BASELINE BACKGROUND RADIATION IN OFFICES WITHIN FEDERAL UNIVERSITY OF TECHNOLOGY, OWERRI

BY

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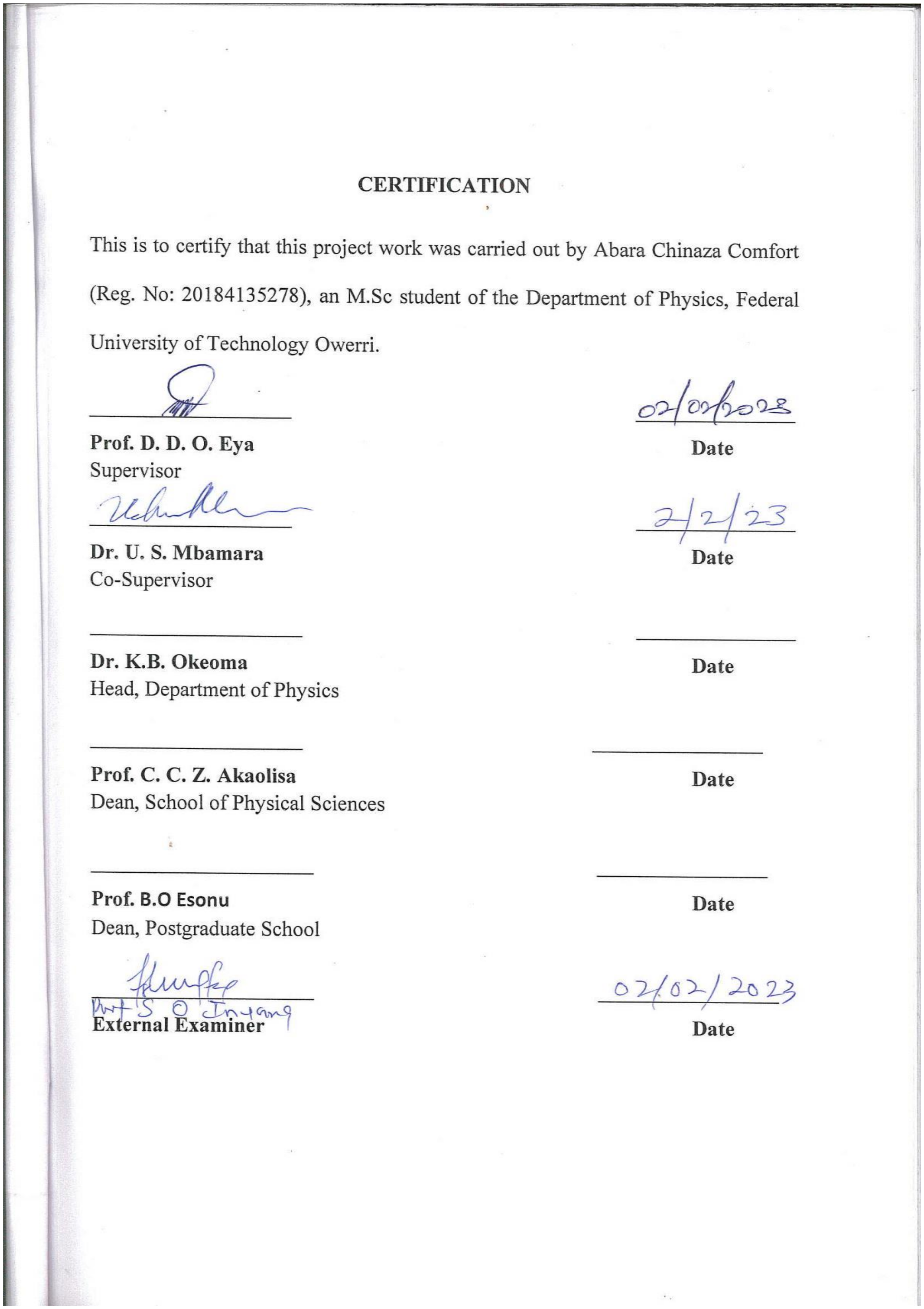
CERTIFICATION



CERTIFICATION

This is to certify that this project work was carried out by Abara Chinaza Comfort (Reg. No: 20184135278), an M.Sc student of the Department of Physics, Federal University of Technology Owerri.

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DEDICATION

This work is dedicated to the memory of my mother, Pastor Mrs Nkechi Abara.

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ABSTRACT

The background radiation of various offices in the various Departments in Federal University of Technology, Owerri (FUTO) was assessed. The study area is located at N5°23.5615’ and E 6°59.175pp8’. The background radiation level was assessed using a well calibrated digital Geiger – Muller Counter GCA – 04W. The indoor background radiation of about five offices in each of the fifty Departments (also the center for energy and power systems research) in FUTO was measured. The average value of the measured background ionizing radiation (BIR) is 0.0052 µSv/h and standard deviation of 0.0035 µSv/h which is much lower than the world average of 0.274 µSv/h. The highest value obtained was observed in the Department of Food Science and Technology as 0.0873±0.0432µSv/h, while the lowest value was recorded in Mathematics Department as 0.0006±0.0001µSv/h. Radiological hazard indices from the BIR measurement was obtained and the highest value of the absorbed dose rate was recorded in the Department of Food Science and Technology as 75.934 nGy/h. The lowest value was recorded as 0.548 nGy/h in Mathematics Department. The highest value is significantly higher than the world average of 59 nGy/h. For the annual effective dose equivalent (AEDE), the average value for all the offices is 22.313±14.092 µSv/y, which is lower than the world average of 410 µSv/y. Also, the lowest value of excess life cancer risk (ELCR) is 0.007×10^{-3} in Mathematics. The highest value is 1.024×10^{-3} in Food Science and Technology Department, which is significantly higher than the world average of 0.29×10^{-3}. In the Departments of Crop Science, Financial Management Technology, and Centre for Energy & Power Systems Research, values of 0.301×10^{-3}, 0.351×10^{-3} and 0.393×10^{-3} respectively were recorded and found to be higher than the world average value of 0.29×10^{-3}. The results showed that, of all the Departments, the Department of Food science and Technology might pose the highest radiological risk due to having the highest levels of BIR and resulting hazard indices. Generally, FUTO is relatively safe from the hazards of BIR.

Keywords: baseline background, radiation, radiation in offices, types of radiation, FUTO.

Chapter I: Introduction

1.1 Background of the study

Natural background radiation is the radiation from our natural environment that can be caused by cosmic rays, natural radioactive elements of the earth and from the human body. The Natural radiation depends on radioactive elements present in each area and as such, one conducts investigation to determine the natural environmental radiation present, (Ademola, Bello, and Caleb, 2019). The levels of radioactivity can be used to assess public dose rates and radioactive contamination and predict changes in environmental radioactivity caused by industrial activities, nuclear accidents, and other human activities. Potassium-40, uranium-238, and thorium-232 and their decay products are important natural radionuclides that contribute largely to the radiation dose received by humans (Ramachandran, 2011).

Natural radiation exposures are contributed by high cosmic rays in the atmosphere and the radionuclides which are primordial and present everywhere in the earth crust, and the human body. Human activities as well can modify some exposure to natural radiation. Some of these examples can be seen in the processing of phosphate fertilizer, quarry activities, fossil fuel combustion, and others. These activities lead to an enhanced levels of environmental radiation exposure (Gary, 2005).

People can also be exposed to some enhanced level of natural radioactivity at their place of work, in living homes and some indoor settings for activities (David, 2005).

Radiation, both natural and artificial can be beneficial and harmful at the same time and it has different forms and intensities. The harmful effect of radiation can lead to sicknesses like cancer, mutation of gene, cataract, bones and blood cells destruction, at the worst case, death of the individual (Fornalski, 2015). Some of the materials used for our buildings which includes soil and rock majorly are the sources of radiation exposure to the environment because the radionuclide contaminates the environment. Also radon gas from rocks is abundant with natural radioactivity in the environment (Allison, 2015).

Man is exposed to ionizing radiation naturally by radioactive substance present in his environment. The harmful effect of the radiation can be due to high dose or prolonged low dose exposure and because of these effects, ionization radiation should be monitored to ensure that the level of its exposure is as low as reasonably achievable (ALARA principle) (Allison, 2016).

In order to protect wildlife and humans, a worldwide annual equivalent dose rate limit of exposure to ionizing radiation was set by the International Commission on Radiation Protection (ICRP) to 1mSv/yr public dose limit, while for indoor activities like offices, and laboratories, the United Nation Scientific Committee on the Effects of Atomic Radiations (UNSCEAR) set the average effective dose limit to 2.4mSv/yr (UNSCEAR 2000).

Studies has shown that in Nigeria, indoor background radiation has received less attention compared to the outdoor (Basirjafari 2013) Studies also show that high levels of background radiation can be found in buildings, and humans majorly spend time indoors (buildings), from living houses, office, religious institutions and malls. (Inyang, Essien and Jeremiah, 2017) A survey by World Health

Organization (WHO) and International Commission on Radiation Protection (ICRP) shows that human beings live about 80% of their time indoors and about 20% outside. With this, we see that the probability of indoor exposure to high levels of radiation is high (Atomic & Agency, 2005).

The energy and intensity of radiation determines the dose, time of exposure, type of radiation exposed, area exposed, and depth and energy deposition. To determine the biological effectiveness and health effect of the dose, some quantities, such as effective dose, absorbed dose and equivalent dose have been adopted. Also, biological effect does not only depend on the total dose on the affected tissue, but also the rate the dose was received.

The amount of radiation absorbed by an object per unit mass of the material is defined as the Absorbed dose (D) with gray ($1Gy=1Jkg^{-1}$) as the S.I unit. The rate at which an absorbed dose is received by an object is known as the absorbed dose rate (DR) with units in Gys^{-1} and $mGyhr^{-1}$ (Ramachandran, 2011).

The Sievert (Sv) is the SI unit of Effective dose. Quantities that are measured in Sieverts are designed to represent the stochastic biological effects of ionizing radiations. A Sievert is a very large unit of dose and often millisieverts (mSv) or microsieverts (μSv) are used. An older unit of radiation dose is the roentgen equivalent in man (rem).

1 Sv = 100 rem.

A rem is a large dose of radiation, so the millirem (mrem), which is one thousandth of a rem, is often used for the commonly encountered doses. (Ramachandran, 2011).

1.2 Aim and Objectives of Study

The aim is to ascertain the indoor background radiation of various offices in. F.U.T.O

The objectives of the study are as follows:

- To ascertain the level of background radiation in the various offices in Federal University of Technology, Owerri.
- To determine the level of background radiation in various offices in F.U.T.O.
- To determine the radiation dose to the staff in the various offices.

1.3 Justification of Study

This study will present the background radiation doses and radiation hazard indices various offices in F.U.T.O are exposed to.

1.4 Scope of Study

This study entails the use of Geiger Muller Counter to determine the level of indoor baseline background radiation in offices located within Federal University of Technology, Owerri.

Chapter II: Literature review

2.1 Radiation

Radiation is the emission of energy as electromagnetic waves or as moving subatomic particles, especially high-energy particles which cause ionization. Electromagnetic radiation, such as infrared, radio waves, visible light, microwaves, ultraviolet, x-rays, gamma radiation (γ), and Acoustic radiation, such as ultrasound, sound, and seismic waves (This depends on the medium by which it is transmitted (Usikalu,Akinyemi, Achuka, 2014).

Radiation is divided into ionizing or non-ionizing, it is relative to the energy of the radiated particles. Ionizing radiation can carry up to 10 eV and such energy can ionize atoms and molecules. This is very important because of the great harm caused to living organisms. Radioactive materials that emit alpha, beta, or gamma radiation are common sources of ionizing radiation (Weisstein, 2014.) Other sources include X-rays from medical examinations and positrons, neutrons and some other particles that make up the cosmic rays especially the secondary cosmic rays. The ionizing part of electromagnetic spectrum is made up of gamma rays, X-rays and the higher range of ultraviolet light (Usikalu et al., 2014). Electromagnetic radiation includes radio, microwaves, infrared, visible light, ultraviolet, X-rays, gamma rays. The only difference between them is their wavelength. What they have in common is that they propagate by a changing electric field inducing a changing magnetic field which induces a changing electric field and so on. Quanta of electromagnetic radiation are called photons.

Particle radiation includes beta and gamma radiation. What they have in common is that they propagate due to the momentum of the particles they are made up from.

Beta particles are very similar to electrons but can have positive or negative charge. Alpha particles are identical to the nuclei of helium atoms, they are made up of two protons and two neutrons. (Trevor Boardman, 2018)

2.1.2 IONIZING RADIATION

Ionizing radiation is radiation that travels as a wave or particle carrying sufficient energy to knock out electrons from atoms or molecules, making them ionized (Ramli, 2014). Ionizing radiation consists of strong energetic subatomic particles, ions or atoms moving with high speed (usually speed of light), and electromagnetic waves with high energy from the electromagnetic spectrum (Martin, 2010).

Ionizing radiation includes gamma rays, X-rays, and the higher part of ultraviolet electromagnetic spectrum. Non-ionizing radiation includes the lower part of ultraviolet, visible light and laser light, infrared, microwaves, and radio waves. In the ultraviolet, there is not much difference between the ionizing and non-ionizing radiation. This is so because different molecules and atoms ionize at different energies (Bari, Amin and Abdulkareem, 2015).

Alpha particles, Beta particles and neutrons are typical ionizing subatomic particles found in radioactive decay. Most products of radioactive decay are ionizing because the energy of its radioactive decay is high. Naturally occurring subatomic ionizing particles are muons, mesons, positrons, and other particles like cosmic rays (Bari, Amin and Abdulkareem, 2015). Cosmic rays are produced by stars and certain events such as supernova explosions. Some radioisotopes on Earth can be produced by cosmic rays (example, carbon-14), which can decay and produce ionizing radiation. The primary source of background ionization radiation on earth is cosmic rays. X-ray tubes can be used to generate ionizing radiation artificially (Olarinoye, James, Moses, Akueche,2010). Human senses are not capable of detecting ionizing radiation, which is why radiation equipment like Geiger counters must be used to show the presence of radiation and measure it. Ionizing radiation is applied widely in fields like medicine, nuclear power, research, manufacturing, construction, etc., but this poses dangers to health if proper measures are not taking when exposed. Exposure to ionizing radiation causes damage to living tissue, and this causes radiation burns, cell damage, radiation sickness, cancer, and death (Masok, 2018).

2.1.3 TYPES OF IONIZING RADIATION

Alpha, Beta, neutron particles, gamma and X-rays are the forms of ionizing radiation. All forms are caused by unstable atoms, which have energy and mass. The energy and mass in the forms of radiation must be released to get to the stable state (Masok, 2018).

2.1.4 ALPHA RADIATION

This is the release of an alpha particle from the nucleus of an atom. When an atom undergoes radioactive decay giving off a particle called alpha particle which consists of two protons and neutrons respectively, we say it is an alpha particle. Alpha particles are made up of charge and mass, and because of this, they interact strongly with matter. It travels only a few centimeters in air. Alpha particle is less harmful in an open aired space, unless it is ingested in food or air, and this causes serious damage (Usikalu et al., 2014).

An alpha decay is a type of radioactive decay in which an atomic nucleus emits an alpha particle and decays into a different atomic nucleus. An example of alpha decay process occurs in the uranium-238 nucleus that decays into thorium-234 nucleus. The rate at which this occurs is called the half-life, or the time that it takes for half of the amount of a substance to decay. (Asikoglu, 2012)

The forces that act in the nucleus of the atom are electromagnetic force, strong nuclear force, and weak nuclear force. The strong nuclear force only acts over a very small distance, so when the atom gets too large the repulsion forces between the protons become greater, causing particles to leave the nucleus. One of the particles that can leave the nucleus is an alpha particle, which has two protons and two neutrons. With two protons, this particle is the same as a helium-4 nucleus.

A general equation for this type of alpha decay radiation is:

$${}^{A}_{Z}\mathrm{X} \rightarrow {}^{Z-4}_{Z-2}\,\mathrm{Y} + {}^{4}_{2}\,\mathrm{He}. \qquad \textbf{(2.1)}$$

2.1.5 BETA RADIATION

This is the release of beta particle from the nucleus of an atom. Electron or positron are forms of beta radiation being released from an atom. It travels further in air up to few meters; it can be stopped by a thick piece of plastic or even a stack of paper because it has a smaller mass. It can penetrate the skin just a few centimeters, it poses little external health risk, but the main threat is when the beta radiation is ingested (Nivesh, Gayathri, Priya, 2017).

In β^- decay, the weak interaction converts an atomic nucleus into a nucleus with atomic number increased by one, while emitting an electron (e^-) and an electron antineutrino (ν_e).

β^- decay generally occurs in neutron-rich nuclei. The generic equation is:

$${}^{A}_{Z}\mathrm{X} \rightarrow {}^{A}_{Z+1}\mathrm{X}' + \mathrm{e}^- + \bar{\nu}_\mathrm{e} \quad [1] \qquad \textbf{(2.2)}$$

where A and Z are the mass number and atomic number of the decaying nucleus, and X and X' are the initial and final elements, respectively (Nivesh, Gayathri, Priya, 2017).

Another example is when the free neutron decays by β^- decay into a proton (p):

$$\mathrm{n} \rightarrow \mathrm{p} + \mathrm{e}^- + \bar{\nu}_\mathrm{e}.$$

(2.3)

At the fundamental level, this is caused by the conversion of the negatively charged down quark to the positively charged up quark by emission of a W^- boson; the W^- boson subsequently decays into an electron and an electron antineutrino:

$$\mathrm{d} \rightarrow \mathrm{u} + \mathrm{e}^- + \bar{\nu}_\mathrm{e}. \qquad \textbf{(2.4)}$$

The nuclear symbol representing an electron (beta particle) is

$${}_{-1}^{0}\mathrm{e} \text{ or } {}_{-1}^{0}\beta$$

(2.5)

Thorium -234 is a nucleus that undergoes beta decay, with the nuclear equation (Nivesh, Gayathri, Priya, 2017).

$${}_{90}^{234}\mathrm{Th} \rightarrow {}_{-1}^{0}\mathrm{e} + {}_{91}^{234}\mathrm{Pa}$$

(2.6)

2.1.6 GAMMA RADIATION

This is the release of high-energy wave from the nucleus of an atom. Gamma radiation can travel further than alpha or beta because it has no mass or charge, and on average, it loses half of its energy after traveling about 500 feet. It can only be stopped by dense or thick materials of high atomic number like lead or depleted uranium and this is the most efficient for shielding (Ramachandran, 2011).

Gamma ray production accompanies nuclear reactions of all types

(Ramachandran, 2011).

$${}_{92}^{238}\mathrm{U} \rightarrow {}_{2}^{4}\mathrm{He} + {}_{90}^{234}\mathrm{Th} + 2{}_{0}^{0}\gamma$$

(2.7)

2.1.7 X-RAYS

This consists of high energy electromagnetic radiation. It is the release of a high energy wave from the electron cloud of an atom. X-rays and gamma rays are similar, but the difference is that X-rays originated from the electron cloud. Excess energy can be released when electron is de-accelerated such as moving from a higher energy level to a lower energy level. X-rays have longer wavelength and lower energy than gamma radiation. Radiography is an example. (Ramachandran, 2011).

X-rays are a form of electromagnetic radiation with wavelengths ranging from 0.01 to 10 nanometers. In the setting of diagnostic radiology, X-rays have long enjoyed use in the imaging of body tissues and aid in the diagnosis of disease. Simply understood, the generation of X-rays occurs when electrons are accelerated under a potential difference and turned into electromagnetic radiation (Nivesh, etal, 2017).

An X-ray tube, with its respective components placed in a vacuum, and a generator, make up the basic components of X-ray production. Essential components of an X-ray tube include a cathode, and an anode separated a short distance from each other, a vacuum enclosure, and high voltage cables forming the X-ray generator attached to the cathode and anode components. In the generation of X-ray production, a cathode filament machined in a cathode cup is activated, causing intense heating of the cathode filament. The heating of the filament leads to the release of electrons in a process called thermionic emission. The released electrons form in an electron cloud at the filament surface, and repulsion forces prevent the ejection of electrons from this negatively charged cloud (Usikalu et al., 2014).

Upon application of a high voltage by an X-ray generator to the cathode as well as the anode, there is an acceleration of electrons ejected to an electrically positive anode. The filament and the focusing cup determine this path of acceleration. The number of electrons is measured in the form of milliampere (mA) units, where 1 milliampere is equal to 6.24 x 10^15 electrons/s. Electron kinetic energy (measured in keV) is related to the applied voltage. The tube voltage, tube current, and exposure duration (measured in seconds) are adjustable by the user (Nivesh, etal, 2017)

Once the high kinetic energy electrons finally reach the anode target, this initiates the process of X-ray production. Tungsten is often the usual anode target, although other material targets are also employed. Electrons come extremely close to the nucleus of the target, causing a deceleration and change in direction, converting the kinetic energy to electromagnetic radiation in a process known as “breaking radiation” or bremsstrahlung. (Taqi, Shaker, Battawy, 2018)

The output is a spectrum of X-ray energies. Incident electrons can also result in ionization, whereby the approaching electron can remove a second electron belonging to an atom of the anode target, losing its energy through ionization or excitation. This process leads to an emission of a photon as the electron orbit vacancy gets filled by an orbital shell electron from a further out shell.

Considering orbital energies and their differences are unique in atoms, this leads to a “characteristic X-ray” with energies that can serve as a fingerprint unique to each anode target. Bremsstrahlung X-rays, however, constitute the majority of X-rays produced in this process (Ramachandran, 2011)

2.1.8 NEUTRON RADIATION

Neutron radiation as a free neutron presents itself as a form of ionizing radiation. Usually, it is released as a result of induced nuclear fission. They travel hundreds or thousands of meters in air and can be stopped by hydrogen rich material like concrete or water. It cannot ionize an atom directly because it has no charge. They are absorbed into a stable atom, therefore making it unstable and likely to release ionizing radiation of another type. Neutrons are the only type of radiation capable of turning other materials radioactive (Ramachandran, 2011).

Neutron radiation is a neutron emitted from the nucleus of an unstable isotope. Neutrons have a relative atomic mass of 1 and relative charge of 0 (Ibese, F. 2020)

Neutrons are emitted when the ratio of neutrons to protons is too large or when a massive unstable nucleus splits into two smaller nuclei in a process of nuclear fission.

Neutron radiation is not directly ionizing but is as penetrating as gamma-rays. Neutron sources are kept inside a block of lead with a hole that only allows the neutrons out in one direction. Neutron radiation is too dangerous to handle directly so it must be done from behind a thick lead screen (Basirjafari, S. 2013)

Neutron emission is usually stimulated by bombarding nuclei with other particles. The neutron sources have a very short half-life so they do not need to be kept in sealed Lead containers for long before they are no longer dangerously radioactive.

Neutrons are used to stimulate nuclear fission in both nuclear reactors and nuclear bombs (Basirjafari, S.2013)

$$ {}^{A}_{Z}X \rightarrow {}^{A-1}_{Z}Y + {}^{1}_{0}n \qquad \textbf{(2.8)} $$

$$ {}^{18}_{8}O \rightarrow {}^{17}_{8}O + {}^{1}_{0}n \qquad \textbf{(2.9)} $$

2.2 BACKGROUND RADIATION

Background radiation is a measure of the level of ionizing radiation present in the environment at a particular location which is not due to deliberate introduction of radiation sources (El-gamal, Hussien, Saleh, 2019).

Background radiation originates from a variety of sources, both natural and artificial. These include both cosmic radiation and environmental radioactivity from naturally occurring radioactive materials (such as radon and radium), as well as man-made medical X-rays, fallout from nuclear weapons testing and nuclear accidents. Background radiation is present in every part of our environment and daily activities. (El-gamal, Hussien, Saleh, 2019).

This type of radiation comes from many sources which can be either man-made or natural. These includes environmental radioactivity from naturally occurring radioactive materials like radon and radium, cosmic radiation, artificial means like X-rays, fallouts from nuclear weapon testing and accidents.

The International Atomic Energy Agency defines background radiation as a measure of dose rate attributed to all sources other than one source (International Atomic Energy Agency, 2007).

This definition comes to play where measurements are taken in a specified source where there is an existing background radiation that can affect the measurement. Furthermore, if there is no specified radiation source, then the total reading taken from such a place is the dose of background radiation from that place, then the ambient dose is measured for sake of the environment (Trevor Boardman, 2018).

Terrestrial radiations come from natural radioactive elements in the earth i.e. the ground, trees, stones and walls of buildings contribute about 0.28mSv/year, and its sources vary from place to place. They are classified into building materials and soils surface (Mehdizadeh S, Faghihi R, Sina S, 2011).

It is important to determine population's exposure to radiation from building materials, because almost 80% of our life is spent indoors, and all building materials mostly constitute rock and soil. These two materials include natural radioactive isotopes such as 232Th and 238U decay series and 40K (Shahbazi-gahrouei, 2013).

2.2.1 NATURAL BACKGROUND RADIATION

Common natural radioactivity is found in rocks and soil which make up the planet earth, in water, oceans and building materials. Every part of the earth has natural radioactivity with no exceptions (Taqi, etal 2018).

Soil consists of radioactive nuclides. They belong to natural radionuclides like the members of the uranium and thorium decay series. Natural radioactivity involves external exposure due to gamma radiation and this depends absolutely on the geological and geographical conditions of different levels and regions in the world (Slaper, Stoop, 2000) .

The different levels of terrestrial radiation are dependent on the geological composition of each lithological area and the content of the rock from which soils originated in each area which has radioactive elements of thorium, uranium, and potassium. (Isam salih, 2003).

All building materials contain variable amounts of radioactivity. Example, materials extracted from rock and soil contains natural radionuclides of the uranium, thorium and isotopes of potassium. Man-made radionuclides can also be present, example cesium, which results from the dumping of weapons (contaminations from war). These are sources of both internal and external radiation exposures. Inhalation of radon gas is an example of internal radiation (Dawam, Mangset, 2015).

Gamma rays' penetration is an external exposure. About 50% of natural exposure of people is from radon gas, and it is the leading cause of cancer in patients suffering from respiratory and gastrointestinal system problems, and it has been discovered that the highest percentage of radon enters the body through drinking water and breathing. Once the water is supplied to consumers, exposure of the radon is spread through inhalation and ingestion. Radon in water is spread when rain falls, washing plates, flushing toilets, washing clothes etc. The matter is deposited in the lungs, where the radiation is released and this causes lung cancer. Radon can also be deposited in other parts of the body through ingestion thereby exposing the internal organs. Stomach cancer can be caused by ingestion of radon. Asides the effect of soils to the population group using it in building, food containing radionuclides can also affect the human body by entering the food and ground water from deeper soil layers (Khan, 2015)

2.2.2 ARTIFICIAL RADIATION

Humans are exposed to radiation through different man-made sources. These sources include uses of radioactive and high energy radiation sources in medical diagnosis, industries, coal burning, residues from nuclear test, etc. There are some artificial sources that are low in radiation emission, such as building materials, phosphate fertilizers, minerals from crushed rocks, some components of a television set (especially those with cathode ray tubes), smoke detectors, etc (Dawam and Mangset, 2015).

Most times, radioactivity from nuclear reactors is contained safely, but small percentage escapes as liquid or gas and might contaminate the air or water supply, another example is nuclear accidents.

2.2.3 AIRBORNE SOURCES

Radon which is an airborne radioactive gas emanates from the ground, and it is known as the highest source of natural background radiation. Radon, its isotopes, parent radionuclides and the decay products contribute greatly to an average dose of 1.26mSv/h inhaled (Pennington W, 2017)

Radon is naturally in the atmosphere in trace amounts. Majorly, radon exposure occurs inside homes, schools and workplaces. Radon gas is trapped indoors after it enters buildings through cracks and other holes in the foundation

Radon is apparently the decay product of uranium and its common in the earth crust, but it is usually more concentrated in rocks with ore. It leaks out of the ores and enter deep into the atmosphere or into the ground water and also buildings. This thereafter can be inhaled into the lungs and can stay over a period of time after the exposure. Radon occurs naturally yet its exposure can be enhanced or reduced by human activity either by constructions, poor basement ventilation, poorly sealed floor, these can expose the residents to high concentrations of radon (Slaper, Stoop, 2000).

2.3 RADIOACTIVITY

This occurs naturally in a number of substances. Atoms of this substance emit invisible but energetic radiations spontaneously and it penetrates materials that are not translucent to visible light (Lawson, 1999).
In other words, Radioactivity is the spontaneous disintegration of unstable atomic nuclei to form more energetically stable atomic nuclei (El-gamal, 2019).
Radioactive decay is a first order process which occurs when a small amount of mass is converted to energy. Different species are characterized by their own half-life or the length of time it takes for initially large number of those nuclei to have decayed to half of its original number.

Radioactive decay is a random process which occurs at the level of individual atoms. In radioactive decay, a large amount of energy is released.

It is not possible to ascertain when an atom will decay, irrespective of how long the atom has existed. Furthermore, in other to get a significant number of identical atoms, the overall decay rate is called decay constant.

Radioactivity has a wide range of benefits, especially in medicine, but can be harmful to living cells if not handled properly. (Lawson, 1999)

Radioactive decay is given as

$$-\frac{dN}{dt} = N\lambda$$

where $\frac{dN}{dt}$ is the number of decays per second

(2.10)

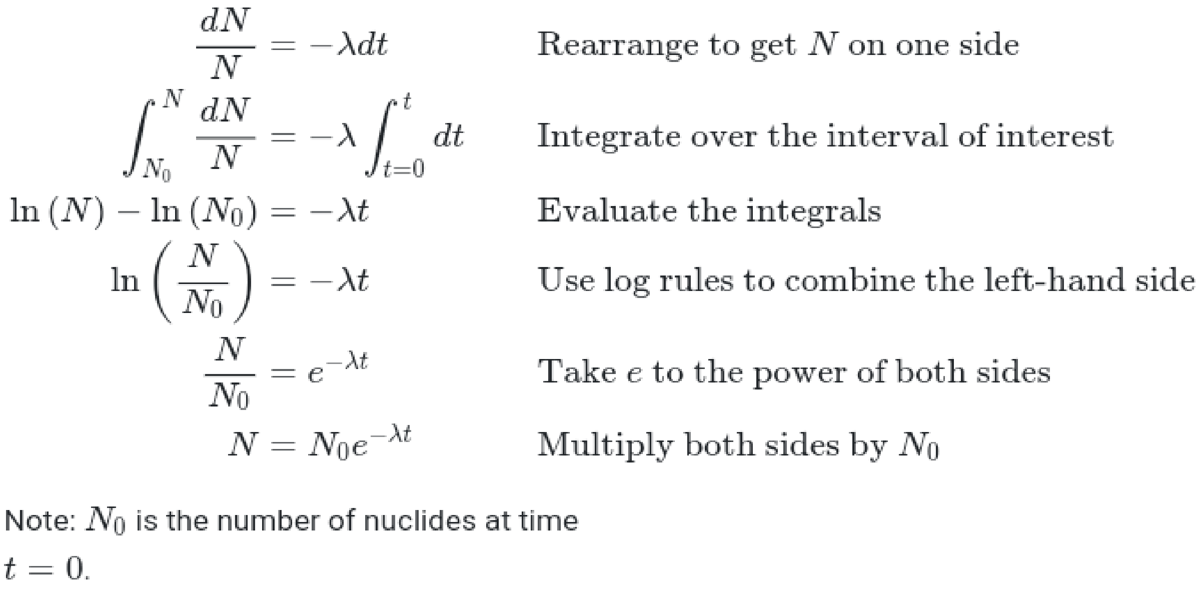
N is the number of particles

λ is the decay constant

−dN(t)dt=λ∗N(t)−dN(t)dt=λ∗N(t)

Where the minus sign refers to the decaying or decrease in the number of nuclei N(t) over time. So, the radioactive mass is reduced exponentially following the formula:

N(t)=N(0)∗e−λ∗tN(t)=N(0)∗e−λ∗t.



$$\begin{aligned}
\frac{dN}{N} &= -\lambda dt && \text{Rearrange to get } N \text{ on one side}\\
\int_{N_0}^{N} \frac{dN}{N} &= -\lambda \int_{t=0}^{t} dt && \text{Integrate over the interval of interest}\\
\ln(N) - \ln(N_0) &= -\lambda t && \text{Evaluate the integrals}\\
\ln\left(\frac{N}{N_0}\right) &= -\lambda t && \text{Use log rules to combine the left-hand side}\\
\frac{N}{N_0} &= e^{-\lambda t} && \text{Take } e \text{ to the power of both sides}\\
N &= N_0 e^{-\lambda t} && \text{Multiply both sides by } N_0
\end{aligned}$$

Note: N_0 is the number of nuclides at time $t = 0$.

2.3.1 COSMIC RADIOACTIVE SOURCES

It has been shown that 8% of our radiation exposure comes from outer space including the sun (Eisenbud, 1997). Cosmogenic radionuclides are produced by these bodies and deposited by stable nuclides of atoms bombarded by cosmic ray interactions. Examples of cosmogenic radionuclides include: C-14, H-3, and Be-7 and most of these radionuclides have shorter half-life when compared to the primordial radionuclides. Exposure to cosmic radiation increases with increasing heights, therefore people who live in higher levels and fly on airplanes experience a higher dose of cosmogenic radionuclides. While radon enters our body through breathing, cosmic particles enter through the skin. The air shields us from cosmic radiation. This implies that the more air between us and space, the more shielding we have from cosmic radiation (World Nuclear Association, 2016).

2.4 HAZARDS

The dangers associated with background radiation are through breathing and ingestion into our body and external exposure where there has been incessant radiation exposure. Respirators are needed in dry processes, where natural background radiation become air borne and have chances of entering the body (Slaper, H. and Stoop, P. (2000)).

Some elements found in the earth e.g., radon and also by-products from it can be very harmful if dosage is high. These elements are significant to bones because when they enter the body, they migrate to the bone tissue and are concentrated there. This can then cause cancer of the bone and other bone related diseases. The concentration of radium and other by-products of the radionuclide build over time, and with several years of exposure, workers without standard respiratory protection can develop bone cancer and other abnormalities. Therefore, every worker needs a standard respiratory protection and failure to have it, the worker if exposed can decide to seek medical compensation or additional wages from the company he is working with. (Cooper, 2005)

Radium radionuclides emit alpha, beta and gamma rays. The radiation emitted from a radium 226 atom is about 96% alpha particles and 4% gamma rays. Alpha particles are identical with helium-4 nuclei. Alpha particles move short distances in air, only 2–3 cm, and cannot penetrate through a dead layer of skin or the human body. The half-life for radium 226 is about 1,620 years, and can live in the body for the lifetime of the human, and this can cause damage after a period of time.

Beta particles has high positrons and high energy electrons. They can be both ionizing and non-ionizing depending on the energy. In terms of the penetrating power, it can be stopped few millimeters by plastic. This radiation when compared to radium 226 decay, is very small. Radium 228 emits beta particles, and this calls for concern to the human health because it enters into the body through inhalation and ingestion (Slaper and Stoop, 2000).

The gamma rays emitted from radium 226, which is the 4% of the radiation, are harmful to humans with increased exposure. Gamma rays have high penetrating power and some can pass through metals.

Alpha and beta particles are harmful once they get inside the body. Respirators with filters should be worn regularly by nuclear workers to avoid inhalation of contaminated dust and air. Annual limits on intake (ALI) and Derived air concentrations (DAC) are measurements and are calculated values based on the dose an average employee working 2,000 hours a year may be exposed to. The limit exposure currently in the United States is 1 ALI, or 5 rems per year. A rem, or Roentgen equivalent is a measurement of absorption rate of radiation on parts of the body over a long period of time (Slaper, Stoop, 2000).

A DAC is a concentration of alpha and beta particles that a worker is exposed to for 2,000 hours of work. Exposure to large amounts of radioactivity can cause nausea, vomiting, hair loss, diarrhea, hemorrhage, destruction of the intestinal lining, central nervous system damage, and death. It can also cause DNA damage and increases the risk of cancer, especially in young children and fetus, and this depends on the amount of radiation they are exposed to and their different sensitivity. The effects of radioactive pollution vary between individuals. Exposure to large amounts of radiation leads to chronic diseases, cancer or death in the shortest possible time, while exposure to small amounts of radiation can cause diseases that are not very serious but tends to develop over a period of time. The risk associated with the developing diseases increases if the person is still constantly exposed to the radiation and the increased dose can cause cancer after some years (Okoro, Sanni, 2019).

2.5 RADIATION PROTECTION

Radiation protection is a means of protecting people from the effects of exposure to ionizing radiation which is harmful to human. This harmful exposure can be from a source of radiation on the external part of human body or internal part by ingestion or inhalation of contaminated radioactive substance, according to the International Atomic Energy Agency (IAEA).

Ionizing radiation is used widely in medicine and industry and it poses a significant threat and damage to human tissues. Ionization radiation has health effects which are caused by high exposure of living tissue to radiation and “stochastic” effects caused by low level exposure example radiation induced cancer (Das, 2018).

The reduction of dose using some protective measures such as time, distance and shielding is important in radiation protection. The duration of this exposure should be minimized completely and the distance from the source should as much as possible be maximized and shielded from the source wherever shielding is possible. In line with this, to measure the personal dose uptake in occupational exposure or in case of emergency, for external protective measures, personal dosimeters are used and bioassay techniques are applied in the case of internal exposure (Das, 2018).

For the assessment of radiation protection and dosimetry, the International Commission on Radiation Protection (ICRP) and International Commission on radiation Units and Measurements (ICRU) published recommendations and data used to measure the biological effects on the human body of certain levels of radiation, and advised acceptable dose uptake limits (Nair MK, Nambi KS, 1999).

The international system of radiological protection has been developed, maintained and recommended by the ICRP, and this is based on the study carried out by researchers to estimate the risk associated with the received dose level. The objective of this program is to be able to “manage and control ionizing radiation exposure so as to prevent the risk associated with deterministic and stochastic effects to an extent reasonably achievable”. These recommendation by the ICRP is upheld by both national and regional regulators and most countries work towards maintaining a secure radiation environment and setting dose limitation standard in accordance to the ICRP (IAEA GUIDE VIENNA, 2018).

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:

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 radioactive source (IAEA GUIDE VIENNA, 2018).

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 (IAEA GUIDE VIENNA, 2018).

Shielding: Sources of radiation can be shielded with solid or liquid material, which absorbs the energy of the radiation. The term 'biological shield' is used for absorbing material placed around a nuclear reactor, or other source of radiation, to reduce the radiation to a level safe for humans (IAEA GUIDE VIENNA, 2018).

2.5.1 TYPES OF EXPOSURE

Chronic Exposure: This is known as the amount of dose received by the whole body regularly over a long period of time. This is common with radiation workers and causes effects that occur later such as hereditary effects, cancer and cataract (CPEP, 2018).

Acute Exposure: This is the amount of dose received by the whole body over a short period of time. This causes effects such as erythema, sterility and radiation sickness (CPEP, 2018).

2.5.2 TYPES OF EXPOSURE SITUATIONS

The International commission for Radiological protection (ICRP) maintains some types of radiation exposure;

2.5.3 PLANNED EXPOSURE

This is defined as a situation whereby radiological protection is planned ahead of time even before exposure and the level of exposure expected can be predicted. A known example is occupational exposure whereby the personnel is to work in a radiation environment (Ramli, A.T. 2014)

2.5.4 EMERGENCY EXPOSURE

This is an unexpected situation that happens without been predicted and such situation requires urgent protective measures. An example is an emergency nuclear fallout caused by natural disaster or the likes (Pernicka, 1999).

2.5.5 EXISTING EXPOSURE

This is a situation whereby the exposure already exists and certain proactive measures and control are taken. Some of these can be from naturally occurring radioactive materials existing in the environment (I.M.G. Thompson, BØtter-Jensen, Deme, Pernicka, 1999).

2.5.6 DOSE UPTAKE REGULATIONS

ICRP makes use of the following principles in situations where the exposure can be controlled (CPEP, 2018).

Principle of Justification: In case of any alteration, the exposure should rather be useful more than the harmful effect, and the unnecessary use of radiation is not permitted, this means that the advantages of this radiation must outweigh its disadvantages (International Atomic Energy Agency (IAEA), 2004).

The principle of justification requires that any decision that alters the radiation exposure situation should do more good than harm. In other words, the introduction of a radiation source should result in sufficient individual or societal benefit to offset the detriment it causes. (I.M.G. Thompson, BØtter-Jensen, Deme, Pernicka, 1999).

Principle of Limitation of Doses: Every personnel and individual must be protected from the risks associated with this radiation and the total dose of the individual apart from the medical exposure should not exceed the appropriate limits recommended by the ICRP (Ibese, F. 2020).

Principle of Optimization: In this process, the situation seems to be justified. This is so because the probability of getting exposed, the number of people exposed and the level of exposure individually should be kept As low as reasonably achievable (ALARA) (Ibese, F. 2020).

2.5.7 FACTORS AFFECTING EXTERNAL DOSE UPTAKE

Some factors control the dose or amount of radiation received from a source and the exposure to radiation (ALARA). The factors include;

Time: The time of exposure should be reduced so that the dose received by an individual will be small. Minimizing the time and work schedule of personnel is an effective way of reducing external dose uptake.

Dose rate × exposure time = Total dose

Distance: Based on the inverse square law which states that "the exposure rate from a small source of radiation is inversely proportional to the square of the distance from the source. This means that increasing distance reduces dose.

Shielding: This is known as protective measures put in place to reduce radiation to a level safe for humans. The source can be shielded with solid or liquid material that is capable of absorbing the energy emitted from the radiation. Biological shield is placed around a nuclear reactor because of its ability to absorb energy and reduce the radiation to safe level for individuals (United States Nuclear Regulatory Commission, 2010).

2.5.8 EXTERNAL RADIATION PROTECTION

External exposure occurs when the whole body is exposed to radiation field from an external source. Ionizing radiation produces very high energy radiation fields and exposure to it affects the individual (Pernicka, 1999).

External exposure is radiation that comes from somewhere outside the body and interacts with us. The source of radiation can be a piece of equipment that produces the radiation, like an x-ray machine, or it can be from radioactive materials in a container. The amount of external radiation exposure received is related to the distance from the source, the energy of the emitted radiation, the total amount of radioactive material present or the machine setting, and the time of exposure. Radiation workers can control and limit their exposure to penetrating radiation by taking advantage of time, distance, and shielding (United States Nuclear Regulatory Commission, 2010).

Reduce Time: By reducing the time of exposure to a radiation source, the dose to the worker is reduced in direct proportion with that time. Time directly influences the dose received: if you minimize the time spent near the source, the dose received is minimized. For example, if possible, interview a nuclear medicine patient before drug administration not after (United States Nuclear Regulatory Commission, 2010).

Increase distance: When appropriate, increase the distance between you and the radiation source (e.g., sealed source, x-ray tube). The exposure rate from a radiation source drops off by the inverse of the distance squared. For example, if a problem arises during a fluoroscopy procedure, stand on the image intensifier side of the C-arm if possible, or, when not assisting, step away from the patient if feasible (El-gamal, Hussien, Saleh, 2019).

Use shielding: The third exposure control is based on the proper radiation shields, automatic interlock devices, and in-place radiation monitoring instruments. Except for temporary or portable shields, protective drapes, lead or lead equivalent aprons, this type of control is usually built into the particular facility, such as concrete walls next to a radiation oncology accelerator (United States Nuclear Regulatory Commission, 2010).

2.5.9 INTERNAL RADIATION PROTECTION

When radiation is either ingested or inhaled results in stochastic or deterministic effects depending on the dose of radiated materials involved.

The risk associated with low level internal source is the same with the risk in the external source provided it is the same amount (Thompson, 1999).

Internal radiation intake from a radioactive material occurs through some pathways;

1. Through inhaling air contaminated by radon gas and other radioactive particles.
2. By absorbing some vapors like tritium oxide by body contact, affecting the skin.
3. By injecting some medical radioisotopes into the body like technetium-99.
4. Through the ingestion of contaminated food or liquids.

In order to reduce occupational hazards arising from both airborne particles and radiochemical, it is advisable to use glove boxes. To protect individuals from breathing in these airborne radioactive particles, it is advised that individuals wear respirators with filters. In a specialist laboratory, concentration of radioactive content in food and drink can be measured (Ibese, F. 2020).

2.6 RECOMMENDED LIMITS ON DOSE

The ICRP recommends some limits for dose uptake. Situational, planned, emergency and existing situations and different limits for different groups (Otolorin , etal, 2020).

Planned exposure – limits given for occupational, medical and public exposure. The occupational exposure limit of effective dose is 20 mSv per year, averaged over defined periods of 5 years, with no single year exceeding 50 mSv. The public exposure limit is 1 mSv in a year (ICRP, International Commission on Radiological Protection, 2017).

Emergency exposure – Here, the limits are same as the limits for occupational and planned exposure which is under planned exposure.

Existing exposure – These are situations already in existence when the decision on the control measure has to be taken, this includes situations that has been prolonged after emergencies (ICRP, International Commission on Radiological Protection, 2017).

2.7 ALARA PRINCIPLE

ALARA is an acronym for radiation safety which means “As low as reasonably achievable”. This principle is designed to minimize radiation doses and reducing the release of radioactive materials into the environment. This principle not only minimize doses but also help prevent unnecessary exposure to radiation in the environment. Shielding, time, and distance are three major principles in limitation of doses (ICRP, 2017).

2.7.1 ANNUAL OCCUPATIONAL RADIATION DOSE LIMITS

The recommended annual occupational dose limits for humans and animals after some biological studies has it that maximum annual occupational dose limits on

1. Whole body ………….. 5,000 mrem/yr
2. Extremities ……………. 50,000 mrem/yr
3. Lens of the eye ………. 15,000 mrem/yr
4. Fetus (gestation period) …. 500 mrem/yr
5. Public (individuals) …… 100 mrem/yr (Paracelsus, UNL Environmental Health and Safety p402).

Note : 1,000 mrem = 1rem

Table 2.1: AVERAGE ANNUAL HUMAN EXPOSURE TO IONIZING RADIATIONS IN MILLISIEVERTS (msv) PER YEAR. (Hendry, Jolyon H Simon, etal; 2009)

Radiation source	World average	Remark
Inhalation of air	1.26	mainly from radon, depends on indoor accumulation
Ingestion of food & Water	0.29	(K-40, C-14, etc.)
Terrestrial radiation	0.48	depends on soil and building material

from ground		
Cosmic radiation from space	0.39	depends on altitude
subtotal (natural)	2.40	sizeable population groups receive 10–20 mSv
Medical	0.60	Worldwide figure excludes radiotherapy US figure is mostly CT scans and nuclear medicine.
Consumer items	-	cigarettes, air travel, building materials, etc.
Atmospheric nuclear testing	0.005	peak of 0.11 mSv in 1963 and declining since; higher near sites
Occupational exposure	0.005	worldwide average to workers only is 0.7 mSv mostly due to radon in mines; US is mostly due to medical and aviation workers.
Chernobyl accident	0.002	peak of 0.04 mSv in 1986 and declining since; higher near site
Nuclear fuel cycle	0.0002	up to 0.02 mSv near sites; excludes occupational exposure

Other	-	Industrial, security, medical, educational, and Research
subtotal (artificial)	0.61	
Total	3.01	millisieverts per year

2.8 PERSONAL RADIATION DOSIMETERS

Radiation dosimeter is a very important instrument for measuring personal dose of exposure to radiations. The instrument is used to measure external radiation dose uptake over some period of time by the individual wearing it. It is used in detecting strong penetrating radiation such as Gamma, X-ray, beta etc. but it is not used in measuring weak penetrating radiations such as alpha particles. (Masok, 2018)

Recently, thermo luminescent dosimetry (TLD) badges and electronic dosimeters are used in the measurement of personal dose. Electronic dosimeters are built in such a way that it gives a warning signal if the threshold has been reached, and this helps workers working in places like nuclear power plants and laboratories using radionuclides etc. to control their radiation dose uptake (Masok, 2018).

Some types of wearable dosimeters for ionizing radiation include:

1. Film badge dosimeter

2. Quartz fiber dosimeter
3. Electronic personal dosimeter
4. Thermo luminescent dosimeter

2.9 RADIATION SHIELDING

Different types of materials can be used in the shielding of gamma or x-rays especially if it is used in big quantity. Ionization radiation of different types interact with different shielding materials. The stopping power of radiation particles is dependent on the effect of its shielding. Different techniques are used in shielding, but the type to be used is dependent on the particle and the energy of its radiation (Paracelsus, 2012).

The intensity of radiation is limited by shielding and this depends on the thickness of the shielding material. Shielding reduces the intensity of radiation depending on the thickness (Paracelsus, 2012)

Generally, shielding increases its effectiveness when the atomic number increases.

In x-ray laboratories, the walls in the lab where the x-ray generator is kept may contain lead shielding like lead sheets or even during construction, the plastering of the walls may contain barium sulphate. Radiographers view the target through a lead glass screen or enter the room wearing lead aprons.

Shielding strength or "thickness" is measured in units of g/cm^2 (Masok, 2018).

2.10 GEIGER MULLER COUNTER

Geiger counter is one of the instruments used in the detection and measurement of ionization radiation. It has various applications ranging from experimental physics, radiation dosimetry, and radiological protection and also in the nuclear industry (Nivesh, Gayathri, Priya, 2017).

Gamma rays, alpha particles and beta particles are ionizing radiation detected by Geiger counter and it uses the ionization effect produced by the Geiger Muller Tube. It is a portable hand-held instrument for radiation survey, and its sensitivity is high. Although it has some limitations in measuring very high radiation rate and the energy of the incident radiation (Shahbazi, Setayandeh, Gholami, 2013).

2.11 PRINCIPLES OF GEIGER MULLER COUNTER

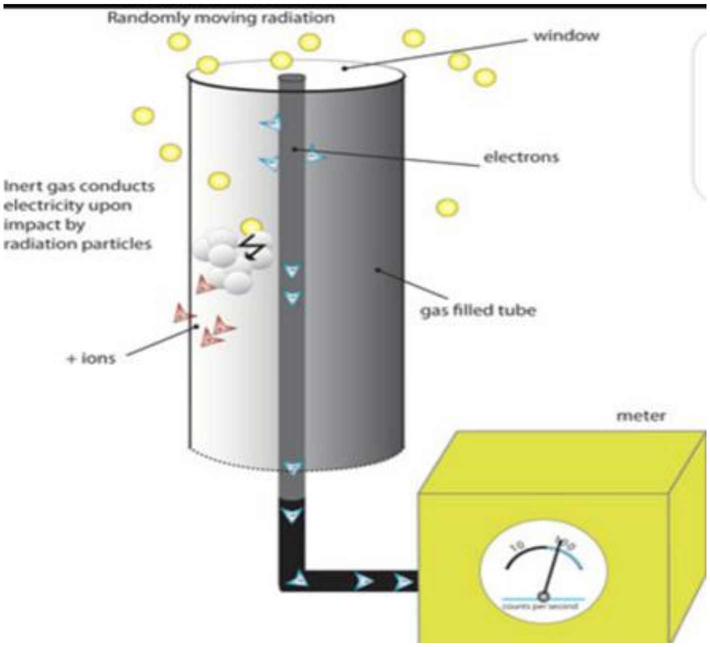


Fig 2.11: Geiger counter (Nivesh, Gayathri, Priya, 2017)

A Geiger counter consist of the probe or tube which is the sensing element responsible for the detection of radiation and the visual display unit which shows the result. The digital detector can detect alpha, beta and gamma radiations. The main element in this detector is the probe or tube with a gas filled chamber. The wall of the GM tube is a thin metal cylinder (cathode) surrounding a center electrode (anode). It has a thin mica window in the front, it allows the passage of detection of alpha particles. The tube is filled with Neon, Argon and Halogen gas.(Slaper, Stoop, 2000).

When exposed to ionization radiation, the radioactive particles enter the tube thereby colliding with the gas and more electrons are released. When this happens, positively charged ions are discharged and the negatively charged electrons become attached to a high voltage middle wire. When the number of the electron that has built up around the wire gets to a threshold, it generates an electric current (Slaper, Stoop, 2000).

This is responsible for the temporary closure of a switch and generates an electric pulse that shows on the meter as counts per minute or seconds and its intensity increases as the ionizing radiation increases, this also causes the alarm blaring when switched on. The instrument also uses a high voltage, typically 400–900 volts that has to be applied to the Geiger Muller tube for it to work (Shahbazi, Setayandeh, Gholami, 2013).

The readout of the detected radiation is of two types; it displays as a count rate either counts per minute or counts per second, or total number of counts over a certain set period (Shahbazi, Setayandeh, Gholami, 2013).

Chapter III: Materials and Methods

3.1 Geographical Location of The Study Area

Federal University of Technology, Owerri (FUTO) is located at Owerri West Local Government Area of Imo State, Nigeria. It has coordinates N5°23.5615’ and E 6°59.1758’. The institution is bounded by the communities like Eziobodo, Ihiagwa, Obinze, and Umuchima. The University has a population of about 400,000 as at 2006 and covers over un100km2 in area (NBC, 2010). Owerri is bordered by the Otamiri River to the east and the Nworie River to the South. It also has some important educational institutions in its environs, which includes Imo State Polytechnic, Umuagwo, Federal Polytechnic Nekede, Imo State University, African Institute of Science and Technology, Alvan Ikoku Federal College of Education and so many Secondary schools (Onoh, etal, 2017).

It has ten Schools and fifty Departments (futo.edu.ng, 2021) as listed below:

- School of Agriculture and Agricultural Technology (SAAT)
- School of Engineering and Engineering Technology (SEET)
- School of Electrical systems Engineering
- School of Physical Sciences (SOPS)
- School of Biological Sciences (SOBS)
- School of Management and Management Technology (SMAT)
- School of Health (SOH)
- School of Environmental Science (SOES)
- School of Basic Medical Sciences (SBMS)

- School of Information and Communication Technology (SICT)

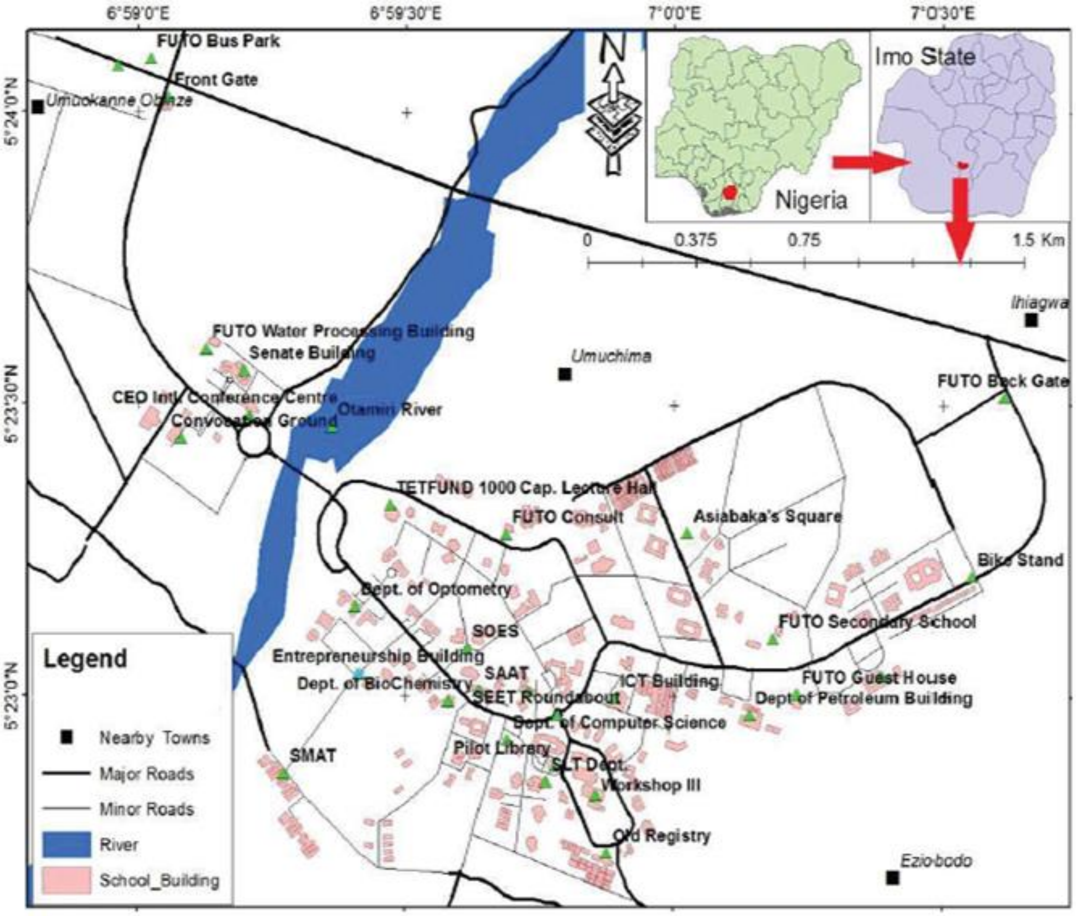


Figure 3.1: Geographical map of FUTO (Eke & Emelue, 2020)

3.2 Background Radiation Measurement

The background radiation level in this work was assessed using a factory calibrated digital Geiger – Muller Counter GCA – 04 and GCA – 04W. This instrument measures the Natural Background Radiation rates in count per minutes (CPM) and count per seconds (CPS).

The indoor background radiation of about five offices of all the departments in FUTO was measured. The instrument was always checked to ensure the battery of about 9 volts was always active to ensure an accurate reading. The counter was set to mSv and readings were taken after one minute. The Geiger–Muller counter was held at about one meter above the ground level at an open space for best results. Measurements were taken at three different parts of the office, (widow, middle and entrance) and fifty Departments were covered. At each point, the total count was recorded for 60 seconds. Five successive readings were taken at each point so that the mean could be obtained. Each count was converted to micro – sievert per hour (µSv/hr). The GM counter is shown in Fig. 3.3.

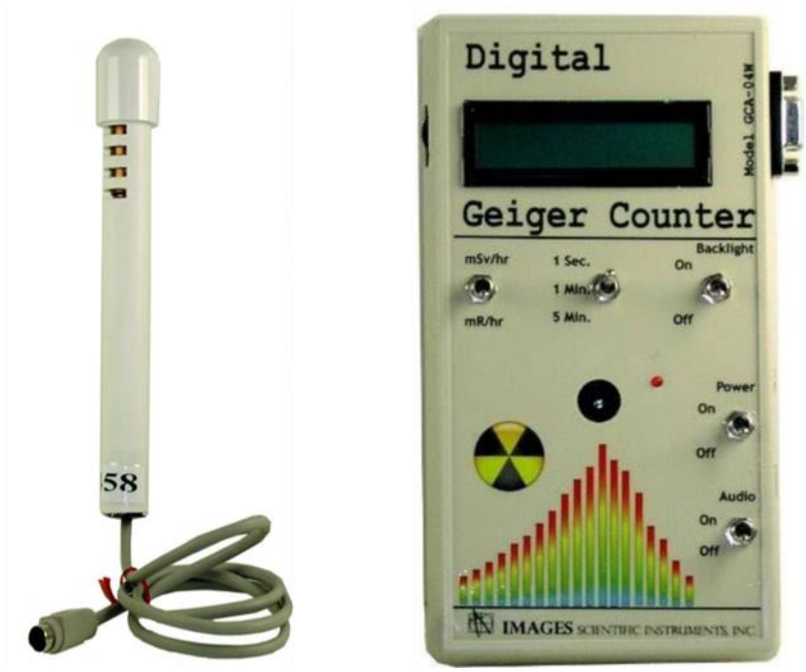


Figure 3.2: Digital Geiger Muller Counter, Models GCA– 04 and GCA – 04W

(Malltina inc. Images Scientific, Digital Geiger Counter with Wand, 2019)

3.3 Evaluation of Hazard Indices

The measured data of the background ionizing radiation (BIR) were used to calculate the absorbed dose rate (D), the Annual effective dose equivalent (AEDE) and the excess life cancer risk (ELCR).

The absorbed dose rate (D), was calculated using the conversion factor (Onoh, etal, 2017).

$$1\mu Rh^{-1} = 8.7nGyh^{-1} = \frac{8.7\times 10^{-3}}{\left(1/8760y\right)}\mu Gyy^{-1} = 76.212\mu Gyy^{-1} \qquad (3.1)$$

The conversion factor was also used.

1 CPM = 0.01μSv/hr

The effective dose equivalent (AEDE) was computed from the absorbed dose rates. Dose conversion factor of 0.7 $Sv\ Gy^{-1}$ and an occupancy factor for indoor exposure of 0.8 were used in the computation. The annual effective dose was calculated from

$$AEDE = D_{nGyh^{-1}} \times 0.8 \times 8760h \times 0.7_{SvGy^{-1}} \qquad (3.3)$$

$$AEDE = D_{nGyh^{-1}} \times 4.905\mu Sv \qquad (3.4)$$

Following from the calculated values of the AEDE, the excess life cancer risk was calculated

$$ELCR = AEDE_{mSvy^{-1}} \times LE \times RF \qquad (3.5)$$

Where LE is the life expectancy which was taken as 55 years for Nigeria as given by World Bank records. (Das, 2018) RF is the fatal risk factor which is taken as 0.05 Sv^{-1} (Das, 2018)

Chapter IV: Results and Discussions

4.1 Background Ionizing radiation

The results of the background ionizing radiation measurements are given in Table 4.1.1 to 4.1.11. A total of 255 measurements were taken around the FUTO environment. The average value of 0.0052 µSv/h standard deviation of 0.0035 µSv/h is much lower than the world average of 0.274 µSv/h. This shows that the amount of naturally occurring radioactive elements present in the environment is low. The highest value was observed in Food Science and Technology Department as 0.0873±0.0432 µSv/h, while the lowest value was recorded in Mathematics Department, 0.0006±0.0001 µSv/h. The BIR measurements as compared with the world average are plotted in Figure 4.1. (Rutherford, 1909).

BACKGROUND IONIZING RADIATION MEASUREMENTS

FOR THE DEPARTMENTS, MEASUREMENT IN (µSv/h).

Table 4.1.1 School of Agriculture and Agricultural Technology (SAAT)

Department	**Mean(±SD)×10^{-3} (µSv/h)**	**Min. (µSv/h)**	**Max. (µSv/h)**
Agric Economics	0.0010±0.0004	0.00052	0.00153
Agricultural Extension	0.0010±0.0001	0.00078	0.00104
Animal science	0.0009±0.0002	0.00078	0.00130
Crop science	0.0257±0.0216	0.00120	0.04515
Fishery & Aquaculture Technology	0.0011±0.0003	0.00078	0.00165
Soil science	0.0019±0.0012	0.00065	0.00572
Agricultural Technology	0.0011±0.0002	0.00083	0.00133

Table 4.1.2 School of Engineering and Engineering Technology (SEET)

Department	**Mean(±SD)×10^{-3} (µSv/h)**	**Min. (µSv/h)**	**Max. (µSv/h)**
Civil Engineering	0.0043±0.0027	0.00087	0.01427
Mechanical Engineering	0.0021±0.0018	0.00087	0.00528
Electrical and Electronics Engineering	0.0010±0.0004	0.00061	0.00138
Food Science and Tech.	0.0873±0.0432	0.00094	0.33977
Polymer and Textile Engineering	0.0161±0.0101	0.00083	0.04934
Agricultural Engineering	0.0009±0.0002	0.00065	0.00114
Petroleum Engineering	0.0008±0.0002	0.00065	0.00104
Chemical Engineering	0.0009±0.0003	0.00038	0.00114
Materials and Metallurgical Engineering	0.0018±0.0010	0.00078	0.00321

Table 4.1.3 School of Electrical systems engineering (SOES)

Department	**Mean(±SD)×10^{-3} (µSv/h)**	**Min. (µSv/h)**	**Max. (µSv/h)**
Electrical and Electronics Engineering	0.0010±0.0004	0.00061	0.00138
Mechatronics Engineering	0.0017±0.0012	0.00073	0.00336
Computer Engineering	0.0013±0.0010	0.00065	0.00172
Telecommunication Engineering	0.0008±0.0001	0.00069	0.00104

Table 4.1.4 School of Physical Sciences (SOPS)

Department	**Mean(±SD)×10^{-3} (µSv/h)**	**Min. (µSv/h)**	**Max. (µSv/h)**
Physics	0.0009±0.0003	0.00037	0.00164
Geology	0.0010±0.0002	0.00082	0.00121
Science Laboratory Tech.	0.0008±0.0002	0.00052	0.00104

Chemistry	0.0010±0.0004	0.00052	0.00155
Mathematics	0.0006±0.0001	0.00052	0.00078
Statistics	0.0046±0.0022	0.00255	0.00739

Table 4.1.5 School of Biological Sciences (SOBS)

Department	**Mean(±SD)×10^{-3} (μSv/h)**	**Min. (μSv/h)**	**Max. (μSv/h)**
Biology	0.0009±0.0002	0.00069	0.00113
Microbiology	0.0011±0.0004	0.00065	0.00156
Biotechnology	0.0100±0.0086	0.00071	0.02437
Biochemistry	0.0015±0.0006	0.00054	0.00206

Table 4.1.6 School of Basic Medical Sciences (SBMS)

Department	**Mean(±SD)×10^{-3} (μSv/h)**	**Min. (μSv/h)**	**Max. (μSv/h)**
Anatomy	0.0020±0.0015	0.00056	0.00616
Physiology	0.0013±0.0007	0.00054	0.00460

Table 4.1.7 School of Management and Management Technology (SMAT)

Department	**Mean(±SD)×10^{-3} (µSv/h)**	**Min. (µSv/h)**	**Max. (µSv/h)**
Financial management technology	0.0300±0.0164	0.00585	0.04533
Management Technology	0.0012±0.0002	0.00105	0.00143
Transport Management	0.0012±0.0003	0.00080	0.00143
Maritime Management Technology	0.0014±0.0005	0.00069	0.00180

Table 4.1.8 School of Health (SOH)

Department	**Mean(±SD)×10^{-3} (µSv/h)**	**Min. (µSv/h)**	**Max. (µSv/h)**
Dental Technology	0.0009±0.0001	0.00068	0.00130
Optometry	0.0008±0.0001	0.00073	0.00086
Public Health	0.0010±0.0003	0.00052	0.00120

Prostetics and Orthopaedic Tech.	0.0008±0.0001	0.00069	0.00104
Biomedical Technology	0.0009±0.0002	0.00066	0.00104

Table 4.1.9 School of Environmental Science (SOES)

Department	**Mean(±SD)×10^{-3} (µSv/h)**	**Min. (µSv/h)**	**Max. (µSv/h)**
Architecture	0.0010±0.0003	0.00065	0.00143
Building Tech.	0.0010±0.0003	0.00069	0.00125
Environmental Technology	0.0018±0.0016	0.00091	0.00468
Quantity surveying	0.0017±0.0010	0.00078	0.00334
Surveying and Geo-informatics	0.0012±0.0004	0.00078	0.00173
Urban and Regional Planning	0.0008±0.0002	0.00065	0.00104

Table 4.1.10 School of Information and Communication Technology (SICT)

Department	**Mean(±SD)×10^{-3} (µSv/h)**	**Min. (µSv/h)**	**Max. (µSv/h)**
Information Technology	0.0010±0.0002	0.00082	0.00128
Computer science	0.0013±0.0002	0.00104	0.00164

Table 4.1.11 Office of the Director of Centre for Energy and Power systems research

Department	**Mean(±SD)×10^{-3} (µSv/h)**	**Min. (µSv/h)**	**Max. (µSv/h)**
Centre for Energy and Power systems research	0.0335±0.0012	0.02660	0.04736

Table 4.1.12 Mean of all Departments and World Average

Mean	**0.0052±0.0035**
World Average	**0.274**

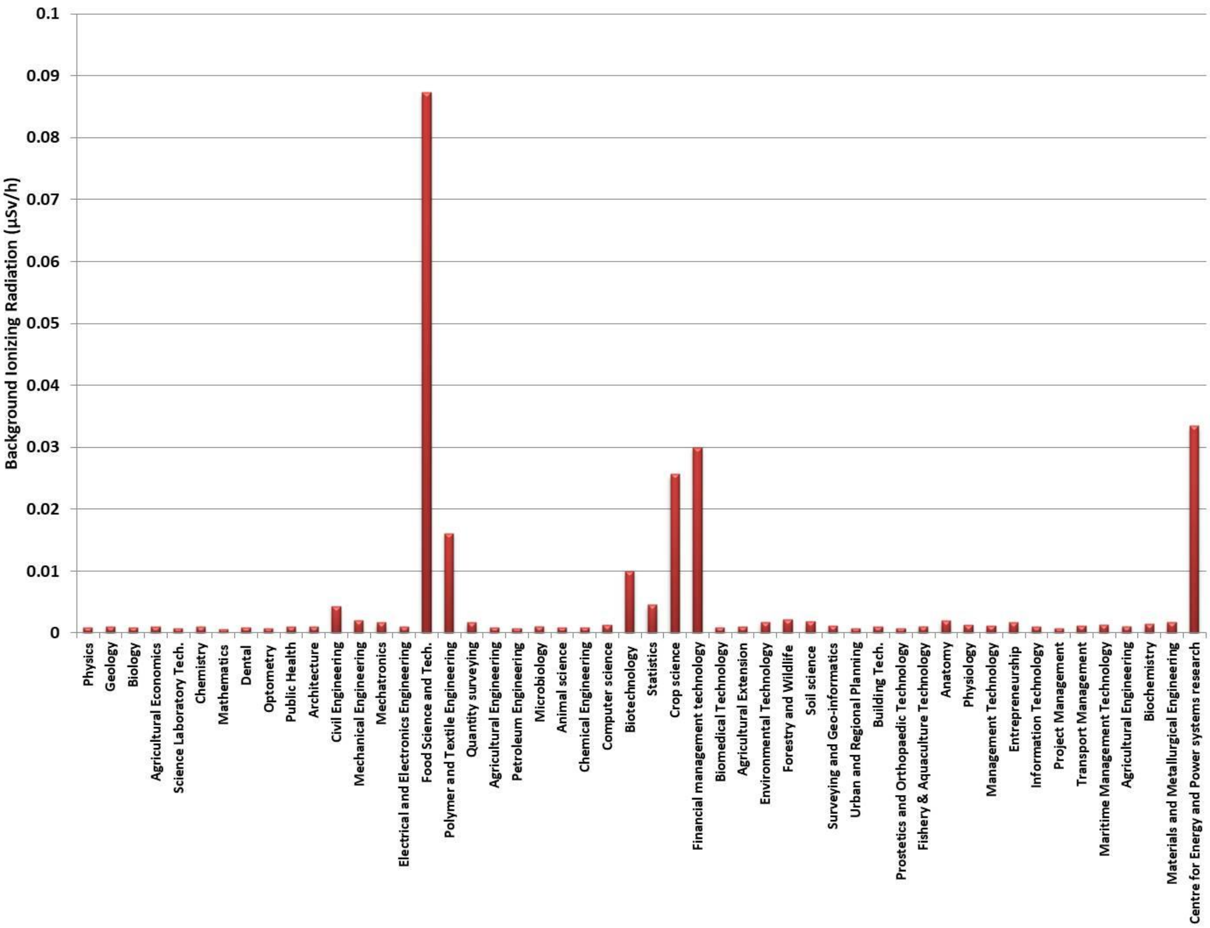


Figure 4.1: BIR measurements for the various Departments compared with the world average 0.274

It may be possible that the cause of the high values observed was from the building materials which might contain radioactive particles or due to the fact that the location was a former dump site.

4.2 Hazard Indices

The maximum value of the absorbed dose rate was recorded in the Department of Food Science and Technology as 75.934 nGy/h and the minimum value was recorded as 0.548 nGy/h at Mathematics Department. The highest value is significantly higher than the world average of 59 nGy/h (UNSCEAR, 2000). All other values are lower than the world average. The absorbed dose rates are displayed in Figure 4.2 with comparison to the world average.

For the annual effective dose equivalent (AEDE), the minimum and maximum values were recorded as 2.688 µSv/y and 372.456 µSv/y at Mathematics and Food science and Technology departments respectively. The average value for all the offices is 22.313±14.092 µSv/y, which is lower than the world average of 410 µSv/y (UNSCEAR, 2000).

Correspondingly, the lowest value of excess life cancer risk (ELCR) of 0.007×10^{-3} was observed in Mathematics. The highest value is 1.024×10^{-3} and observed in Food Science and Technology Department, which is significantly higher than the world average of 0.29×10^{-3} (UNSCEAR, 2000). In the Departments of Crop Science, Financial Management Technology, and Centre for Energy & Power Systems Research, values of 0.301×10^{-3}, 0.351×10^{-3} and 0.393×10^{-3} respectively were recorded and found to be higher than the world average value of 0.29×10^{-3}.

Possible causes for the values of the hazard indices in the Department of Food Science and Technology might be that the materials used in building the structure might have been contaminated with some radioactive particles, also, the building is situated in a former dump site which may also contribute to the high rate of hazard indices.

Furthermore, the department of Mathematics might have the lowest hazard indices because the building materials have low or no radioactive contamination.

Figures 4.3 and 4.4 respectively show AEDE and ELCR in comparison to the world average.

HAZARD INDICES FOR THE DEPARTMENTS

Table 4.2.1: School of Agriculture and Agricultural Technology (SAAT)

Department	**Absorbed Dose Rate (nG/hr)**	**AEDE (μSv/yr)**	**ELCR×10^{-3}**
Agricultural Economics	0.844	4.140	0.011
Agricultural Extension	0.844	4.140	0.011
Animal science	0.809	3.968	0.011
Crop science	22.350	109.627	0.301
Fishery &Aquaculture Technology	0.974	4.778	0.013
Forestry and Wildlife	1.897	9.305	0.026
Soil science	1.627	7.980	0.022

Table 4.2.2: School of Biological Science (SOBS)

Department	**Absorbed Dose Rate (nG/hr)**	**AEDE (µSv/yr)**	**ELCR×10^{-3}**
Biochemistry	1.288	6.318	0.017
Biology	0.818	4.012	0.011
Biotechnology	8.735	42.845	0.118
Microbiology	0.914	4.483	0.012

Table 4.2.3: School of Basic Medical Sciences (SBMS)

Department	**Absorbed Dose Rate (nG/hr)**	**AEDE (µSv/yr)**	**ELCR×10^{-3}**
Anatomy	1.775	8.706	0.024
Physiology	1.096	5.376	0.015

Table 4.2.4: School of Engineering and Engineering Technology (SEET)

Department	**Absorbed Dose Rate (nG/hr)**	**AEDE (µSv/yr)**	**ELCR×10^{-3}**
Agricultural & Bio resources Engineering	0.783	3.841	0.011
Chemical Engineering	0.783	3.841	0.011
Civil Engineering	3.767	18.477	0.051
Electrical& Electronics	0.879	4.311	0.012

Engineering			
Food Science & Technology	75.934	372.456	1.024
Materials &Metallurgical Engineering	1.557	7.637	0.021
Mechanical Engineering	1.801	8.834	0.024
Mechatronics Engineering	1.496	7.338	0.020
Petroleum Engineering	0.705	3.458	0.010
Polymer& Textile Engineering	13.964	68.493	0.188

Table 4.2.5: School of Environmental Science (SOES)

Department	**Absorbed Dose Rate (nG/hr)**	**AEDE (µSv/yr)**	**ELCR$\times 10^{-3}$**
Architecture	0.879	4.311	0.012
Building Technology	0.896	4.395	0.012
Environmental Technology	1.583	7.765	0.021
Quantity surveying	1.479	7.254	0.020

Surveying &Geoinformatics	1.061	5.204	0.014
Urban & Regional Planning	0.713	3.497	0.010

Table 4.2.6: School of Health Technology (SOHT)

Department	**Absorbed Dose Rate (nG/hr)**	**AEDE (µSv/yr)**	**ELCR×10^{-3}**
Biomedical Technology	0.800	3.924	0.011
Dental Technology	0.783	3.841	0.011
Environmental Health Science	0.931	4.567	0.013
Optometry	0.696	3.414	0.009
Prosthetics &orthotics	0.713	3.497	0.010
Public Health	0.853	4.184	0.012

Table 4.2.7: School of Information and Communication Technology (SICT)

Department	**Absorbed Dose Rate (nG/hr)**	**AEDE (µSv/yr)**	**ELCR×10^{-3}**
Computer science	1.131	5.548	0.015
Information	0.827	4.056	0.011

Technology			

Table 4.2.8: School of Management Technology (SMAT)

Department	Absorbed Dose Rate (nG/hr)	AEDE (µSv/yr)	ELCR×10^{-3}
Entrepreneurship	1.496	7.338	0.020
Financial management technology	26.057	127.810	0.351
Management Technology	1.061	5.204	0.014
Maritime Management Technology	1.175	5.763	0.016
Project Management	0.731	3.586	0.010
Transport Management	1.079	5.292	0.015

Table 4.2.9: School of Physical Science (SOPS)

Department	Absorbed Dose Rate (nG/hr)	AEDE (µSv/yr)	ELCR×10^{-3}
Chemistry	0.844	4.140	0.011
Geology	0.870	4.267	0.012
Mathematics	0.548	2.688	0.007

Physics	0.740	3.630	0.010
Science Laboratory Tech.	0.713	3.497	0.010
Statistics	3.993	19.586	0.054

Table 4.2.10: Office of the Director of Centre for Energy and Power systems research

Department	**Absorbed Dose Rate (nG/hr)**	**AEDE (µSv/yr)**	**ELCR×10^{-3}**
Centre for Energy and Power systems research	29.162	143.040	0.393

Table 4.2.11: Mean of All Departments and World Average

Mean	**4.549±2.0470**	**22.313±14.092**	**0.061±0.012**
World Average	**59.000**	**410.000**	**0.290**

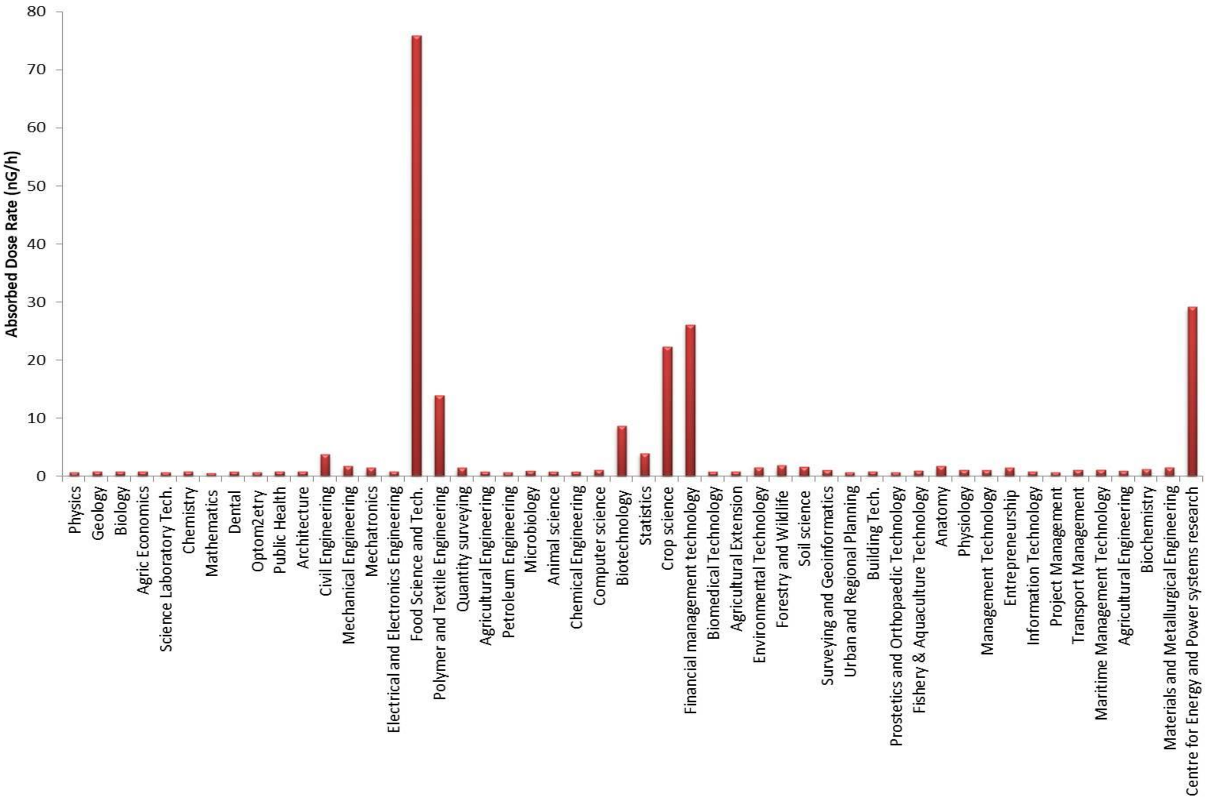


Figure 4.2 Absorbed dose rate for the various departments compared with the world average of 59.000 (nG/hr).

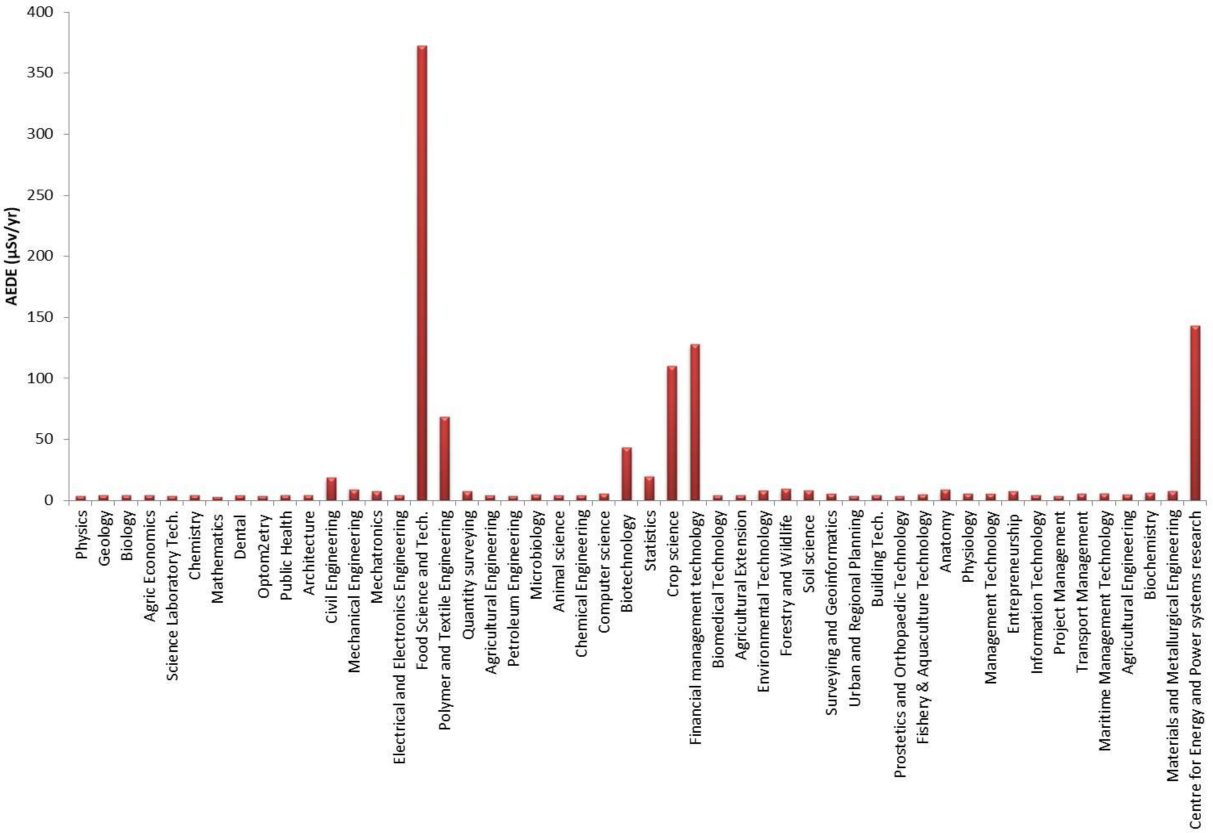


Fig 4.3 Annual effective dose equivalent for the various departments compared with the world average of 410.000(µSv/yr).

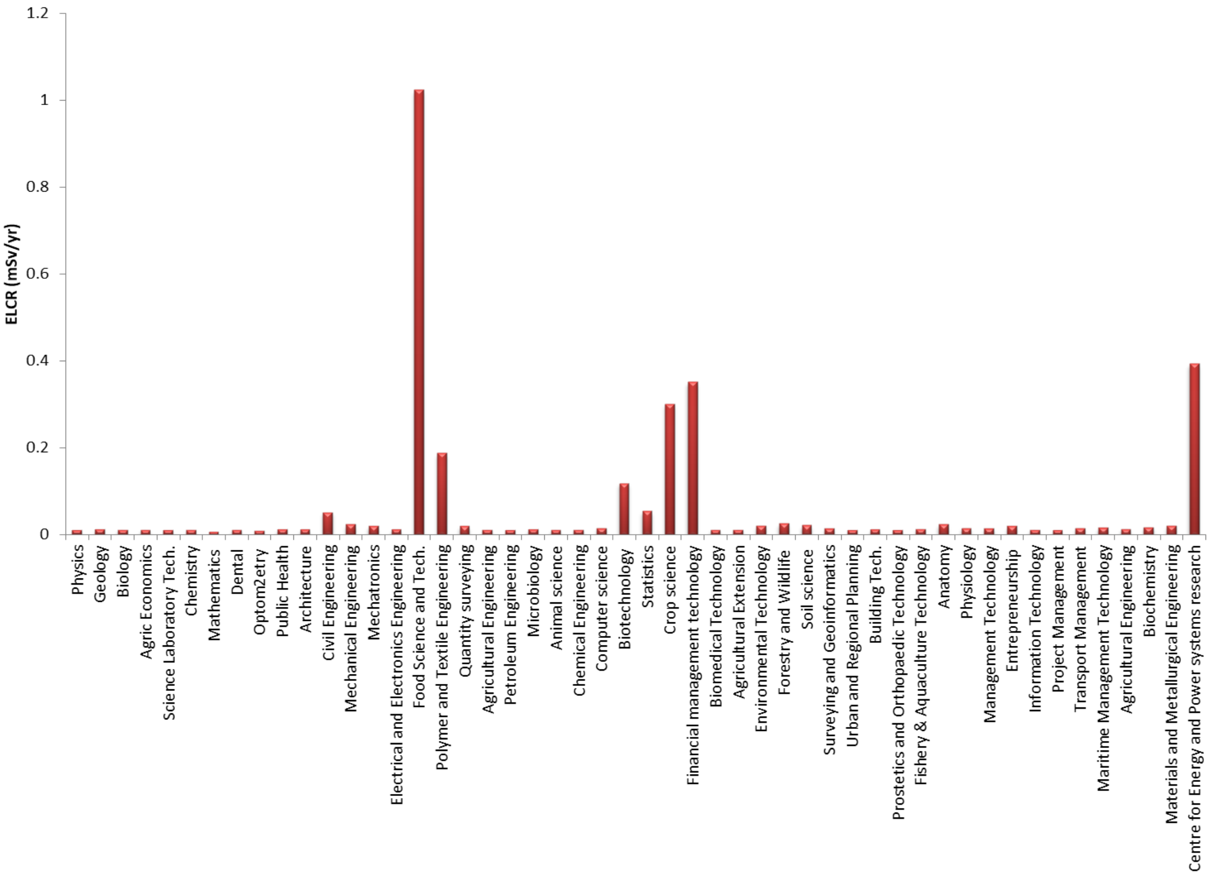


Fig 4.4 Excess Life cancer risk for the various departments compared with the world average of 0.290 ELCR×10^{-3}.

4.4 Discussions

Results from the fifty Departments within the Federal University of Technology, Owerri are presented from Table 4.1.1 to Table 4.1.11. The BIR measurements indicated low significant levels of exposure within the offices as all values recorded were below the world average. The average value reported for the study is 0.0052 ± 0.0035 μSv/h. The most significant exposure was observed in the Department of Food science and Technology and this could be from the building materials within the offices or the surrounding environment. This indicates that, the level of radionuclides is relatively higher than in other Departments studied. Other studies have also reported BIR measurements for different locations. For instance, Etuk et al., (2017), reported a value of 0.11 μSv/h. Ramli et al, (2014) reported 0.176 ± 0.02 μSv/h and 0.148± μSv/h for Akwanga and Keffi towns respectively. In Itu, a value of 0.042± 0.02 μSv/h was reported by Ekong et al., (2019). Also, Ugbede & Benson, (2018) reported a value of 5.4 ± 0.1 μSv/h in Enugu which is relatively higher. On a similar note, Olarinoye and co-workers, in their study of BIR within Niger state college of Education and Federal University of Technology Minna, reported values of 0.171 μSv/h and 0.184 μSv/h (Olarinoye et al., 2010). In quarry sites in Ebonyi, a value of 0.18± 0.01 μSv/h (Echewezo & Ugbede, 2020). Similarly, James et al., (2020) reported a value of 0.113 ± 0.022 μSv/h. In comparison to other studies within Nigeria, the mean value of the BIR for this study is significantly lower.

Generally, the absorbed dose rate due to BIR was found to be low indicating little or no radiation hazards. In the Department of Food Science and Technology, the radiation hazard is very significant and should be a source of concern since the value is significantly higher than the world average. The value is higher than those reported in Greece, New Zealand, USA, UK, Poland, Norway (UNSCEAR, 2000).

Similarly, Ekong et al., (2019) reported a lower value of 9.312 nGy/h for Itu in south-south, Nigeria. Conversely, Basirjafari et al., (2014), reported a significantly higher value of 100.5 nGy/h for south-eastern Iran.

The mean AEDE indicates low radiological risk from the BIR, since it is just about 5.4% of the world average. With that in mind, it is observed that the highest value from Food science and technology department is about 91 % of the world average, which is a source of long-term concern. In comparison to other studies, much has been reported on AEDE that compare to the present study. Baraya et al., (2019) reported a higher value of 1.726 ± 0.35 mSv/y at Kano state polytechnic. Isiekwene & Ononugbo, (2018), reported 0.165± 0.01 mSv/y. similarly, Ranli et al., (2014), reported a value of 1.08 ± 0.15 mSv/y. A value of 0.67 mSv/y has been reported for Adamawa state university (Ndatuwon & Agadi, 2020). Ugbede & Benson, (2018) also reported 0.672 mSv/y. In Abuja, James etal., (2018), reported 0.556± 0.10 mSv/y. Ekong et al., (2019) reported a significantly high value of 21.85 mSv/h for Itu. These values of the sampled studies are observed to be higher than the values of this study.

The ELCR in three Departments (Crop Science, Financial Management Technology and Centre for Energy and Power Systems Research) are higher than the world average value, implying significant risk of cancer due to BIR exposure. The highest value recorded in Food science and Technology Department is 1.024×10^{-3}. This mammoth value is of serious concern. In other studies, Isiekwene & Ononugba, (2018) reported 2.03×10^{-3}. Ugbede & Benson, (2018) reported 0.54×10^{-3} for Enugu. In Kallan district, Kerala, the ELCR reported is quite high at 20.56×10^{-3}

(Monica et al., 2016), while James & co. (2020), reported $1.945\times10^{-3} \pm 0.379\times10^{-3}$ which is higher than the value reported for this study.

Some other comparison is made of the results of the present study with those of other studies found in the literature.

Indoor gamma dose rates in the high background radiation area of Abeokuta, south western Nigeria shows that the absorbed close rate in the dwellings vary from 0.077 to 0.397µsv/hr with an overall mean of 0.201±0.074µsv/hr, the calculated annual effective doses in the study area range from 0.540 to 2.782msv with average of 1.406±0.521msv. While in the present study, the BIR on the average ranges from 0.0052±0.0035, AEDE ranges from 22.313±14.092, ELCR has the average of 0.061±0.012, and ADR is 4.549±2.0470. The BIR of the present study is significantly lower than the BIR of this study.

Measurement of Background Gamma Radiation Levels at Niger State College of Education Minna and Federal University of Technology Bosso Campus (FUTB) was reported to be; the dose rate range obtained are: at the Niger State College of Education Minna (NCM), the dose rate varies from 0.125 μSvh^{-1} to 0.171μSvh^{-1}; at the Federal University of Technology Bosso Campus (FUTB) it was between 0.152 μSvh^{-1} and 0.184 μSvh^{-1}; and at the Federal University of Technology GidanKwano campus (FUTG) it was between 0.137μSvh^{-1} and 0.184μSvh^{-1}. In all the 34 points surveyed the mean dose rate was 0.154 μSvh^{-1} with a standard deviation of 0.017μSvh^{-1}. While in the present study, the BIR on the average ranges from 0.0052±0.0035, AEDE ranges from 22.313±14.092, ELCR has the average of 0.061±0.012, and ADR is 4.549±2.0470. The BIR of the present study is significantly lower than the BIR of this study.

Measurement of Indoor and Outdoor background ionizing radiation levels of Kwali General Hospital, Abuja, results show that the dose equivalent results obtained range from 0.100±0.001 µSv/h to 0.124±0.007 µSv/h with an average of 0.107±0.003 µSv/h for indoor measurement. While in the present study, the BIR on the average ranges from 0.0052±0.0035, AEDE ranges from 22.313±14.092, ELCR has the average of 0.061±0.012, and ADR is 4.549±2.0470. The BIR of the present study is significantly lower than the BIR of this study. It is possible that the hospital uses some radioactive equipment which led to the high values recorded.

Assessment of background ionizing radiation dose levels in quarry sites Located in Ebonyi State, Nigeria produce indicated dose rates ranging from 0.14 to 0.18 µSv/h with mean of 0.15±0.01 µSv/h at the excavation section (ES) and 0.16 to 0.19 µSv/h with mean value of 0.18±0.01 µSv/h at the while the values obtained at the quarrying section (QS) are respectively higher than those measured at the ES, they are all higher than the worldwide average value of 84 nSv/h signifying BIR elevated environments. The estimated mean annual effective dose (AED) and excess lifetime cancer risk (ELCR) are 0.27±0.03 mSv/y and 0.94×10^{-3} respectively at the ES and 0.31±0.02 mSv/y and 1.07×10^{-3} at the QS. The obtained AED values for all the sites are well above the outdoor worldwide average value of 0.07 mSv/y but lower than the International Commission on Radiological Protection recommended permissible limits of 1.0 mSv/y for the general public. Meanwhile, the BIR on the average ranges from 0.0052±0.0035, AEDE ranges from 22.313±14.092, ELCR has the average of 0.061±0.012, and ADR is 4.549±2.0470 in the present study. Measurement of background ionizing radiation in the Federal University of Technology Owerri, Nigeria using calibrated digital Geiger counter was reported which centered on outdoor radiation of buildings in FUTO. The results showed that the outdoor radiation dose values range from 0.07µSv/hr to 0.23µSv/hr while the mean from the outdoor radiation measurements is 0.144µSv/hr and the standard deviation, 0.034µSv/hr. No indoor measurements were taken as compared to this present study. In the present study, the BIR on the average ranges from 0.0052±0.0035 µSv/h, AEDE ranges from 22.313±14.092 mSv/y, ELCR has the average of 0.061±0.012 mSv/y, and ADR is 4.549±2.0470. The BIR of the present study is lower than the BIR of this study.

Table 4.3 presents the BIR measurements from other studies in the literature with the results compared to the present study. The result of this study is found to be significantly lower than the other studies.

In Table 4.4, the indoor absorbed dose rate of the present study is compared with other studies in the literature. The mean values of the present study are significantly lower than all the other studies.

Table 4.3 Indoor BIR from studies within Nigeria

Location	**BIR Measurement (µSv/h)**	**Reference**
Unity park, Uyo, Akwa Ibom state	0.11	Etuk, Essiet & Agba, 2017
Akwanga, Nasarawa state	0.176±0.02	Ramli, Aliyu & Saleh, 2014

Keffi Town, Nasarawa state	0.148±0.02	Ramli, Aliyu & Saleh, 2014
Itu, Nigeria	0.042±0.02	Ekong et al., 2019
Abeokuta, Nigeria	0.201±0.74	Ife & Iyobosa, 2018
Enugu	5.4±0.10	Ugbede & Benson, 2018
Niger state college of Education, Minna	0.171	Olarinoye et al., 2010
Federal University of Technology, Minna	0.184	Olarinoye et al., 2010
Offa, Kwara state	0.0132	Nwankwo & Akoshile, 2005
Abuja, Nigeria	0.113±0.022	James et al., 2020
Quarry sites in Ebonyi state	0.18±0.01	Echeweozo & Egbede, 2020
Federal University of Technology, Owerri	0.0052±0.0035	Present study

Table 4.4 Indoor Absorbed dose rates from studies inside and outside Nigeria.

Location	**Absorbed dose rate (nGy/h)**	**References**

Muzaffarabad, Turkey	81.61	Rafique, 2013
Poonch, Turkey	102.70	Rafique,Basharat,Azhar,2013
Greece	32	Clouvas,Xianthos, Antonopoulos-Domis, 2004
New Zealand	20	UNSCEAR, 2000
United states of America (USA)	38	UNSCEAR, 2000
United Kingdom (UK)	60	UNSCEAR, 2000
Poland	67	UNSCEAR, 2000
Norway	80	UNSCEAR, 2000
China	100	UNSCEAR, 2000
Portugal	102	UNSCEAR, 2000
Italy	105	UNSCEAR, 2000
Itu, Nigeria	9.312	Ekong et al., 2019
South Eastern Iran	100.5	Basirjafari et al., 2014
University of Port Harcourt	119.92	Isiekwene & Ononugbo, 2018
Federal University of Technology (F.U.T.O)	4.549	Present study

Chapter V: Conclusions and Recommendations

5.1 CONCLUSION

This study examines the level of background ionizing radiation (BIR) in various Departments within Federal University of Technology Owerri (F.U.T.O.). The measurements of the background ionizing radiation were taken using a Geiger-Muller counter in various offices within fifty Departments in FUTO. From the BIR measurements, the Hazard indices, absorbed dose rate, annual effective dose equivalent (AEDE) and excess life cancer risk (ELCR) were calculated.

The results of the study showed that for all the Departments, the Department of Food science and Technology is associated with the highest radiological risk because it has the highest levels of background radiation (0.0873±0.0432 µSv/h), and hazard indices. The Department of Mathematics has the least (0.0006±0.0001 µSv/h.) calculated radiological risk.

The results indicate that the level of BIR in all the Departments were lower than the world standard. The hazard index was also lower than the world standard in most of the Departments except for a few departments where the estimated hazard indices were higher than the world recommended standard. This could be a source for concern. In general, it can be concluded that the BIR in FUTO is relatively safe.

5.2 RECOMMENDATIONS

From the results of this study, the following recommendations are made:

1. Further studies should be carried out to determine the sources of the high levels of BIR within some parts of the school.
2. It is also important that some offices where the levels of BIR are higher than the world standard should be relocated especially those located near telecommunication masts.

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