio waves. Ultraviolet rays are generally categorized as non-ionizing radiation although some ultraviolet rays do cause ionization.



**Fig.2.** The relationship between types of radiation and the electromagnetic spectrum [12]

## 2. Statement of the Problem/Justification

Radiation is energy that comes from a source and travels through space at the speed of light. This energy has an electric field and a magnetic field associated with it, and has wave-like properties. Radiation can also be called “electromagnetic waves. We are all exposed to radiation. This work deals with ionizing radiation. This radiation can disrupt atoms, creating positive ions and negative electrons, and cause biological harm or radiation sickness (poisoning). Radiation poisoning happens when radioactive materials give off a form of energy that travels in waves or particles that get into a person’s body and cause harm. This energy is called radiation. When a person is exposed to radiation, the energy penetrates the body. Most of the common types of radiation come from radioactive materials but some types are produced in other ways. The process by which a neutral atom or molecule becomes charged is called ionization and the resulting entity is an ion. Ionizing radiation includes x-rays, gamma rays, alpha particles, beta particles, neutrons, and a variety of cosmic rays.

The alpha particle is a positively charged energetic helium nucleus, consisting of two neutrons and two protons. It is emitted in the radioactive decay of the heaviest nuclides in the periodic table [17]. It is a relatively massive particle with only a short range in the air (1 – 2 Cm) and can be completely absorbed by paper or skin. Alpha radiation can be very dangerous if it enters the body via inhalation or ingestion because large exposures can affect contiguous tissues such as the lining of the lung or stomach.

The beta particle is a high-speed electron that is emitted by nuclei of atoms as a result of energy released in a radioactive decay process involving the transformation of a neutron into a proton. Beta particles are much smaller than alpha particles and can be absorbed completely by sheets of plastic, glass, or metal. It does not normally penetrate beyond the outer layer of the skin. Nevertheless, large exposures to high-energy beta emitters can result in skin burns and can be very dangerous if inhaled or ingested. Beta particles will pass through a hand, or a thin layer of material like paper or wood, but are stopped by a thin layer of metal.

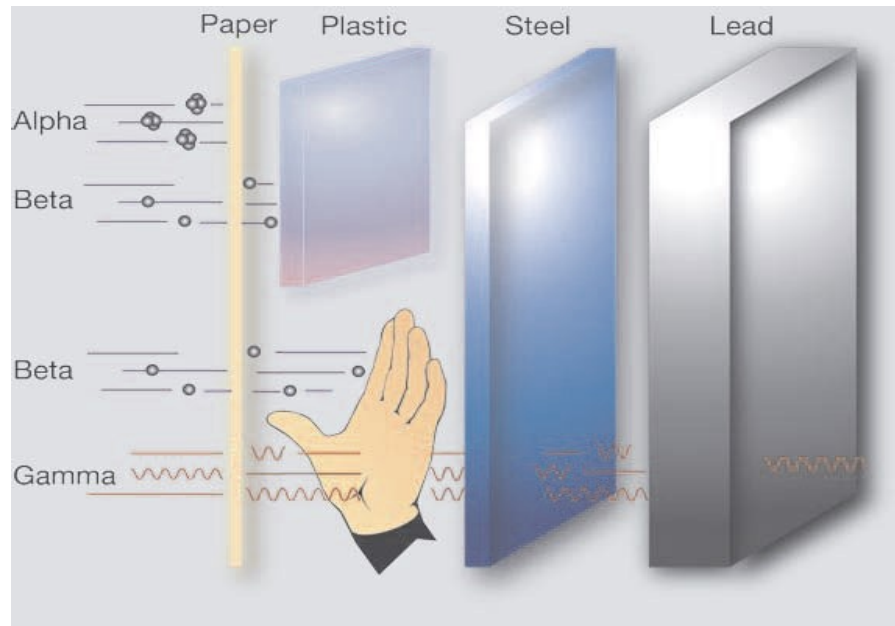
Gamma rays are electromagnetic radiations emitted by radioactive nuclei as packets of energy, called photons, and usually accompany the emission of beta particles from the nuclei. Gamma radiation causes ionization in atoms when it passes through matter basically as a result of interaction with electrons. It can be very penetrating and only a substantial thickness of dense materials like lead or steel can provide shielding. It can as a result deliver significant doses to internal organs without ingestion or inhalation.

X-rays are high-energy photons, like gamma rays, that are produced artificially by the rapid slowing down of an electron beam. X-rays are penetrating and in the absence of shielding by dense materials can deliver significant doses to internal organs.

Neutron radiation is a neutron emitted by an unstable nucleus, particularly during atomic fission and nuclear fusion. Neutrons are often produced artificially apart from being a component of cosmic rays. They are electrically neutral particles and can be very penetrating when they interact with matter or tissue. They can cause the emission of beta and gamma radiation. So, it requires heavy shielding to reduce exposures.

Cosmic radiation emanates from the deep sea. It is a combination of various types of radiation including protons, alpha particles, electrons, and other different high-energy particles. All the high-energy particles strongly interact with the atmosphere and as a result, cosmic radiation at ground level

primarily becomes muons, electrons, neutrons, positrons, and photons. Most of the doses at ground level come from muons and electrons.



**Fig.3.** The penetrating power of different types of Radiation. From least to most penetrating, they are  $\alpha < \beta < \text{neutron} < \gamma$ . [9]

When the nucleus of an atom decays, energy is released in the form of either particles or waves. Both alpha decay and beta decay release particles (alpha particles, and either positrons or beta particles, respectively). Both methods release ionizing radiation. Gamma radiation is a form of ionizing radiation that produces a chemical change in the substance through which it passes.

### 3. Radiation Exposure and Pathways

"Radiation exposure" refers to the situation where the body is in the presence of radiation. It is a measure of the ionization of air due to ionizing radiation from photons that is gamma rays and x-rays. **Radiation exposure is computed using**  $F = \Gamma \times a / r$ , where  $F$  is the exposure rate,  $r$  is the distance,  $a$  is the source activity, and  $\Gamma$  is the exposure rate constant, which is dependent on the particular radionuclide used as the gamma ray source. A material's radioactivity is measured in becquerels (Bq, international unit) and curies (Ci, U.S. unit). Because a curie is a large unit, radioactivity results are usually shown in picocuries (pCi). A picocurie is one trillionth of a curie. The higher the number, the more radiation released by the material. Dosimeter is a device used to detect and measure exposure to radiation. The most common handheld, portable instruments for detecting and measuring ionizing radiation are the Geiger counter with Geiger Muller (GM). There are two types of radiation exposure, "internal exposure" and "external exposure." See Figure 4.

External exposure means receiving radiation that comes from radioactive materials existing on the ground, suspended in the air, or attached to clothes or the surface of the body. Conversely, internal exposure is caused

- (a) when a person has a meal and takes in radioactive materials in the food or drink (ingestion);
- (b) when a person inhales radioactive materials in the air;
- (c) when radioactive materials are absorbed through the skin (percutaneous absorption); (d) when radioactive materials enter the body from a wound (wound contamination); and (e) when radiopharmaceuticals containing radioactive materials are administered for medical treatment.

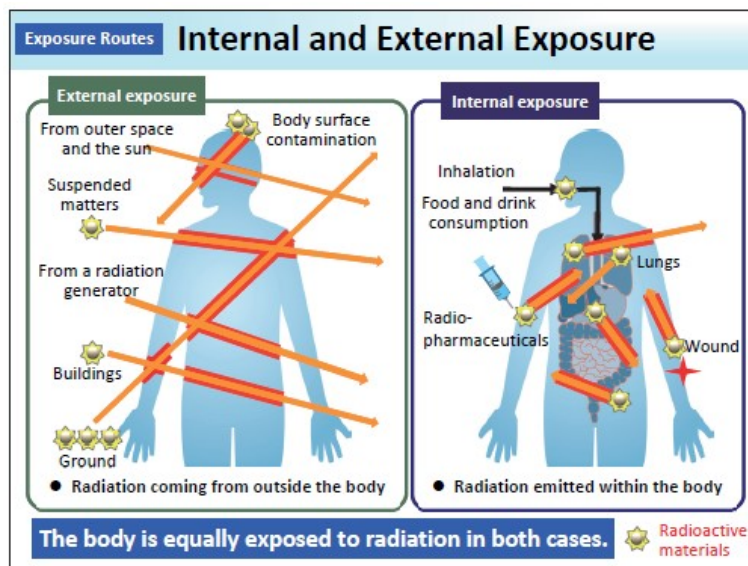


Fig.4. Radiation Exposure Route [15]

Once radioactive materials gain entry into the body, the body will continue to be exposed to radiation until the radioactive materials are excreted in the urine or feces (biological half-life) or as the radioactivity weakens over time. The difference between internal exposure and external exposure lies in whether the source that emits radiation is inside or outside the body. The body is equally exposed to radiation in both cases as shown in Figure 4.

The SI unit of exposure is the Coulomb per Kilogram (C/Kg), however, the roentgen (R) is commonly used internationally in the nuclear industry [2].

1 R equals 0.000258 C/Kg; there are approximately 3876 roentgens in one Coulomb per kilogram. The exposure unit is designated only for limited energy range X- or Gamma radiation interacting with air. For a given radiation field, the dose will depend on the type of matter which absorbs the radiation. Just like drugs, the effect of radiation depends on the amount you have received. The dose is the measure of energy per unit mass deposited by ionizing radiation. **Absorbed dose** is the concentration of energy deposited in tissue as a result of exposure to ionizing radiation.

It means the energy absorbed by human tissue. X-rays, unlike sunlight, can penetrate deep into the body and deposit energy in internal organs. X-rays can even pass through a person's body. For example for an exposure of 1 roentgen by gamma rays with an energy of 1 MeV, the dose in air will be 0.877 rad, the dose in water will be 0.975 rad, the dose in silicon will be 0.877 rad, and the dose in averaged human tissue will be 0.965 rad (Carron, 2007).

Radiation dosage can be measured in various ways. Some of the units used are Grays, Sieverts, rems, and rads. They are used in a similar way, but 1 rad is equivalent to 0.01 Gray.

1. Below 30 rads: Mild symptoms will occur in the blood.
2. From 30 to 200 rads: The person may become ill.
3. From 200 to 1,000 rads: The person may become seriously ill.
4. Over 1,000 rads: This will be fatal.

It is not possible to avoid some exposure to ionizing radiation, thus we are constantly exposed to radiation from a variety of naturally occurring and human-produced sources. Exposure to ionizing radiation occurs in many occupations. Some workers are exposed to natural or artificial sources of radiation. A summary of the annual average exposure dose of ionizing radiation and the range of artificial sources are also listed in Table 1.

## 4. Health Effects of Radiation Exposure on Humans

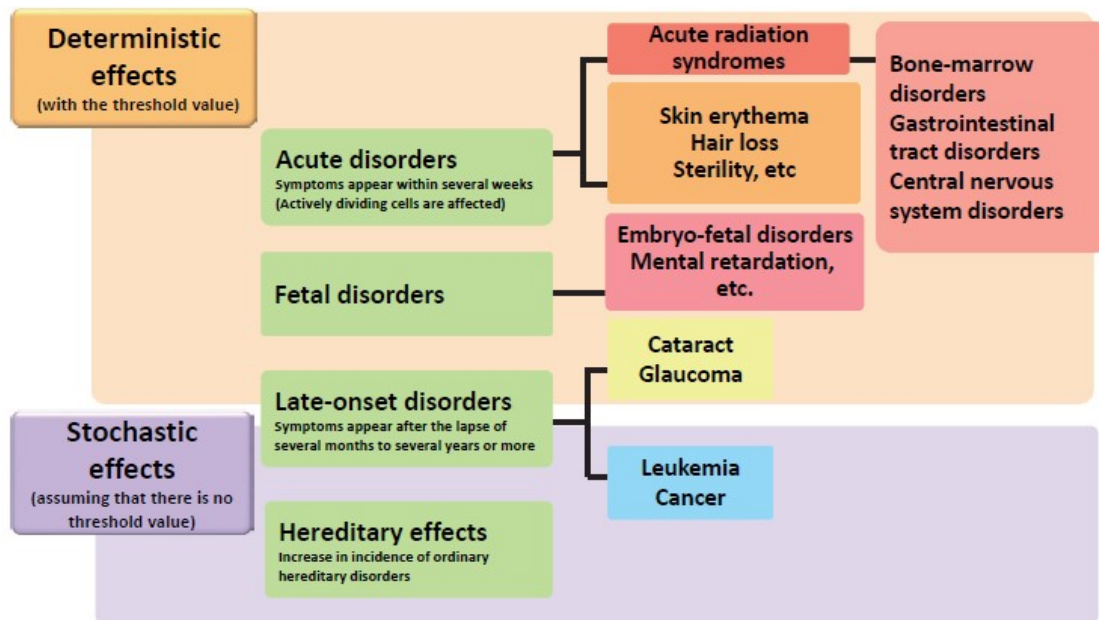
The effects of radiation depend on the type, energy, and location of the radiation source, and the length of exposure. The biological effects of radiation are divided into two classes. The first class consists of exposure to high doses of radiation over a short time producing acute or short-term effects known as **deterministic effects**. The second class represents exposure to low doses of radiation over an extended period producing chronic or long-term effects which is also known as **stochastic effects**. These effects are depicted in Figure 5. In general, ionizing radiation is harmful and potentially lethal to living beings. Thus, all biological damage effects begin with the consequence of radiation interactions with the atoms



forming the cells. Radiation effects on humans proceed in this sequence from the lowest to the highest levels as noted below.

**Table 1:** Annual average doses from all sources (in mSv) [19]

Source	Annual average dose (Worldwide)	Typical range of individual doses	Comments
<b>Natural sources of exposure</b>			
Inhalation (radon gas)	1.26	0.2 – 10	The dose is much higher in some particular dwellings
External terrestrial	0.48	0.3 – 1	The dose is higher in some geographical locations
Ingestion	0.29	0.2 – 1	
Cosmic radiation	0.39	0.3 – 1	The dose increases with altitude
Total of natural sources	2.4	1 - 13	
<b>Artificial sources of exposure</b>			
Medical diagnosis(not therapy)	0.6	0 – several tens	Individual doses depend on specific examinations
Atmospheric nuclear testing	0.005	Some higher doses around the test site still occur	The average has fallen from a peak of 0.11 mSv in 1963
Occupational exposure	0.005	0 – 20	The average dose for all workers is 0.7 mSv. Most high exposures are due to natural radiation (specifically radon in mines)
Chernobyl accident	0.002 <sup>d</sup>	In 1986, the average dose to more than 300,000 recovery workers was nearly 150 mSv, and more than 350,000 other individuals receive doses greater than 10mSv.	The average in the northern hemisphere has decreased from a maximum of 0.04 mSv in 1986.
Nuclear fuel cycle (public exposure)	0.0002 <sup>d</sup>	Doses are up to 0,02 mSv for critical groups at 1 km from some nuclear reactor sites	
Total of artificial sources	0.6	From essentially zero to several tens	Individual doses depend primarily on medical treatment



**Fig. 5.** Effects of Radiation on the Human Body [15]

Radiation Causes Ionizations of ATOMS→MOLECULES→CELLS→→TISSUES→ORGANS→THE WHOLE BODY.

Deterministic effects do not appear unless having been exposed to radiation exceeding a certain level (threshold). Most of the deterministic effects are categorized into acute disorders whose symptoms appear within several weeks after exposure. High doses tend to kill cells, while low doses tend to damage or change them. High doses can kill so many cells, that tissues and organs are damaged. This in turn may cause a rapid whole-body response often called Acute Radiation Syndrome (ARS). Low doses spread out over long periods do not cause an immediate problem to any body organ. The effects of low doses of radiation occur at the level of the cell, and the results may not be observed for many years. Every acute

exposure will not result in death. The health effects of short-term radiation exposure are shown in Table 2.

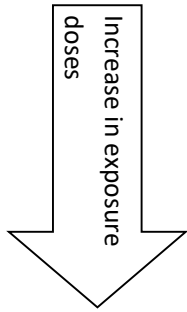
**Table 2: High-Dose Effects Of Radiation [20]**

Exposure (rem)	Health Effect	Time to Onset (without treatment)
5–10	changes in blood chemistry	—
50	nausea	hours
55	fatigue	—
70	vomiting	—
75	hair loss	2–3 weeks
90	diarrhea	—
100	hemorrhage	—
400	possible death	within 2 months
1000	destruction of the intestinal lining	—
	internal bleeding	—
	death	1–2 weeks
2000	damage to the central nervous system	—
	loss of consciousness;	minutes
	death	hours to days

The table above depicts a wide range of biological effects of high-dose radiation. The health effects range from changes in blood chemistry to death. Short-term exposure to tens of rems of radiation will likely cause very observable symptoms or ailment; while a dose of about 500 rems is estimated to have a fifty percent probability of causing the death of the victim within 30 days of exposure. Exposure to radioactive emissions has a cumulative effect on the body during a person's lifetime, which is another reason why it is vital to eschew any unnecessary radiation exposure. Effects on the skin include erythema (reddening like sunburn), dry desquamation (peeling), and moist desquamation (blistering). Skin effects are more likely to occur with exposure to low-energy gamma, X-ray, or beta radiation. Most of the energy of the radiation is deposited on the skin's surface. The dose required for erythema to occur is relatively high, more than 300 rad. Blistering requires a dose over 1,200 rad. Hair loss, also called epilation, is similar to skin effects and can occur after acute doses of about 500 rad. Sterility can be temporary or permanent in males, depending upon the dose. In females, it is usually permanent, but it requires a higher dose. To produce permanent sterility, a dose over 400 rad is required for the reproductive organs. Cataracts (a clouding of the lens of the eye) appear to have a threshold of about 200 rad. Neutrons are especially effective in producing cataracts because the eye has a high water content, which is particularly effective in stopping neutrons.

Whole-body exposure to radiation exceeding 1 Gy (1,000 mGy) at one time causes disorders in various organs and tissues, leading to complicated clinical developments. This series of disorders in organs is called acute radiation syndrome, which typically follows a course from the prodromal phase to the incubation phase, the onset phase, and finally to the convalescent phase or death in the worst case as shown in Table 3

**Table 3: Acute Radiation Syndromes [15]**

DETERMINISTIC EFFECTS OF ACUTE RADIATION SYNDROMES TIME WHEN THE ACUTE RADIATION SYNDROMES APPEAR LAPSE OF TIME			
PRODROMAL PHASE - 48 Hours	INCUBATION PHASE 0 – 3 Weeks	ONSET PHASE	CONVALESCENT PHASE (OR DEATH)
<ul style="list-style-type: none"> <li>Nausea or Vomiting (1 Gray or more)</li> <li>Headache (4 Gray or more)</li> <li>Diarrhea (6 Gray or more)</li> <li>Fever (6 Gray or more)</li> <li>Disturbance of consciousness (8 Gray or more)</li> </ul>	No Symptom		<ul style="list-style-type: none"> <li>Hematopoietic disorders (Infection, bleeding)</li> <li>Gastrointestinal tract disorders</li> <li>Skin injury</li> <li>Nerve and blood vessel disorders</li> </ul>

\* Acute radiation syndromes observed in the case of whole-body exposure to radiation exceeding 1 Gy (1,000 mGy) at one time  
Nausea

From prodromal symptoms that appear within 48 hours after the exposure, exposure doses can roughly be estimated. Exposure to radiation exceeding 1 Gy may cause loss of appetite, nausea, and vomiting, and exposure to radiation exceeding 4 Gy may cause headaches, etc. When exposure doses exceed 6 Gy, such symptoms as diarrhea and fever may appear.

In the onset phase after the incubation phase or as the dose increases above 150 rad, one of the three radiation syndromes (disorders) appears or begins to manifest itself, depending upon the level of the dose. These syndromes are hematopoietic (blood-forming organ), gastrointestinal tract, and central nervous system (brain and muscles). Disorders mainly appear in organs and tissues highly sensitive to radiation. In general, the larger the exposure dose, the shorter the incubation phase. As noted, there is nothing that can be done if the dose is high enough to destroy the gastrointestinal or central nervous system. That is why bone marrow transplants do not always work.

## 5. Effects of Exposure to Low Doses of Radiation – Stochastic Effects

Most of the radiation doses that are received by members of the public and by radiation workers—that are commonly referred to as "low doses." are in this category of stochastic effects. Stochastic effects are effects whose incidence cannot be completely denied even with low-dose exposure. They are managed on the safe side in general under the assumption that there is no threshold value. Stochastic effects are caused by mutation of cell genes, such as cancer and hereditary disorders. Radiation may damage DNA, which may result in genetic mutation. Each mutation is not likely to lead to diseases independently, but theoretically, the possibility of causing cancer or a hereditary disorder cannot be completely denied. So, cancer or hereditary disorders are managed on the safe side with the assumption that there is no threshold dose.

The three categories of effects of exposure to low doses of radiation are genetic, somatic, and in-utero. The genetic effect has to do with the mutation of the reproductive cells passed on to the offspring of the exposed individual. Radiation that causes genetic damage directly damages the reproductive organs, and therefore affects any offspring that individual may have after the damage has occurred. Radiation damage is done to genes and chromosomes, which can be passed on to future generations. Studies of survivors of the Hiroshima and Nagasaki bombings and the Chernobyl survivors in Ukraine have shown that there are increased rates of stillbirths, miscarriages, and infant deaths. If the children survive past the first few years of life, they tend to develop leukemia or microcephaly (slower cranial development), have birth defects (limbs missing, large growths), or have mental impairments. Health Canada acknowledges that exposure to even minute doses of radiation from medical procedures such as X-rays or CT scans can have repercussions on the unborn fetus and therefore it is recommended that no procedures involving ionizing radiation be performed during pregnancy.

**The somatic effect** is the effect primarily suffered by the individual exposed. Since cancer is the primary result, which is sometimes called the Carcinogenic Effect. Somatic damage directly affects the individual exposed to the radiation and does not deal with after-effects in future generations. Somatic effects are, from an occupational risk perspective, the most significant since the individual exposed (often the radiation worker) suffers the effects (cancer). This effect is of the greatest concern. Radiation-induced cancer is well documented. Several studies have shown a direct correlation between the induction of cancer and exposure to radiation. Some of the populations studied and their cancer types are:

1. Lung cancer - uranium miners
2. Bone cancer - radium dial painters
3. Thyroid cancer - therapy patients
4. Breast cancer - therapy patients
5. Skin cancer - radiologists
6. Leukemia - bomb survivors, in-utero exposures, radiologists, therapy patients

**In-Utero Effects.** The in-utero effect is the effect of radiation on the developing embryos. Since the effect, suffered by a developing embryo/fetus, is seen after birth some thought this to be a genetic effect. This is a special case of the somatic effect since the embryo/fetus is the one exposed to the radiation not the reproductive cells of the parents. The actual effects of exposure in-utero that will be observed will depend upon the stage of fetal development at the time of the exposure. These effects are:

- (i) Intrauterine Death
- (ii) Growth Retardation Developmental Abnormalities and
- (iii) Childhood Cancers



## 6. Radiation Protection and Dose Limits

There have been many studies on the health impacts of radiation since ionizing radiation can destroy biological organs in the human body. Damage by radiation cannot be reversed. Once the cells are damaged, they are not repaired. Up till now, medicine has no means to do this. Therefore, the only option is for someone who has been exposed to seek medical attention as fast as possible. More importantly, unnecessary exposures to radiation need to be reduced. The severity of the effect increases with the size of the dose [4]. Stochastic effects occur randomly and the probability of occurrence is dependent on the size of the dose. All doses must be kept as low as reasonably achievable (ALARA) with the dose limits recommended by the ICRP to avoid unnecessary exposure causing the biological effects of radiation-to-radiation workers and the general public. The recommendations of the ICRP for radiation protection standards are based on three general principles as follows [4] [13]:

1. Justification – any practice which does not produce a sufficient benefit to the exposed individuals should not be adopted.
2. Optimisation – all exposures within a practice shall be kept as low as reasonably achievable (ALARA) considering economic and social factors.
3. Dose limitation – individuals should receive exposure doses within the recommended limits.

In ICRP Publication 60, the recommended dose limits were set and estimated from the detrimental effect of the radiation whereby the prevention of deterministic effects and the limitation of stochastic effects were considered. The dose limits recommended by ICRP are shown in Table 4.

**Table 4:** ICRP 60 recommended effective dose limits [10]

Application	Dose limit Occupational	Public
Whole body	20 mSv <sup>a</sup> per year Average over a defined Period of 5 years <sup>b</sup>	1 mSv <sup>a</sup> in a year
Annual equivalent dose in Lens of the eye	150 mSv	
Skin	500 mSv	
Hand and feet	500 mSv	

<sup>a</sup> To find the recommended limit in rem, 1 mSv = 0.1 rem. <sup>b</sup> Maximum dose in any single year does not exceed 50 mSv.

For occupational exposure, the annual effective dose that the whole body is uniformly irradiated is limited to 20 mSv averaged over a defined period of 5 years to limit the probability of stochastic effects. The dose can be allowed to be over 20 mSv but can not exceed 50 mSv in any single year. The dose limit of a member of the general public is set to be lower than a group of radiation workers, at 1 mSv per year. To prevent deterministic effects, occupational equivalent dose limits of 500, 500, and 150 mSv per year are recommended for the skin, the hands, the feet, and the lens of the eye, respectively. The annual equivalent doses for individual members of the public are limited to 15 mSv for the lens of the eye and 50 mSv for the skin [13] [14]. The harmful effects of radiation can be avoided by observing some simple rules as recommended [1]. The rules are:

1. Make good use of radiation detectors if you work around radioactive materials.
2. Use Time Distance and Shielding to Protect Yourself. Putting distance and shielding between you and a radiation source is an immediately effective way of reducing your exposure.
3. Use a Respirator or Face Mask.
4. Reduce wireless phone use.
5. Avoid wireless keyboards, mic, etc.
6. Turn your phone off at night while sleeping.
7. Do not stay under sun rays for a long period.

## 7. Conclusion and Recommendations

Radiation exposure is a measure of the ionization of air due to ionizing radiation from photons, which are gamma rays and X-rays. There are various detrimental effects due to exposure to ionizing radiation. The interaction of radiation with biological organisms can lead to the damage and death of living cells and/or to genetic mutation. The common symptoms include loss of appetite, fatigue, fever, nausea, vomiting, diarrhea, and possibly even seizures and coma. In addition to the radiation types and energy, the biological effect of radiation is concerned with the sensitivities of irradiated organs or tissues. The effects depend on the amount, the nature of radiation, and the dose received by the matter. For a given radiation field, the dose will depend on the type of matter which absorbs the radiation. Just like drugs, the effect of radiation depends on the amount you have received.

Human beings are inevitably exposed to ionizing radiation either from external exposure arising from radioactive sources outside the body or internal exposure which comes from radioactive materials inside the body [18][19]. Many studies concerning the biological effects of radiation have been carried out since ionizing radiation can damage biological organs in the human body. These studies aim to establish dose limits to protect radiation workers and members of the public from radiation exposure. In as much as radiation sickness is concerned, there is no established sure method to guard against it permanently. It is never possible and not necessary to eschew all radiation exposure. The risk posed to human health by most sources is negligible. What matters most is the magnitude of the exposure. Just like drugs the higher the dosage the higher the effect or impart. To this, we recommend that to reduce unnecessary exposure to radiation, radiation workers and the public should adhere to safety precautions such as

1. Staying out of the sun during the hot sunshine and making use of sunscreens or putting on skin covering wears. This is in particular for those living in the tropical regions where the sun is very tense and sunshine of very long duration
  2. Making use of radiation source devices such as CT scans and X-rays only if necessary, particularly for children.
  3. Getting the doctor to know if you are or may be pregnant before having an x-ray, PET, or CT scan.
- More importantly, unnecessary exposures to radiation need to be reduced.

Finally, in addition to the above safety precautions, we advise and recommend the usage of the most current and advance technology gadgets that ward off radiation and Electro pollution called the Ener – Chi Pendants and Diffuser. These products are from Alliance In Motion Global and was made in the United States of America. The Ener-Chi Pendant is the newest upgraded carrier of the iProtect 24/7, which makes it the world's first mobile round-the-clock protection against bacteria, viruses, and Electromagnetic Field (EMF) radiation. The pendant is infused with subatomic technology, electromagnetic and subtle energies that lessen the harmful impact of EMF radiation, helps improve the body's natural balance, flexibility, stamina performance and endurance. It also assists in renewing cells and strengthening the immune system. The Ener-Chi Diffuser is a thin disk you can stick on any electronic devices such as cellular phones, laptops, tablets, television sets and others to counteract the serious and long term harmful effects of Electromagnetic Field(EMF)radiation and electro pollution.

## Compliance with Ethical Standards

**Conflicts of interest:** Authors declared that they have no conflict of interest.

**Human participants:** The conducted research follows the ethical standards and the authors ensured that they have not conducted any studies with human participants or animals.

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