Radiation Risk Assessment in Mining Site Area of Paago Iseyin Local Government Oyo State Southwest Nigeria

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Certification

This is to certify that Ezekiel Oyedokun Oyegbemi with matriculation number LCU/PG/002051 carried out this research work titled "Radiation Risk Assessment in Mining Site Area of Paago Iseyin Local Government Oyo State Southwest Nigeria in the Department of Physics, Faculty of Natural and Applied Sciences, Lead City University, Ibadan, Oyo State, Nigeria for the Award of Master science degree (MSc) in Physics and the work has not been presented and submitted elsewhere for the award of a degree, or any other purpose.

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Dedication

This research study is dedicated to the Almighty God who in His infinite mercy has been the Alpha and Omega throughout the world, my lovely father may his soul rest in perfect peace and my sweet mother Mrs. Oyegbemi Comfort for her love and care. You shall live long to eat the fruits of your wobble in Jesus might name (amen).

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Abstract

The hazards of being overexposed to ionizing radiation at various mining sites are of great concern to environmental scientists. This study aims to measure the activity concentrations of potassium ^{40}K, Uranium^{238}U, and Thorium ^{232}Th radionuclides at various mining sites of Paago, Iseyin Local Government, Oyo state, Southwestern Nigeria using a well calibrated HPGe detector. Twenty (20) soil samples were obtained, analyzed, and compared with the WHO recommended standard. The results obtained indicate that ^{40}K, ^{238}U, and ^{232}Th values ranging from 58.40 to 950.41 Bqkg-1, 5.57 to 24.22 $Bqkg^{-1}$, and 4.1 to 25.93 $Bqkg^{-1}$. The gamma absorbed dose rate in the soil samples ranged from 6.85 $nGyh^{-1}$ to 45.73$nGyh^{-1}$, with mean absorbed dose rate lower than the WHO recommended average value of 59 nGh^{-1}. The annual effective dose rates in the air varied from 14.26 to 19.74μ $Svyr^{-1}$ with an average value of 17.99 μSvy^{-1}, while the highest and lowest values of radium equivalent in the soil were 113.68Bqkg-1 and 21.62$Bqkg^{-1}$. It was concluded that all the values obtained for external and internal hazard indices were less than unity and the means activity concentration of the three radionuclides was lower than the world average recommended value indicating that the study areas pose no significant radiological threat to the populaces. These values also indicate that crops planted around the study area maybe safe for consumption.

Keywords: Radionuclides, effective dose rate, gamma absorbed dose rate, mining sites, Paago

Word Count: 220

Table of Contents

List of Tables

List of Figures

Chapter One

Introduction

1.1 Background to the Study

Radioactivity occurs when unstable nuclei spontaneously disintegrate and emit nuclear particles and energy to attain stability. The nuclear particles emitted in the process of radioactivity include heavily charged α-particles (${}_2{}^4He$) and the light β-particles (${}_1{}^0e$) or (${}_1{}^0e$) together with neutral and lighter particles called neutrinos[1]. The natural sources of radioactivity are either terrestrial (primordial radionuclides) or extra-terrestrial (cosmic rays). About 85% of the natural background radiation exposure to the environment comes from primordial sources that is known to constitute[2]. All the radionuclides found in nature are classified into three primordial-formed before the creation of the earth; cosmogonic formed as a result of cosmic ray interactions; artificial radionuclides–formed due to human activities[3]. The natural gamma radiation, especially from the series ^{232}Th and ^{238}U radionuclides and their decay products; and the non-serial ^{40}K radionuclide represent the main external source of radiation exposure to the environment. The radioactivity levels are related to the activity concentrations of the decay series of ^{238}U and ^{232}Th and non-series ^{40}K radionuclides in the parent rocks from which the soils originate[3]. The soil retains radioisotopes (radionuclides) in varying amounts and acts as the major source of continuous exposure of man to either internal or external ionizing radiation[4]

The knowledge of radionuclide distribution and radiation levels in the environment is important for assessing the effects of radiation exposure due to both terrestrial and cosmogonic sources.

Artificial man-made radioactivity is emitted by nuclear power plants, industrial plants, and research facilities. The emissions due to artificial radioactivity are very small in normal operations; however, a large quantity of radioactivity can be released into the environment through accidents and the dumping of radioactive waste in a particular environment. Soil may be contaminated through mine tailings, application of fertilizers, and disposal of metal wastes, gasoline, and paints, wastewater irrigation, pesticides, spillage of petrochemicals[5]. Human has always been exposed to radiation from naturally occurring radionuclides. These naturally occurring radionuclides comprise primordial radionuclides such as uranium ^{238}U, thorium ^{232}Th, potassium (^{40}K), and nuclides of ^{14}C, ^{87}Rb. The substances in which these naturally occurring radionuclides show up are described by the acronym Naturally Occurring Radioactive Materials (NORM) and these are known to have a wide occurrence. These radionuclides are not uniformly distributed thus; the knowledge of their distribution in soil plays an important role in radiation protection. Soil not only acts as a source of continuous radiation exposure to humans but also as a medium of migration for the transfer of radionuclides to biological systems. Radiation can cause sterility, making reproduction impossible and also stunting growth, and cancerous. It can also cause mutations in developing embryos, which are usually detrimental or even fatal[6].

Nigeria is well endowed with vast land including arable vegetation for agriculture and mineral resources. Excessive exposure to radiation can lead to long term health hazards like cancer, mental disorder, and genetic mutation, in workers and the general public. Reported that continuous industrial and human activities contribute significantly to elevated radioactivity on surface and subsurface soils when compared to those contributed by geogenic or natural processes. This can likely lead to health hazards for the mechanics,

automobile owners, and others; especially when the pollution is ignored or not given attention.

The need for accurate information on the levels of radiation within the mining sites and lacks of data on the radiation level of the study area lays credence to this research work. Therefore, it is necessary to monitor the radiation exposure, and determine the health effects as well as the potential impacts on the environment[7].

1.2 Statement of the Problem

The activity concentration of the radioactive elements which include ^{238}U, ^{232}Th, and ^{40}K depends on the soil type, mineral content, geological features, and geological condition of an area. However, human activity such as mining may augment the distributions and levels of radioactivity in the soils of any mining area and thereby posing more radiological health hazard to an individual who uses the soil. This projects aims to estimate radiation doses and hazards that may emanate from using the soil around the study area.

1.3 Aim and Objectives of the Study

The aim of this research is to assess radiation risk of the activity concentrations of the natural radionuclide in the soils from Paago mining sites; in Iseyin Local Government Oyo State, Southwest Nigeria. The objectives are to:

(i) measure activity concentrations of some natural radionuclide's (^{40}K, ^{232}Th and ^{238}U) in the soil samples from the mining site

(ii) calculate gamma exposure dose levels to the environment of the study area

(iii) Compare the result with the world standard recommendation and make relevant recommendations.

1.5 Significance of the Study

This research is so significant in its application to the environmental problems such as the detection of radioactive pollution in soils, groundwater, rock, mining area, and air. Hazards to humans or to the environment posed by mining and milling waste arise not only from its radioactive radioactivity but also from the presence of toxic chemicals and other materials in the waste. Achieving a consistent regulatory approach to protect against these different hazards is a challenge for national regulators[8].

Radioactivity and radiation levels in various environmental samples have been of great concern in many countries. The knowledge of natural radioactivity present on farmland will guild in the assessment of possible risks associated with external exposure to radiation through inhalation. Exposure to natural radioactivity is a function of the natural radioactive elements present in that area[3].

In addition, radioactivity of an area can be used to estimate the dose rates and the risk associated with over- exposure to the natural radionuclides that are used to calculate the abundance of thorium, uranium, and potassium on the surface and these natural elements contribute greatly to the dose received by humans.

Radionuclides can be transferred to food chain through soil, rocks and water bodies since they contain appreciable quantities of radioactive element. These studies will help to determine the absorbed dose and Annual effective does and its impacts on human bodies[9].

In addition, this study will help us to test for the correlation between activity concentrations and major oxides present in the soil samples.

1.6 Scope of the Study

The scope of the present study includes assessment of radiation risk of ^{238}U ^{232}Th and ^{40}K and chemical composition of soil samples collected from mining site area, estimating radiological hazard indices, and establishing the correlation between the activity and elemental concentrations in soil samples. Results obtained from these studies are to be discussed and compared with the world average value in correlation with previous studies of (ICPR) international commission on radiological protection and the United Nations Scientific

Committee on Effect of Atomic Radiation (UNSCEAR) [8,9].

1.7 Geological Setting of Nigeria

Nigeria geological basement complex is located between lat. 4°N - 15°N and Longitude.3°E - 14°E, within the Pan African mobile belt in-between the West African and Congo craton. Nigeria basement complex is grouped into three broad lithological which are the Precambrian Basement Complex composed mainly of migmatite gneiss, Older Granites and schist belt[12]. The north-central Nigeria which is made up of the Triassic-Jurassic and orogenic Younger Granite province and some rocks comprising the geology of Nigeria are the sedimentary basins of Nigeria comprise of the Chad basin of the northeast, the Niger-delta in the south, the Benue trough linking the Chad basin to the Niger-Delta and the Niger basin forming an aborted link from the Sokoto basin to the Niger-Delta [13].

Nigeria is located in the Tropics with tropical temperature range between 21°C - 44° C, temperature variation in Nigeria varies according to the two major seasons which are the rainy season from April to October and dry season from November to March. Southwestern Nigeria basement complex lies between latitudes 7°N and 10°N and longitudes 3°E and 6°E.

Southwestern Nigeria is on the crystalline basement rocks with the amphibolite, migmatite gneisses, granites and pegmatites. Other important rock units are the schists, which composed of biotite schist, quartzite schist, talk-tremolite schist, and the muscovite schist [14]. There are seven States in the southwestern part of Nigeria which are Lagos, Osun, Oyo, Ogun, Ondo and Ekiti. In terms of Lithology, Osun and Oyo belong to crystalline basement complex, Ondo and Ekiti belong to topmost-cretaceous region, which comprises of shale and sandstone, Ogun State belongs to basement complex (undifferentiated) region, while Lagos State belongs to geological area of post-cretaceous [15].

1.8 The Study Area

Pago mining site in Iseyin Local Government in Oyo State covering or lies between latitude 7°57'0''N to 80''N and longitude: 3°30'0''E to 3°40'0'' E. It is a settlement that is situated at the Iseyin central, south-western Nigeria. The average elevation of the study area is about 266m. the climate of the study area is distinguished by averagely high temperature. Moderate to heavy rainfall is experienced in the study area between March and July annually, an average annual rainfall of 1.247mm. the Relative Humidity (RH) is at its peak at the early hours of the day, which decrease towards the post meridiem. The minimal and maximal RH is experienced between December-February and July September annually. The continental air mass blows dry air (with little or no moisture) across the region during the dry season. In turn, the tropical air mass takes charge in the rainy seasons.

In Nigeria, four hydrogeological provinces have been reported in literature, these include; Volcanic-, Precambrian basement-s consolidated and unconsolidated sedimentary rocks. The study area Oyo state is located on latitude: 7°9'39"N, longitude: 3°20'54"E. Ibadan like other southwestern states enjoys a tropical climate with two seasons which are wet and dry

seasons with an approximate 130 day of dry[6]. The mean annual rainfall and temperature are about 1270 mm and 28°C respectively while the estimated mean annual potential evaporation is 1100 mm [3]. The city is underlain by crystal-line pre-Cambrian basement complex of igneous and metamorphic origin noted for their rather poor ground-water bearing properties and high contents of natural radioactive elements. Map showing paago mining site, in Iseyin local government in Oyo State[15].

SITE DISCRECPTION

From Ibadan oyo state capiter take bush gointo Iseyin Town drop at Oja oba market in Iseyin, then teke motor cycle going to NYSC camp drop at the camp and take another motor cycle goin to paago village. The mining site is 10 km away from NYSC camp.

1.9 Expected Contribution to Knowledge

This research work would make the under listed contributions to knowledge

i) The finding will enhance our knowledge on mining exposure, distributions, and levels of radioactivity in the soils of any mining area and thereby posing more radiological health hazard to an individual who uses the soil. ii) it will serve as a reliable guide to future radiation risk in the study areas.

iii) It will assist world health organisation (WHO) to manage radiation as well as environmental monitoring.

1.10 Operational Definition of Terms

i) **Activity**: activity is the number of nuclear transformations occurring in a given quantity of a radioactive substance per unit of time.

ii) **Radioactivity:** radioactivity is the spontaneous disintegration of the radioactive element by which alpha, beta parties, and gamma rays are emitted with a large

amount of energy released iii) **Radionuclide:** a radionuclide is a radioactive element that undergoes nuclear decay iv) **Half-life**: half-life of a radionuclide is defined as the time required by a given

radionuclide to reduce to half of its original value

v) **Secular Equilibrium:** secular equilibrium occurs in a radioactive decay chain when the half-life of the daughter radionuclide is much shorter than the half-life of the parent radionuclide such that the decay rate of the parent nuclide is approximately equal to the production rate of the daughter nuclide vi) **Absorbed Dose:** Absorbed dose is the amount of energy per unit mass absorbed by

irradiated objects vii) **Exposure:** exposure is the amount of ionizing radiation that may strike an object

(human) when in the vicinity of the radiation source ix) **UNSCEAR:** United Nations Scientific Committee on Effect of Atomic Radiation

x) **Assessment**: is the process of gathering and discussing information from multiple and diverse sources to develop a deep understanding of any topic.

xi) **Risk:** is the chance that a hazard will cause harm xii) **Radiation:** is an energy that comes from a source and travel through a space at the

speed of a light. This energy has an electric field and a magnetic field associated with it, and has wave like properties.

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Chapter Two

Literature Review

2.1 Natural Radioactivity

Natural radioactivity is a source of continuous exposure to human beings. It is present in the human environment due to the presence of cosmogonic and primordial radionuclides in the earth's crust. It is present in the air, water, skin, and vegetation. Cosmogonic radionuclides are produced by the interaction of these cosmic rays with atomic nuclei present in the atmosphere, while the primordial ones i.e. the terrestrial background radiations are formed by the process of Nucleosynthesis. The study of naturally occurring radiation and environmental radioactivity has led to a great interest in extensive surveys in Nigeria and many countries. Natural sources still contribute majorly to almost 80% of the radiation exposure collected from the world's population[1].

This natural radioactivity varies from one place to another due to the variation of some natural minerals and local geology. The presence of these natural occurring radionuclides in the environment may result in an external and internal dose, received by a certain population exposed to them directly and via the ingestion and inhalation[7]. Thus, it is important to give the baseline date on radiation levels in the assessment of the radiological impact on a population as a result of the radiation emitted by these radionuclides which will be used by policymakers for appropriate use. Various sources of radiation and radioactivity in the environment exist. Such as Gamma radiation emitted from naturally occurring radionuclides which are also called terrestrial background radiation. It represents the main external source of irradiation of the human body once it is present within that environment. These radionuclides are being absorbed by plants and animals and so make their way into the food

chain[2,7,9].Human beings are exposed to radiation from various sources outside their bodies such as cosmic rays and gamma ray emitters which are found in soils, water, food, air, and building materials. Studying the levels of radionuclide distribution in the environment it will provide essential radiological information and create awareness among those within the environment. The level of

radioactivity in the soil varies widely and it is very important to monitor the naturally occurring radionuclides in soil[3].

Radionuclide (radioactive nuclide, radioisotope, or radioactive isotope) is a nuclide that has excess nuclear energy, making it unstable. This excess energy can be used in one of three ways: emitted from the nucleus as gamma radiation; transferred to one of its electrons to release it as a conversion electron: or used to create and emit a new particle (alpha particle or beta particle) from the nucleus. During those processes, the radionuclide is said to undergo radioactive decay. These emissions are considered ionizing radiation because they are powerful enough to liberate an electron from another atom. The radioactive decay can produce a stable nuclide or will sometimes produce a new unstable radionuclide which may undergo further decay[8]. Radioactive decay is a random process at the level of single atoms: it is impossible to predict when one particular atom will decay. However, for a collection of atoms of a single nuclide the decay rate, and thus the half-life ($T_{1/2}$) for that collection, can be calculated from their measured decay constants. The range of the half-lives of radioactive atoms has no known limits and spans a time range of over 55 orders of

magnitude[4]Radionuclides occur naturally, or are artificially produced in nuclear reactors, cyclotrons, particle accelerators or radionuclide generators. There are about 730 radionuclides with half-lives longer than 60 minutes; thirty-two of those are primordial radionuclides that were created before the earth was formed. At least another 60

radionuclides are detectable, either as daughters of primordial radionuclides or as radionuclides produced through natural production on Earth by cosmic radiation. Most of those are only produced artificially and have very short half-lives. For comparison, there are about 252 stable nuclides. In theory, only 146 of them are stable, and the other 106 are believed to decay via alpha decay, beta decay, double beta decay, electron capture, or double electron capture[5].

All chemical elements can exist as radionuclides. Even the lightest element, hydrogen, has a well-known radionuclide, tritium. Elements heavier than lead, and the elements technetium and promethium, exist only as radionuclides. (In theory, elements heavier than dysprosium exist only as radionuclides, but some such elements, like gold and platinum, are observationally stable and their half-lives have not been determined).

Unplanned exposure to radionuclides generally harms living organisms including humans, although low levels of exposure occur naturally without harm. The degree of the harm will depend on the nature and extent of the radiation produced, the amount and nature of exposure (close contact, inhalation, or ingestion), and the biochemical properties of the element; with increased risk of cancer the most usual consequence. However, radionuclides with suitable properties are used in nuclear medicine for both diagnosis and treatments. An imaging tracer made with radionuclides is called a radioactive tracer. A pharmaceutical drug made with radionuclides is called a radiopharmaceutical[6].

2.1.2 Effects of Exposure to Ionizing Radiation

The emergent radioactivity and ionizing radiation have led to increasing concerns about its impact on human biological systems. When ionizing radiation passes through a living system, it ionizes the atoms and molecular structures and thereby causing biological damage

to the living system. The biological damage resulting from exposure to ionizing radiation is observed in three stages molecular, cellular, and organic. Before any radiation injury manifests in the living system, it begins with the damage at the molecular level which results in to change in the structures of the molecular cell.

A cell has a specialized function described by the structure of its constituents and its exposure to ionizing radiation disturbs the chemical balance and functions cell [7]. Ionizing radiation interacts with cells directly and indirectly. Direct interaction of ionizing radiation causes much more severe damage by removing electrons in important molecules (DNA), disrupting their

structures and functions. Indirect interaction involves ionization of water (H_2O) to form H_2O^+ ion which further reacts with water to form hydrium ion (H_3O^+) and hydroxyl radical (OH^-) as shown in equations 2.1 and 2.2

$$H_2O \qquad H_2O \quad e \tag{2.1}$$

$$H_2O \quad H_2O \quad H_3O \quad OH \tag{2.2}$$

The hydroxyl (OH^-) radical has an unpaired electron that is highly reactive with all biological molecules (DNA, proteins, enzymes) causing damage and disrupting the physiological processes of the molecules. Radiation-induced damage at cellular level is associated with measurable somatic and genetic damage in the body of the organism; however, the amount of somatic and genetic damage depends on the level and/or type of ionizing radiation exposure, the ability of the radiation to interact with human tissue, and the size and specific parts of the body exposed[8].

An individual suffers somatic radiation damage when significant amounts of tissue are affected, it is classified as either early (acute) or late somatic effect[9]. When a substantial dose of ionizing results in damage in the irradiated organism within minutes, hours, days, or weeks, it is termed early somatic effect (acute radiation syndrome), the effects include nausea, fatigue, erythema, epilation (loss of hair), a blood disorder, fever, depression in sperm count, an intestinal disorder. On the other hand, late somatic effects appear months or years after exposure to ionizing radiation. These effects may result from exposure to natural background radiation over several years however; late somatic effects of ionizing radiation are associated with a threshold dose below which the effect does not normally occur. This is termed the deterministic effect (non-stochastic effect). The severity of the biological damage in deterministic effect increases as the dose increases. Stochastic effects (probabilistic effects) are non-threshold biological damages in which the chance of occurrence is proportional to the dose of ionizing radiation; examples include cancers and genetic alterations[10].

Human activities such as quarrying and mining are the means of enhancement of the natural background radiation expose to the general public and the environment. The exposure can be external from the atmosphere and the earth's crust to the human body, internal from the radionuclides inside the human body through ingestion and/or inhalation. Man-made source of radiation has significantly contributed to the presence of radionuclides and exposure to our environment due to technological and research advancement[10]. The production of nuclear fission products after the discovery of radioactivity, for both war and peaceful applications as used in modern day medicine, industry and research has contributed to the radiation exposure of humans and the environment[11].

Man-made sources of radiation come mostly from radiation generating devices such as x-ray machines for medical diagnosis and therapy; nuclear accelerators for the study of nuclear transmissions; nuclear reactors for energy production and nuclear weapon for warfare. However, significant contamination and exposure may arise when the man-made sources are not properly managed during application. For instance, the nuclear power accident at the Chornobyl-4 nuclear power installation in 1986 involved the release of a huge amount of various radionuclides into the atmosphere[4]. The common man-made radionuclides include Tritium (^{3}H) strontium-90 (^{90}Sr), iodine-131 (^{131}I), caesium-137 (^{137}Cs) and americium-241 (^{241}Am) (; ^{10}Uranium-238 and Thorium-232 are the most common radioactive elements decay which slowly produces other radioactive elements.[12]As contaminants the water and in the air, radionuclides are colorless, odorless, and tasteless, and typically cannot be detected by human senses, unlike many other contaminants that may exhibit undesirable color, odor, or taste. Natural radioactivity and its effect on human health have recently become a major concern to the environment. The World Health Organization (WHO) and its Member States have always advocated that all people deserve the right to have an adequate supply of a clean environment. Although the Nigerian Government has set agencies to look into it and put in place various policies to address it lack of political wheel has been the major obstacle hindering its implementation[13].

2.1.3 Health Effects of Non-ionizing Radiation

A biological effect occurs when a change can be measured in a biological system after the introduction of some type of stimuli. However, the observation of a biological effect, in and of itself, does not necessarily suggest the existence of a biological hazard, or health effect. A

biological effect only becomes a safety hazard when it "causes detectable impairment of the health of the individual or of his or her offspring". Biological effects could be physiological, biochemical, or behavioral changes induced in an organism, tissue or cell[14].

Non-ionizing radiation usually interacts with tissue through the generation of heat. The hazards depend on the ability to penetrate the human body and the absorption characteristics of different tissues. There are still many uncertainties about the severity of the effects of both acute and chronic exposure to various types of non-ionizing radiation. Generally, the public is concerned about the risks from ELF, RF, and MW. However, the greatest risk to the public probably arises from natural UV radiation[15].

Damage from optical radiations is largely confined to the eye, skin, and falls into two categories –thermal damage and photochemical damage. Despite having insufficient energy to ionize atoms, single photons of ultraviolet radiation can damage tissue through disruption of bonds within DNA molecules and give a long-term risk of cancer. This must be borne in mind when determining allowable exposures. Visible light and IR only produce damage through high-intensity multi-photon interactions The biological effects induced are essentially the same for both, but lasers (coherent light) are capable of producing higher irradiances and can heat localized volumes of tissue to a high enough temperature to produce rapid physical changes[16].

2.1.4 Radiation

Radiation is the emission or transmission of energy in the form of waves or particles through space and is part of our everyday environment. This includes electromagnetic radiation such as radio waves, microwaves, infrared, x-rays, ultra-violet light, visible light, and gamma

radiation. The word radiation is coined from the phenomenon of wave radiation (traveling outward in all directions) from a source.

People are exposed to radiation from cosmic rays (radiation from outer space), as well as to radioactive materials found in the floors, soils, water, walls of our homes, schools or offices, food, air, and also inside the body. Human-made radiation sources are widely used in medicine, industrial application, and research. There are two types of radiation; ionizing and non–ionizing radiation[17].

2.1.5 Ionizing Radiation

Ionizing radiation is a type of energy released by atoms that travel in the form of electromagnetic waves (gamma or x-rays) or particles (neutrons, beta, or alpha). Ionizing radiation can remove electrons from the atoms, i.e. they can ionize atoms. In terms of natural radiation sources, there are more than 60 different naturally occurring radioactive materials present in the environment, with radon gas being the highest contributor to human exposure. Ionizing radiation carries more than 10eV, which is enough to ionize atoms and molecules and break chemical bonds[18].

The probability of ionizing radiation causing cancer is dependent upon the absorbed dose of the radiation and is a function of the damaging tendency of the type of radiation (equivalent dose) and the sensitivity of the irradiated organism or tissue (effective dose).

Most ionizing radiation originates from radioactive materials and cosmic rays, and as such is naturally present in the environment, since most rocks and soils have a small concentration of radioactive materials. Because radiation is invisible and not directly detectable by human

senses, instruments such as Geiger Muller Counters are usually required to detect its presence. In some cases, it may lead to secondary emission of visible light upon its interaction with matter.

Ionizing radiation has many practical uses in medicine, research construction, but presents a health hazard if proper measures against undesired exposure are not followed. Exposure to high ionizing radiation causes damage to living tissues, burns on the skin, cell damage, radiation sickness, cancer death[19].

2.1.6 Health Effects of Radiation

Radionuclides can be hazardous to living tissue when they are inside an organism where radiation released can be immediately absorbed. They may also be hazardous when they are outside of the organism but close enough for some radiation to be absorbed by the tissue. Radionuclides move through the environment and into the body through many different pathways: air, water (both groundwater and surface water), and the food chain. Knowing these pathways make it possible to take necessary control measure to reduce their intake by aquatic animals, terrestrial animals, and human beings to minimal levels[20].

The environment is filled with radionuclides which can be dangerous if they are present at elevated concentrations. These radionuclides can be divided into two groups based on their sources, naturally occurring radionuclides such as ^{238}U, ^{232}Th, and ^{40}K and artificial radionuclides such as ^{137}Cs. The naturally occurring radionuclides are present in the rock, and soil are easily transported into the environment through plants and water. The radiological impact from the above nuclides is due to radiation exposure of the body by the

gamma rays and irradiation of the lung tissues from inhalation of radon and its progeny. From the natural risk point of view, it is necessary to know the dose limits of public exposures and to measure the natural environmental radiation level provided by ground, air, water, foods, building interiors, etc., for the estimation of the exposures to natural radiation sources. In assessing the radiation exposure, it is pertinent to determine the distribution of the radionuclide[21].

The terrestrial component of the background is often due to various radioactive nuclides that are present in the air, soil, water, and building materials whose abundances vary significantly depending on the geological and geographical features of a region. Nonetheless, the level of background radiation in a region is also considerably affected by man-made sources including those from nuclear activities and accidents. The environment and health are interrelated. Health risks related to natural radioactivity are of great concern and require assessment to estimate the risks[22].

Monitoring for radioactive materials are therefore of primary importance for humans, organisms, and environmental protection, but rapid and accurate methods for the assay of radioactivity are essential. When outdoor, human beings are exposed to natural terrestrial radiation that originates predominantly from the upper 30 cm of the soil Humans are also exposed to contamination of the food chain which occurs as a result of direct deposition of radionuclides on plant leaves, root uptake from contaminated soil, sediment, or watered from direct ingestion of contaminated water[23].

In recent times cancer is assuming greater importance in the health agenda throughout the world, in developing as well as in developed countries. In Nigeria, it has assumed

prominence as a major cause of mortality in the last few decades. A rough estimate of incidence for malignant neoplasm in Ibadan was 33.7 and 45.1 per 100,000 for males and females, respectively in the 1960s and presently about 100,000 new cases of cancer are reported every year. Given the current population projections, it is expected that by the year 2010 about 500,000 cases will occur annually. The common malignant tumors in Nigeria are those of; (i) breast, (ii) cervix, (iii) liver, (iv) skin, (v) lymphoid tissue except Burkitt's lymphoma, (vi) prostate, (vii) connective and soft tissues, (viii) Burkitt's lymphoma and (ix) stomach. The effects of low-level radiation (~10-3 mGy) on human carcinogenesis have been investigated on a large scale in recent years[24].

Radiation produces both useful and harmful effects depending on the amount of dosage received. The harmful effects of radiation (ionizing) are either stochastic or non-stochastic. When ionizing radiations interact with body cells chemical reactions occur. Exposure risks to natural radiation can be assessed with a linear, no threshold dose response relationship, since there is no dose below which there is absolutely no risk associated, and experimental data on this are unavailable. Stochastic (delayed) effects of radiation occur years later in a exposed individuals, it includes cancer induced cases and genetic effects while non-stochastic are immediate or non-delayed effects. These effects are proportion to exposure and dosage and may result in large number of deaths as was experienced in Chernobyl disaster where 2 out of 30 operators died immediately and several others later[24] In limiting stochastic affects various tissues are considered in radiation measurements; with accordance to recommendations by the international commission on radiation protection[25]. Skin and bone surfaces have a weighting factor of 0.01 while gonads have a factor of 0.20 because

gonads are very sensitive to radiation resulting in genetic mutation, thus there is a need for great care to reduce exposure to these organs.

Radiation is reported to increase the incidence of cancer in high doses. The U.S. EPA claims radon is the second leading cause of lung cancer, with smoking the lead, which accounts for 85% to 90% of this disease. Epidemiological investigations on people living in high radiation areas have shown that cancer incidence in these areas is not statistically different from nearby populations who have much lower radiation doses and similar socioeconomic conditions. Background and medical radiation exposure limits have not been set but the LNT model cannot give the limits. The public should therefore be kept to low dose exposure as possible since high exposure cause undesired biological effects on human beings[26].

The acceptance by society of the risks associated with radiation is conditional on the benefits to be gained from the use of radiation. Nonetheless, the risks must be restricted and protected against by the application of radiation safety standards. It is therefore essential that activities involving radiation exposure is subjected to certain standards of safety in order to protect the individuals, who are exposed to radiation, be it occupationally, for medical diagnostic or therapeutic purposes, or as members of the public.

It has been established that chronic exposure to even low dose rate of nuclear radiation from an irradiated building has the potential to induce cytogenetic damage in human beings. One of the radionuclides around man's environment that contributes high amount of potential lethal dose is radon; which causes the majority of deaths resulting from lung cancer of particular concern for indoor background ionizing radiation is the incidence of the invisible, odourless radioactive gas ^{222}Rn which is a member of the Uranium radioactive series. The estimate shows that of the 2.4 mSv/yr annual exposure from all ionizing sources, 40% is contributed by internal exposure to radon alone. A strong correlation between radon

exposure (inhalation) and the prevalence of lung cancer has also been reported[27]. Statement implies that the risk of death from exposure to radon at work and at home could be greater than the one observed from traveling by car and the estimated risk of lung cancer from radon exposure could be greater than the observed risk of lung cancer from all the remaining causes. In Malaysia, cancer (stomach, breast, lung, liver, leukemia, and thyroid) is one of the major health problems, it has been certified medically that cancer is the fourth leading cause of death. Most adverse health effects of exposure to ionizing radiation may be grouped into general categories;

(i) Deterministic effects (harmful tissue reactions) due in large part to killing or malfunction of cells following high doses from radiation burns.

(ii) Stochastic effects (cancer and heritable) effects involve either cancer development in exposed individuals owing to mutation of somatic cells or heritable disease in the offspring owing to mutation of reproductive cells.

Cancer and heritable mutations are called stochastic (probabilistic) effects. Cancer or mutation behaves the same whether the organ received a high absorbed dose or a low one, all that changes are the odds (probability) of a cancer forming or a mutation occurring. Cancer risks are also known to vary with age at exposure and attained age, with risks being higher for those exposed as children.

The damaging effects of ionizing radiation come from the package of high energy that is released from radioactive sources. Although different types of ionizing radiation have several patterns of energy release and penetrating power, there's no general property that comes from natural radioactive materials. While the sources differ, the types of radiation are

the same which means we can directly compare doses from artificial sources of ionizing radiation to those from natural sources[28].

2.2 Theoretical Review

2.2.1 Sources of Ionizing Radiation

Natural sources of radiation usually release ionizing radiation at low levels, which also means the amount of radiation absorbed by our bodies (doses) is usually small. Ionizing radiation is produced from natural or artificial radioactive materials such as uranium, thorium, and potassium-40 that exists in the materials that make up the planet earth. This leads to exposure to alpha, beta, and gamma radiation including radioactive radon gas. Natural radioactive is presents in the air we breathe, foods we eat, water we drink, and even in our bodies. For example, a very small fraction of the potassium in our bodies is radioactive. We are also exposed to natural ionizing radiation that comes from outer space and passes through the atmosphere of the planet. Besides natural radioactivity, the radiation background has been increased artificially due to the evolution of civilization. The artificial sources of radiation that have currently the highest impacts on the environment and population are as follows; Medicine sources of ionization radiation, nuclear explosions, Consumer products, nuclear power plants and their fuel cycle, and Chemical usage. We all face risks in everyday life. It is impossible to eliminate them all, but it is possible to reduce them. The use of coal, oil, and nuclear energy for the maintenance of some home appliances is associated with some sort of risk to human health, however small. In general, society accepts the associated risks in order to derive the relevant benefits[29].

2.2.2 Non-ionizing Radiation

Non-ionizing radiation is radiation in the part of the electromagnetic spectrum where there is insufficient energy per quantum (photon energy) to ionize atoms or molecules that is to completely remove an electron from an atom or molecules, instead of producing charged ions when passing through matters, non-ionizing radiation has sufficient energy only to excitation, the movement of an electron to a higher energy state. It includes electric and magnetic fields, radio waves, microwaves, and optical radiation, which consist of infrared, visible, and ultraviolet radiation. Its kinetic energy is small to produce charged ions when passing through matter. The associated particles (photons) have only sufficient energy to change the rotational, vibrational, or electronic valence configurations of molecules and atoms[30]. The effect of nonionizing forms of radiation on living tissue has only recently been studied.

Non-ionizing radiation encompasses both natural (such as sunlight or lightning discharges etc.) and human-made (seen in wireless communication, industries, mechanic sites, a scientific and medical application) sources of electromagnetic fields. Electric power supplies and appliances are the most common sources of low frequency electric and magnetic fields in our living environment. Non-ionizing radiation is capable of causing thermal-ionization if it deposits enough heat to raise temperatures to ionization energies. These reactions occur at far higher energy than with ionization radiation, which requires only single particles to cause ionization. A familiar example of thermal ionization is the flame-ionization of a common fire, and the browning reactions in common food items induced by infrared radiation, during broiling-type cooking. The non-ionizing portion of electromagnetic radiation consists of electromagnetic waves that are not energetic enough to detach an electron from atoms or

molecules and hence cause their ionization. These include radio waves, infrared, microwaves, and (sometimes) visible light. The occurrence of ionization depends on the energy of the individual particles or waves, and not on their number. An intense flood of particles or waves will not cause ionization if these particles or waves do not carry enough energy to be ionized unless they raise the temperature of a body to a point high enough to ionize small fractions of atoms or molecules by the process of thermal-ionization. Due to the fact that radiation cannot be seen with the eyes, an instrument called the detectors is used to check/detects its presence. A particle (radiation) detector is a device used to detect, track, and identify ionizing particles, such as those produced by nuclear decay, cosmic radiation, or reaction produced in a particle accelerator. Detectors can measure the particle energy and other attributes such as momentum, spin, the charge, particle type, in addition to merely registering the presence of the particles. Non-ionizing radiation can produce non-mutagenic effects such as inciting the thermal energy in biological tissue that can lead to burns[31].

2.2.3 Radiation Dose

The biological effects of ionizing radiation vary with the type and energy. A measure of the risk of biological harm is the dose of radiation that the tissues receive. The unit of absorbed radiation dose is the Sievert (Sv). Since one Sievert is a large quantity, radiation doses normally encountered are expressed in milli-sievert (mSv) or micro-sievert (μSv) which is one thousand or one millionth of a Sievert. For example, one chest x-rays will give about

0.2mSv of radiation dose.

On average, our radiation exposure due to all natural sources amounts to about 2.4 mSv a year-though this figure can vary, depending on the geographical location by several hundred percent. In homes and buildings, there are radioactive elements in the air. These radioactive elements are radium-226, uranium-235 and thorium-232 present in many sorts of rocks and other materials present in the soils. By far the largest source of natural radiation exposures comes from varying amounts of uranium and thorium in the soil around the world[32].

The radiation exposure due to cosmic rays is very dependent on altitude and slightly on latitude; people who travel by air, thereby are high radiation exposure to radiation. Human beings are surrounded by naturally occurring radioactive elements in the soil and stones especially those working on contaminated soil and are bathed with cosmic rays entering the earth's atmosphere from outer space[33].

2.2.4 Beneficial Effects of Ionizing Radiation

Radionuclides are used in two major ways: either for their radiation alone (irradiation, nuclear batteries) or for the combination of chemical properties and their radiation (tracers, biopharmaceuticals).

a. In biology, radionuclides of carbon can serve as radioactive tracers because they are Chemically very similar to the nonradioactive nuclides, so most chemical, biological, and ecological processes treat them in a nearly identical way. One can then examine the result with a radiation detector, such as a Geiger counter, to determine where the provided atoms were incorporated. For example, one might culture plants in an environment in which the carbon dioxide contained radioactive carbon; then the parts of the plant that incorporate atmospheric carbon would be radioactive.

Radionuclides can be used to monitor processes such as DNA replication or amino acid transport.

b. In nuclear medicine, radioisotopes are used for diagnosis, treatment, and research. Radioactive chemical tracers emitting gamma rays or positrons can provide diagnostic information about internal anatomy and the functioning of specific organs, including the human brain. This is used in some forms of tomography: single-photon emission computed tomography and positron emission tomography (PET) scanning and Cherenkov luminescence imaging. Radioisotopes are also a method of treatment in hemopoietic forms of tumors; the success of the treatment of solid tumors has been limited. More powerful gamma sources sterilize syringes and other medical equipment.

c. In food preservation, radiation is used to stop the sprouting of root crops after harvesting, to kill parasites and pests, and to control the ripening of stored fruit and vegetables.

d. In industry, and mining, radionuclides are used to examine welds,s detect leaks, study the rate of wear, erosions corrosion of metals, and for on-stream analysis of a wide range of minerals and fuels.

e. In spacecraft, radionuclides are used to provide power and heat, notably through radioisotope thermoelectric generators (RTGs) and radioisotope heater units (RHUs).

f. In astronomy and cosmology, radionuclides play a role in understanding the stellar and planetary processes

g. In particle physics, radionuclides help discover new physics (physics beyond the Standard Model) by measuring the energy and momentum of their beta decay products.

h. In ecology, radionuclides are used to trace and analyze pollutants, study the movement of surface water, and measure water runoffs from rain and snow, as well as the flow rates of streams and rivers.

i. In geology, archaeology, and paleontology, natural radionuclides are used to measure the ages of rocks, minerals, and fossil materials[34].

2.2.5 Soil Contamination

The transforming of crude oil into petrochemicals, including gasoline and lubricating oil for use by automobiles, has led to worldwide contamination of air, water and soils is dangerous for human and ecosystem health. Soil plays a vital role in maintaining the balance of the earth's ecosystem, but contamination by petroleum products is a current problem in several countries in the world[35]. The deleterious effects of these petroleum products on the soil are due to toxic components that are radioactive. The petroleum products are composed of saturated hydrocarbon, aromatic hydrocarbon, and non-hydrocarbon compounds, and traces of nitrogen, phosphorus, and organic matter, which are easily absorbed into the soil surface[35]. However, as engine oil is used in automobiles, it picks up several of additional compounds from engine wear. These include iron, copper, sulfur, dirt, and ash because of the additives and contaminants, spent motor oil disposal can be more environmentally damaging than unused oil[35]. These additives and contaminants may cause both short and long term effects if they are allowed to enter the environment through water ways or soil. Once the engine oil is drained off an engine, it is no longer clean because it has picked up materials, dirt particles, and other chemicals during engine operation, thus such lubricating oil is now classified as spent oil. The increase in the number of vehicles in Nigeria has necessitated a higher production and use of spent oil and has subsequently given rise to the generation of large

quantities of spent oil at the time of servicing the vehicles. This spent oil is considered ordinary waste the by majority of the workers of the automobile mechanic workshops in Nigeria, which dispose of the oil by a spillage on the topsoil. Our environment is composed of several layers of the atmosphere that are continually active, hence, pollutant gases emitted from point sources like automobile exhaust, forest fires, and power plants would eventually get to other regions of the soil by dispersion or rainfall. The spills from lubricants, gasoline, diesel, and by products of used and spent oil constitute the major pollutants in automobile mechanic villages. The increasing number of automobiles and associated wastes, with subsequent increase in emission levels and waste handing is a serious environmental concern in Nigeria is compounded by the frequency of oil spillage[35].

In addition, damaged motor spare parts and components dumped in the mechanic sites are highly radioactive due to the spent oils used in servicing and repairing, all this activity revealed that environmental pollution occurs due to spillage and improper disposal of these products either in low or large quantity. When this spillage occurs, the radioactive concentration of the soil and the environment will tend to increase[35]. Radionuclides that find their way into the environment may cause harmful effects such s as radioactive contamination. They can also cause damage if they are excessively used during treatment or in other ways exposed to living beings, by radiation poisoning[36]. Potential health damage from exposure to radionuclides depends on a some of factors, and "can damage the functions of healthy tissue/organs. Radiation exposure can produce effects ranging from skin redness and hair loss, to radiation burns and acute radiation syndrome. Prolonged exposure can lead to cells being damaged and in turn lead to cancer. Signs of cancerous cells might not show up until years, or even decades, after exposure[37].

Radionuclides are produced as an unavoidable result of nuclear fission and thermonuclear explosions. The process of nuclear fission creates a wide range of fission products, most of which are radionuclides. Further radionuclides can be created from irradiation of the nuclear fuel (creating a range of actinides) and of the surrounding structures, yielding activation products. Theses complex mixtures of radionuclides with different chemical and radioactivity makes handling nuclear waste and dealing with nuclear fallout particularly problematic[38].

2.3 Previous Work

Paulnah carried out a radiological assessment of grains, vegetables, fruits, and tuber crops cultivated in Okemesi township, Ekiti state, Nigeria. The radioactivity levels in the different types of food crops were compared with similar studies within and outside Nigeria. The radioactivity levels in the fruit crops were comparable with values obtained in fruits from Iraq but exceeded values reported from high background radiation areas in India. Values obtained for tuber crops were lower than values reported from oil and gas producing areas in the Niger delta but higher than the report from Ghana. Radioactivity levels in the grain crops exceeded values reported from Ile-Ife except for 232Th but were however lower than values obtained in Jos from tin mining town. Values obtained for the vegetable crops were comparable with values from vegetables cultivated in the vicinity of iron and steel smelting company at Ile-Ife, but exceeded values from Lagos and Iraq except for ^{40}K. An atom whose nucleus is unstable is referred to as a radionuclide[39]. The excess energy possessed by this nucleus is transmitted to newly created radiation particles, resulting in the release of gamma, alpha or beta particles or radiation [40]. Energetic particle or wave which navigates vacuum or medium that contains matter, which is not necessary for its movement is known as radiation. Effects of radiation on man is dependent on the absorbed or ingested

dose among other factors. These effects could be somatic or genetic, stochastic or deterministic (Hall, 2000)[40]. Researches regarding the analysis of natural radioactivity in foodstuff have been propelled to the forefront in recent years, and it has become an important aspect of the environmental monitoring program. Food is one of the major pathways through which radionuclide is transferred to man. It is therefore necessary to estimate the radiation doses obtained from the ingestion of contaminated food. Cultivation of crops meant for consumption on contaminated soils result in the transfer of radio activity from soil to the roots of such crops, which is consequently shifted to human diet. The two major pathways by which natural radionuclide enter into man are ingestion and inhalation. This ingested radionuclide could be concentrated in certain parts of the body thereby causing damage. With the aforementioned facts in mind, this study aimed to extensively investigate the concentration40 K, of238U and 232Th in some food samples and provide adequate information about the Annual Effective Dose due to the consumption of food grown in the study area[41].

Fasanmi scooped samples of soil from twelve sites within the Okemesi town in EkitiWest local government area in Ekiti State, South-western Nigeria with a population of about 79,563 residents. It is situated on latitude 7.82N and longitude 4.92E and sits 541 meters above sea level. The town lies between two ridges rich in quartzite running approximately north-south with lands rich in agriculture. The town forms a conglomerate of undulating valley and low lands. Since hills and rocks are natural reservoirs of radionuclide and rich in

Uranium, Okemesi a town with a hilly terrain becomes an interesting site for this research. The schematic map of the study area is displayed. In general, areas where activities that contribute to the elevation of natural radioactivity in the environment are prevalent, reported

higher value than this study. Natural radioactivity levels of ^{40}K , ^{238}U and ^{232}Th, Annual Effective Dose (AED) and Excess Life Time Cancer Risks (ECLR) due to consumption of food cultivated in Okemesi township, Ekiti State Nigeria has been measured and determined in this study. Specific activity of the radionuclides in the samples was within the limit[8]. However 33% of the values obtained for the AED exceeded the specified limits while all the estimated values obtained for the ELCR were higher than the limit 0.2 x 10^{-3}. It can be concluded from the study that consumption of food grown in the study area over a long period of time can induce harmful effects on humans. This should not be alarming because averagely, individuals relate or interfere with other communities or regions during their life time. However, regular monitoring of radioactivity levels in food in the area is recommended[42]

Ibrahim used using Sodium Iodide-Thallium Gamma Spectroscopy to determine 226Ra, 232Th and 40K natural activity concentrations in some mining areas in central Nasarawa State, Nigeria. 21 soil samples were collected from the accessible areas of 7 major sites identified as the most mined areas of the zone. The mean activity concentrations were 32.52±4.65, 56.23±2.30 and 403.96±7.29 Bq/kg for ^{226}Ra, ^{232}Th and ^{40}K respectively. The value obtained for ^{226}Ra was a bit lower compared to world average while values for ^{232}Th and ^{40}K were higher than the world average value. The average background radiation absorbed doses at two spots were 5.81±0.08 and 8.45±0.56 mSv/y. These were higher compared to worldwide average of 1.00 mSv/y stipulated by UNSCEAR (2000).

Ajayi assessed the activity concentrations of some natural radionuclide's (^{40}K, ^{232}Th and ^{238}U) in tuber crops and soil samples collected from eight (8) different towns of Ekiti State have been measured. The activity concentrations of ^{40}K, ^{232}Th and ^{238}U in tuber crops (cassava, cocoyam and yam) and their soils from the spot of where they were planted in

strategic areas of Ekiti State have been measured using Gamma Ray Spectrometer Hyper Pure Germanium Detector. The mean activity concentrations of ^{40}K, ^{232}Th and ^{238}U for the tubers were found to be 31.970 ± 4.308, 2.409 ± 0.389 and 1.381 ± 0.241 in $Bqkg^{-1}$ (dry weight). The mean activity concentrations of natural radionuclide's and standard deviation of ^{40}K, ^{232}Th and ^{238}U in the soils where they were planted are 225.887 ± 9.932, 14.894 ± 1.98, 7.670 ± 1.174 and 108.601 ± 34.980, 6.590 ± 1.998, 4.096 ± 1.200, in $Bqkg^{-1}$ respectively. The soil-to-tuber transfer factor (TF) of ^{40}K, ^{232}Th, and ^{238}U for cassava, cocoyam and yam, were measured and ^{238}U (TF) values from soil-to- cocoyam were found to be higher than those of yam and cassava. The transfer factors (TF) for ^{40}K from soil to yam were found to be higher than those of cassava and cocoyam. The mean absorbed dose rate, annual effective dose, annual gonadal dose equivalent for the soils from the locations were estimated to be 24.202 $nGyh^{-1}$, 0.0297 mSv y^{-1} and 0.172 mSv y^{-1} respectively. Results of external and internal radiation hazard indices were obtained and found to be less than unity. The excess lifetime cancer risk was calculated to be 9.0 using the risk factors of International Commission on Radiological Protection (ICRP) and Biological Effects of Ionizing Radiation. All measured natural radioactivity, doses, hazard indices, transfer factor and excess lifetime cancer risk were all found to be within the recommended limits. This work provides a good baseline data of natural radioactive element for tubers and soils of Ekiti State and its radiological impacts. It implies that consumers of tuber crops in Ekiti State are not at health risk[43].

Orosun assessed the concentrations of U-238, Th-232, K-40, and gamma dose rate (DR) was carried out over a laterite mining field in Ilorin-south, Nigeria. Materials and Methods: A well-calibrated Super-Spec (RS-125) gamma spectrometer was used to measure the activity concentrations of ^{232}Th , ^{40}K, ^{238}U and gamma doses rate at 1 m above the ground level

over the laterite mining field. Fifty (50) measurements of the activity concentration of the radionuclide were obtained at about 1.0 m above the topsoil. For each point, measurements were taken four (4) times for better accuracy. Results: The overall mean of the activity concentrations of ^{40} K, ^{238} U, and ^{232}Th are 81.38, 43.89, and 38.79 Bqkg-1 respectively. The mean value for DR was found to be 46.44 nGy/hr. The mean activity concentrations of U-238 and Th-232 are higher than the recommended limits provided by UNSCEAR. This is a cause for worry as significant enhancement in the concentration of U-238 and Th-232 will increase the level of the background radiation and possibly render the soil unfit for use in building and construction. The results of most of the radiological impact parameters (RIP) are above the limits provided by UNSCEAR. From the results, it implies that the risk of indoor gamma radiation exposure is high for this lateritic soil. So the lateritic soil from this minefield may not be too suitable for building and construction purposes[44].

Eshiemomoh determined concentration of natural radioactive A well calibrated Super-Spec (RS-125) gamma spec was used to measure the activity concentrations of 40K, 238U, 232Th and gamma doses rate over a granite mining field in Asa, Kwara State, North-central Nigeria. The results of the activity concentrations were used to estimate the corresponding radiation hazard parameters to assess the suitability of the granite for building and construction purpose[45].

Natural radionuclides are broadly dispersed in the Earth crust. They are found in significant concentrations in many mineral rocks. Granites, just like other mineral rocks, may possibly hold deposits of natural radionuclide's like ^{238}U, ^{232}Th, their progenies and the non-series ^{40}K [26]. The activity concentrations of these radio nuclides may differ even within a particular block of granite. If present, these radio nuclides will decay to give off radon and some amounts of gamma and beta radiations. Human exposure to ionizing radiation resulting from

these radio nuclides and their progenies can cause cancer and other radiation health effects, damaging critical organs of the body which could even lead to death. For granites used for building and construction of houses, these dangerous radiations will be released over the lifetime of using such buildings. So the knowledge of the concentrations of these radio nuclides in building materials is fundamental for estimating the level of public exposure to radiations, since most residents spend approximately 80% of their time indoors. In order to reduce these radiation risks, the United State Environmental Protection Agency recommended that all houses should be tested for these radio nuclides, whether they contains granite countertops or not [27]. Such an action is not economically feasible for a third world country like Nigeria. So, researchers resolve to monitoring and assessments of the mine fields where the building materials (mineral rocks or soils) are mined originally and their finished products[45].

The levels of ^{238}U, ^{232}Th, their respective progenies and the non-series ^{40}K have been studied in different building materials (both raw and finished products) from different parts of the country, but none has been carried out in Kwara State despite the increasing level of granite mining and usage in this part of the country. Also, data from University of Ilorin Teaching Hospital (UITH) shows that 74 different cancers of 2246 (891 male and 1355 female) cancer patients within the age of 1–105 were recorded at the University of Ilorin Teaching Hospital (UITH) cancer registry between the period of 2007 and 2016. Therefore, a pioneer study which is based on internationally verified methodology regarding assessment of radiological health implications on the general populace due to granite mining in this part of the country is apposite[46].

A well calibrated Super-Spec (RS-125) gamma spec was used to measure the activity concentrations of ^{40}K, ^{238}U, ^{232}Th and gamma doses rate over a granite mining field in Asa, Kwara State, North-central Nigeria. The results of the activity concentrations were used to estimate the corresponding radiation hazard parameters to assess the suitability of the granite for building and construction purpose. The results of the activity concentrations showed that the mine field is loaded with thorium and potassium which as a result enhances the outdoor gamma radiation dose rate. The estimated mean values of D_{in}, EAD indoor and AGED are above the recommended limits which follows that the danger of indoor gamma radiation exposure is high and the residents may not be safe from indoor ionizing radiation overexposure if the granite is used for building. Other hazard parameters are close to the recommended limits. The study therefore concludes that Nigerian Environmental Protection Agency (NEPA) and other regulatory bodies should implement specific statutory requirements and laws to regulate the high rate of mining activities in the State and the country at large. And in accordance with international recommendations quoted in the Basic Safety Series No.115 from the IAEA, the use of building materials containing enhanced concentrations of NORM should be controlled and restricted under the application of the radon safety standards[47].

Assessment of radiological hazards in the phosphate mining area of Kpogamé, Togo. This study focused on the measurement of natural radionuclide Ra-226, Th-232, and K-40 concentrations in Kpogamé phosphate mining in south-eastern part of Togo, and the estimation of associated hazard indices such as radium equivalent activities, absorbed dose rate, gamma radiation representative level index for individuals living in around the study area, external and internal hazards, annual effective dose rate, and the excess lifetime cancer

risk. Results obtained were compared with that in literature and internationally recommended levels. High activity concentrations found for Ra-226 and Th-232 were attributed to some highly rocky nature locations. The values of radium equivalent activity obtained in the present study were higher when compared to the values reported for some other countries, the high values of the external and internal hazard indices observed were related to the high level of activity concentrations of natural radio nuclides in Kpogamé area due to its environmental geology. The absorbed dose and annual outdoor effective dose equivalent estimations were higher than the recommended worldwide but lower than the maximum limit recommended by NCRP. The excess lifetime cancer risk estimated values was also higher than the world average value. It was also noticed that higher values were obtained from parts of the old extraction's locations having high rocky geology. Numerous cancer deaths annually reported in the world have been linked to the high excess lifetime cancer risk factor which is the product of the environmental radioactivity. Therefore, it is recommended to restore the mining sites soil after extraction of the ore and put these areas under control to avoid public access and avoid also any kind of activities like agriculture and grazing animals that can expose populations by ingestion. This will help to optimize the probability to have a cancer in this mining area of Kpogamé[48]. Finally, a comprehensive assessment of environmental issues associated with the phosphate ore related activities in Kpogamé phosphate mining region, including the quantification of impacts were highlighted, and recommendations for responding to future environmental contamination from phosphate ore operations were made. This paper focused on the measurement of natural radionuclides Ra-226, Th-232, and K-40 concentrations in Kpogamé phosphate mining in south-eastern part of Togo, and the estimation of associated hazard indices such as radium equivalent activities, absorbed dose rate, gamma radiation representative level index for individuals

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Ionizing radiation exposure levels and associated health risk in some selected solid mineral mining sites Edo-North, Nigeria Ionizing radiation exposure rate and its associated health

risks were assessed using Digilert 200 and Rados Radiation Monitoring Meter, integrated with Geographical Positioning System (Garmin GPSMAP 76S) of some selected solid mineral mining sites across Edo-North Nigeria. The mean exposure rates show some characteristic range of 0.010±0.005 $mRhr^{-1}$ to 0.027 $mRhr^{-1}$ across the entire study. The obtained mean exposures rates at all the mining pits were higher than the ICRP standard limit of 0.013 $mRhr^{-1}$, except at freedom limestone mining pit where we recorded 0.010 mRh^{-1}. It was also observed that limestone mining sites exhibited low exposure rate while granite mining sites exhibited high exposure rate[48]. The computed equivalent dose rate ranges from 1.049 $mSvy^{1}$ to 2.287 $mSvy^{-1}$, which is well above the recommended permissible limit of 1.0 $mSvy^{-1}$ for the general public. 91.7% of the mining sites recorded higher absorbed dose rate but the mean AEDE recorded across the entire study area are below the ICRP standard. The average excess

lifetime cancer risk shows variation from 0.472 x 10^{-3} to 1.27 x 10^{-3}. By this result, the probability of contacting cancer due to radiation exposure is higher in places like Cinoma pit, Cetraco pit, Niger-Cat pit, Jigom pit, Quarries pit and Petra-Quarries pit. The natural radioactivity levels of ^{238}U, ^{232}Th and ^{40}K have been measured in 56 soil samples from the gold mine tailings and 10 soil samples from the control area using gamma spectrometry using broad energy germanium detector (BE6530). The average activity concentrations in $Bq{\cdot}kg^{-1}$ for ^{238}U from the mine tailings were comparably higher than the worldwide average. However, those of ^{232}Th and ^{40}K were comparable to the worldwide average and other countries. The average values for Ream from the mine tailings were also calculated and observed to be higher than 370 $Bq{\cdot}kg^{-1}$, which is a recommended safe limit to avoid exposure to radiation hazards from the area. The outdoor average dose rate in air from terrestrial gamma rays was also found to be higher than the worldwide average of 59

nGy·h^{-1}. Calculated average *AEDE* values from the mine tailings for members of the public were also above the world average. The radiological hazard indices calculated in the present work were higher than unity, presenting a potential radiological hazard to the population in the area. The average values for the external hazard (H_{ex}) and internal hazard (H_{in}) from the mine tailings were found to be 2.4 and 4.5 respectively. The results obtained in this study have established baseline information on natural radioactivity, which can be used as a reference point for future work in the area. The natural radioactivity levels of ^{238}U, ^{232}Th and ^{40}K have been measured in 56 soil samples from the gold mine tailings and 10 soil samples from the control area using gamma spectrometry using broad energy germanium detector (BE6530). The average activity concentrations in Bq·kg^{-1} for ^{238}U from the mine tailings were comparably higher than the worldwide average. However, those of ^{232}Th and ^{40}K were comparable to the worldwide average and other countries[49]. The average values for Raeq from the mine tailings were also calculated and observed to be higher than 370 Bq·kg^{-1}, which is a recommended safe limit to avoid exposure to radiation hazards from the area. The outdoor average dose rate in air from terrestrial gamma rays was also found to be higher than the worldwide average of 59 nGy·h^{-1} .

Calculated average *AEDE* values from the mine tailings for members of the public were also above the world average. The radiological hazard indices calculated in the present work were higher than unity, presenting a potential radiological hazard to the population in the area. The average values for the external hazard (H_{ex}) and internal hazard (H_{in}) from the mine tailings were found to be 2.4 and 4.5 respectively. The results obtained in this study have established baseline information on natural radioactivity, which can be used as a reference point for future work in the area[49]. The natural radioactivity levels of ^{238}U, ^{232}Th and ^{40}K have been measured in 56 soil samples from the gold mine tailings and 10 soil

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The environment around us always contains small amounts of Natural Occurring Radioactive Materials (NORMs), which have existed since the formation of the earth. Their availability in the environment is generally at levels that are not potentially harmful to human health. A major concern comes when the levels are elevated as a result of human practices like mining or natural hazards like earth quakes.

In nature, mining involves the production of large quantities of waste, which may contaminate soils over a large area, thereby negatively impacting the environment and human health.

Mining is one of the major causes of elevation of NORMs concentrations on the earth's surface causing health risks to humans, especially when inhaled or ingested. The most important NORMs in radiation protection are radionuclides from the Uranium-238 (^{238}U) and Thorium-232 (^{232}Th) decay series. Potassium-40 (^{40}K), a non-series radionuclide, also contributes significantly to human exposure in the environment. Therefore, the knowledge of ^{238}U, ^{232}Th and ^{40}K activity concentrations is important in the evaluation of absorbed doses that can lead to the estimation of their radiological hazard to the population[50].

The series NORMs produced from these mining activities continue to decay until a stable nuclide is formed. In this decay process, ionizing radiation that produces biological damage to human organs is emitted. For instance, epidemiological studies have shown high mortality

rates from respiratory diseases and lung cancer in miners working underground in the Erz mountains of Eastern Europe. More human evidence of the harmful nature of ionizing radiation was also reported by early radiologists and persons working in the radium industry. Both empirical observations and epidemiological studies have consistently shown carcinogenic properties of ionizing radiation. Survivors of the Hiroshima atomic bomb exposed to radiation above one Sievert showed a significant increase in the incidence of leukemia. In South Africa, the gold mining industry has existed for over a century. As a result, mine tailings are littered everywhere, particularly in the Wonder contain spruit Catchment Area (WCA), posing a threat to local communities. The communities living around these areas are threatened by radioactive pollution mainly caused by uranium. In 2009, the Gauteng Department of Agriculture and Rural Development reported that the gold-bearing ore in the WCA contained almost ten times the amount of uranium than the gold itself. Although, this was reported on a wide area, there is limited scientific information in the study area about the radiological hazards of NORMs to the population. As a result, a radiological hazard assessment was carried out in order to evaluate the health risk to the population in the mining area[51].

The natural radioactivity levels of ^{238}U, ^{232}Th and ^{40}K have been measured in 56 soil samples from the gold mine tailings and 10 soil samples from the control area using gamma spectrometry using broad energy germanium detector (BE6530). The average activity concentrations in $Bq \cdot kg^{-1}$ for ^{238}U from the mine tailings were comparably higher than the worldwide average. However, those of ^{232}Th and ^{40}K were comparable to the worldwide average and other countries. The average values for Raeq from the mine tailings were also calculated and observed to be higher than 370 $Bq \cdot kg^{-1}$, which is a recommended safe limit to avoid exposure to radiation hazards from the area. The outdoor average dose rate in air

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Determination of natural radioactivity levels and radiological hazards in environmental samples from artisanal mining sites of Anka, North-West Nigeria Naturally occurring radio nuclides emanate from diverse sources; these include primordial radio nuclides, terrestrial and cosmic radio nuclides . Naturally occurring radioactive materials can be modified or enhanced by human activity. Hence, such activities have contributed to the exposure of man and the environment. Furthermore, radiation exists everywhere on the earth crust and exposure from natural background radiation is the largest component of total radiation exposure received by most people. The measurement of gamma radiation dose from environmental sources is of significance because radiation of natural origin is the principal contributing factor to the non-internal dose globally. The activity concentrations of radio nuclides in the environment vary according to the geological formation; radio nuclides in rocks are easily mobilized into the environment through natural and human processes in Nigeria, there exist about forty to fifty various types of untapped sub-terrain resources in the Earth; however, informal or artisanal mining of these minerals have been carried out in certain communities without recourse to environmental remediation, leading to the accumulation of naturally occurring radioactive waste in the environmental. Anka in North

West Nigeria is noted for crude mineral mining and processing by Artisans along with farming and cattle rearing. Anka has been the focus of artisanal gold mining for several years because of its rich mineral resources[53]. The mining and processing of gold and other mineral are regarded as a lucrative means of raising revenue in some parts of the North West region. These mineral deposits exist in alluvial and eluvia areas and in the major vein from different segments of the schist belt, which is characteristic of the geology of the study area Artisanal mining and processing in Anka communities are considered a major source of exposure to ionizing radiation; people, animals and the environment are exposed to this radiation emanating from natural radio nuclides present in rocks soils, sediments, water and even plants. The study area has been subject of environmental contamination; cases of deaths among children of ages 0–5 years have been reported by [52]. Soils and materials contaminated with the products from sluicing and waste materials from mining and ore processing are also considered sources of exposure. The materials used in the construction of buildings in the area are mostly sourced locally; which are made up of straw-roofed and mud-brick buildings and they lack openings hindering good ventilation, Hence, environmental hazard associated with Naturally Occurring Radioactive Materials (NORMs) associated with the artisanal mining and ore processing is of great health concern. Similarly, the use of contaminated equipment and indiscriminate disposal of waste materials on farmlands and water bodies contribute to radiation exposure. The purpose of this work is to evaluate the radiological hazards from the concentrations of ^{226}Ra, ^{232}Th and ^{40}K measured in rock, soil, and sediment samples from artisanal mining area of Anka. The excess lifetime cancer risk was also computed in this study[53].

Heavy metals, radio nuclides activity and mineralogy of soil samples from an artisanal gold mining site in Ile-Ife, Nigeria: implications on human and environmental health The Ife-

Ilesha schist belt of the Nigerian Basement Complex is renowned for artisanal gold mining activities owing to the occurrence of gold-bearing eluvial deposits within and around the belt. However, gold mining operations in Ile-Ijesha axis are carried out haphazardly without consideration of probable health risks that might be posed to the miners and local community by heavy metals and naturally occurring radio nuclides materials (NORMs) contents in the soil. This study was therefore conducted to determine the mineralogy, heavy metals contents and radionuclide activity of soil samples collected from a gold mining site in Ile-Ife with a view to assessing the consequential health and radiological risks. Thirty-five (35) soil samples were collected from abandoned and active excavating pits over the entire area using stainless-steel spade[55]. The heavy metals and radio nuclides concentrations and mineralogical compositions of the samples were obtained by Atomic Absorption Spectroscopic (AAS), gamma ray spectrometry and X-ray diffraction (XRD) methods, respectively. The contamination indices consisting of Enrichment Factor (EF) and Index of geo-accumulation (I_{geo}) were calculated from heavy metals concentrations. The sequence of the average concentrations of heavy metals in the soil samples decreases as follows: Pb $(72.93 \pm 4.60) >$ Cd $(58.26 \pm 3.25) >$ Cr $(42.81 \pm 3.00) >$ Zn $(33.66 \pm 2.71) >$ Mn $(24.60 \pm 1.80) >$ Ni (23.93 ± 2.51). The mean EF values of the measured heavy metals occurred in the order of Cr > Pb > Zn > Cd > Ni. The I_{geo} values of the measured heavy metals (except Pb) were less than one (< 1) revealing practically uncontaminated condition of the studied soil[54]. The radiation dose and radiological hazard risks were estimated by employing absorbed dose, effective dose, radium equivalent, gamma index, external hazard index, excess life cancer risk and representative level. The hazard index values of all the measured heavy metals were < 1 indicating no significant non-carcinogenic effects. The average activity concentrations of ^{40}K, ^{238}U and ^{232}Th are 259.23 ± 84.20 Bqkg^{-1},

185.48 ± 73.31 Bqkg^{-1}, 11.93 ± 4.68 Bqkg^{-1}, respectively. All the radiological indices were below the world average values stipulated by the radiation monitoring bodies. The result of the XRD indicates the preponderance of quartz, and biotite, as well as subordinate amounts of plagioclase, kaolinite, ilmenite, andradite, actinolite and microcline in the soil samples, pointing to a schistose source rock, which is probably gold-bearing. The current study indicated practically low contamination of the Ile-Ife gold mining site soils by heavy metals, low radiological risk from NORMs and prospect of mineral exploration in the area if well established procedure is followed[55].

The radiological health implications to humans due to the use of kaolin from kaolin mines in Nigeria. A calibrated RS-125 spectrometer was used in-situ to monitor the activity concentrations of ^{40}K, ^{238}U, ^{232}Th and dose-rate of kaolin minefields in Ilorin-south and Ilorin-west, Nigeria. The in-situ monitoring and measurements were done in 90 locations selected at random in the study areas. The *in-situ* measurements were consolidated via laboratory analysis of 48 samples of Kaolin bricks using lead-shielded NaI(Tl) detector. The estimated average values for all radiological hazard parameters for the in-situ measurements of Ilorin-west are higher than that of Ilorin-south minefield. However, the opposite was the case with the laboratory analysis of the bricks[56]. This apparent conundrum was due to the higher values of ^{238}U observed in the samples of bricks from Ilorin-south. In addition, the measured activity concentration of the primordial radio nuclides in the Kaolin bricks from both mines are lower than the on-site measurements. This was attributed to the contribution from other terrestrial materials on-site. The 5th, 50th, and 95th percentiles of the cumulative probabilities for the excess lifetime cancer risk using the Monte Carlo simulation are

167.00×10^{-6}, 281.00×10^{-6}, 414.00×10^{-6} for Ilorin-west (in-situ), 104.00×10^{-6},

232.00×10^{-6}, 392.00×10^{-6} for Ilorin-south (in-situ), 706.00×10^{-6}, $1{,}250.00 \times 10^{-6}$, $1{,}900.00 \times 10^{-6}$ for Ilorin-west (lab), and 742.00×10^{-6}, $1{,}480.00 \times 10^{-6}$, $2{,}460.00 \times 10^{-6}$ for Ilorin-south (lab), respectively. Therefore, the cancer risks are within the acceptable limits for both mining sites. This study is useful in developing radiation risk assessment models for decision makers in different fields of environmental sciences[57].

Radiation Exposure Due to Natural Radionuclides in Gemstone Mining Area in Olode, Ibadan

South Western Nigeria Many materials found in the earth's crust contain small but measurable amounts of naturally occurring radioactive materials (NORM) which are sources of man's exposure to ionizing radiation. This contribution could be higher in areas where there has been enhancement due to industrial activities such as mining of ores which contain this at levels much higher than those present in the crust. Among the operations which may lead to significant increase in exposure to natural radiation sources are mining of ore, extraction of rare earth elements (REEs) etc. This has the potential to increase the radiation dose received by workers and the general public. Pegmatites, which are coarse grained igneous or metamorphic rocks and generally of granitic composition, are characterized by a wide range of accessory minerals containing REEs. They are a common feature throughout the Nigerian Basement Complex. Pegmatites may be simple or complex; the complex ones in particular often have associated with them economic elements such as Tin, Tantalite, Columbite etc.

The Sn-Nb-Ta bearing pegmatites, first described by Jacobson and further elaborated by Wright were known mainly from a broad ENE-WSW trending belt about 600km x 125km and are significantly mineralized The belt was an important tin producer for many years and Nigeria's tin fields were among the important ones globally. In recent times, there has been

a resurgence of interest in Nigeria's pegmatite occurrences because of their associated metal and gemstone mineralization.

Apart from the known Nigerian pegmatite belt, the metallogeny of the rare metal pegmatites has been further elaborated [4]. This has led to increased activities by artisanal miners and discovery of new rare metal pegmatite fields beyond the known belt. They are now more widely distributed than previously known and are found to be important sources of precious and semi-precious stones such as beryl, aquamarine, tourmaline etc[58]. These new Solid Minerals have played a significant role in the economic and social development of the country. The Gbayo mines around Olode which is the focus of this work belongs to one of these fields: The Ibadan–Oshogbo field of rare metal pegmatites. As a result of the presence of these NORMS in mineral products and wastes, workers particularly miners engaged in such operation face the risk of such exposure, the knowledge of which is important for assessing the dose received or making reliable estimates of doses to workers. The investigated mines are located at Olode, Ibadan South Western Nigeria. The pegmatites which serve as the main hosts for these minerals intrude older lithologic units (schists) of the Basement Complex[29,59].

The pegmatite mineralogy is simple and comprises quartz microcline and albite feldspar, muscovite and biotite. At Olode, the pegmatite is mined for beryl which is found embedded in the hard rock. Mining is by crude open cut, sometimes mechanically assisted, method. Hand drilling is usually employed followed by blasting. The blasted rock is hand-cobbed to recover the valuable minerals and the waste rock is discarded. Exploitation has been going on for some years and wherever the water table is reached, diesel pumps are employed to evacuate the water[60].

In the course of the exploitation, enormous quantities of mine wastes have been generated leaving behind heaps / mounds of mine residues and a highly devastated landscape. Except for the area around the Jos Tin-Columbite fields and mills in North Central Nigeria which has been investigated for NORM risks and associated radiological risks[30], there is little or no published NORM-related work on the implications of the exploitation of the rare metal pegmatites in the southwestern part of the country.

In this work, we report the results of investigation on the natural radioactivity due to NORM and the potential radiological implications/occupational radiation risks of the mining operations on the mine workers and the surrounding environment. Solid minerals have played a significant role in the economic and social development of the country. Nigeria has a long but discontinuous history of mining and the country is a prominent exporter of about 34 mineral commodities including tantalite and columbite among others. The country has Initiated deep and wide-ranging reforms to promote the development of the mining sector leading to more discoveries and massive widespread mining activities with attendant negative effects not only on the workers and general public, but also on the environment over the years.

Not only that, the area is within Ibadan metropolis, one of the largest and most populated cities in tropical Africa attracting more people in search of means of livelihood from mining. The study area is situated in Gbayo, west of Olode village in south eastern part of Ibadan[61].

A well calibrated high purity Germanium detector(HPGe) has been used to determine the activity contents as well as the derived absorbed dose and the dose equivalent rates in the rocks (gemstone-bearing pegmatites), slurry soils (Mine wastes) and water samples of the Gbayo mine site in Olode, Ibadan south western Nigeria. The radio nuclides identified with

regularity belong to the naturally occurring decay series headed by ^{238}U and ^{232}Th as well as the non-series ^{40}K. The results obtained were very low while comparing these with similar work from the Jos processing site which was several magnitudes greater. This is due to the presence of radioactive minerals such as Monazite and Xenotime present in the Younger Granites where metals such as Tin and Columbite are extracted. This study has also shown that the principal source of radioactivity in the area is actually the pegmatites and not the Biotite Gneiss. Although the results are well below the international threshold limits, prolonged exposure could lead to some severe health hazards not only to the workers, but also to the general public either directly or indirectly Also, physical disturbance and instability of the land surface will promote erosion activities and flooding of the area, thereby rendering land employed for agricultural activities unsuitable for such purpose. Hence, there is a need for land reclamation in the area. It is also vital that similar works be carried out on other mines within the Ibadan-Oshogbo rare metal pegmatite field and the country as a whole[61].

Environmental radioactivity and associated radiological hazarding surface soils in Ho Chi Minh City, Vietnam Many radioactive nuclides occurring naturally in soils, rocks and building materials produce external radiation, which causes exposures to human population. Primordial radio nuclides, i.e., 238U, 232Th and 40K with the half-lives equivalent to the age of the earth, in surface soils contribute significantly in terms of dose[31]. 238U decay series could also be referred to as 226Ra series due to its main contribution (98.5%) to the total gamma dose[32]. One of the key factors determining the exposure to an individual is the radioactivity concentrations in surface soils. Moreover, soil is the main source to distribute radio nuclides to other environments such as water, air, sediments, biological systems and food grains. Thus, evaluating the natural radioactivity level in surface soils and radiological

exposure are highly important for establishing a baseline data of background radiation, evaluating the effect to human health, and studying the characteristics of geological structure. In addition, for environmental protection purpose, assessment of natural radioactivity in surface soils is considerably essential to monitor the change of background activity. Natural radioactivity level has been extensively studied in many countries. In Vietnam, several studies have also been performed to assess natural radioactivity in soils. The radioactivity in soils and external exposure dose in the South of Vietnam were investigated in a previous work. Southern Vietnam consists of 19 provinces covering the area of 64,000 km^2. However, as reported in the previous work, the total number of soil samples in the whole region was 106.

This means that only few samples was collected in a province, e.g., 16 soil samples in Ho Chi

Minh city, which may not be enough to assess natural radioactivity level in the southern Vietnam. Another study assessed the activity concentrations in surface soils based on the measurements of 39 samples collected in the urban central of the city. Ho Chi Minh city, consisting of 24 districts, is the biggest city of the country, contributing significantly in the transportation and economic development in the southern region of Vietnam and Southeast Asian countries. Therefore, further comprehensive assessment of natural radioactivity in the city for the purpose of baseline data establishment and environmental protection is considerably beneficial[62].

Measurement of environmental radioactivity of primordial radioactive nuclides in surface soils in Ho Chi Minh city has been carried out using an HPGe detector for establishing database of activity concentrations and associated radiological hazards. 120 soil samples were collected evenly in 24 districts of the city. This is considered as a significant

contribution to existing research. The activity concentrations of 226Ra, 232Th and 40K vary in the ranges of

9.6–48.5, 14.8–59.6 and 10.9–637 Bq kg^{-1}, with the average values of 21.1±1.3, 36.6±1.3 and 279±29 Bq kg^{-1}, respectively. The average Raeq in the city is about 94.9±4.7Bq kg^{-1}. This value is approximate the world average value. The contributions of ^{226}Ra, ^{232}Th and ^{40}K to the Raeq are 22.2, 55.1 and 22.6%, respectively[62].

Radiological hazard indices have also been calculated. The results show that the radiological hazard indices are much lower than the safety limits. This implies no significant effect to human health. Acknowledgements This research was performed as part of the employment of the authors at Dalat Nuclear Research Institute and Duy Tan University. Compliance with ethical standards Conflict of interest. The authors declare that they have no conflict of interest regarding the publication of this paper[61]. Radiation Sources and effects of ionizing radiation.

Report of the United Nations Scientific Committee on the Effect of Atomic Radiation to General Assembly. Technical Report. United Nations, New York[62]. Sources and Effects of Ionizing Radiation, Annex B: Exposures of the Public and Workers from Various Sources of Radiation. Comparative study of natural radioactivity levels in soil samples from Natural Radiation in the Rocks, Soils, and Groundwater of Southern Florida with a Discussion on Potential Health Impacts. Natural radiation is a normal part of the environment that emanates from two main sources: cosmic radiation, which originates in outer space and passes through the atmosphere, and the decay of radionuclides (radioactive isotopes or radioisotopes) in the soil and rock. Radionuclides undergo spontaneous disintegration into daughter nuclides with an associated emission of ionizing radiation in the form of alpha and

beta particles and gamma rays. Daughter nuclides may be either stable or may themselves be radionuclides which also undergo radioactive decay. Essentially all rocks exhibit a low-level of natural radioactivity that is due to the decay of radionuclides that are typically present in minute quantities (e.g., parts per million). The natural radiation levels of soil and rock depend upon their concentrations of radionuclides and the specific activity of the radionuclides, which is defined as the number of decays per unit time per unit amount of substance. Specific activity is an inverse function of the half-life of the radionuclide and may be calculated based on numbers of decays of either the radionuclide or may also include decays of daughter radionuclides[63].

The primary sources of natural radioactivity in rock and soil are radionuclides of the elements uranium, thorium, and potassium (referred to as radioelements), specifically the uranium-238, thorium-232, and potassium-40 decay chains. The emitted radiation is due to both the decay of the parent radionuclides and their daughter radionuclides. The natural radiation of soil and rock depends upon mineralogical composition. Rocks composed of minerals with relatively high concentrations of uranium, thorium, and potassium have relatively high natural radioactivity. Soils typically reflect the radioelement concentrations of their parent rock. Radionuclides within rock and sediment may contribute to the radioactivity of groundwater only if they are dissolved or leached out of the source rocks and/or sediment and remain in solution (i.e., are not subsequently removed by precipitation or sorption reactions). The quantity of radionuclides that are released into the groundwater depends upon their concentration in mineral crystals or absorbed on sediments, and very importantly, the rate of dissolution, leaching, and desorption[64].

Human exposure to ionizing radiation is of interest to the population in general. The U.S.

Environmental Protection Agency (USEPA) estimates that the average human receives about 620 millirem of exposure to ionizing radiation per year. The exposure profile occurs via three fundamental pathways, including natural influx from space (altitude dependent), local soils (radon and other radionuclides), and via health care procedures (e.g., CT scans, x-rays, therapeutic procedures). Average annual exposure to ionizing radiation of the United States population. Southern Florida contains naturally occurring radioactive substances in rocks, soils, groundwater, and indoor air at various concentrations.

In addition, radioisotopes associated with atmospheric testing of nuclear weapons have accumulated in the soils and sediments of southern Florida and sometimes are mobilized into groundwater While radioactively in the soils and sediments of a carbonate platform is normally quite low, southern Florida may be an exception which should be of interest to the international community because background testing should be done even in areas where radioactively is not expected to occur. Human exposure to the naturally occurring radionuclides in southern Florida is generally limited to wind-blown organic soils, breathing of indoor radon gas, and in certain cases, the drinking of well water enriched in radionuclides. Radionuclides generally are removed in public drinking water systems via the treatment process which can be aeration (radon only), coagulation/filtration, lime-softening, ion exchange, activated alumina, or membrane processes Removal efficiencies range from 80 to 99% depending on the process used and the characteristics of the radionuclide[65] . Exposure to radionuclides in drinking water most likely comes from domestic self-supply wells for which there are no regulatory requirements to test for water quality. The concentrations of radioactive materials found in the southern Florida environment are herein documented with an assessment of potential health risks[65].

Radioactivity levels and transfer factor for granite mining field in Asa, North-central Nigeria Natural radioactivity measurement and dose assessment are important aspects of radiation protection. The goal of this study is to validate the previous results obtained from the in-situ measurements in the study area in order to ascertain the level of radiation hazards to the populaces living around the mining site. A 3 × 3-inch lead-shielded NaI(Tl) detector was used to measure the activity concentrations of ^{40}K,^{238}U and^{232}Thin soil, water and guinea corn grain samples collected from a granite mining field in Asa, Kwara State, North-central Nigeria. The overall mean activity concentrations of ^{40}K,^{238}U and ^{232}Th are 441.06, 11.51 and 15.42 Bqkg^{-1}for the soil samples, 20.67, 0.66, and 0.88 BqL^{-1} for the water samples and 214.31, 5.25 and 8.86 Bqkg^{-},^{1}respectively for the grain samples. The bio-accumulation/transfer factors are 0.49, 0.46 and 0.58 for ^{40}K,^{238}U and ^{232}Th respectively. The mean values of all the radiological hazard parameters are within the permissible limit recommended by the United Nations Scientific Committee on the Effects of Atomic Radiation. Consequently, the risk of indoor and outdoor gamma radiation exposure is comparatively less for these Granite soils. Hence, the results in this study will reference future studies in terms of basic radiological data[66].

Natural radionuclides such as ^{238}U, ^{232}Th, their progenies and the non-series ^{40}K are generally spread in the earth. Considerable amounts of these radionuclides exist in many mineral rocks including granites. So, granites may possess significant number of natural radionuclides like ^{238}U, ^{232}Th, their progenies and the non-series ^{40}K. The concentrations of these radionuclides are not evenly spread within a particular brick of granite. These radionuclides decay to release dangerous ionizing radiations that are known to cause cancer and other radiation health effects, damaging critical organs of the body. Radionuclides in mineral soil like granite find their way into waterways (drinking water) and possibly taken

up by plants, thereby becoming available for further redistribution within food chains. They can therefore, eventually be passed on to human beings through food chains, and so may present an environmental threat to the health of local populations. So, information about the concentrations of these radionuclides in the environment is fundamental for estimating the level of public exposure to ionizing radiations[67].

Studies on the levels of these natural radionuclides and their respective progenies have been carried out in different parts of Nigeria. An in-situ measurement of these radionuclides was carried out on this granite mining field using handheld RS125 gamma-spec by an earlier work by , which reveals that the activity concentrations of ^{40}K, ^{238}U and ^{232}Th are higher than their respective recommended limits. This call for further investigation into waterways and food chain using higher resolution '3×3' lead shielded NaI (Tl) detector. This is important because in-situ measurements may not sufficiently provide the quantitative activity concentrations of radionuclides. Therefore, the goal of this research is to validate the results obtained from the in-situ measurements in the study area in order to ascertain the level of radiation hazards to the populaces living around the mining site. Also, this study will serve as baseline radiological risk assessment for this granite mining field in Asa LGA, Kwara State, North-central Nigeria. Twenty-four (24) samples of granite bricks were collected randomly from the mining sites under study. These samples were sent to the laboratory where macroscopic traces of glass, rubber, hair, animal and plant matter were removed to ensure that the materials to be analyzed are free from such contaminants. The samples were grinded using agate mortar and sieved through a 1 mm sieve mesh and stored in well labelled plastic containers (Marinelli cylindrical beakers) sealed using adhesive tape to prevent the escape of Rn gas and kept for 40 days to ensure secular radioactive

equilibrium before the Gamma-Ray spectrometry. A total of 12 samples of water and 12 samples of guinea corn were also collected randomly from the mining site under study. The guinea corn was grinded into powder form using electric blender. The water and the grinded guinea corn samples were collected in a fit rubber test containers (Marinelli cylindrical beakers). Each Marinelli beaker was washed thoroughly with liquid detergents, dried in an oven, wiped with acetone and then dried again in an oven . All the samples were stored in marinelli cylindrical beakers sealed using adhesive tape to prevent the escape of Rn gas and kept for 40 days to ensure secular radioactive equilibrium before the gamma-ray spectrometry[68].

A well calibrated 3 × 3 inch lead-shielded NaI(Tl) detector was used to measure the activity concentrations of ^{40}K, ^{238}U, and ^{232}Th in soil, water and guinea corn grains cultivated around a granite mining field in Asa, Kwara State, North-central Nigeria. The results of the activity concentrations obtained were used to estimate the corresponding radiation impact parameters in order to assess the level of radiological hazards to the populace in the study environment. The results of the activity concentrations showed that the mine field is more loaded with ^{40}K compared with ^{238}U and ^{232}Th. Also, all the measured activity concentrations of ^{40}K, ^{238}U and ^{232}Th are lower than their respective *in situ* measurements reported. This was believed to be due to the contribution of earth materials to the gamma ray detection for the *in situ* measurements. The estimated mean values of the entire radiation hazard index are within the recommended limits. Hence, the danger of exposure to ionizing radiation is less. It is recommended that the Nigerian Environmental Protection Agency (NEPA) and other regulatory bodies in Nigeria should enforce statutory requirements of mining activities in the State and the country at large in accordance with international[69].

Measurement of Activity Concentration Levels of Radionuclides and Assessment of Radiation Hazards for Well Water Samples Collected from Baghdad Governorate, Al-Sadr City, Iraq

In this study, Natural radioactivity levels of water from samples of 10 wells and at different depths 7, 3, and 12 meters were measured with a gamma-ray spectroscopy device using High Purity Germanium HPGe detector. The samples were collected from different areas of Sadr City, east of Baghdad Governorate. Al-Sadr city is considered as one of the important areas in the capital, Baghdad, due to its population density, which constitutes about 45% of the province's population. It is very important to assess the radiation risks in these samples because the population still depends on this water in their daily life. The concentration of naturally occurring radionuclides was determined U-238, Th-232, K-40 as all sample's concentration is higher than the permissible limits according to UNSCEAR 2000. Measurements included the values of natural radioactivity were calculated as the Radium Equivalent Activity Raeq 0.22, External Hazard Index Hex 0.000595, Internal Hazard Index H_ in 0.00119, Representative Level were collected The index Iγ 0.001467 and the alpha index I_α 0.0011, the exposure rate Raexp μR/h 0.418, and also calculated the air absorbed dose Dγin nGy/h 0.10164, Dγout nGy/h 0.2024, Dγtotal nGy/h 0.30404, AGED 0.6798, AEDEin 0.000124, AEDE_out 0.000993 and $AEDE_{total}$ 0.001117, lifetime cancer risk ELCRout 0.000436, ELCRin 0.003475 and ELCRtotal 0.003911.

Mining is one of the world's most dangerous occupations Over the years, many mining associated accidents have occurred in various parts of the world, often with significant loss of life Such mining accidents remind us of how dangerous mining jobs can be and how explicitly hazardous underground mining continues to be .Similarly, surface mining

blasting-related risks (although not specific to underground mining operations) and their consequences could be worsened and may result in mass widespread accidents.

Mining accidents and fatalities among the Artisanal and Small-scale miners (ASMs) occur in the process of mining metals, minerals, and energy materials (i.e., not construction materials). Thousands of miners die from these mining accidents each year, especially in coal and hard rock mining. Although surface mining is usually less hazardous than underground mining, the participation of artisanal and small-scale miners in barite mining fields has increased the number of mining fatalities across the upper and middle Benue Trough. Artisanal and small scale mining (ASM) in Nigeria employed about 0.5 million as of 2015, and in 2021 over 2 million. These miners' and mining communities' contribution to societal development is vital. Both occupational and environmental health and safety issues must be addressed at the mines and workplaces objectively[70].

Heavy metal contamination due to mining and mineral processing (washing) has become one of the most silent but significant environmental side effects. Studies in the literature have reported on acidification and acid mine drainage associated with the mining of coal, gold, and other minerals containing pyrite and galena (FeS_2 and PbS). Barite is one mineral or ore that has not been examined to pose such a threat. Barite mineral, although non-carcinogenic, may be associated with lead sulphide (PbS) and encrusted with pyrite or iron pyrite microcrystal. Tetraoxosulphate (vi) acid mine runoff is unavoidable when barite tailings containing sulphide minerals are exposed to water and oxygen. The consequence is acidification of water and can increase the release of other heavy metals such as iron, zinc, copper, lead, cadmium, arsenic, and barium.

Previous reviews on safety and risk analysis have shown the relevance of workplace safety models in the safety-critical assessment of risks, either at mines or in any other activities where dangerous tools are used. Several safe assessment methods have been developed to address the quality and productivity of workers that sustain severe accidents at work and uncovered the adverse effect of heavy metal contaminants and other critical environmental threats to human health. Researchers have examined ways to domesticate some of these advanced safe mining methods in Nigeria but with little positive results. This is because many local miners believed the "advance" safe mining strategies have no direct correlation and cannot provide solutions to the type of mining hazard peculiar to them. Moreover, nothing much seems to have changed regarding miners' and government attitudes to mineral exploration. Miners appear to have nothing to worry about despite the dozens of unreported cases of mining accidents. The significance of wearing safety kits such as mining boots, hand gloves, eye goggles, and clothes specifically designated for mining only at the site should be communicated again. There is also a claim that the institutional policy guilds' activities of artisanal and small-scale miners (ASM) caters to chemical contamination due to barite mining. However, the miners' and mining sites' managers are unaware of the safety data sheet, which is a minimum requirement for the operation of mines. Therefore, it is helpful to engage these local miners in discussing prevalent mining accidents and fatalities that have profound health implications and develop safe assessment methods, processes, and programs to prevent the reoccurrence of mining hazards[70].

This paper reviews mining activities by the artisanal and small-scale miners in Nigeria and presents safe mining strategies. It identifies mining accidents that are peculiar to artisanal and small-scale miners (ASMs), revises existing but weak and inadequate mining policy,

and assesses potential mining risks to human health due to mining and social lifestyles of the miners. Questionnaires were administered to local miners (part-time and full-time) within the middle Benue Trough of Nigeria to identify hazards. Water from barite ponds and effluents was also analyzed to characterize associated risks and recommend safe mining protocols and controls, especially for the barite mining sector. Two research questions were investigated in the study. These are: (1) Certain mining accidents and their adverse effect on miners are traceable to miners' refusal to use safe mining kits and (2) Artisanal barite mining contributes to severe heavy metal contamination. Field survey and heavy metal contamination assessment of water in barite ponds and recycled wastewater at barite mine sites validated the research questions.

There are legal and regulatory documents and institutions that govern the activities of artisans and small-scale miners in Nigeria. The is an existing legal, regulatory, and institutional frameworks for Nigeria's mining sector. Aside from the frameworks, policy objectives guide the everyday activities within the mineral value-chain. These objectives include but are not limited to comprehensive actions on the acquisition of rights, mine ownership requirement and restrictions, minerals processing and export, transfer mineral rights, land use, environmental, mineral titles, health and safety, and constitutional law. Despite these frameworks, Nigeria's mining sector is yet to reach its full potential Research has shown that enacting an Act and introducing laws or policies to drive Nigeria's mining sector can strengthen the regulatory frameworks ss. However, there were no prior works on health, mine safety, and mining hazard prevention procedures until March 2016, when the Nigerian government acknowledged mercury and lead (Pb) health risks. Mining accidents are not limited to chemical hazards. It also includes every form of harm against the miners,

mining communities, and resources located within the mining environment. This set of rules is mandatory and must be enforced by every player within the mining and mineral business.

The sources of hazards associated with the sector include chemical, physical, and mechanical. Major mining accidents occur due to the use of crude and sharp tools by artisanal and smallscale miners to extract minerals. Some of past and current mining hazards or accidents in different parts of Nigeria. These hazards are traceable to the illegal mining and mineral extraction practices done by artisanal miners in Nigeria. Stone quarrying and solid minerals exploration dominate artisanal and small-scale mining (ASM) activities in Nigeria[71].

The survey results agree that artisanal barite mining is dominated by men (mostly young adults) and has a lower literacy level as reported on the general status of artisanal and small scale mining (ASM) in Nigeria. Previous research has shown that artisanal miners of gold, gemstones, diamond, galena, limestone, zinc have similar gender distribution and are exposed to peculiar risks and difficult tasks associated with their profession. Miners are predominantly unskilled and semi-skilled, as observed with artisanal miners that specialize in gold, gemstone, granite, and sand mining. This agrees with the general state of several mining sites managed by artisanal and small-scale miners in Nigeria.

In the survey, it was quite true that some of the miners felt their present medical conditions are due to factors other than mining. Several works reported in the literature have shown that all miners are vulnerable to mining hazards aside from previous medical conditions, except for those using complete protective kits during mining. Artisanal miners are exposed to dust risk, which lowers the Forced Expiratory Volume (FEV) and Forced Vital Capacity (FVC).

Such results have shown that miners that abuse drugs as stimulants may not experience reduced lung function (fibrosis), defective oxygen diffusion, and impaired pulmonary function in the short term. However, exposure to heavy metal contamination would further worsen the present medical conditions[71].

Post-survey discussion with miners reveals that artisanal barite miners do not have the financial capacity to fund bills of medical examinations. Most artisanal miners earn lower than the cost of medical treatment. They would prefer self-medication or visit a traditional medical practitioner for medical consultation and treatment as no medical facilities and personnel available. Miners illicitly use nicotine to fight body weakness and other symptoms that requires an adequate medical examination. Also, it is uncertain whether owners of mining sites offer medical care to miners as there is no part of the mining policy or institutional frameworks that compelled or enforced employers to provide for the medical care of miners. Miners are encouraged to use safety kits during mining and seek medical attention when necessary. The need for annual medical outreach to mining sites is recommended for medical counseling, diagnosis, treatments, and referral of miners with severe medical conditions to access medical facilities[72].

High values of HQs for Ba and Pb increase HI's value for water sample TB1. However, the case is different for sample TB2, posing no observable hazard to human health. The use of such water for various applications and eating aquatic lives such as fishes loaded with heavy metals is unsafe. Also, the heavy metal contamination risk assessment revealed that water from barite ponds and wastewater returned into the river are contaminated by lead and barium. The chronic daily intake (CDI), health quotient (HQ), and health index (HI) for these heavy metals in the water samples suggest that an adverse effect due to non-

carcinogenic risk is expected. The use of affordable water filters such as carbon filters specifically designed to remove lead and Ba will help to reduce the quantity of heavy metals consumed in drinking water. The foremen, managers, and owners of mining sites, mineral processors within the mining industries, and academia, as stakeholders, were interviewed verbally to identify major inhibitors to safe mining in Nigeria. The inhibitors identified include funding, lack of enforcement, infrastructural needs, and insecurity[60].

Project Funding: The Nigerian government has done a lot through the Federal Ministry of Mines and Steel Development (MMSD) in the reform of institutional framework, establishment of ASM Directorate, Solid Minerals Development Fund (SMDF), Mineral Sector Support for Economic Diversification Project. However, some of the stakeholders in the industry and research institutions complained that funds for the projects hardly get to the mine inspectors to develop safety procedures and protocols.

Regulations and Sanctions: Although many regulations and sanctions have been established, implementation has been lacking. Mine inspectors hardly visit mine sites, and minimal awareness is created among the miners on safety and health hazards.

Infrastructural Collapse and Decay: The infrastructural imbalance within the country has completely paralyzed the power, transportation, mines, and minerals sector of the economy. However, the outright privatization of electricity generation and distribution and rail transportation should encourage investments in mining equipment importation for local mineral beneficiation and development of mines[61,73].

Security and illegal mining: Most recent and ongoing security challenges within the middle belt, Northeastern and Niger-delta regions of Nigeria can be addressed by developing a

robust corporate social responsibility program to alleviate the suffering of the people living within the mineral mining and processing communities. The enactment of the mining act and collaborations among the foreign investors and experts will assist the Nigerian government in the development of a workable mining framework and a road map significantly required for relevance within an acceptable safe mining operation[69].

Impact of COVID-19 on Health of Miners

The first official case of the coronavirus disease 2019 (COVID-19) pandemic was announced in Nigeria on February 27, 2020. In the advent of the COVID-19 pandemic, Nigeria's mining industry experienced sudden downtime, reducing its contribution to the national gross domestic product (GDP). The recent drop-in commercial activities and demand for minerals has also worsened the situation. Also, there are cohorts of individuals facing health and financial challenges during the pandemic. Aside from the older people, miners and mining community' respiratory health is at stake due to the fact that some miners have pre-existing medical complications. There is, however, no specific data or literature on incidents of COVID-19 related cases or the death of miners. Other subsidiary concerns among the artisanal and small-scale miners, who do not have a stable income for feeding and medical tests, surround the ability to continue routine medical examination and treatment during the pandemic. Therefore, the participation of private health providers and global aid agencies is critical at this point[72].

In the real sense, the right time to implement innovative and strategic plans, cultivate safety information-seeking behavior in artisanal and small-scale miners (ASMs), and enforce safe mining practices to ensure that miners and the mining activities are safe, is now. Such plans are not limited to remote collaboration, adoption of digital capabilities, safety training on the

use of safe mining kits, strict observance of work ethics, occupational and environmental health safety protocols, and personal hygiene in addition to local CDC protocols on COVID19 prevention, and vaccination of miners. Also, in collaboration with the Capstone team in the United Kingdom, the Nigerian government is reassessing the existing roadmap for mineral exploration amidst new challenges and opportunities due to the pandemic.

Policy Imperatives and Strategies for Fostering Safe Mining

Mining in Nigeria is regulated by the Constitution of the Federal Republic of Nigeria, 1999, the Nigerian Minerals and Mining Acts, 2007. The Nigerian Minerals and Mining Regulations, 2011 are the significant regulations and policies that control the artisanal and small-scale mining (ASM) activities in Nigeria. These policies directly address issues related to mineral exploration, environmental protection, and safety. Policies on the environment, health, and safety have been the focus of this study. Although laws should enforce strict observance of these policies for all miners, only legal holders of mineral titles can be tracked.

There are reports on Nigeria's government effort to formalize over 1.5 million artisanal and small-scale miners (ASMs) into cooperative groups. However, information available to miners is limited[73].

Mine Inspectors and Mine Cadastral Officer are responsible for information dissimilation, but their ratio to ASMs is about 1:200 to 1: 10,000. There is an urgent need to strengthen information aids and sources to formalize artisanal and small-scale miners in Nigeria. An information sharing framework can be supported by government declaration for a Miners' Day, a public holiday entirely given to massive sensitization on safe mining issues, safety education and awareness, medical outreaches, and miners networking. Considering mining

as a hazardous endeavor, formalizing ASMs into groups will ensure adequate operations management and encourage the participation of relevant stakeholders such as Medical Doctors and Paramedics, rock mechanics, and mining engineering experts. Given the above, existing policies should guarantee safe mining at all mining sites in Nigeria.

There exists a generalized future mining plan in Nigeria called Nigerian Mining Road Map, but the content only speaks to the public without any commitment to ensure its compliance. As earlier mentioned, owners of mining sites and the government are more concerned with the business of mining and not the quality of mineral extraction, safety of life, and the mining environment. The road map proposes the path to mining prosperity and not to ensuring a responsible and sustainable mineral extraction. However, as part of the plan to diversify the economy due to the pandemic, the Ministry of Mines and Solid Minerals Development (MMSD) is considering using Science and Technology in solid mineral exploitation. This includes the use of satellites for mining data acquisition for solid mineral exploration and Artificial Intelligence (AI) to ensure mining safety and efficiency of mineral processing methods. There is a need to adopt an automated safe mining strategy or incorporate minebased technology such as mine remoting and an automated mining system. This is key to envisioning sustainable barite mining; however, a stable power supply (electricity) is needed to drive this technology contained in the mining road map[74].

This study identifies and reviews mining accidents peculiar to artisanal and small-scale mining (ASM) to re-iterate that mining accidents have severe consequences on miners and their environment. It revises existing but weak and inadequate mining policy, assessing potential mining risks to human health due to the mining and social lifestyles of the miners. Results show that artisanal miners are exposed to polluted water, air, and farmland. The

consumption of water from barite ponds poses a relatively high risk to human health over a long period of time. Therefore, it can be concluded that mineworkers are exposed to a certain level of risks either knowingly or ignorantly due to artisanal barite mining. Adverse noncarcinogenic risks due to Pb and Ba in water and a worsening of health via illicit drug intake are expected. Operational therapy and practices such as sensitization on the danger of drugs to health, the importance of taken sufficient rest, and the use of safety tools and affordable water filter have been recommended to ensure safer artisanal mining activities. To envision the future of barite mining, detailed recommendations on the need for annual medical outreach to mining sites and the use of technology (Al) for future mining were presented. Some peculiar safe mining protocols and controls to reduce the daily chronic intake (CDI) of heavy metals in water (barite pond and tailings) are also mentioned

Cardiovascular diseases are the leading cause of death worldwide. Cardiovascular disease was the underlying cause of death for about a third of the 2.8 million deaths in the USA in 2018: ischaemic heart disease accounted for 42% and stroke for 17% of all cardiovascular disease deaths. Worldwide, ischaemic heart disease ranks first in years of life lost and stroke ranks third. Consistently identified independent risk factors include age, smoking, diabetes mellitus, hypertension, obesity, and increased total and low density lipoprotein or decreased high density lipoprotein cholesterol. A heritable genetic component for coronary heart disease has also been reported Environmental factors might also contribute to cardiovascular disease risk and exposure to ionising radiation during radiotherapy can damage the heart. Radiotherapy doses to the heart and other organs or tissues of relevance to the cardiovascular system can be very high, with doses to some regions of the heart exceeding 40Gy in previous years; although doses tend to be lower among groups treated for non-malignant disease than for cancer, and lower among people treated for cancer in more recent

years. Many older studies of radiotherapy and cardiovascular disease do not have detailed individual radiation organ dosimetry or data for concomitant chemotherapy drugs, of which some types (eg, vinca alkaloids including vincristine, and anthracyclines including doxorubicin) are cardiotoxic, irrespective of the administration of concomitant radiotherapy Concomitant chemotherapy is often correlated with radiotherapy dose therefore confounding of the dose response is possible[69].

The Life Span Study of the Japanese atomic bomb survivors provides evidence of increased risk of cardiovascular disease at lower levels of dose, less than 5 Gy, and with mean doses of much less than 0.5 Gy. No findings suggested an appreciable non-linear association in the radiation dose-response for cardiovascular disease mortality in the Life Span Study data, although the form of the dose-response relation, particularly at doses less than 0.5 Gy, is uncertain. Therefore, the extent of cardiovascular disease risk is uncertain for low doses (<0.1 Gy), which are characteristic of doses from medical diagnostic exposures. Emerging, and still controversial, evidence suggests that exposure to much lower doses and dose rates of radiation, in particular occupational and medical diagnostic exposure might be associated with excess risk of cardiovascular disease. Claims have been made of a no effect dose threshold for cardiovascular disease mortality in the Life Span Study, below which no radiation induced excess risk exists, although this finding has been disputed. Observational epidemiological studies are likely to have difficulty in detecting increased risk at low dose levels because the main types of cardiovascular disease of concern are very common in the population as a whole and because of the multiple contributory risk factors that are potentially confounding. The International Commission on Radiological Protection has classified cardiovascular disease as a tissue reaction (formerly termed a deterministic effect), with an approximate nominal threshold dose of 0.5 Gy independent of dose rate. This level

is determined by linear models fitted to epidemiological data that yield less than a 1% lifetime risk. As such, this threshold is a practical one but is not a true no effect dose threshold.

In this systematic review and meta-analysis, we research the risks of radiation associated cardiovascular disease that have been observed in therapeutically or diagnostically exposed cohorts. Risks among groups exposed to generally lower levels of radiation dose (with maximum dose <0.5 Gy) or low dose rate (<5 mGy/h) are also assessed, specifically in the Life Span Study and in groups that are occupationally and environmentally exposed. Attention is concentrated on studies with informative individual organ dosimetry. In contrast to previous systematic reviews, which were published at least 10 years ago, we do not limit our inclusion to the lower dose literature; a previous review and meta-analysis covered literature up to about 2016, but the review was not systematic[70].

Our systematic review and meta-analysis supports an association between acute high dose and chronic low dose radiation exposure and most types of cardiovascular disease. Low dose and low dose rate exposure tend to be associated with higher risk per unit dose. Although heterogeneity complicates a causal interpretation of these findings, this heterogeneity is markedly reduced if attention is restricted to higher quality studies or to studies at lower dose or dose rate. Our findings suggest that radiation detriment might have been significantly underestimated, implying that radiation protection and optimization at low doses should be rethought. The possible mechanisms for risk at low doses and low dose rates are, in contrast to the situation at higher doses and dose rates, relatively poorly understood, thus underscoring a crucial need for further research in this area. Further research is also needed to assess modifications of radiation effect by other lifestyle and medical risk factors[71].

The activity concentrations of natural radionuclides ^{226}Ra, ^{232}Th and ^{40}K in soil samples from the North Region of Burkina Faso around the mining site of Kalsaka were measured by gamma spectrometry using high purity germanium detector. Radiological hazard assessment due to such natural radioactivity was also investigated. The average activity concentration of ^{226}Ra, ^{232}Th and ^{40}K were found to be 26.06 ± 1.50 Bq.kg^{-1}, 33.27 ± 1.97 Bq.kg^{-1} and 133.11 ± 13.69 Bq.kg^{-1} respectively. The average absorbed dose was 0.038 µGy/h whereas the annual committed effective dose was 0.050 ± 0.003 mSv.y^{-1}. The average radium equivalent activity concentration was 83.89 Bq.kg^{-1}. The external and internal hazard indices were 0.23 and 0.30 respectively which are three times less than one. The activity utilization index was 0.6 Bq.kg^{1} with maximum of 0.79 Bq.kg^{-1}. The mean effective dose rate of 0.05 ± 0.003 mSv.y^{-1} and the mean values of Ra_{eq} and H_{ex} and H_{in} for the studied area are below their respective permissible limits, thus indicating that radiation hazard is not significant in this area[72].

Assessment of Groundwater Samples from Mining Area in the North Region of Burkina Faso. The activity concentrations of Natural Radionuclides 238U. 232Th and 40K in groundwater samples were measured using a Gamma Spectrometry with High Purity Germanium detector.

Also. Radiological Hazard due to these Natural Radionuclides through water ingestion is investigated. The mean activity concentrations of 238U, 232Th and40K in water samples from boreholes were found to be 0.36 ± 0.07 Bq.L-1. 0.50 ±0.09 Bq.L^{-1} and 5.32 ± 0.76 Bq.L^{1} respectively[73]. The average Annual Committed Effective Dose was 0.16 ± 0.02 mSv. The results obtained are below the recommended levels of 10.0 Bq.L^{-1} and 1.0 Bq.L^{-1} for 238U and 232Th respectively for drinking water quality established by the WHO and 1

mSv per year dose limit recommended by the ICRP for public radiation exposure. These results indicate insignificant radiological hazard due to ingestion of NORMS in drinking water from boreholes by the communities in this area. Radionuclides are present everywhere in the natural environment. The main natural contributors to external exposure from gamma-radiation are the uranium and thorium series together with potassium 40 (40K) and may be present in small quantities on the surface of the earth. Long-lived radioactive elements such as uranium, thorium and potassium and their decay products. such as radium and radon are examples of Naturally Occurring Radioactive Materials

(NORMs). These elements have always been present in the earth's crust and atmosphere since the beginning of creation. The 238U and its daughters rather than 226Ra and its daughter products are responsible for the major fraction of the internal dose receive by humans from naturally occurring radionuclides. Even though the concentrations of these radionuclides are widely distributed in nature, they have been found to depend on the local geological conditions and as a result vary from place to place. Throughout the history of life on earth, organisms have been continuously exposed to radiation mainly from cosmic rays in the atmosphere, and from naturally occurring radionuclides which are ubiquitously distributed in all living and non-living components of the biosphere . A wide range of activity concentrations in a wide variety of materials is reported. Mining has been identified as one of the potential sources of exposures to NORM Within the last ten years there are many mining companies operating in Burkina Faso and some are even implanting. However in the other developing countries, in Burkina Faso mining activities have not been duly controlled and as a result no radiological regulatory controls are really applied[74]. Therefore, there is general lack of awareness and

knowledge of the radiological hazards and exposure levels by legislators, regulators and operators. The objective of the study was to assess the level of NORM in the North region of Burkina Faso surrounding the mining site of Kalsaka. This involve measuring the activity concentrations of 238U, 232Th and 40K in groundwater samples from Kalsaka area around the mining site assessing the Radiological Hazard and risk associated with exposure to the members of the community living in this area.

A study by Adagunodo in which the radiation exposure assessment was determined around the Odo-Oba dam in Oyo state. The study concluded that the radioactivity levels posed no significant risks to the farmers within the area. [75.]

Darko also conducted preliminary studies on the occupational exposure to NORM from underground and surface mining in the Ashanti region (Ghana) gold mines. The assessments were performed using gamma spectrometry. The computerized system was coupled to a 3×3 squared inch NaI(Tl) measuring assembly. Employing the ICRP dose estimation methods, the annual effective doses were estimated to be 0.26 and 1.83 mSv for surface and subsurface mines respectively. The results obtained for surface mines were below the 1.00 mSv per year threshold while results for underground mines were above the 1.00 mSv per year stipulated threshold for workplace exposure (ICRP, 2007). Natural background radioactivity of soil samples at the hotspot areas around Kinta District, Perak (Malaysia) were analysed by Kuan using HPGe detector system. The soil activity ranged 43-307 Bq/kg for 238U, 63-1377 Bq/kg for 232Th and 29-166 Bq/kg for 40K with mean values of 178, 841 and 104 Bq/kg respectively. Mean levels for 238U and 232Th indicate significant deposit of uranium and thorium within the observed area. It was recommended that the data obtained can be used as a reference for comparison with future evaluations.

At the locality of two Minna (Nigeria) tertiary institutions, background radiations were assessed by *in-situ* measurements by Olarinoye (2010). 34 points across the institutions were marked and assessed using a mobile radiation dosimeter (Geiger-Mueller tube-based). Dose rates obtained at Niger State College of Education Minna (NCM) varied from 0.13 to 0.17 μSv/h. Dose rates at the Federal University of Technology Bosso Campus (FUTB) varied from 0.15 to 0.18 μSv/h. While at the FUT Gidan-Kwano campus (FUTG) the dose rate was between 0.14 and 0.18 μSv/h. The mean dose rate for the surveyed points was 0.15 μSv/h with equivalent 0.19 mSv/y average annual effective dose. This value was below the recommended 1.00 mSv/y stipulated by the ICRP for non-occupational population[76].

Odumo carried outs radiologically surveyed and assessed some Migori gold mining sites (Macalder, Masara, Mikei, and Osiri) of southern Nyanza (Kenya). An innovative method employing a mono-channel Na(Tl) system was used to deduce the activities of 40K and the progenies of 232Th and 226Ra. The radiation levels range widely from 80 to 413 Bq/kg, 12 to 145 Bq/kg and 21 to 258 Bq/kg for 40K, 232Th and 226Ra, respectively. The deduced absorbed dose in air varied from 16 to 178 nGy/h (with 42 nGy/h average). While the radionuclides' activity concentration and the estimated annual absorbed dose were below the world's average, the amount of dust at the mines was quite high. The results obtained show that the artisanal miners are exposed to several levels of radionuclides and dust and calls for necessary precautions[77].

Faanu conducted studies to assess the exposure of the public to NORM from the processing of gold ore from Tarkwa gold-mine in Ghana. Samples of water, dust, rock, and soil were examined employing Neutron Activation Analysis (NAA) and direct gamma spectrometry techniques. Sequentially, 15.2, 26.9 and 157.1 Bq/kg were the average activity concentrations for 238U, 232Th and 40K in the soil/rock samples.. The mean activity

concentrations measured in the dust samples were respectively 4.90 and 2.75 μBq/m3 for 238Uand 232Th. The total annual effective dose to the public was estimated to be 0.69 mSv. Upon comparison with the world average value of 1 mSv/annum, Faanu concluded that the results stipulate an insignificant public exposure from gold mining activities in Tarkwa.

From the State of Andhra Pradesh (India), Reddy surveyed the extent of natural background radioactivity. This was aimed at establishing baseline radioactive data in the proposed uranium mining sites in the Lambapur and Peddagattu areas. 238U activities in the depthless soil of the region ranged 100-176 Bq/kg, with a mean of 138.24 Bq/Kg. 232Th ranged 64-116

Bq/Kg, with 83.15 Bq/kg average. The 40K ranged 309-373 Bq/kg, with 343.20 Bq/kg mean. The mean radiation levels of 238U and 232Th in the study locations were observed to be quite with contrast to the Indian national as well as International averages[78].

Abdulkarim scooped samples of soil from twelve sites within the Yankandutse artisanal gold mining belt in Kaduna State, Nigeria. The activities of 40K, 226Ra and 232Th in the soil samples were determined using gamma ray spectroscopy method. The average concentrations of 40K, 226Ra and 232Th in sequence were 382.01, 2.08 and 47.23 Bq/kg. The mean activity concentration of potassium and radium were below the UNSCEAR stipulated average of 400.00 and 35.00 Bq/Kg respectively while that of thorium was above the global average of 30.00. In the same year Abdulkarim and Umar scooped twelve soil samples from the gold mining site of Tsofon-gwari (Colonial, Jiniya and Katsina) in Kaduna state. The observed samples contained insignificant amounts of 226Ra and 40K. Their activities varied with average values of 2.39 and 390.95 Bq/kg respectively while 232Th in the soil varied with an average value of 51.98 Bq/Kg which was above global average (Abdulkarim and Uma). Hence, indicating significant thorium levels in the soil. For the

same region, investigated the activity concentrations of naturally occurring radionuclides (238U, 232Th and 40K) in gold ore mined from Birnin Gwari artisanal goldmine. Instrumental Neutron Activation Analysis (INAA) technique was employed in this case. Twelve samples were collected from pits at different depths. The activity concentration due to 238U ranged from 6.18±3.7 to 66.69±4.9 Bq/Kg with 37.36±5.45 Bq/Kg mean, 232Th concentrations ranged from 16.65±0.8 to

87.29±1.2 Bq/Kg with 62.69 ± 6.33 mean and 40K range from 85.13±4.5 to 1564.69±57.9 Bq/Kg with a mean value of 997.52±11 9.97 Bq/Kg. These results revealed high levels of radioactivity within the gold mine. Thus, gold mining in the area poses radiological risks to miners and members of the public. Aimed at identifying and quantifying fore-standing gamma-emitting NORM associated with mining activities in Northwestern Nigeria, Innocent collected soil samples from 10 different mining sites in Zamfara State for gamma spectroscopy analysis. A laboratory based γ-ray NaI(Tl) system was used to obtain values of activity concentration ranging from 227.10 ± 7.54 to 590.44 ± 10.57, 4.68 ± 3.52 to 18.98 ± 0.84 and 40.58 ± 1.85 to 94.92 ± 2.75 Bq/kg for 40K, 238U and 232Th respectively. The absorbed dose rate in the soil sample ranged from 9.47 ± 0.31 to 24.62 ± 0.44, 2.16 ± 1.62 to 8.77 ± 0.39 and 24.51 ± 1.12 to 57.33 ± 1.66 nGy/h respectively for 40K, 238U and 232Th. The net absorbed dose rate estimated for the sites was 59.70 nGy/h and the estimated annual effective dose for the study ranged from 52 to 106 μSv/y, with an average of 73 μSv/y (Innocent). Thus, revealing that the radiation exposure level for members of the public in the study areas is within the safety limit[79].

Doyi carried out measurements of radon and gamma radiation levels in the underground artisanal gold mines in Tongo, Ghana. Solid State Nuclear Track Detectors (SSNTD) were

used to estimate the mean 222Rn concentration and dose rates during the Harmattan season The measurements obtained 32 for 222Rn concentrations were less than the action level of 500 Bq/m3 recommended by ICRP for workplaces. The activity concentrations of 40K, 232Th and 238U were determined using gamma-ray spectroscopy method. Average specific activities due to 238U, 232Th and 40K for the mining sites were 66.29, 294.43 and 1964.29 Bq/kg in sequence. Therefore, revealing significant radiation levels above UNSCEAR (2000) stipulated average[80].

Ibrahim used using Sodium Iodide-Thallium Gamma Spectroscopy to determine 226Ra, 232Th and 40K natural activity concentrations in some mining areas in Central Nasarawa State, Nigeria. 21 soil samples were collected from the accessible areas of 7 major sites identified as the most mined areas of the zone. The mean activity concentrations were 32.52±4.65, 56.23±2.30 and 403.96±7.29 Bq/kg for 226Ra, 232Th and 40K respectively. The value obtained for 226Ra was a bit lower compared to world average while values for 232Th and 40K were higher than the world average value. The average background radiation absorbed doses at two spots were 5.81±0.08 and 8.45±0.56 mSv/y. These were higher compared to worldwide average of 1.00 mSv/y stipulated by UNSCEAR (2000).

From the gold mining area in Itagunmodi, Osun State of south-western Nigeria, the specific activities of NORM in soil samples were measured by gamma spectrometry using Sodium Iodide detector by Ademola. The average activity concentrations of 238U, 232Th and 40K determined in the soil from the mining sites were 55.3, 26.4 and 505.1 Bq/kg respectively. Except for 232Th, these values are above UNSCEAR global average. However, lower radiation levels were recorded in the normal living with mean values of 8.8±1.9, 17.5±2.7

and 102.8±12.1 Bq/kg for 238U, 232Th and 40K in sequence. The averages for radium equivalent activity concentration, external and internal hazard indices in the study area were below the world averages. According to Ademola, mining activities in Itagunmodi poses no radiological hazard to the general public[81].

Girigisu assessed the radiation levels from Awwal artisanal gold mining exercises in Kebbi State. Results reveal average activities of 23.85±2.01, 18.80±1.21 and 425.96±5.56 Bq/Kg for 226Ra, 232Th and 40K respectively. The average outdoor gamma dose was 34.26 nGy/h while the mean annual effective dose rate was 0.042 mSv/year which is less than 1.00 mSv/year benchmark given by UNSCEAR (2000). Radiologically, the values obtained are low and do not imply any significant health concerns to the local population.

However, Girigisu reported that they were unprofessional practices such as ignoring the use of gas mask while working in the dust-filled mine cafes and at the mills. This could also potentially expose workers to risks from inhalation of respiratory crystalline silica radon gas. The specific activities of 238U, 232Th and 40K were measured in 60 soil samples by AlGazaly using a NaI(Tl) gamma-ray spectrometry system. The samples were collected from sites around the uranium mine in the Abu-Skhair in Najaf province, Iraq. Computed mean values for 238U, 232Th and 40K specific activities were 77.33, 9.36 and 426.31 Bq/kg respectively. The study also examined radium equivalent (Raeq) with an average of 123.54±8.88 Bq/kg. A comparison of the measured values with the corresponding worldwide average values shows that the most specific activity of 238U and 40K radionuclides in the studied samples were higher than world average activity values[82].

Aliyu radiologically surveyed selected mining sites (Kumar barite, Akiri copper, Azara barit, Ribi barite, Adudu lead, Keana salt and the Abuni zinc mines) in Nigeria's home of solid minerals (Nasarawa State). The activity concentrations of primordial radionuclides (226Ra, 232Th and 40K) in the surface soils/sediment samples were determined using sodium iodidethallium gamma spectroscopy. The result shows that the activity concentrations of 40K were higher than the world average. However, the annual effective dose rates (in mSv/y) were less than unity for all the mines. The external hazard indices for all the mines were less than unity. Thus, indicating minimal radiological risks associated with mining in the State. Kamunda evaluated the radiological hazards associated with exposure to NORM from gold mine tailings in the province of Gauteng in South Africa using gamma spectroscopy to measure activity concentrations in 56 soil samples from the mine tailings and 10 soil samples from a control area. The average activity concentrations in Bq/kg for 238U, 232Th, and 40K from the mine tailings were found to be 785.3 ± 13.7, 43.9 ± 1.0 and 427.0 ± 13.1 respectively while the average activity concentrations from the control area in Bq/Kg were found to be 17.0.1 ± 0.4, 22.2 ± 0.5 and 496.8 ± 15.2 for 238U, 232Th, and 40K respectively.

Radiological hazard parameters calculated from these activity concentrations were higher than recommended safe limits (Kamunda). In particular, average values for the external hazard (Hex) and the internal hazard (Hin) from the mine tailings were 2.4 and 4.5 respectively. Both values were higher than unity, posing a significant health risk to the population in the area[83].

Nwankpa also assessed 20 samples of soil from different illegal gold mines in Erinmo, Osun State of Nigeria. HPGe detector was used to quantify NORM in the soil. Radiation levels

vary from 9.01±1.7 to 35.4±3.7, 10.9±2.8 to 37.5±4.6 and 99.0±12.3 to 182.8±18.5 Bq/Kg for

238U, 232Th and 40K in sequence with averages of 21.9±2.1, 23.4±2.9 Bq/Kg and 136.5±18.2 Bq/Kg respectively. Hence, it was opined by Nwankpa that there were no uranium or thorium deposit in Erinmo due to uranium and thorium specific activities that fall within the earth crustal mean for normal environmental. Estimated radiological parameters were also below global threshold values, indicating minimal radiological contamination in Erinmo mines. Radionuclides concentration in the surface soil of the uranium mining area of

Tongliao, China, using gamma spectrometry, the estimated average activity concentrations of 238U, 232Th, 226Ra, 40K and 137Cs were 27.53, 15.89, 12.64, 746.84 and 4.23 Bq/kg respectively. Except for 40K, these values were below recorded global averages. The averages for absorbed dose rate in the air, annual effective dose, radium equivalent activity, external and internal hazard indices computed were all within the bearable limits[84].

Faanu (2021) ascertained the levels of NORM in the new eastern concession area of Perseus Mining (Ghana) Limited. This was done prior to processing of gold ore within and around the region. The study was based on situ measurements of external gamma dose rate at 1 m above ground level as well as laboratory analysis by direct gamma spectrometry to quantify 238U, 232Th and 40K in soil samples. The average absorbed dose rate was determined to be 0.08 μGy/h. Individually, the mean concentrations of 238U, 232Th, and 40K in the soil were 65.1, 71.8 and 1168.3 Bq/Kg. These values were all above the UNSCEAR (2000) reported global average and results to an annual effective dose of 0.91 mSv/yr that was slightly below the 1.00 mSv threshold for public exposure. It was the opinion of Faanu that previous

mining activities had not imparted negatively in terms of radiological hazard to the communities in this area. However, these results suggest concerns for further radiological evaluation and monitoring in consideration miners health and environmental safety. Silver assessed the levels of primordial radionuclides in mine tailings from mines in Southwestern Uganda. The specific activity concentrations of 238U, 232Th and 40K in the samples varied from 35.5 to 147.0 Bq/Kg, 119.3 to 376.7 Bq/Kg and 141.0 to 1658.5 Bq/Kg respectively. The mean absorbed dose rates in sequence for Mashonga Gold Mine, Kikagati Tin Mine and Butare Iron Ore mine were 181.2, 167.2 and 191.6 nGy/h. These values were more than three times the world-wide average value of 57 nGy/h. Thus, Silver suggested that the mine tailings (soil) from these areas should not be used as major building material to minimize radiological hazards.

Radionuclides activities in soils in the vicinity of 10 solid mineral mining sites in Enugu, Nigeria were investigated by Osimobi. Sodium iodide gamma spectroscopy was used to assess 4 soil samples and 1 control sample obtained from each of the sites. The results obtained indicated mean concentration values of 33.2, 77.7 and 100.7 Bq/kg for 226Ra, 232Th and 40K in sequence. The averages deduced for the radiological risk parameters were 67.5 ηGy/h for the Absorbed Dose Rate (DR), 82.8 μSv/y for the Annual Effective Dose Equivalent (AEDE), 151.4 Bq/Kg for the Radium Equivalent (Raeq) and 457.1 mSv/y for the Annual Gonadal Equivalent Dose (AGED) which was high compared to the control value of 177.7 mSv/y and the WHO tolerable value of 300 mSv/y.

Gamma-ray spectrometry using NaI(Tl) detector was employed by Ibraheem to determine NORM concentrations in the Asir region of Saudi Arabia. Soil samples assessed were fetched from several locations (Muhail Asir, Abha and Khamis Mushait) within the area. The results show the variations of NORM concentrations from 38.2±0.1 to 44.1±0.1,

23.49±0.20 to 41.9±0.2 and 182.5±1.0 to 251.5±1.3 Bq/Kg for 226Ra, 232Th and 40K respectively. Estimated averages were all below the UNSCEAR (2000) stipulated global average[85].

According to Ibraheem, the data obtained will serve as baseline level of radionuclides that occur naturally in the study area. Also, the results will be useful for tracking and evaluating pollution inventory within the boundaries of the surveyed areas. Suleiman reported minimal level of radiation exposure around Erena mining sites in Niger State, Nigeria.[7] soil samples were collected and analyzed using a laboratory NaI(Tl) γ-ray spectrometer at the Centre for Energy Research and Training (CERT), Ahmadu Bello University Zaria. The activity concentrations for 40K ranged from 48.52±3.58 to 1002.96±9.80 Bq/Kg, for 226Ra it ranged from 23.29±2.20 to 75.32±5.09 Bq/Kg and for 232Th the range was from 23.83±2.05 to 59.29±2.39 Bq/Kg. However, the mean values of activity concentrations and radiological parameters were below the global screening levels. Therefore, Suleiman suggested that no radiological risk was envisaged to the populace of the study areas and the miners working on the mining sites. Using Radiation Inspector Alert meter (EXP+ model), measurements were made at four different Stations (A, B, C and D) within the vicinity of artisanal gold mining sites in Luku, Niger state by Sabo. The investigation revealed averages 1.66, 1.5, 1.48 and
2.12 mSv/yr respectively for stations A, B, C and D. The radiation levels recorded from the sampling stations exceeded the 1.00 mSv/yr threshold set by the International Commission for Radiological Protection (ICRP) for public exposure. Thus, indicating that the community is at risk of exposure to high radiation dose resulting from artisanal gold mining activities. In reducing radiation emissions and their resulting harm to the community, Sabo recommended

the adoption of strict regulations and enforcement of mining policies such as at 2007 Minerals and Mining Act that formally disallowed illegal exploration and/or exploitation of Minerals[86].

Saïdou (2019) investigated natural radiation exposure and its health effects in mining and ore bearing regions of Cameroon from 2014 to 2017. Air kerma rates were measured using carborne survey method. The air kerma rate range between 25–102, 28–71, 23–80 and 34–102 nGy/h in Poli, Lolodorf, Betare-Oya and Douala. The corresponding mean air kerma rate was 57, 47, 44 and 65 nGy/h respectively in the aforementioned regions. The average value of in Poli and Douala city were found to be equal and higher than the world average value of 57 nGy/h given by UNSCEAR (2000). In-situ gamma spectrometry was used to determine activity concentrations of 238U, 232Th and 40K in soil. The highest activity concentrations of 238U, 232Th and 40K were found in the uranium and thorium bearing region of Lolodorf[87]. According to Saïdou (2019), natural radioactivity level seems to be normal in most of the surveyed areas. However, there are many points where activity concentrations of natural radionuclides are largely above the world average values. Natural radioactivity at separate locations of the uranium-rich zones of Lambapur- Peddagattu and Seripally areas in Telangana state, India were assessed by Raghavendra. (2019. The average activity concentrations of 48.07±22.30, 230.77±89.26 and 807.08±255.87 Bq/kg were observed for 238U, 234Th, and 40K in the soil respectively. The annual effective dose was realized to be comparable with similar studies in India and the several regions of the globe. Published results reviewed have shown an uneven distribution of NORM across different regions with several values recorded below globally estimated averages. Such results indicate insignificant amount of the specified radionuclides while those above the global

average indicated significant deposits of radionuclides in the observed region. Values for radiological parameters above threshold values stipulated by the UNSCEAR (2000) imply radiological implications of artisanal gold mining and other human activities occurring in the said region. Thus, signifying the need for environmental monitoring, regulation and control because exposure to radiations, no matter how small the doses are, poses radiological risks to man and the environment. This review also buttresses the need for evaluations to assess the radiological impact of artisanal gold mining in regions where radiological parameters have not been measured[67],

2.4 Conceptual framework (model)

2.4.1 Ionization Energy

Ionization energy, also called ionization potential, is the energy necessary to remove an electron from the neutral atom.

$X + \text{energy} \rightarrow X^+ + e^-$ where X is any atom or molecule capable of being ionized, X^+ is that atom or molecule with an electron removed (positive ion), and e^- is the removed electron.

A nitrogen atom, for example, requires the following ionization energy to remove the outermost electron.

$N + IE \rightarrow N^+ + e^-$ IE = 14.5 eV

The ionization energy associated with removal of the first electron is most commonly used. The *n*th ionization energy refers to the amount of energy required to remove an electron from the species with a charge of (*n*-1).

1st ionization energy

$X \rightarrow X^+ + e^-$

2nd ionization energy

$X^{+} \rightarrow X^{2+} + e^{-}$

3rd ionization energy

$X^{2+} \rightarrow X^{3+} + e^{-}$

Ionization Energy for different Elements[68]

There is an ionization energy for each successive electron removed. The electrons that circle the nucleus move in fairly well-defined orbits. Some of these electrons are more tightly bound in the atom than others. For example, only 7.38 eV is required to remove the outermost electron from a lead atom, while 88,000 eV is required to remove the innermost electron.

In general, the ionization energy increases moving up a group and moving left to right across a period. Moreover:

- Ionization energy is lowest for the alkali metals which have a single electron outside a closed shell.
- Ionization energy increases across a row on the periodic maximum for the noble gases which have closed shells
- Most people fear ionizing radiation. Certainly it can cause death if we are exposed to too much, and the most recent symbol for it makes it clear to stay away from it. However, ionizing radiation, like many things, is not bad unless a living organism is exposed to too much of it.

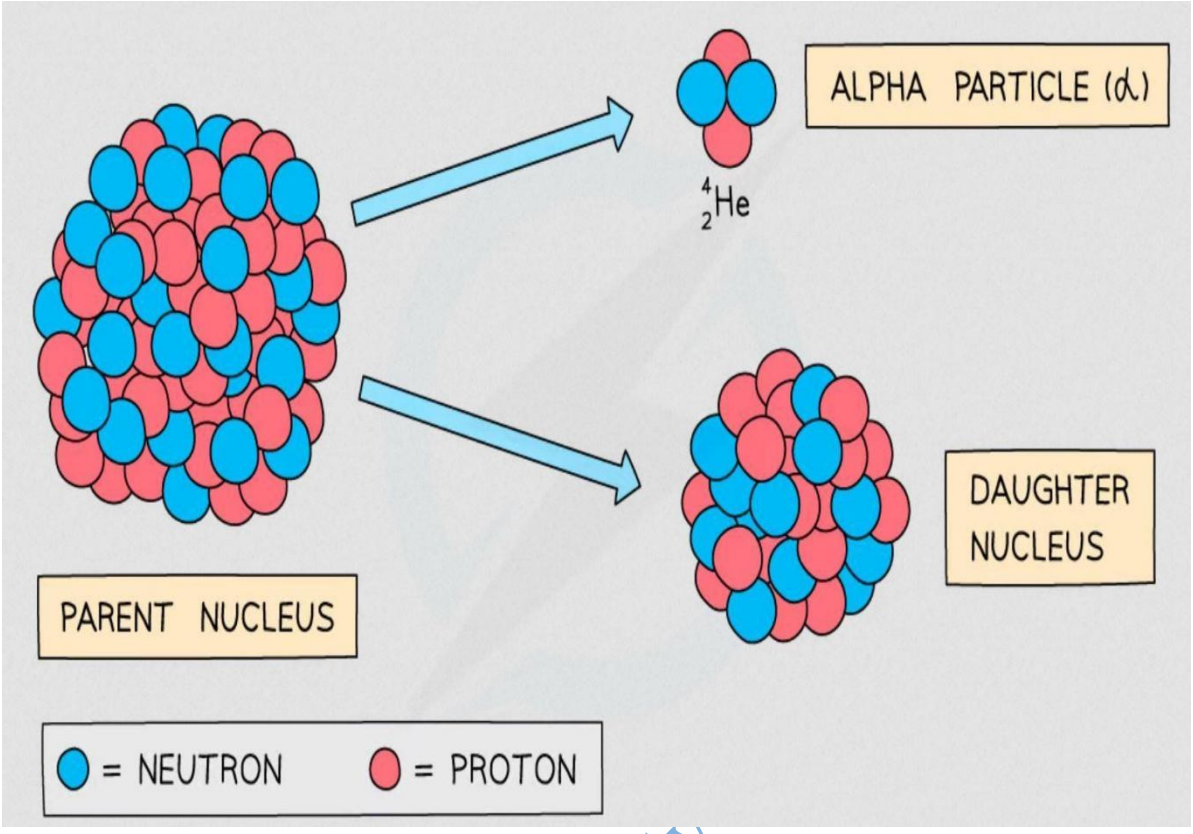
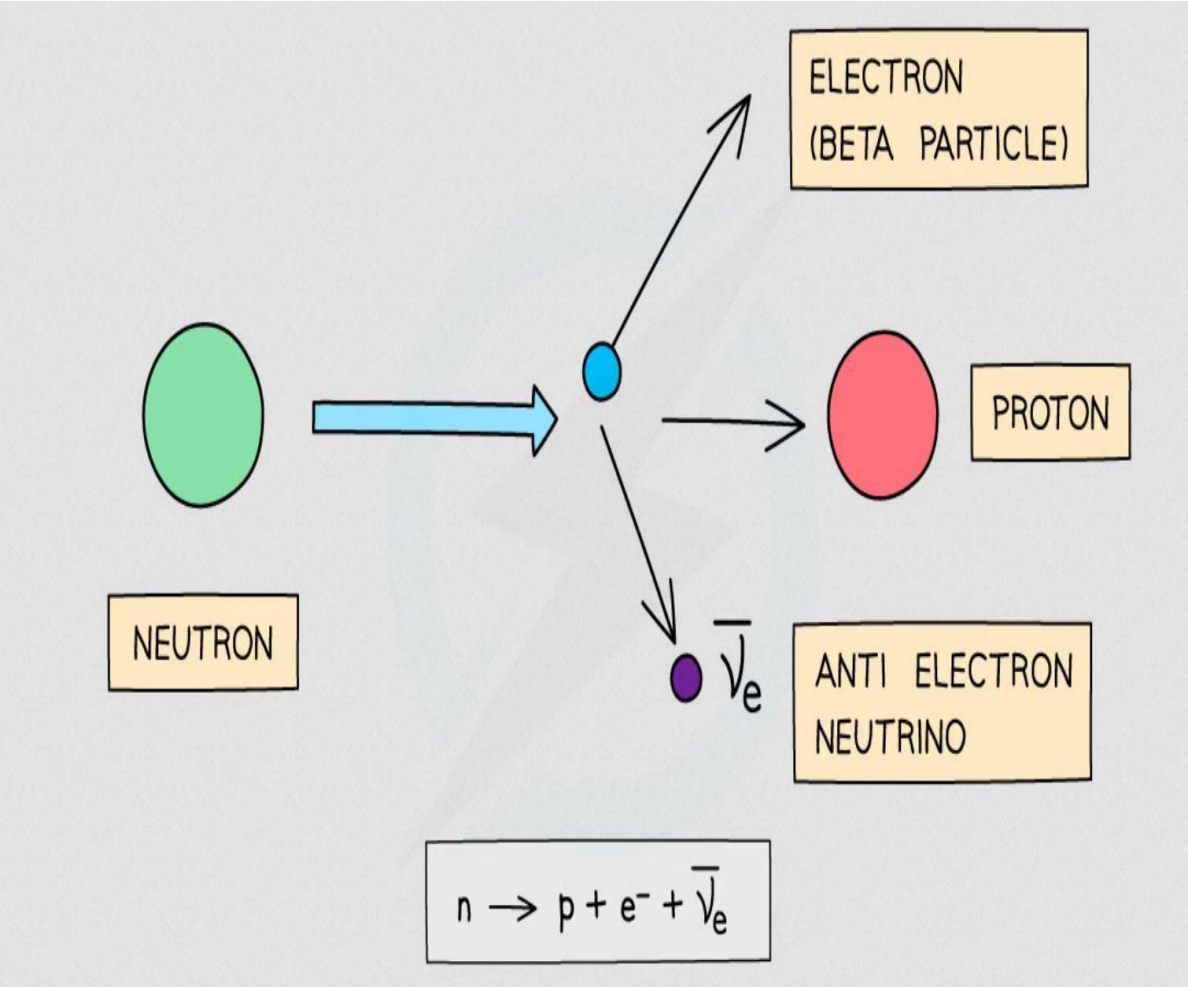


Figure: 2.1: Alpha decay: Alpha decay: a nucleus ejects an alpha particle (Helium Nuclide) which is identical to an ionized helium nucleus.

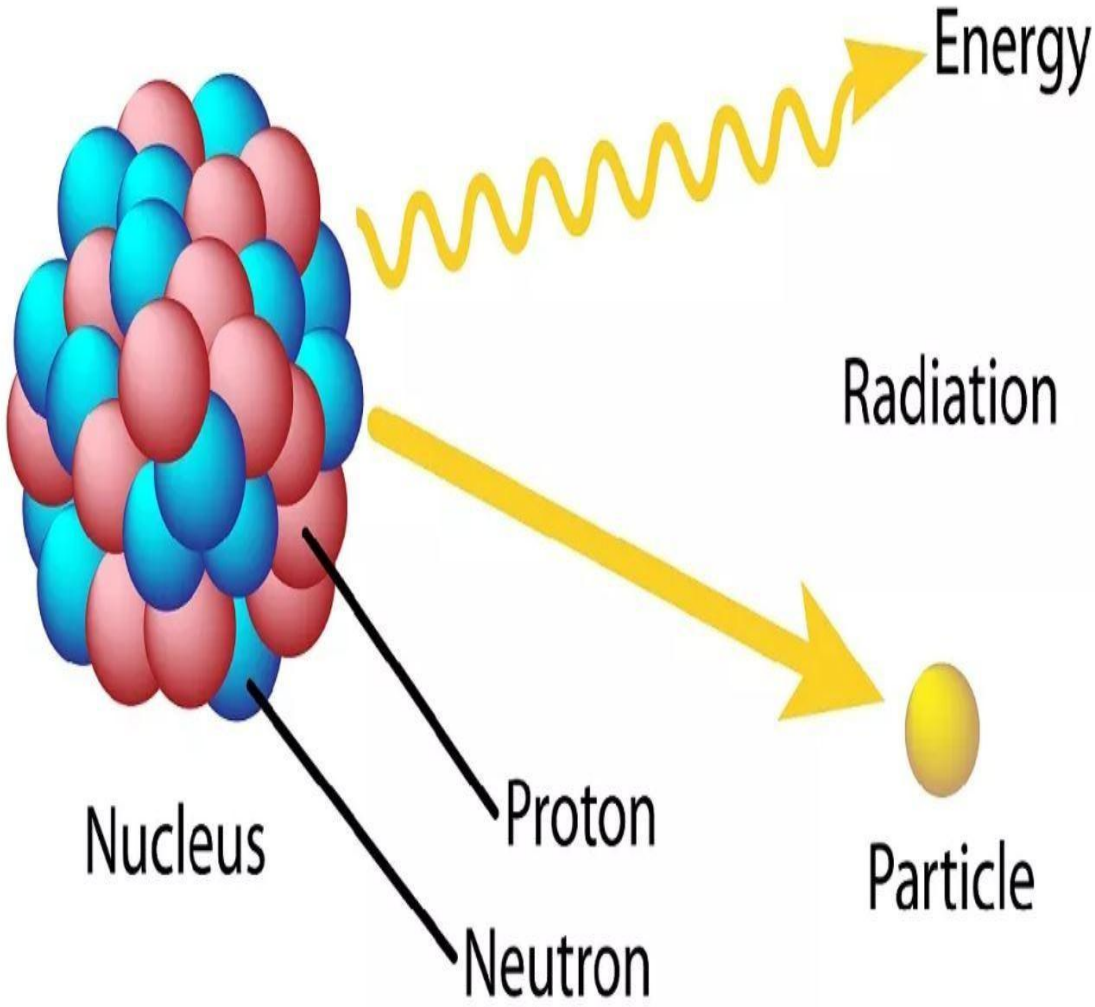
Source: Ashika Vijay http://www.savemyexams.com/gcse/physics_combined-science/aqa/18/revision-notes/4atomic-structure/4-2-atoms--nuclear-radiation/4-2-4-alpha-decay/ (updated: 2022)



Beta Decay: Transformation of a nucleon to another type within the nucleus and emission of beta particles

Source: Ashika Vijay

https://www.savemyexams.com/gcse/physics/edexcel/18/revision-notes/6-radioactivity/6-2radioactive-decay/6-2-5-beta-decay/ (updated: 2022)



Radioactive Decay

Source: Robert Hazen https:// https://www.wondriumdaily.com/radioactive-decay-kinds-and-properties/ (updated: 2021)

Beta minus decay happens when a neutron within an atom's nucleus transforms into a proton tron and an antineutrino are ejected out of the nucleus of an atom. For a beta plus decay a proton transforms to a neutron and a positron (similar to an electron but with a positive charge) and a neutrino are ejected out of the nucleus.

Ionizing radiation is any type of particle or electromagnetic wave that carries enough energy to ionize or remove electrons from an atom. There are two types of electromagnetic waves that can ionize atoms: X-rays and gamma-rays, and sometimes they have the same energy. Gamma radiation is produced by interactions within the nucleus, while X-rays are produced outside of the nucleus by electrons. There are officially two types of ionizing radiation that are energetic particles emitted during an interaction within the nucleus. The alpha particle is composed of two protons and two neutrons, or a helium nucleus. The beta particle is either a positron or an electron. Neutrons emitted during some nuclear decay processes are often included as ionizing particles but they do not actually ionize an atom directly. Neutrons interact with another nucleus, which may result in a secondary process involving ionizing radiation[74].

The word "radiation" arises from the phenomenon of waves *radiating* (i.e. traveling outward in all directions) from a source. This aspect leads to a system of measurements and physical units that are applicable to all types of radiation. Because such radiation distributes itself as it permeates through space, and as its energy is conserved (in vacuum), the intensity of the radiation from a point source follows an inverse-square law in relation to the distance from its source. Like any ideal law, the inverse-square law approximates a measured radiation intensity to the extent that the source approximates a geometric point.

The Ionized Atom

- Radioactive atoms have unstable blends of protons and neutrons.
- Radioactivity is the spontaneous release of energy from an unstable atom to get to a more stable state.
- Ionizing Radiation is the energy that comes out of a radioactive atom.

- Radioactive isotopes are radioactive atoms of the same element that have different numbers of neutrons.

Properties of Radioactive Isotopes

- Radioactive atoms can give off four types of ionizing radiation: alpha particles, beta particles, gamma rays, and neutrons.
- Each type of radiation has different properties that affect how we can detect it and how it can affect us.
- Radioactive decay happens when an unstable atom gives off radiation and changes into a more stable atom of a different element.
- The length of time it takes for half of the radioactive atoms in a group of radioactive isotopes to decay is called a half-life[75].

2.4.2 Radioactive Decay

There are three types of radioactive decays in nature:

- *α-decay* –a helium nucleus ($^4_2$He) is emitted
- *β-decay* – where electrons or positrons (*particles with the same mass as an electron, but with a charge exactly opposite to that of an electron*) are emitted;
- *γ-decay* – high energy (hundreds of keV or more) photons are emitted[76].

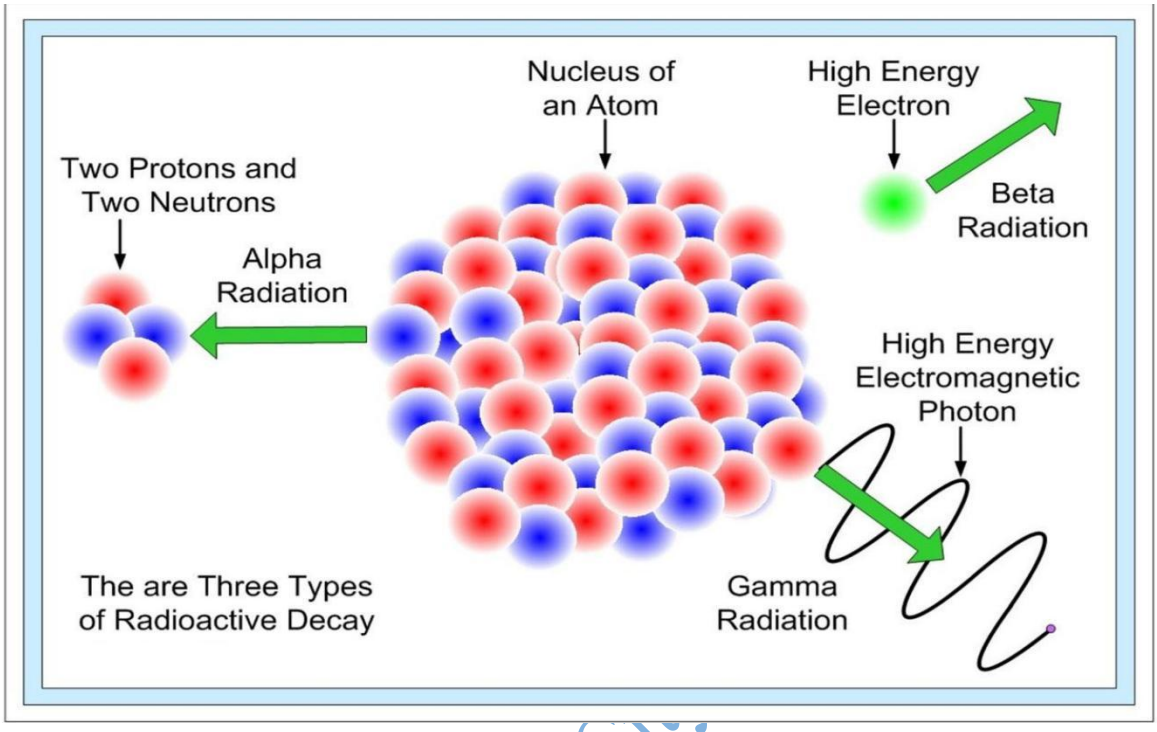


Figure: 2.4 physics current radiation decay Source:
Haygot Technologies, Ltd.
https:// www.Toppr.com / guides / physics current radiation decay.com (Updated: 2020)

Endnotes

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Chapter Three

Methodology

3.1 Material

1 Polythine bags

2 Spring balance

3 Meter rule

4 GPS

5 Cutlass

6 Hand trowel

3.2 Sample Collection

A total of twenty (20) sampling gridss of 3 by 4 m^2 each were mapped within each mining pitch locations (ESS1 to ESS20) were randomly taken for the analysis (Figure 3.2 to figure 3.7). This was carried out in order to assess the radiation risks of mining sites' exposure to natural radioactivity in Paago village Iseyin Central Local Government, Oyo State Nigeria.

In each pitch, soil samples were collected. The samples were then thoroughly mixed, packed in polythene bags and labeled to form a representative sample. The procedure was repeated for all the pitches in each of the mining sites considered for this research[33].

The result obtained is expected to reveal the radionuclide dispersions in the area and be used for further hazards' evaluation. In respect of this, the samples collected were dried under ambient temperature for number of weeks, and sieved by a 2 mm mesh to remove larger objects.

The samples were then transported to International Institution of Tropical and Agriculture (IITA) Laboratory in Ibadan for further processing and preparation before spectrometry analysis. i.e Inductively Coupled Plasma Mass Spectrometry (ICP-MS)

Moreover, **Figure: 3.1** is a study area and where all sample point were collected; and **Figure 3.2 to figure 3.7** were randomly taken for the analysis

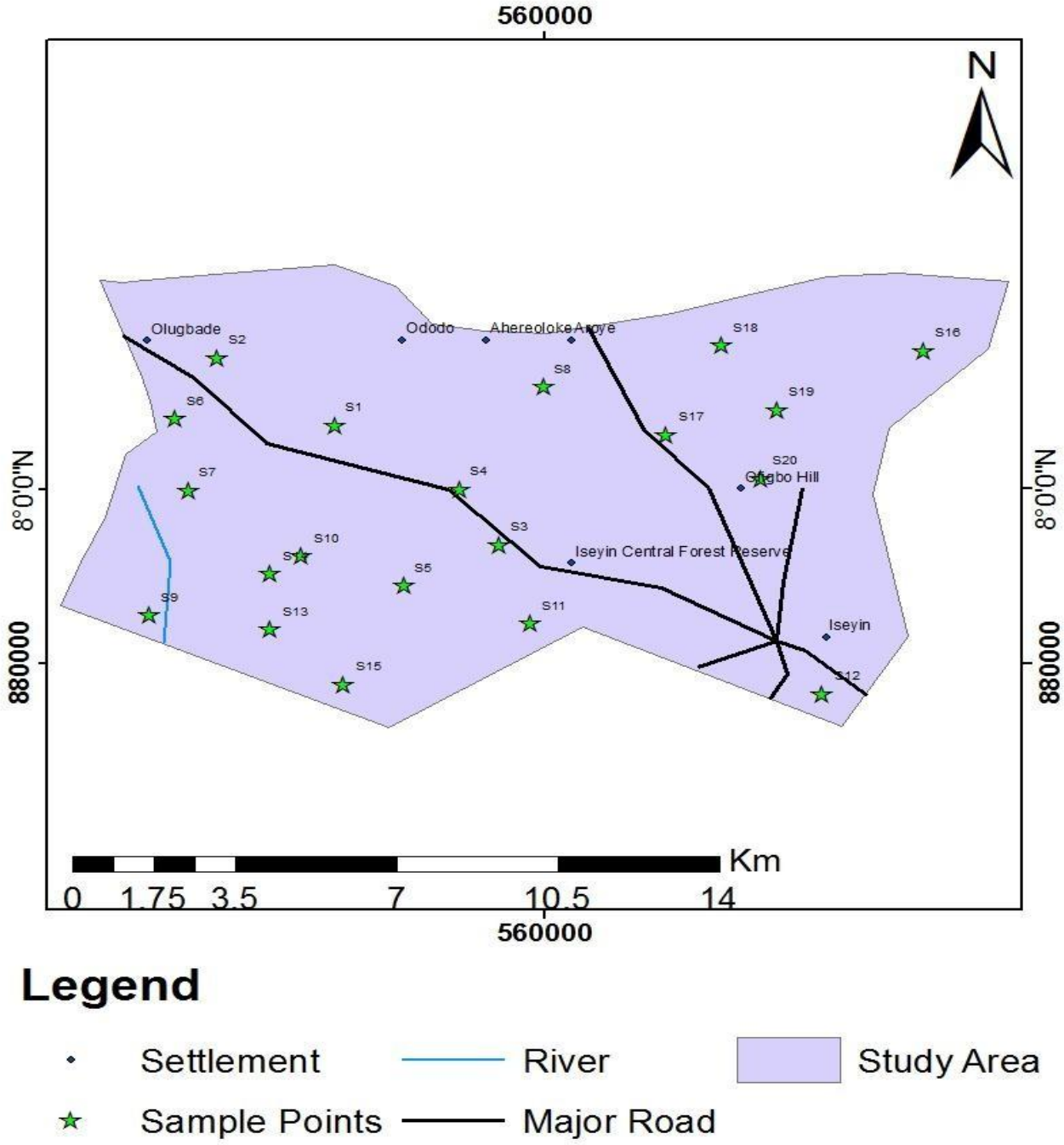


Figure 3.1. Map showing the sample points

Source: Researcher 2022

3.3 Sample Preparation

The soil-garbage samples were oven dried at a steady temperature of 110^0C for 6 hours to remove all the moisture and to ensure a constant mass for all the samples. The oven dried samples were pulverized, sieved with a 2mm sieve to attain the same matrix , Each samples was packed into a plastic sock and it was taken to International Institution of Agriculture IITA Laboratory in Ibadan where Inductively Coupled Plasma Mass Spectrometry (ICP-MS) will be used to determine the concentrations. Then 200 g each of the samples were weighed, packed into a clean and radon- impermeable plastic container of uniform size and sealed for a period of about 30 days to allow for secular equilibrium between ^{226}Ra and ^{228}Ra and their respective gaseous progenies prior to gamma spectroscopy. The standard reference soil sample was also packed into a container of the same geometric configuration to determine the background radiation.

3.3.1 Sample Preparation for Radioactivity Measurements

Each soil sample was crushed, pulverized and homogenized. The sample was then dried and sieved with a <0.16mm mesh-size before dried in an electric temperature-controlled furnace at 110^0C temperature for 4 hours to remove moisture (if any).

200g each of the dried samples was carefully weighed using an electronic balance with a sensitivity of 0.01mg into a gas-tight radon Impermeable, cylindrical polyethylene container of 2cm uniform base diameter and sealed. The container was substantially fit to sit on the 2cm x 2cm Nal(TI) detector used for the study. Each sample was packed into a plastic sock and it was taken to International Institution of Tropical and Agriculture (IITA) Laboratory in Ibadan Oyo State for analysis.

The analysis was carried out in International Institute of Tropical and Agricultural which is one of the International Geochemical Laboratories to Geoscientists world-class geochemical and assaying laboratories to geoscientists. Inductively Coupled Plasma Mass Spectrometry (ICP-MS) was used to determine the concentrations of radionuclides (^{238}U and ^{232}Th) and potassium (^{40}K) in the samples. ICP-MS is one of the techniques used for radionuclide and elemental analysis either solid or liquid samples. The detection limit of ICP-MS for ^{238}U, ^{232}Th and ^{40}K are 0,05ppm, 0,1ppm and 0,01% respectively[1]

The samples were dried at 110^0C in the oven to constant weight and further grounded to a powder. After grinding of each sample, high pressure compressor air with nozzle was used to blow the remnant from the grinder in order to avoid cross-contamination. The samples were digested and were transferred to Teflon beakers for evaporation using a hot plate. The residues were dissolved in 10% HNO_3 for fifteen minutes to ensure complete digestion, which was finally dissolved in 100ml of HNO^3. The certified soil reference material (calibration standard) was digested with the same proportion of HNO^3 for quality control analysis. Prior to the ICP-MS analyses, standard solutions were prepared from SPEX Multi-element Plasma Standard in order to obtain the calibration curves for the analyses. Each sample was analyzed thrice to monitor the reproducibility of each result, which is in line with the standard procedures highlighted [2].

The concentrations of potassium, uranium and thorium in each soil sample were given in percent (%) and parts per million (ppm) respectively. Eqs. (X_1) to (X_3) were further used to covert respective concentration to Becquerel per kilogram (Bq kg^{-1}) in accordance with models[3]. The activity concentrations' results from Acme Labs (in % and ppm) and the

converted results (in Bq kg^{-1}) by Adagunodo 2021b are revealed below:

1% of ^{40}K = 313 Bq kg^{-1} …… (x_1)

1ppm of ^{238}U= 12,35 Bq kg^{-1} ……..(x_2)

1ppm of ^{232}Th = 4,06 Bq kg^{-1} ……..(x_3)

3.4 Radiation Detection

The presence of radiation in the environment can be detected through radiation detecting devices[3]. However, no single device can do all kinds of radiation, specification of each device is based on the types of radiation, the ranges of radiation energy (KeV or MeV) and counts per unit time (minutes, hours or seconds). Analysis of radionuclides in a given material is usually performed by the well-established method of gamma-ray spectrometry (IAEA, 1989). Nal(TI) scintillation detector and germanium detectors has poor resolution compared to ICP OES or ICP-MS detectors, but ICP-EOS is preferable in the analysis of natural radionuclide in soil samples due to their relatively higher efficiency and it works under room temperature conditions[4].

3.5 Inductively coupled plasma - optical emission spectrometry

ICP-OES equipment

It has been since 25 years ago ICP optical emission spectrophotometers (ICP-OES) began to be widely used, and is now one of the most versatile methods of inorganic analysis. Its features are often compared to atomic absorption spectrophotometers. In which the excitation temperature of air-acetylene flame measures 2000 to 3000 K, the excitation temperature of argon ICP is 5000 to 7000 K, which efficiently excites many elements. Also, using inert gas (argon) makes oxides and nitrides harder to be generated[5].

ICP-OES (Inductively coupled plasma - optical emission spectrometry) is a technique in which the composition of elements in (mostly water-dissolved) samples can be determined using plasma and a spectrometer. The technique has been commercially available since 1974 and thanks to its reliability, multi-element options and high throughput; it has become a widely applied in both routine research as in more specific analysis purposes[5].

The GI and the spin-off company B-WARE having two ICP-OES systems; iCAP 6000 (Thermo Fischer Scientific, Bremen, Germany), and the high-end system ARCOS (Spectro Analytical, Kleve, Germany) ICP, abbreviation for Inductively Coupled Plasma, is one method of optical emission spectrometry. When plasma energy is given to an analysis sample from outside, the component elements (atoms) are excited. When the excited atoms return to low energy position, emission rays (spectrum rays) are released and the emission rays that correspond to the photon wavelength are measured. The element type is determined based on the position of the photon rays, and the content of each element is determined based on the rays' intensity[6].

To generate plasma, first, argon gas is supplied to torch coil, and high frequency electric current is applied to the work coil at the tip of the torch tube. Using the electromagnetic field created in the torch tube by the high frequency current, argon gas is ionized and plasma is generated. This plasma has high electron density and temperature (10000K) and this energy is used in the excitation-emission of the sample. Solution samples are introduced into the plasma in an atomized state through the narrow tube in the centre of the torch tube[6].

3.6 Principle of Inductively coupled plasma - optical emission spectrometry

The solution to analyze is conducted by a peristaltic pump though a nebulizer into a spray chamber. The produced aerosol is lead into an argon plasma. Plasma is the forth state of

matter, next to the solid, liquid and gaseous state. In the ICP-OES the plasma is generated at the end of a quarts torch by a cooled induction coil through which a high frequency alternate current flows. As a consequence, an alternate magnetic field is induced which accelerated electrons into a circular trajectory[7]. Due to collision between the argon atom and the electrons ionization occurs, giving rise to stable plasma. The plasma is extremely hot, 6000-7000 K. In the induction zone it can even reach 10000 K. In the torch desolvation, atomization and ionizations of the sample takes place. Due to the thermal energy taken up by the electrons, they reach a higher "excited" state. When the electrons drop back to ground level energy is liberated as light (photons). Each element has an own characteristic emission spectrum that is measured with a spectrometer. The light intensity on the wavelength is measured and with the calibration calculated into a concentration[7].

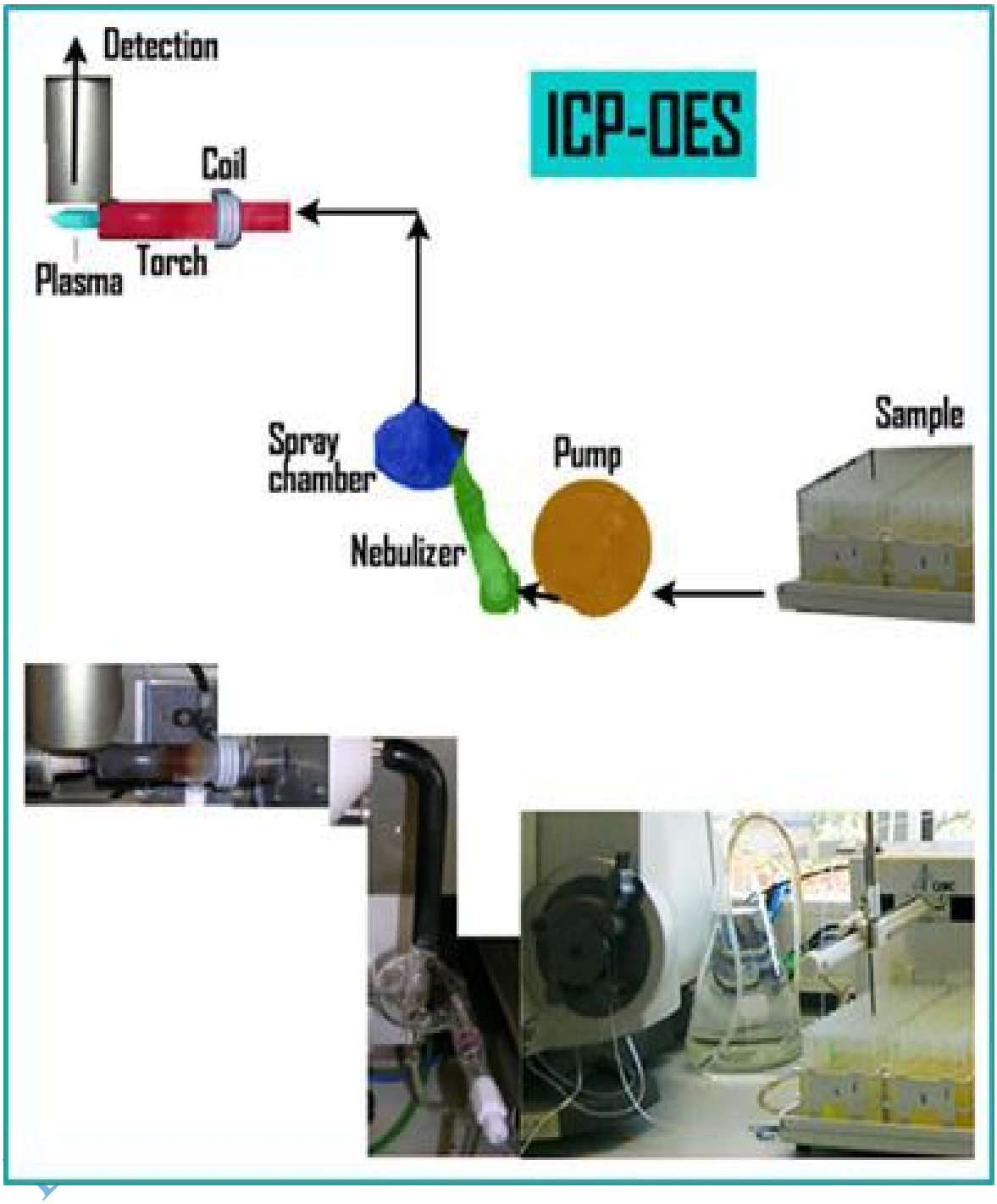


Figure: 3.7 ICP Optical Emission Spectrometry Principle file:///views/ru-baseline/images/backgrounds/opac-60.png

3.6.1 ICP Optical Emission Spectrometry Principle

ICP, abbreviation for Inductively Coupled Plasma (figure3.7), is one of the methods of optical emission spectrometry. When plasma energy is given to an analysis sample from outside, the component elements (atoms) are excited. When the excited atoms return to low energy position, emission rays (spectrum rays) are released and the emission rays that correspond to the photon wavelength are measured. The element type is determined based on the position of the photon rays, and the content of each element is determined based on the rays' intensity[8].

To generate plasma, first, argon gas is supplied to torch coil, and high frequency electric current is applied to the work coil at the tip of the torch tube. Using the electromagnetic field created in the torch tube by the high frequency current, argon gas is ionized and plasma is generated. This plasma has high electron density and temperature (10000K) and this energy is used in the excitation-emission of the sample. Solution samples are introduced into the plasma in an atomized state through the narrow tube in the center of the torch tube[8].

3.7 ICP - OES Calibration

Calibrate the ICP – Spec machine with standard reference solution of known concentrations to prepare a CALIBRATION STANDARD CURVE. The blank is run first saved, then all the Calibrating Stds would be run. ICP –Spectroscopy is a comparative or relative analytical method. The composition of a sample can only be calculated by comparing the emitted intensities to the intensities emitted from a sample of known concentration, called a Calibration Standard. A calibration curve is a mathematical expression that relates measured intensities to a set of known concs.

Standardization is process of analyzing many standards in order to acquire data to establish relationship between intensity and concentration. A standard is a material of known concentration or composition that closely resembles the sample to be analyzed in both chemical and physical nature[9].

A standard is also a sample which contains known quantities of elements comprising it. Standards are used to standardize the spectrometer before analyzing unknown samples. Examples are NIST Stds like Corn Bran, (NIST 8433), Apple Leaves (NIST 1568a), Soft Wheat Flour (NIST 8438), Tobacco Leaves (ASPAC 62), Wheat Grain (ASPAC 64)[9].

3.7.1 Preliminary Characterization and Optimization

An electrospray/inductively coupled plasma dual-source time-of-flight mass spectrometer for rapid metallomic and speciation analysis: instrument design

Initial characterization and optimization of the instrument were performed by using DC glow discharges based upon the cell design described by McClenathan and Hieftje.[64] Two glow discharge cells were operated in place of the ICP and ESI sources to demonstrate that a single set of reflection parameters served for both channels (.Fig. 3.7). The long-term stability of the glow discharge sources permitted the identification and eventual elimination of noise sources not related to the ionization source (e.g. interference noise pickup, turbomolecular pump electronic noise, and electronic crosstalk between the two channels) without a significant change in signal level[10].

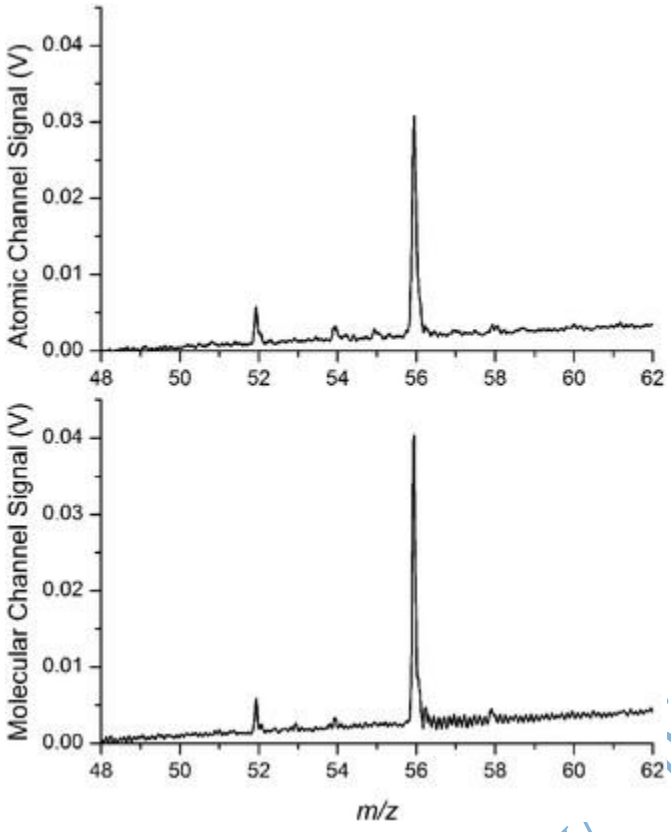


Figure 3.8: Simultaneous dual dc-glow discharge mass spectra

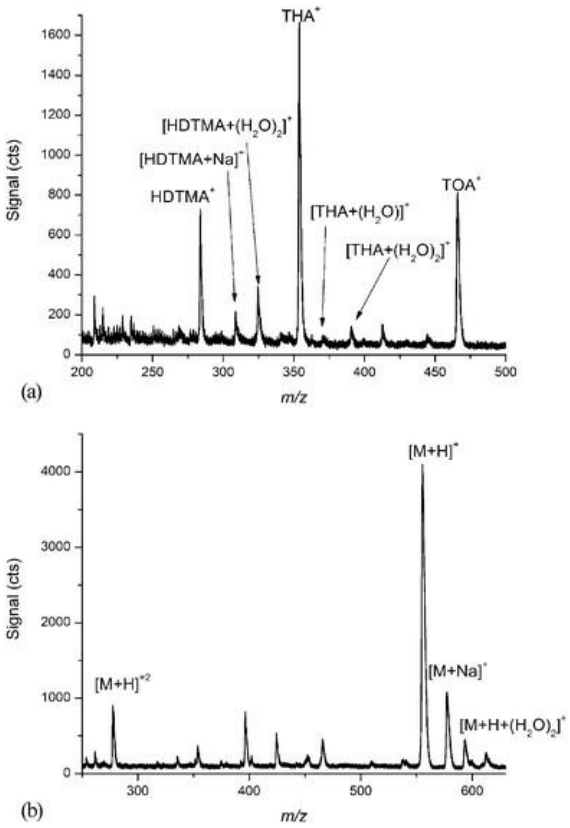
https://pubs.rsc.org/image/article/2009/MT/b816732j/b816732j-f7.gif[11]

Simultaneous dual dc-glow discharge mass spectra of iron isotopes from a stainless steel sample (Fig. 3.8). The top spectrum is taken from the atomic channel and the lower spectrum from the molecular channel[11].

During the initial characterization of the ESI interface, a flowing atmospheric-pressure after glow source was used for optical alignment and optimization. The benefit of this source over a low pressure glow discharge is that it operates at atmospheric pressure at temperatures of less than 500 K, so ion energies are similar to those in the ESI source but with greater ion flux[11].

Preliminary characterization of each source (ESI and ICP) was carried out with the other source off. Characterization of both sources during simultaneous operation will be the focus of the next publication in this series. The objective for characterizing the ESI source in this part of the work was to confirm that a variety of intact molecular ions could be produced over a wide mass range. Alkyl-ammonia salts have been demonstrated to serve as effective mass standards for positive-ion. Alkyl-ammonia salts are available over a wide range of masses and typically retain only a single charge, which makes them convenient for optimization and mass calibration. However, the high sensitivity of ESI for these compounds produces substantial memory effects; the residual signal often lingers for months[11].

Fig. 3.9a shows an ESI mass spectrum containing hexadecyltrimethylammonium, tetrahexylammonium , and tetraethylammonium (TOA, 467 Da) (Sigma Aldrich, St. Louis, MO, USA). All of these compounds produced singly charged states along with a series of expected adducts (i.e. Na, H_2O. Fig. 3.9b shows an ESI mass spectrum of leucine enkephalin (YGGFL, 556 Da) (Sigma Aldrich, St. Louis, MO, USA), principally containing the singly charged molecular ion. A small fraction of the doubly charged molecular ion is also observed, along with matrix adducts.



https://pubs.rsc.org/image/article/2009/MT/b816732j/b816732j-f8.gif[12]

Fig.3.9(a&b) Characteristic ESI mass spectrum

Characteristic ESI mass spectrum of hexadecyltrimethylammonium (HDTMA, 285 Da), tetrahexylammonium (THA, 355 Da), and tetraoctylammonium (TOA, 467 Da) fig.3.9 (b) Characteristic ESI mass spectrum of Leucine Enkephalin (556 Da) showing mainly the singly charged molecular ion[12].

An ICP mass spectrum of a multi-elemental solution, shown in Fig. 3.10, covers full elemental mass coverage from $^{6}Li^{+}$ to $^{238}U^{+}$. This particular multi-elemental solution contains most of the common metals discussed in the speciation literature (i.e. Cr, Se, and As)[12]

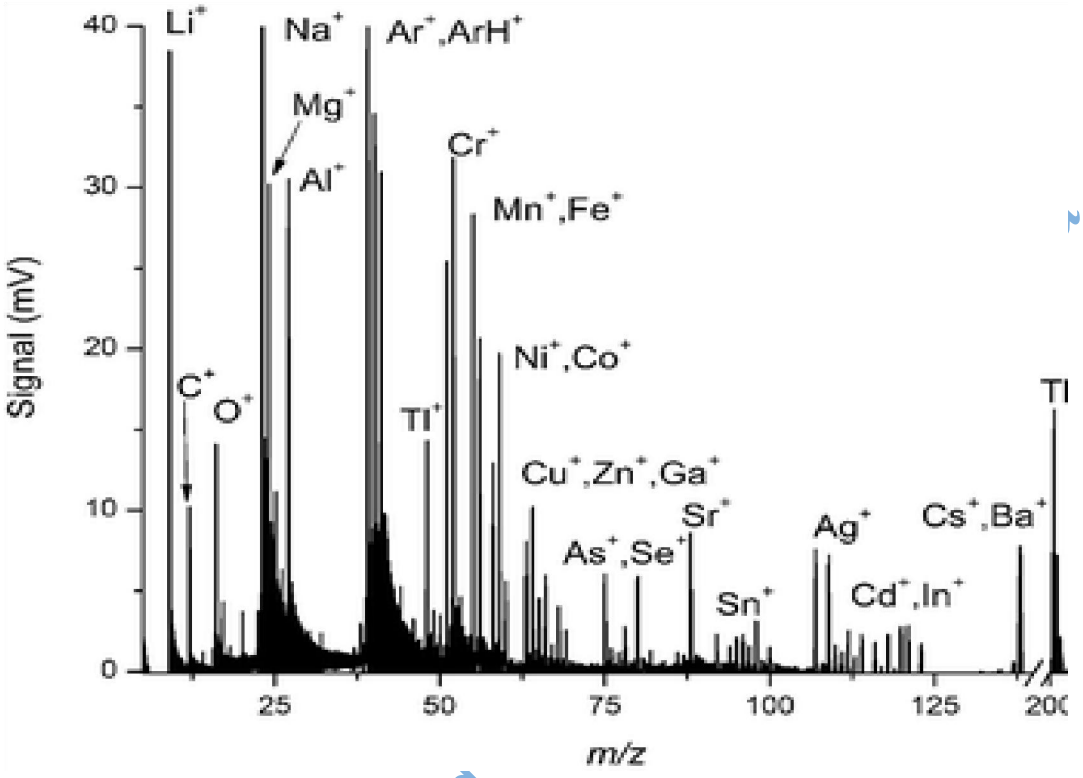


Fig. 3.10 Characteristic ICP mass spectrum of a multi-elemental solution

https://pubs.rsc.org/image/article/2009/MT/b816732j/b816732j-f9.gif[13]

Characteristic ICP mass spectrum of a multi-elemental solution (Fig.3.10), illustrating the full mass range capabilities from $^{6}Li^{+}$ to $^{238}U^{+}$.

Resolution as high as 1500 FWHM was obtained for $^{208}Pb^{+}$ on the ICP channel. As shown in Fig. 3.10 such resolving power is sufficient to provide baseline separation of the individual isotopes of lead. Further work is necessary, though, to reach the target resolving power of 2000[13].

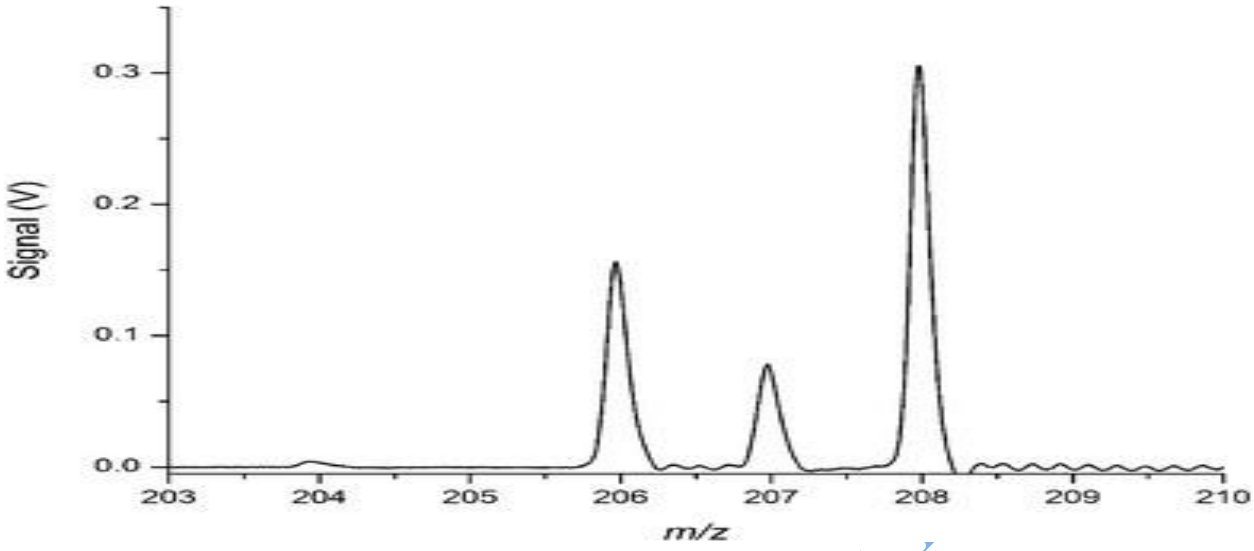


Figure 3.11 Characteristic ICP mass spectrum illustrating resolving power https://pubs.rsc.org/image/article/2009/MT/b816732j/b816732j-f10.gif[13]

Fig. 3.11 is the Characteristic ICP mass spectrum illustrating resolving power of 1500 (FWHM) for $^{208}Pb^{+}$, which is sufficient for baseline resolution of the major lead isotopes[13].

When both channels use identical electric fields from extraction to detection, a single set of reflectron potentials can be used for both of them. In Fig.3. 11 dc-glow discharge sources were used in place of the ESI and ICP sources. The resolution was determined for $^{208}Pb^{+}$ in a solder sample divided between the two GD sources. Both channels used −2200 V post acceleration and no energy discrimination. As Fig. 3.11 demonstrates, the resolution for both channels is optimal under the same set of reflectron conditions. One should not infer from Fig. 3. 11 that the ESI channel has a lower absolute resolving power than the ICP channel. Rather, the difference arises from the use of different focusing ion optics for the two channels, which were developed for different energy ranges and ion flux[13].

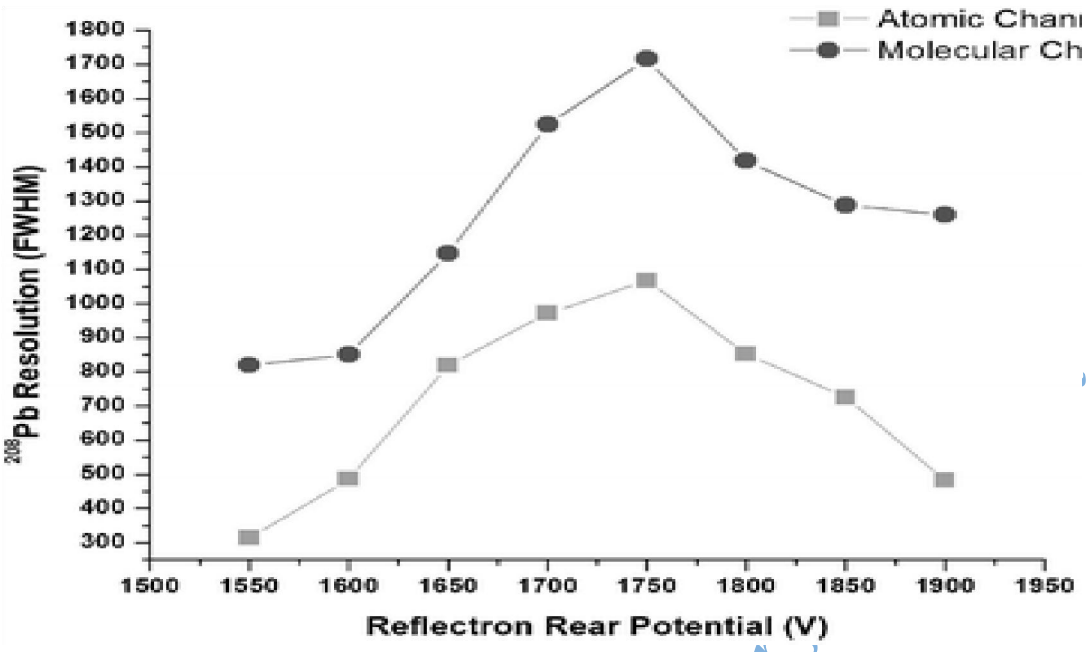


Figure 3.12: Optimization of the reflection potential in the single reflectron https://pubs.rsc.o /image/ article/2009/MT/ b816732j /b816732j-f11.gif[14]

Fig. 3.12 is the Optimization of the reflection potential in the single reflectron used for both channels while operating dc-glow discharge sources. The figure of merit is the resolution (FWHM) of $^{208}Pb^{+}$ produced from a solder sample. Both channels optimize under similar conditions showing that a single reflectron can be used for both channels[14].

While it was found that the use of energy discrimination and detector post acceleration did affect resolution, the difference in optimal reflectron potentials between the two channels was less than 15 V. Hence, a compromise between the optimized conditions for the two channels could be established without significant degradation of resolution on either channel. A dualsource time-of-flight mass spectrometer was designed and constructed to simultaneously produce elemental, isotopic, quantitative, and molecular information on metal-containing species. The described work focuses on the instrument design and on

experimental considerations in operating two sources simultaneously. Initial characterization of the instrument was carried out to optimize an electrospray source and an ICP source independently. Subsequent work will focus on characterization when the two sources are operated simultaneously. The flexible design of the instrument simplifies modification to optimize the energy bandpass of extracted ions and to produce fragment ions from the ESI source. Work is continuing to that end[14].

3.8 Radioactivity Measurements

The soil samples were analyzed using a well calibrated and shielded HPGE detector (Plate 3.2) coupled to a computer resident Quantum MCA 2100R multichannel analyzer (MCA) for 36,000 seconds. The MCA 2100R includes Quantum MCA software for qualitative analysis with all calibrations made through the software. The efficiency calibration of the detector was done using a reference standard mixed source traceable to analytical quality control services (AQCS, USA), which has the certified activities of the selected radionuclides and has a geometrical configuration identical to sample container. The standard sources contained ten uncommon radionuclides. The energy calibration was also performed by using the peaks of the radionuclide present in the standard sources. The channel scale was then converted to an energy scale because the channel number is proportional to energy. The 1460KeV gammaradiation of ^{40}K was used to determine the concentration of ^{40}K in the sample. The gamma transition energy of 1764.5KeV ^{214}Bi was used to determine the concentration of ^{238}U while the gamma transition energy of 2614KeV ^{208}TI was used to determine the concentration of ^{232}Th and gamma transition energy for ^{137}Cs was 661.6KeV[15]. Each soil sample container was placed on top of the detector housed

tightly inside a shield and counted for a period of 36000 seconds. Equation (3.1) shows the relationship between activity concentration and the count rate under the photo peak.

$$C \quad \frac{C_n}{I \, m_s} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3.1)$$

where C is the activity concentration of the radionuclide in the sample ($Bqkg^{-1}$); C_n is the count rate under the photo peak, ε is the detector efficiency at the specific γ-ray energy, I_γ is the absolute transition probability of specific γ-ray and M_s is the mass of the sample (kg). With the aid of the Quantum MCA software, the activity concentration of each sample was obtained. The detection limits (DL) of $21.3Bqkg^{-1}$, $9.1Bqkg^{-1}$ and $4.9Bqkg^{-1}$ for ^{40}K, ^{226}Ra and ^{232}Th respectively were also obtained. The values that were lower than the detection limits in the present study were considered as below detection limit (BDL) of the detector. One-half of the detection limits, DL value was considered for calculating the mean activity concentration and other radiological assessments whenever the concentration of any radionuclide was below the detection level[16].

3.9 Radiological Assessments of the soil samples

3.9.1 Outdoor Annual Effective Dose

Annual effective dose is used to assess potential long term effects that might occur in future due to exposure of the rocks samples by the public. To measure the annual effective doses, both indoors and outdoors, considerations must be made for the conversion coefficient from absorbed dose in air to effective dose and the indoor and outdoor occupancy factors respectively. The conversion coefficient, $0.7SvGy^{-1}$ was recommended by UNSCEAR for the conversion coefficient from absorbed dose in air to effective dose received by adults (UNSCEAR, 2000)[16]. The adults spend about 80% of their time indoors, while the

remaining 20% time is spent outdoors. Therefore, the indoor and outdoor occupancy factors were given as 0.8 and 0.2, respectively. Hence, the annual indoor and outdoor effective doses ($mSvyr^{-1}$)[16]

$$E_D \quad D_R nGh^{1} \quad 8760\,h \quad 0.2 \quad 0.7 \quad 10^{3} \qquad \ldots\ldots\ldots\ldots \quad (3.2)$$

where E_D is the effective dose, D_R is the dose rate in air, 8760 is the time in hour for one year,

0.2 is the outdoor occupancy factor and 0.7 in the indoor occupancy factor[19].

3.9.2 Outdoor absorbed dose rate

The quantity of absorbed dose is the amount of energy per unit mass absorbed by irradiated object. Absorbed dose is the energy responsible for damage in living organism. The absorbed dose rate at 1 m above the ground ($nGyh^{-1}$) is calculated using the expression[16].

$$DR\,(nGy/h) \quad 0.462\,A_{Ra} \quad 0.604\,A_{Ra} \quad 0.0417\,A_K \qquad \ldots\ldots\ldots\ldots\ldots\ldots \quad (3.3)$$

where D_R is the absorbed dose rate in $nGyh^{-1}$, A_{Ra}, A_{Th} and A_K are the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K, respectively. However, annual effective dose AED ($mSvy^{-1}$) to the public due to absorbed dose rate in air can be calculated by converting the total absorbed dose in ($nGyh^{-1}$) using 0.7 $SvGy^{-1}$ as conversion factor (CF) and multiplying by occupancy factor (OF) using equation 3.3.

$$AED \quad D_R \quad 0.2\,x24\,x365\,x0.7 \qquad \ldots\ldots\ldots\ldots\ldots\ldots \quad (3.4)$$

where D_R is the dose rate, 0.7 $SvGy^{-1}$ is the conversion factor for absorbed dose in air to external effective dose, and 0.2 represents the outdoor occupancy factor. This shows that the people in the study area spend approximately 20% of their time outdoors[17].

3.9.3 Radium Equivalent Activity (Ra_{eq})

The radium equivalent activity (Ra_{eq}) is used as a common index to compare the specific activities of samples. It provides a useful guideline in regulating the safety standards on radiation protection for the general public and obtained as the sum of the weighted activities of ^{226}Ra, ^{232}Th and ^{40}K based on the estimation that10 Bq kg^{-1} of ^{226}Ra, 7 Bq kg^{-1} of ^{232}Th and 130 Bq kg^{-1} of ^{40}K will deliver the same gamma dose rate. The radium equivalent was calculated through the use equation 3.5[16]

$$Ra_{eq} \quad C_{Ra} \quad 1.43\, C_{Th} \quad 0.077\, C_{K} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (3.5)$$

where C_{Ra}, C_{Th} and C_K are the activity concentrations (Bqkg^{-1}) of ^{226}Ra, ^{232}Th and ^{40}K, respectively[16].

3.9.4 External Radiation Hazard Index (H_{ex})

External hazard index (H_{ex}) is used to measure the external hazard due to the emitted natural gamma radiation[34]. The external hazard index, H_{ex} estimates the potential radiological hazard posed by the different rock samples for the external gamma dose of materials to 1.5 mGy/year. It is another criterion to assess the suitability of a material. A safety criterion for materials used for building construction is that $Hex \leq 1$ [16]. External hazard index is also calculated using equation 3.6.

$$H_{ex} \quad \frac{C_{Ra}}{} \quad \frac{C_{Th}}{} \quad \frac{C_{K}}{} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (3.6)$$

370 259 4810

Where CRa, C_{Th}, $C_{K\,are}$ the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K respectively.

3.9.5 Internal Radiation Hazard Index (H_{in})

In addition to the external hazard index, there is also a threat to the respiratory organs due to ^{222}Rn, the gaseous short-lived decay product of ^{226}Ra. The internal hazard index (Hin) is defined generally to reduce the maximum permissible concentration of ^{226}Ra to half the value appropriate for external exposure alone (Shiva *et al.*, 2008). Internal exposure to radon and its progeny products is quantified by estimating the internal hazard index[17].

$$H_{in} \quad \frac{C_{RA}}{} \; \frac{C_{Th}}{} \; \frac{C_K}{} \quad \text{..... (3.7) 185 259 4810}$$

Where C_{RA}, CTH, C_K are the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K respectively. If the maximum concentration of ^{226}Ra is one-half that of the normal acceptable limit, then H_{in} will be less than one. For safety precautions in the use of materials in the construction of dwellings, the criterion demands that $H_{in} \leq 1$.

3.9.6 Representative Gamma Index (I_γ)

The gamma index (I_γ) is used as screening tool for identifying materials that might be a threat to human health. The representative gamma index (Iγ) used to estimate the level of γ - radiation hazard associated with the natural radionuclides in specific investigated samples[18]. It is calculated using equation 3.8.

$$I \quad \frac{C_{RA}}{} \; \frac{C_{Th}}{} \; \frac{C_K}{} \quad \text{..... (3.8) 150 100 1500}$$

where C_{Ra}, C_{Th} and C_K, are the activity concentrations (Bqkg^{-1}) of ^{226}Ra, ^{232}Th and ^{40}k.respectively[18,19,20,21,22 ,23 ,24].

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Journal of radiation and nuclear application 6.(2), 2021,129-134.

Chapter Four

Results and Discussion of Findings

4.1 Results

4.1.1 Activity Concentration Natural Radionuclides in the soil samples

The natural activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K have been determined from the soil samples collected from mining sites around Paago area of Iseyin Local Government, Oyo

State, Nigeria and the results are presented in Table 4.1.

Table 4.1: Range and mean of absorbed dose and annual effective dose rates in soil samples from the study areas

Sampling Points	^{40}K(Bq\kg)	^{238}U(Bq\kg)	^{232}Th(Bq/kg)
SAMPLE NO 1	567.558	3.667	0.802
SAMPLE NO 2	333.461	2.154	0.471
SAMPLE NO 3	605.555	3.912	0.856
SAMPLE NO 4	414.815	2.680	0.586
SAMPLE NO 5	317.366	2.050	0.449
SAMPLE NO 6	523.002	3.379	0.739
SAMPLE NO 7	277.083	1.790	0.392
SAMPLE NO 8	459.429	2.968	0.649
SAMPLE NO 9	303.075	1.958	0.428
SAMPLE NO 10	478.503	3.092	0.676
SAMPLE NO 11	190.326	1.230	0.269
SAMPLE NO 12	356.254	2.302	0.504
SAMPLE NO 13	287.126	1.855	0.406
SAMPLE NO 14	529.207	3.419	0.748
SAMPLE NO 15	595.626	3.848	0.842
SAMPLE NO 16	483.518	3.124	0.684
SAMPLE NO 17	523.700	3.384	0.740
SAMPLE NO 18	353.649	2.285	0.500
SAMPLE NO 19	286.114	1.849	0.404
SAMPLE NO 20	313.335	2.024	0.443

Researcher: Oyegbemi Ezekiel 2022

4.1.2 Radiological Assessments Due to The Radionuclides in Soil Samples

Radiological hazard indices which include radium equivalent activity, internal radiation hazard index, external radiation hazard index and representative gamma index is presented in Table 4.3[35]. hazard indices were calculated using equation 3.1, 3.2, 3.3 and 3.5 respectively. The errors in the mean values are the standard deviations which are the spread across the measured values obtained for the samples.

4.1.3 Absorbed Dose Rate and Annual Effective Dose

The absorbed dose rate of soil samples from the study area was calculated using equation 3.2 and the results are represented in Table 4.3. The errors in the mean value and standard deviations obtained from the calculated absorbed dose rate values gotten.

Table 4.1 Range and mean activity concentrations of radionuclides in soil samples from the study area.

Table 4.2: Range and mean of absorbed dose and annual effective dose rates in soil samples from the study areas

Sampling Points	^{40}K(Bq\kg)	^{238}U(Bq\kg)	^{232}Th(Bq/kg)	Absorbed dose (nGyh^{-1})	Collective effective dose (µSvy^{-1})
SAMPLE NO 1	567.558	3.667	0.802	11.41	11.62
SAMPLE NO 2	333.461	2.154	0.471	17.09	20.10
SAMPLE NO 3	605.555	3.912	0.856	11.08	12.29
SAMPLE NO 4	414.815	2.680	0.586	13.03	14.24
SAMPLE NO 5	317.366	2.050	0.449	19.38	20.59
SAMPLE NO 6	523.002	3.379	0.739	14.89	16.10
SAMPLE NO 7	277.083	1.790	0.392	9.72	10.93
SAMPLE NO 8	459.429	2.968	0.649	13.48	14.69
SAMPLE NO 9	303.075	1.958	0.428	10.36	11.57
SAMPLE NO 10	478.503	3.092	0.676	5.64	6.85
SAMPLE NO 11	190.326	1.230	0.269	12.21	13.42
SAMPLE NO 12	356.254	2.302	0.504	8.16	9.37
SAMPLE NO 13	287.126	1.855	0.406	43.60	44.81
SAMPLE NO 14	529.207	3.419	0.748	31.02	32.23
SAMPLE NO 15	595.626	3.848	0.842	44.12	50.73
SAMPLE NO 16	483.518	3.124	0.684	39.40	40.65
SAMPLE NO 17	523.700	3.384	0.740	31.48	32.69
SAMPLE NO 18	353.649	2.285	0.500	18.72	19.93
SAMPLE NO 19	286.114	1.849	0.404	11.88	13.09
SAMPLE NO 20	313.335	2.024	0.443	11.49	12.70

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Table 4.3 The range and mean of radium equivalent, internal, external hazard and gamma representative indices in soil samples from the study areas

Samples	Iγ	Hin	Hex	Rae	ED
SAMPLE NO 1 ESS 1	0.41	0.14	1.66	48.52	771.85
SAMPLE NO 2 ESS 2	0.24	0.08	0.97	28.51	759.02
SAMPLE NO 3 ESS 3	0.44	0.15	1.77	51.76	773.93
SAMPLE NO 4 ESS 4	0.30	0.10	1.21	35.46	763.48
SAMPLE NO 5 ESS 5	0.23	0.08	0.93	27.13	758.14
SAMPLE NO 6 ESS 6	0.38	0.13	1.53	44.71	769.41
SAMPLE NO 7 ESS 7	0.20	0.07	0.81	23.69	755.93
SAMPLE NO 8 ESS 8	0.33	0.11	1.34	39.27	765.92
SAMPLE NO 9 ESS 9	0.22	0.08	0.88	25.91	757.35
SAMPLE NO 10 ESS 10	0.35	0.12	1.40	40.90	766.97
SAMPLE NO 11 ESS11	0.14	0.05	0.56	16.27	751.18
SAMPLE NO 12 ESS 12	0.26	0.09	1.04	30.45	760.27
SAMPLE NO 13 ESS 13	0.21	0.07	0.84	24.54	756.48
SAMPLE NO 14 ESS 14	0.38	0.13	1.54	45.24	769.75
SAMPLE NO 15 ESS 15	0.43	0.15	1.74	50.92	773.39
SAMPLE NO 16 ESS 16	0.35	0.12	1.41	41.33	767.24
SAMPLE NO 17 ESS 17	0.38	0.13	1.53	44.77	769.45
SAMPLE NO 18 ESS 18	0.26	0.09	1.03	30.23	760.13
SAMPLE NO 19 ESS 19	0.21	0.07	0.83	24.46	756.43
SAMPLE NO 20 ESS	0.23	0.08	0.91	26.78	757.92

4.2 Discussion of Findings

4.2.1 Activity concentration

The measured activity concentrations of ^{40}K, ^{238}U and ^{232}Th from the Table 4.1 ranged from 190.326 to 605.555Bqkg^{-1} for ^{40}K, 1.790 to 3.912Bqkg^{-1} for ^{238}U, and 0.269 to 0.802Bqkg^{-1} for ^{232}Th. The average value of 440.446±19.07Bqkg^{-1} was calculated for ^{40}K, 2.846±3.11Bqkg^{-1} for ^{238}U, and 0.623±3.10Bqkg^{-1} was obtained for ^{232}Th. The results from the present study showed that ^{40}K has the highest value of 605.555±1.1Bqkg^{-1} of the three radionuclides, the least activity concentration was found to be 0.269±0.1Bqkg^{-1} for ^{232}Th. The activity concentration of ^{40}K is highest in all the samples and the value is almost as the world average of 420Bq/kg for ^{40}K. The result obtained for ^{40}K indicated that the soil was not as a result of natural weathering of the earth crust rock but as result of decay, accumulation and sedimentation of materials[4]. However, the mean value of activity concentration obtained for ^{238}U was 8.58 ± 4.1Bqkg^{-1} the value is lower than the world average value. The highest value of ^{238}U in the soil sample 3.848Bqkg^{-1}. The lowest concentration for both ^{232}Th and ^{226}Ra radionuclides in soil were 1.849 and 0.269Bqkg^{-1} respectively. The variation occurs in the value obtained from soil may be as a result of several factor such as latitude of the area, geographical soil formation of the study area[1].

The results from the present study areas were compared with other peoples work from different parts of the world. Mean concentration of the primordial radionuclides in the study area compared to similar studies. According to the study conducted the mean activity concentrations of ^{40}K, ^{226}Ra and ^{232}Th were 157.1Bq/kg, 15.2Bq/kg and 26.9Bq/kg, these values for were higher than the result obtained in the present study except for ^{40}K. [24]reported

390.9Bq/kg, 2.39Bq/kg and 52.0Bq/kg, for ^{40}K, ^{226}Ra and ^{232}Th radionuclides respectively, these values were also higher than the results obtained in the present study only for ^{226}Ra which is three times higher worked on natural radioactivity of soil, the result obtained from the present study is compare with what was obtained by United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR)[1].

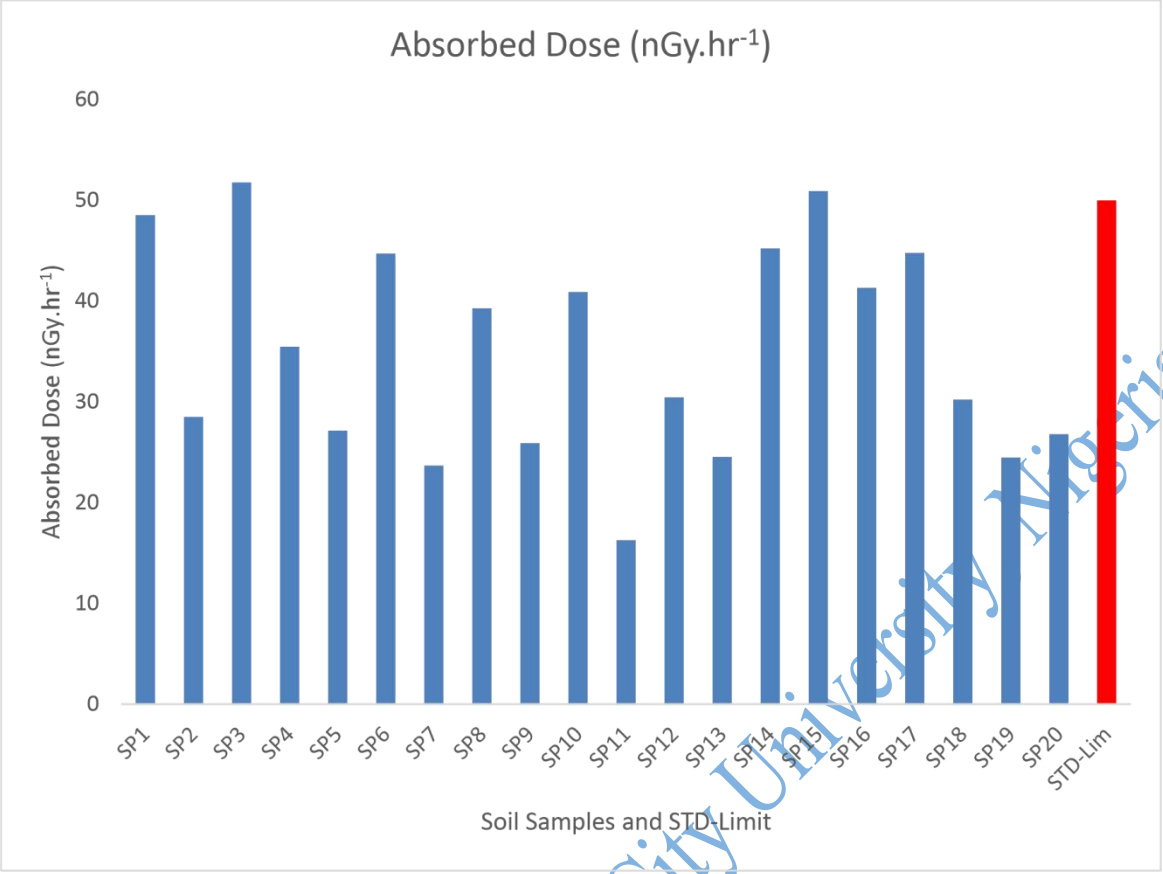

Figure 4.2: Mean activity concentrations of ^{40}K, ^{226}Ra and ^{232}Th radionuclides in soil samples collected from mining site pitch of paago Iseyin Local Government Oyo State Southwest Nigeria.
Bar chart consist of primary axis which scale is from 0.00 to 60.
Researcher: Oyegbemi Ezekiel 2022.
World Average Value: Absorb Dose = 50(nGyh-1)

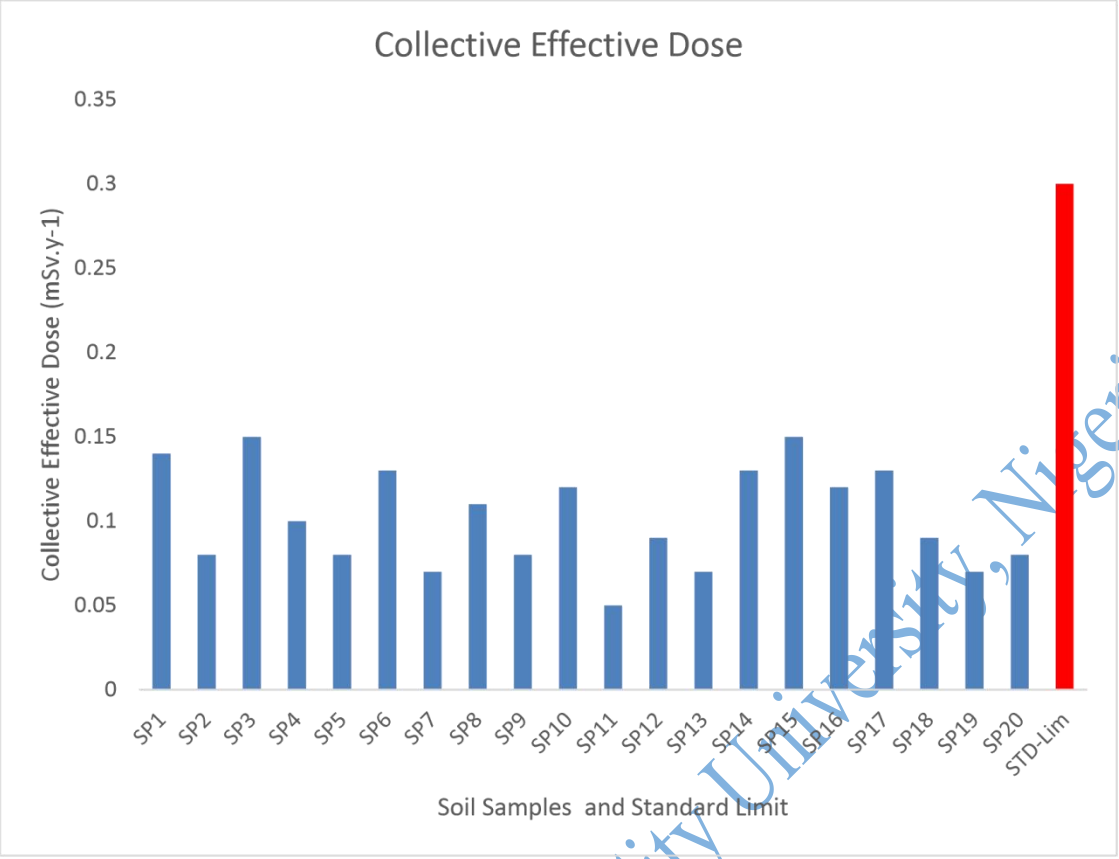

Figure 4.3: Mean activity concentrations of ^{40}K, ^{226}Ra and ^{232}Th radionuclides in soil samples collected from mining site pitch of paago Iseyin Local Government Oyo State Southwest Nigeria.
Bar chart consist of primary axis which scale is from 0.00 to 0.35.
Researcher: Oyegbemi Ezekiel 2022

World Average Value: AED = 0.3(msvy-1)

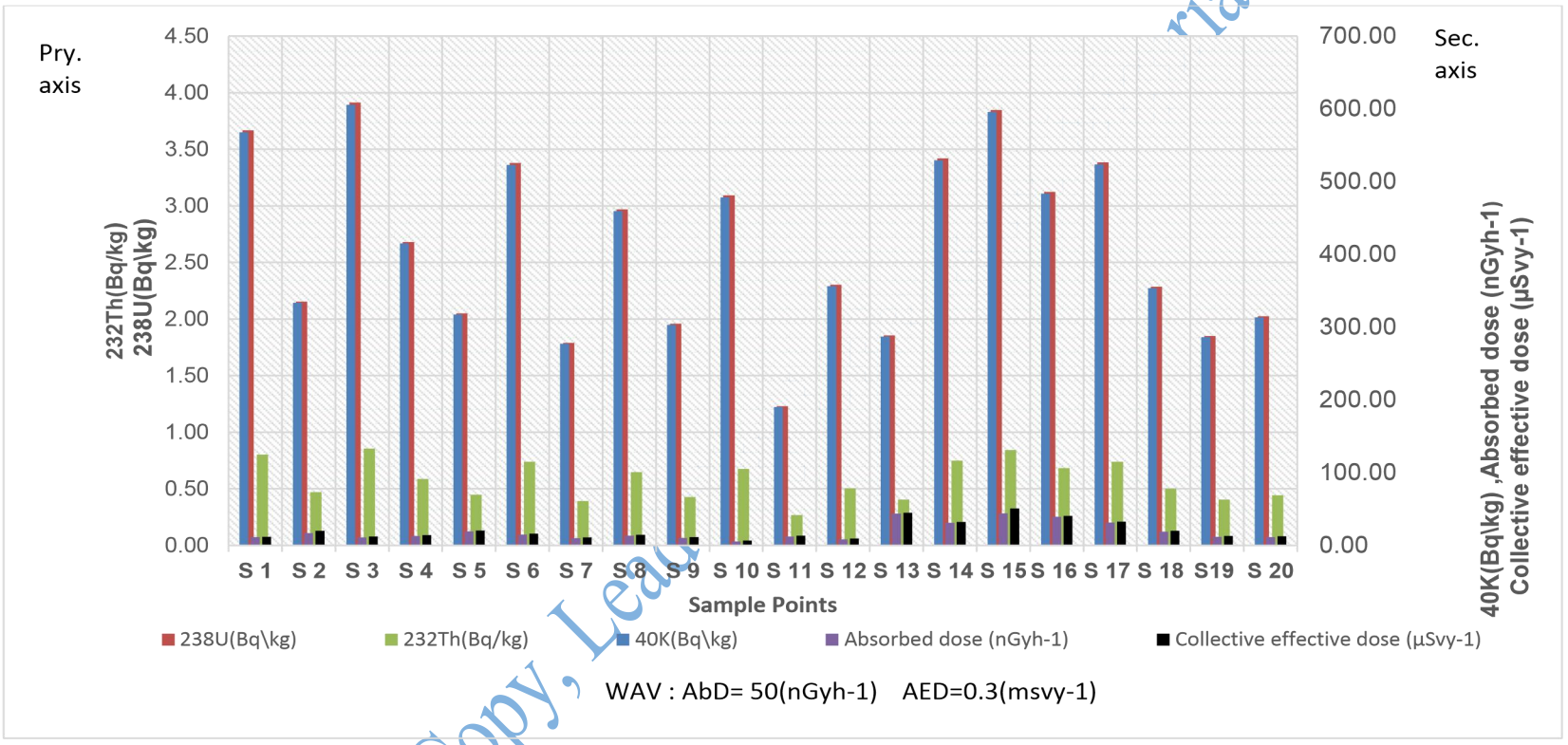

Figure 4.1: Mean activity concentrations of ^{40}K, ^{226}Ra and ^{232}Th radionuclides in soil samples collected from mining site pitch of paago Iseyin Local Government Oyo State Southwest Nigeria.
Bar chart consist of primary axis which scale is from 0.00 to 4.50 and secondary axis from 0.00 to 700.
Researcher: Oyegbemi Ezekiel 2022

4.2.2 Absorbed Dose, Annual Effective Dose and Effective Doses soil from the study area

The gamma absorbed dose rate from the study areas is presented in table 4.2. the values ranged from 6.85nGyh^{-1} to 45.73nGyh^{-1}, however, average absorbed dose rate in the samples from the present study was obtained to be 11.18±2.35nGyh^{-1}. The mean absorbed dose rate in the present study is lower than the world recommended average value of 50nGh^{-1}. reported a similar value in soil from Ijebu-Ode[2]. Reported value of 40.88nGyh^{-1} for the soil in Owowo

village in Ogun state[8]. reported value of 293.27nGyh^{-1} for soil of mining dump site in Jos Nigeria, this value is higher than the mean value reported from the present study[8]. The values of annual effective dose computed for soil sample in the present study were lower than the standard dose[3] criterion of 0.3mSv^{-1}. Therefore, from the radiological point of view, the use of soil from the study areas do not pose significant health hazard and considered to be safe for the artisans whose workshop are situated in the present study areas[36].

4.2.3 Radiological Hazard Indices

Radiological hazard indices include radium equivalent, external hazard index and internal hazard index and representative gamma index (I_γ)[5]. Radium equivalent is an index which gives the sum of gamma radiation from ^{40}K, ^{226}Ra and ^{232}Th, radionuclides in a sample[6]. The maximum value of radium equivalent for building materials must be less than the limit value of 370 Bqkg^{-1} in order to keep the external and internal doses below 1 mSvy^{-1}.

Table 4.3 presents the values of calculated hazard indices from the study areas, the highest value of radium equivalent was 113.68Bqkg^{-1} while the lowest was 21.62Bqkg^{-1} in the soil from the study area[7]. The values of radium equivalent obtained in the present study were

below the recommended value of 370 $Bqkg^{-1}$. In addition, external and internal in the soil from the study area as presented in table 4.3, all the values obtained for external and internal hazard indices were less than unity except in two locations where the value is shows a little deviation from unity, the results show that radiation hazard associated with the soil from the study areas would pose negligible health impact.

Endnote

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Chapter Five

Summary, Conclusion and Recommendations

5.1 Summary of Findings

In this present study, measurements of the activity concentrations of ^{40}K, ^{238}U and ^{232}Th radionuclides have been carried out at various mining sites of Paago village Iseyin local Government around Oke-Ogun area, Oyo state, Southwestern Nigeria using a well calibrated HPGe detector. Twenty (20) soil samples were analyzed and the results as presented in chapter four showed that: ^{40}K. range from 58.40 to 950.41Bqkg^{-1}, ^{238}U ranged from 5.57 to 24.22Bqkg^{-1} and ^{232}Th 4.1 to 25.93Bqkg^{-1}. The means activity concentration of the three radionuclides were lower than the world average value. The values of the gamma absorbed dose rate in the soil samples ranged from 6.85nGyh^{-1} to 45.73nGyh^{-1}. The mean absorbed dose rate in the present study is lower than the world recommended average value of 59nGh^{1}. The annual effective dose rates in the air varied from 14.26 to 19.74μ Svyr^{-1} with an average value of 17.99 μSvy^{-1}. the highest value of radium equivalent was 113.68Bqkg^{-1} while the lowest was 21.62Bqkg^{-1} in the soil from the study area. In addition, external and internal in the soil from the study area, all the values obtained for external and internal hazard indices were less than unity.

The values of the Gamma absorbed dose rate in the soil samples range from 11.62 to 16.08 nGyh^{-1} with a mean value of 14.60nGy-1. The annual effective dose rates in the air varied from 14.26 to 19.74μ Svyr^{-1} with an average value of 17.99 μSvy^{-1}. This value obtained in the study Area were compared with other published value and world values, it indicates that the study areas pose no significant radiological threat to the population and the tuber crops are safe for consumption.

5.2 Conclusion

Having measured the activity concentration of ^{40}K, ^{238}U and ^{232}Th in soil inside various mining sites pitch of Paago village Iseyin local Government in Oke-Ogun area, Oyo state, Southwestern Nigeria, the result of the mean activity concentration of ^{40}K, ^{238}U and ^{232}Th in the soil samples were found to be lower than the international recommended limit. It indicates that the study areas may pose no significant radiological threat to the population and consequently, any physical activity, oil drop, disturbance and instability of the land may not necessary affect the concentration of primordial radionuclide from the study area.

5.3 Recommendations

The effects that high amounts of radioactive element in soil can have deadly effect on human health. The assessment of the radiological impact due to natural radionuclide on population is important in monitoring population exposure and providing data on radiation levels in order to make policy relevant radiation protection. Based on the findings of this present study, the following recommendations were made

i. Government should do more to raise public awareness on the effects of ionizing radiation.

ii. The data obtained are important both for assessing the risk for human health as well as environmental monitoring.

iii. Building should be avoided in areas identified to contain high background radiation

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Appendix

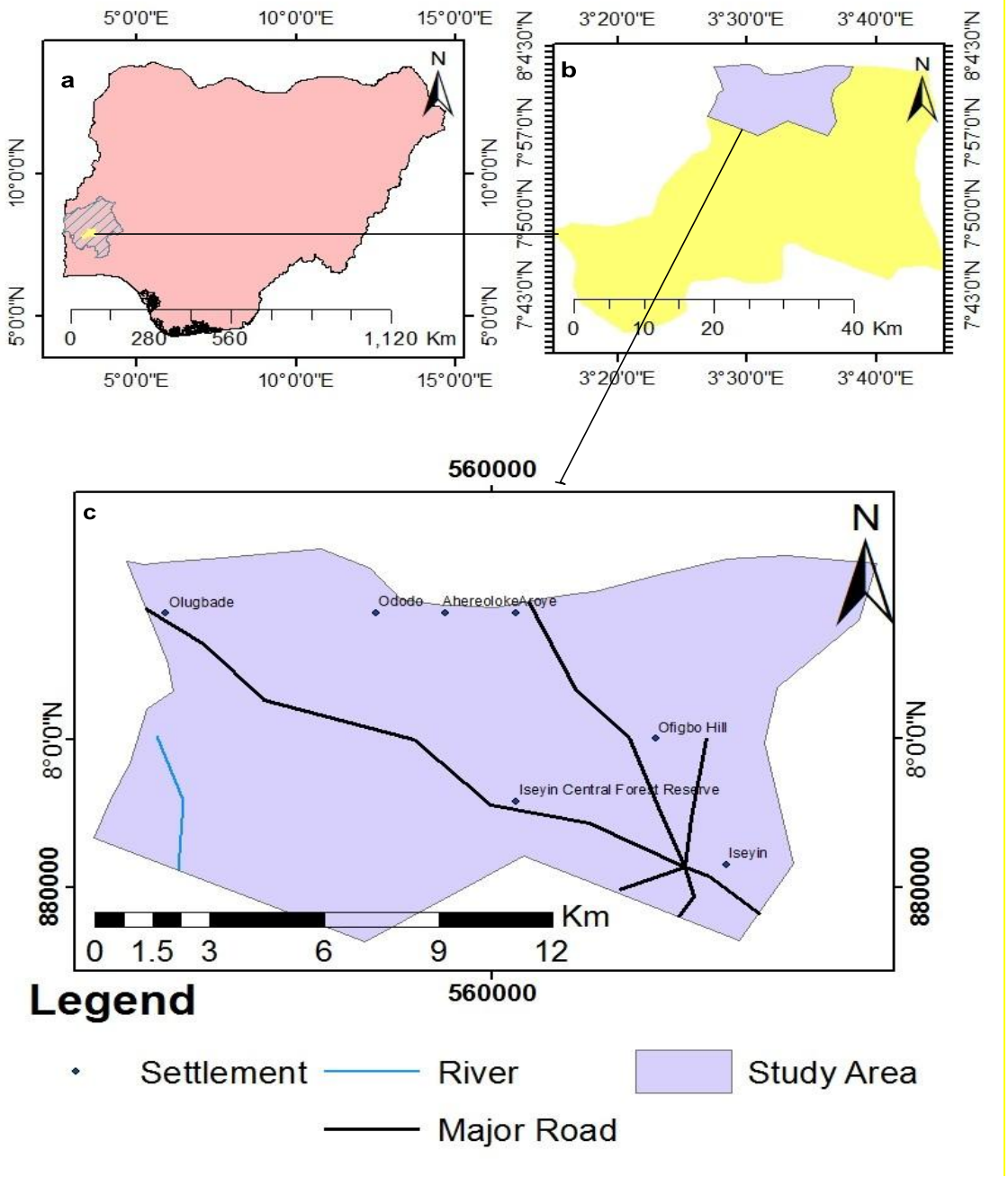

Figure 1.1: map showing mining site in paago village Iseyin central local Govern.

(Researcher: Oyegbemi Ezekiel 2022)

Figure: 3.2: sample collection 1(Ess1)
Researcher: Oyegbemi Ezekiel 2022

Plate: 3.3 sample collection 2 (Ess2)

Researcher: Oyegbemi Ezekiel 2022

Plate: 3.4 sample collection 3 (Ess3)

Researcher: Oyegbemi Ezekiel 2022

Plate 3.5: Sample collection 4 (Ess4)

Researcher: Oyegbemi Ezekiel 2022

Plate 3.6: Sample collection 5 (Ess5)

Researcher: Oyegbemi Ezekiel 2022

Bio-data

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B. Educational Background

Education Institutions	
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Isale Oyo Community Grammar School Oyo	National Examination Council (2004)
Oyo State College of Education	Computer/ Physics (2004)
Ekiti State University	Bachelor of Science in Physics (2010)
Lead City University	Masters of Science in Physics (In view)

C. Working Experience

Work Place		**Date**
1.	Godwill Nursery and Primary School	2004
2.	Winner Group of School	2004
3.	Nurudeen Grammar School	2005
4.	Ogbomoso Grammar School	2005

5.	Commercial Secondary School Oyo	2006
6	Oyo State Fire Services	2006-2012
7.	Nigeria Security and Civil Defends (NSCDC)	2012 – till date

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The University Compliance Certification

This is to certify that the thesis by Ezekiel Oyedokun OYEGBEMI in the Department of Physics, Faculty of Natural and Applied Sciences, Lead City University, Ibadan, Oyo State, Nigeria is in full compliance with the approved University Format and style.

Signature Date

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