DETERMINATION OF RADIONUCLIDE LEVELS OF GINGER GROWN IN SAMBAM GIDA, JABA LOCAL GOVERNMENT AREA, KADUNA STATE, NIGERIA.

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BY

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DECLARATION

I declare that the work in this Dissertation entitled “Determination of Radionuclide Levels of Ginger Grown inSambamGida, Jaba Local Government Area, Kaduna State, Nigeria” has been carried out by me in the Department of Physics. The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this dissertation was previously presented for another degree or diploma at this or any institution.

JulietOkeke	.....	.....
Name of Student	Signature	Date

CERTIFICATION

This dissertation entitled: **Determination of Radionuclide Levels of Ginger Grown inSambamGida, Jaba Local Government Area, Kaduna State, Nigeria** meets the regulations governing the award of the degree of Master of Science (M.Sc.) of the Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

I dedicate this Dissertation to the Almighty God, who gave me the inspiration, knowledge, wisdom and understanding to carry out this work.

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I am grateful to God for the successful completion of my studies in this great citadel of learning. I also want to thank my lecturers in Ahmadu Bello University, Zaria for the knowledge imparted to me and to my supervisors, Dr. R.A. Onoja and Dr. N.N. Garba for reviewing my work. I equally want to use this opportunity to also appreciate the effort of Mal. A.M Vatsa for dedicating his precious time to go through my work. His contributions to this work is immeasurable.

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\

ABSTRACT

Plants used for medicinal and consumption purposes absorbs certain level of Naturally Occurring Radioactive Materials (NORMS) which could affect mankind. This physical absorption process (uptake) has raised concerns. This work was undertaken to assess the uptake of radionuclides by ginger grown in SambamGida, Jaba Local Government Area, Kaduna State, Nigeria. The research was carried out using handheld (RADOS – 120) survey meter for the measurement of the radiation dose level of the area and Sodium Iodide Thallium doped (NaI(TI)) detector for determining the activity concentration of ^{40}K, ^{226}Ra, and ^{232}Th present in the fertilizer used in cultivation, the soil and ginger grown. The radiation dose level measured varied from different sampling points with 0.43µSv/hr as the highest, 0.05µSv/hr lowest, and 0.11 µSv/hr in the control sampling points. The values of activity concentration due to ^{40}K, ^{226}Ra and ^{232}Th in the fertilizer used in planting were 2024.19 Bq/kg**,** 19.26Bq/kg**,** and 62.05Bq/kg respectively. Also, the mean (range) activity concentrations of ^{40}K, ^{226}Ra and ^{232}Th in the soil samples were 301.59 (203.50 to 405.15) Bq/kg, 32.24 (19.54 to 46.59) Bq/kg and 74.21 (38.54 to 121.26) Bq/kg, while that of ginger samples were357.27 (105.12 to 1962.94) Bq/kg, 30.10 (10.51 to 55.35) Bq/kg and 52.10 (10.38 to 119.85) Bq/kg respectively.The results of the transfer factor computed for ^{40}K, ^{226}Ra and ^{232}Th are 1.20, 1.06 and 0.83 respectively, which shows that the ginger crop obtained from these farmlands take up more ^{40}K and ^{226}Ra than it does for ^{232}Th, with the transfer rate of ^{40}K from the soil to ginger being the highest. The mean values of Radium Equivalent activity, Annual Effective Dose Rate, external and internal hazard indices for the soil samples which were found to be 162.42Bq/kq, 0.09 $mSvy^{-1}$, 0.44 and 0.53 respectively, while Radium Equivalent activity and Annual Effective Dose Rate of ginger samples were 132.11Bq/kg and 0.08$mSvy^{-1}$respectively. Generally, the results computed for the radiological health hazards were all within the international standards which are 370 Bq/kg for radium equivalent activity, 1$mSvy^{-1}$ for Annual Effective Dose Rate and unity each for external and internal hazard indices.Based on the results obtained, ginger grown in the study area is considered safe for consumption.

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LIST OF ABBREVIATIONS

NORMs - Naturally Occurring Radioactive Materials

NaI(Tl) - Sodium Iodide doped with Thallium

UNSCEAR – United Nations Scientific Committee on the Effects of Atomic Radiation.

WNA – World Nuclear Association

PM – Photomultiplier

MCA – Multi-Channel Analyzer

ADC - Analog to Digital Converter

FWHM – full width at half maximum

CPM – counts per minute

CPS – counts per second

ID – Identity

ICRP – International Commission on Radiological Protection

et al. – other people are also involved

ELCR – Excess Lifetime Cancer Risk

CERT- Centre for Energy Research and Training

IAEA- International Atomic Energy Agency

ICRU - International Commission on Radiation Units and Measurements

IUR- International Union of Radioecology

LIST OF SYMBOLS

Co-60	–	Cobalt-60
Cs-137	–	Cesium-137
K-40	-	Potassium-40
Th-232	–	Thorium-232
U-238	–	Uranium-238
Ca-40	–	Calcium-40
Ra-226	–	Radium-226
Ba-133	–	Barium-133
Na-22	–	Sodium-22
Mn-54	–	Manganese-54
H_{ex}	–	External hazard index
H_{in}	_	Internal hazard index
D	–	Absorbed Dose Rate
AEDE	_	Annual Effective Dose Equivalent
Ra_{eq}	–	Radium Equivalent Activity
nGy/h	–	nano-Gray per hour
mSv/y	–	milli-Sievert per year
Bq/kg	–	Becquerel per kilogram
MeV	–	mega-electron volts
keV	–	kilo-electron volts
mR/h	–	milli-Roentgen per hour
μSv/h	–	micro-Sievert per hour

cm	–	centimetre
Bq	–	Becquerel
g	-	gram
s	–	second
Ci	–	Curie
$\boldsymbol{\beta}$	–	Beta
eV	–	electron volt

CHAPTER ONE
INTRODUCTION

1.1 Background of the Study

Zingiberofficinale is the botanical name of ginger and belongs to the family*Zingiberaceae.*It is an underground rhizome as well as a perennial tropical crop. Ginger originated in the tropical rainforest in South Eastern Asia, but over centuries has been introduced to various parts of the world like the Caribbean, the Americas and Africa. About half of its world's production comes from India, whereas, its cultivation is extended to China, Australia, Malaysia, Nigeria, Fiji, Brazil and Mexico (Sanderson *etal.*, 2002).

A matured ginger rhizome is fibrous and has a striated texture. The outer skin of the rhizome is brownish in colour while the inner flesh depending on the variety may be red, yellow or white. In the market, ginger is available in various forms; fresh ginger rhizome, powder ginger and dry ginger rhizome. It is a commodity that is highly valued in international markets for it versatile uses.

Nigeria is the third largest exporter of ginger in the world after China and India. Currently, it has become an important cash crop for farmers in most northern parts of the country. In the Nigerian market, ginger is well known and on high demand even though it is quite expensive. Kaduna State stands as the highest producer of the crop while states like Gombe, Bauchi, Benue, Nassarawa among others are major producers of the crop. Kachia, Kagarko and Jaba Local Government Areas are the major producers of ginger in Kaduna state. Nigeria's production in 2005 was estimated at 110,000 metric tonnes (Food and Agriculture Organization; FAO, 2010). Out of this, 10% is locally consumed as fresh ginger while 90% is dried primarily for the export markets.

Ginger (*Zingiberofficinale Roscoe Zingiberaceae*) is one of the most commonly consumed dietary condiments in the world (Surh*et al.* 1998).

It is mostly used as food spice in many Asian and African countries, including Nigeria. It produces a hot, fragrant kitchen spice. It is an important spice used as a condiment in vegetable preparations. Fresh, as well as dried, ginger is used to spice tea and coffee, especially in winter. The oil and oleoresins obtained from gingerare also used in many food items, soft drinks and beverages (Singh *et al*., 2008).

Ginger contains Mg, Ca and P, which play important roles in bone formation, and curbing muscle spasm, depression hypertension, convulsion, nausea, gastrointestinal disorders, paralysis, kidney damage, and a host of other biodysfunctions (Lee and Ahn, 1985; Kikuzaki and Nakatani, 1993; Kikuzaki et al., 1994; Meyer et al., 1995). It is also an important ingredient in herbal medicines for the treatment of rheumatism, nervous diseases, gingivitis, toothache, asthma, stroke, constipation and diabetes (Awang, 1992; Wang and Wang, 2005; Tapsell*et al*., 2006). Ginger extracts exhibit anticholigernic and antihystaminic effects (Qian and Liu, 1992), antihypercholesterolemic effect (Janabai et al., 1984; Tanabe et al., 1993), antihyperlipidaemic effect (Bhandari et al., 1998), antiinflammatory effect (Al-Yahya et al., 1989), antiemetic effect (Philips et al., 1993) and lowers the serum glutamate oxaloacetate transaminase (GOT) and glutamate pyruvate transaminase (GPT) levels (Bhandari et al., 2003). Over the last few years, interest in ginger or its various components as valid preventive or therapeutic agents has increased markedly, and scientific studies focusing on verification of ginger's pharmacological and physiological actions have likewise increased (Aliet al., 2008).

Ginger is very useful in the treatment of migraine, motion sickness (Mowrey and Clayson, 1982;Holtman et al., 1989), and rheumatic disorders (Srivastava and Mustafa,

1989). It is also an antitumor, anticarcinogenic and antitoxic agent (Mascolo et al., 1989; Katiyar et al., 1996; Surh, 1999; Vimala et al., 1999).

The production of this spice has been expanding in most parts of the country, as it can be grown under varied climatic conditions. It thrives well in areas with altitudes from sea level to 1500 m, mean annual temperature of 20–32°C and with total rainfall greater than 1200 mm. Well-drained, fertile and friable soil with enough humus and neutral pH is the ideal soil type for the production of ginger (Asfaw and Demissew 2009). Ginger thrives best in well-drained soils like sandy or clay loam, red loam or lateritic loam. It does best with a soil pH of 5.5 to 6.5. Because the ginger rhizome grows beneath the soil, the soil should be loose, free of rocks, so the rhizome is free to grow (Hailemicheal et al. 2008).

On the average, ginger takes about nine months from time of planting to mature. Harvesting of ginger starts from October and normally continues until April/May. This largely depends on the market situations as ginger can be left on the ground (not harvested) for two years.

Some radionuclides present in the environment are taken up by the plants through the metabolic process and are present in varied concentrations in different parts of the plants (Golmakani et al., 2008, Harb et al., 2014, Karunakara, 1997, Kannan et al., 2002, Lordford et al., 2013 and Petra et al., 2008). Moreover, the plants absorb many elements present in the soil of their root area with or without the necessity of these elements. The transport of these radionuclides also depends on the chemical form of the nuclide, its distribution coefficient, the metabolic requirements of the plant, and physicochemical parameters of the soil such as pH, organic matter, moisture content, etc. (Eisenbud, 1987, IAEA., 2006 and Lordford et al., 2013). The presence of these

elements in the soil is metabolically incorporated into the plants and ultimately find their way into the food chain.

Natural radionuclides are transferred and cycles through natural processes and between the various environmental compartment by entering into the ecosystem and food chain through direct or indirect contamination of natural radionuclides (Adewumi, 2011 and Elujoba et al, 2005).

Type and proximity of parent rock material from which soil formation starts is also a chief factor determining availability and transfer of radionuclide through roots of crops especially in places with heavy presence of granite and igneous rock.

The contamination of soil by atmospheric deposition of toxic metals affects soil properties and further increases plant metal levels through root uptake (Pandey 2009), and eventually these metals are taken up by plants parts and transfer some into the food chain. Consequently, higher soil heavy metal concentration can result in higher levels of uptake by plants (Ebong et al. 2008).

1.2 Statement of the Problem

Previous reviews have emphasized the importance of careful scientific research in establishing the safety and efficacy of potential therapeutic plant remedies and in defining the risks and benefits of herbal medicine (Barrettet al., 1999; Nesset al., 1999; Talalay 2001). Ginger has been used for thousands of years for the treatment of numerous ailments, such as colds, nausea, arthritis, migraines, and hypertension. More and more older adults (i.e., baby boomers) are using complementary and alternative medicine dietary supplements and herbal remedies without advice from a physician on the assumption that these substances will have a beneficial effect (Cohen et al., 2002). However, this might not be a safe or advisable practice, because the estimation of risk to

humans from medicinal plants throughingestion requires a quantitative understandingof the interrelated pathways by which theradionuclides are eventually ingested byhumans (Eisenbud, 1987).

For example, at least one recent survey revealed a significant problem with herb-chemotherapeutic drug interactions in cancer patients and, notably, at least half of the herbal remedies taken by these patients lacked research data documenting their potential interactions (Engdalet al., 2009). Regrettably, a great deal of the information regarding the effectiveness and safety of these remedies has been garnered from anecdotal or historical accounts, and much of the information offered is generally misleading and might even be detrimental (Ernst and Schmidt 2002).

It is well known that there are many contaminants and residues that may harm the consumers of herbal medicines, and naturally occurring radionuclides are one of contaminants amongst them (WHO, 2007).

According to the International Food Safety Authorities Network (INFOSAN, 2011), plants used as food commonly have 40K, ^{232}Th and ^{238} U and their progenies. It is expected that similarities would be found in plants used for medicinal purposes since plants are the primary pathway of natural radionuclides entering into the human body through the food chain (Lordford et al, 2013). More so, the health effects of exposures to Naturally Occurring Radioactive Materials (NORMs) from intake of medicinal plants and herbal preparations in relation to the level of NORMs in medicinal plants are associated with most forms of leukemia and with cancer of many organs such as the bone, lung, breast and thyroid in the long term (United Nations Scientific Committee on the Effects of Atomic Radiation, UNSCEAR, 2000).

Plants absorb dissolved elements in soils, which are subsequently picked up by the humans that eat them, and the elements move up the food chain. The presence of radionuclides in varied concentrations in different parts of the plants may be transferred to human beings, since their parts are used as ingredients in preparing the medicines (Chandrashekara andSomashekarappa, 2016).

Considering such management practices during ginger cultivation like application of organic matter, mineral fertilizers, soil amendments (soil pH adjustment with lime) alongside various cultivation techniques, soils exposed to such practices are not left without traces of radionuclide contents which are absorbed with nutrients through the edible rhizome of ginger roots and transferred via phloem to various parts of the crop where they are required.

Crystalline rocks have been observed to be rich in naturally occurring radionuclides which are the primary terrestrial sources of radiation in the environment (Okedeyiet al., 2012). The terrestrial background radiations are related to the types of rock from which the soil originate (Michaeliset al., 2002). Owing to the inevitable effects of radiations and health risk from these exposures, it is necessary to investigate the quantity and process by which these radionuclides get into plant with respect to ginger crop cultivated in SambamGida Village as it is observed that crystalline rocks are sited on either side of the geographical landscape of SambamGida village and also contain trace of radioactive substances.

In view of the above, even though ginger is generally considered to be safe (Kaul and Joshi 2001), the lack of a complete understanding of its mechanisms of action suggests caution in its therapeutic use (Wilkinson 2000a).

Hence,this work seeks to analyze the radionuclide levels and activitydistribution of radionuclides and the probableeffective radiation dose to humans, through the consumptionof ginger crop grown inSambamGida village ofKaduna State.

1.3 Aim and Objectives

This study aimed at determining the radionuclide levels of ginger cultivated in SambamGida village situated in Jaba Local Government Area,Kaduna state, Nigeria.

The objectives of thisresearch work are:

i. To measure the radiation dose level of the study area.

ii. To determine the activity concentration of ^{226}Ra, ^{232}Th and 40K present in the fertilizer used in cultivation, the soil, and ginger grown in SambamGida village.

iii. To determine the rate of radionuclide transfer from the soil to ginger crop by computing the transfer factor of the measured radionuclides.

iv. To assess the radiological implications associated with the collected samples.

1.4 Justification

So many researches have been conducted by scholars on the elemental analysis and determination of essential and non-essential metal levels of ginger.Also, the role of natural radionuclides in plant and animal metabolism has been established and available in literature. However, the effect and influence of these natural radionuclides on administration of medicinal plants had received little or no attention (Durugboet al., 2012). The possible side effects due to the intake of these medicinal plants or herbal plants are not considered in the group of edible plants that have been studied in the past by nutritionists. Notwithstanding, many edible plants used as spices or fruits such as ginger, onion, pawpaw and mango etc., have medicinal properties and the ingestion of

NORMs through the use of plants had not been recognized or considered significant in terms of quantity (Lordford et al., 2013 and UTEHS, 2014).

Since ginger is a major cash crop in Kaduna state, in the northern part of Nigeria; and is used as a hot fragrance kitchenspice as well as for medicinal purposes, this study has analyzed the radionuclide uptake and the subsequent radionuclide composition in ginger cultivated in this geographical area of Nigeria with an aim of filling the gap in this field at least to some extent and creating an opening for further studies on ginger and closely related plants widely used throughout the country. The outcome of this study will ultimately help to ensure the dietary safety of the society and improving the country's economy by ensuring that theginger exported is safe for consumption.

1.5 Scope of the Study

This study focused on ginger crop grown in SambamGida village situated in Jaba Local Government Area of Kaduna state. The study covered the determination of physical absorption (uptake) level of radionuclides from soil to ginger crop of the study area. A survey meter was also used in determining the background radiation of the sample area.

Activity concentration of the radionuclides 40K, ^{232}Th and ^{226}Ra were obtained using Thallium Doped Sodium Iodide(NaI(Tl)) detector and the results compared. The radiological limiting factors (risk) such as radium equivalent activity, annual effective dose and external and internal hazard indices were also calculated from the results of activity concentrations.

1.6 Limitations

Although, this research was carefully carried out,it is still pertinent to statesome limitations and shortcomings that were encountered in the course of the research work.

This research was specifically carried out in SambamGida Village, Jaba LGA, Kaduna State without expending the research to other geographical areas in Southern part of Kaduna State like, Kafanchan, Kachia, Kagarko and ZangoKataf Local Government Areas due to security threats in these areas.

Also, as at the time of this research, High Purity Germanium (HPGe) radiation detector was faulty and unavailable at Center for Energy Research and Training (CERT) and would have been used to analyze a wide range of other radionuclides present in the sample. This posed a major challenge as only Sodium Iodide Thallium doped (NaI(TI)) detector was used to analyze radionuclide levels of ^{40}K,^{226}Ra, and ^{232}Th in the samples collected.

Lastly, the research was also faced with financial constraints limiting the extent of research.

CHAPTER TWO

LITERATURE REVIEW

2.1 Chemical Constituents of Ginger

Ginger is one of the world's top ten favored spices and has tremendous medicinal value. Ginger can be divided into four principle parts: taste of pungency, essential oil or fragrance, macro/micro-nutrients, and synergists. An oily-resinous substance dissected from the plant comprising 5 to 10 percent of the plant called *ginerol.* This oleoresin was then broken down into close to thirty elements. Gingerolsandzingiberene may be responsible for taste and scent respectively. In fact, within ginger there are hundreds of ingredients that are referred to as synergists. (Jolad et al. 2004)

These interact to make the plant as a whole the powerful healer that it is. There may be dozens of different complex chemical interactions allowing ginger to prevent or benefit conditions like heart attacks, arthritis and ulcers. There are more than four hundred taste, fragrance, nutrient and synergistic constituents interacting to create an endless number of medicinal benefits.

Ginger is a rich source of antioxidants including gingerols, shogaols, zingerones, and more. Ginger has broad-spectrum antibacterial, antiviral, antioxidant, and anti-parastitic properties, to name just several of its more than 40 pharmacological actions (Jolad et al. 2004).

The unique flavor properties of ginger arise from the combination of pungency and aromatic essential oil. The main pungent compounds in fresh ginger are a series of homologous phenolic ketones known as gingerols. The gingerols are thermally unstable and are converted under high temperature to shogaol (Mishra 2009). Shogaols, which are more pungent than gingerols, are the major pungent compounds in dried ginger (Jolad et al. 2004).

The ginger rhizome also contains resin, proteins, cellulose, pentosans, starch and mineral elements. Of these, starch is the most abundant and comprises 40–60% of the rhizome on a dry weight basis. The relative abundance of certain constituents of ginger is determined by the cultivar grown, the environmental conditions of growth and the stage of maturity at harvest (Parthasarathy et al. 2008).

According to Srivastava and Mustafa, (1992); the ginger rhizome has the following chemical composition:

• 60% starch,

• 10% proteins,

• 10% fats,

• 5% fibers,

• 6% inorganic material,

• 10% residual moisture,

• 1-4% essential oil.

A breakdown of the variety of vitamins and minerals contained in 100g of Ginger are:

Carbohydrate - 17.77 g

Dietary Fiber - 2 g

Protein - 1.82 g

Sugars - 1.7 g

Sodium - 13 mg

Vitamin B6 - 0.16 mg

Calcium - 16 mg

Vitamin C - 5 mg

Potassium - 415 mg

Magnesium - 43 mg

Phosphorus - 34 mg

Zinc - 0.34 mg

Folate - 11 mg

Riboflavin - 0.034 mg

Niacin - 0.75 mg

Iron - 0.6 mg

Figures above are per 100g of ginger (Srivastava et al; 1992).

Humans require a suite of mineral elements in varying amounts for proper growth, health maintenance and general wellbeing. Minerals are essential components of our diet that serve as cofactors in the thousands of enzyme- controlled reactions, control the action of nerves and muscles, help maintain the body's water balance, and buffer the pH (acidity) of the cell and extracellular fluids (Minerals-Learn 2010).

2.2 Naturally Occurring Radiation

Natural radionuclides are found in every constituent of the environment; air, water, soil, food and in humans (WNA, 2014). Because it occurs in our natural environment, we encounter it every day through the food we eat, the water we drink, and the air we breathe.It is also in building materials and items we commonly use.This project is concerned with how radionuclides get into food with respect to ginger crop. There are three groupings of naturally occurring radiation, mostly based on where the radiation comes from.

The radiation emanated from soils and rocks is called primordial or terrestrial, while radiation that comes from space is referred to as cosmic or cosmogenic. These are termed as natural radiation sources. Other sources of radiation in the environment

arereferred to as artificial radiation sources due to human activities.For the purpose of this work,the most commonly encountered radionuclides of interest are ^{226}Ra, ^{232}Th, and ^{40}K which fall under the category of the terrestrial natural radiationandwill be investigated to understand how it get into plants during mineral uptake along with the nutrients and accrue in different areas up to the edible parts especially in ginger.

International Atomic Energy Agency(IAEA)in 1996 estimated that 80% of doses contributions in the environment are derived from the natural radionuclides while the remaining 20% is from cosmic ray and nuclear processes. The natural radionuclides of concern in terrestrial environment are mainly potassium (^{40}K), radium (^{226}Ra), thorium (^{232}Th) and the radioactive gas radon which is produced as these naturally- occurring radioisotopes decay. Radon emanates from the ground as a result of the direct decay of naturally-occurring radium and is a major source of radiation exposure (EPA, 2007).

Natural radioactivity is widely spread in the earth's environment and depends primarily on the geological and geographical conditions, and appears at different levels in the soils of each region in the world (UNSCEAR, 2000).

In a variety of concentrations, Naturally Occurring Radioactive Materials (NORMs) have always been present in every part of the earth and in the tissue of all living beings. Natural radionuclides such as ^{238}U, ^{232}Th and ^{40}K can be found almost everywhere; in soil, public water supplies, oil and atmosphere thereby subjecting human beings to reasonable exposure (Varier, 2009).

Natural radioactive decay like ^{238}U and ^{232}Th series in addition to radionuclide that occurs singly such as ^{40}K is found in the atmosphere and the earth in varied levels. The radioactivity in the agricultural land and in soil may transfer to the plants around. The radionuclide available in the environment is transferred to plants by two ways, first of

which is the indirect method uptake from soil through roots. When food plants are developed in a polluted soil, the activity is switched to the roots from the soil and then in shoots. At the end, it transfers to the human diet (Ramiza et al. 2010). This radionuclide can get into the plants during mineral uptake along with the nutrients and accrue in different areas and even it could reach the edible parts (Brianna, 2011). Secondly, there is thedirect method absorption; which occurs through aerial plant areas. A variety of workers have reviewed the presence of radioactivity in the plant organs (Pooja and Rishi, 2014).

2.3 The Uptake of Radionuclide by Plants

To assess the internal doses to humans from ingestion of radionuclides present in agricultural products it is necessary to know the main processes which determine the transport of radionuclides in the environment (Russel, 1966; Peterson, 1983). The available data, generally, do not reflect natural conditions, and the mechanisms of translocation and mobility of radionuclides within the soil-plant system are still not fully understood (Coughtrey& Thorne, 1983; Fresquez et al., 1998; Krouglov et al., 1997; Frissel, 1992; Roca & Vallejo, 1995; Desmet et al., 1990).

The knowledge of the contributions made towards the studies of direct contamination of plant fruits and that of the process of root to fruit transfer can improve the understanding of exposure through ingestion and the mechanisms determining absorption and translocation mechanisms. Several studies on the relations among specific activities of various radionuclides in different environmental compartments have been performed in the last decades (Coughtrey and Thorne, 1983; Fresquez et al., 1998; Krouglov et al., 1997; Howard et al., 1995; Strand et al., 1994; Frissel, 1992; Desmet et al., 1990).

Radionuclides absorbed are transferred to the plant organs and their quantities are determined on the basis of the kind of contamination source and of biological andenvironmental processes. Plant physiology, soil characteristics, nuclide and plant kind areimportant parameters which influence absorption (Coughtrey& Thorne, 1983). During the process of photosynthesis, both the stable inorganic elements and the unstable ones (radioactive element) find their way into plants. Plant-derived foods have the potential to serve as dietary sources for all human-essential minerals that make a significant contribution to daily mineral needs at all stages of the life cycle (Grusak 2002). Mineral uptake by plants can be affected by several factors including mineral concentrations in soils, soil pH, cation exchange capacity, organic matter content, types and varieties of plants, and age of the plant (Jung 2008). In ideal word, we would take in our daily requirement of minerals by eating plants that grow in mineral rich soils (Lokeshwari and Chandrappa 2006).

These nutrients are absorbed from the soilgotten from fragments of nearby rocksby plant root and transferred via their phloem to various parts of the plants where they are required. All mineral elements must be in soil solution and in a specific ionic form in water before they can be absorbed by plants. Water is a solvent essential for chemical processes in the plant and for mineral transport within the plant. About 70-90% of plants' green weight consists of water only (Pillai, 1967).

It is also paramount to note that heavy metals are also present in agricultural soils at low levels. Due to their cumulative behaviour and toxicity, however, they have a potential hazardous effect not only on crop plants but also on human health (Uwah et al. 2009). Contamination and subsequent pollution of the environment by toxic heavy metals have become an issue of global concern due to their sources, widespread distribution and multiple effects on the ecosystem (Yohannes&Bhagwan, 2015).

The contamination of soil by fallout particles is the first step in the process of uptake of radioelement by plants through their root system.

The soluble radioelements are made available for uptake by

1. Surface penetration with rain water or natural erosion processes and
2. Mechanical mixing into the soil by cultivation processes.

According to James *et al.,* (1966); major factors that influence the uptake of radionuclides by plants through their root systems are:

1. Physicochemical properties of the ions of the radioelement
2. Plant species
3. Soil type and chemical characteristicsfrom the parent surrounding rocks.
4. Soil management practices

Assimilation of nutrients or inorganic ions by roots of plants usually involves soluble, exchangeable ions in the soil. When new ions from a mineral fertilizer or from fallout particles are introduced into the soil, they compete with and replace other ions on available exchange sites in the soil (James et al., 1966).

Soil management practices include the addition of organic matter, mineral fertilizers, and amendments (such as lime) to the soil, in addition to various cultivation techniques. These practices can influence the chemical composition of the plant (James et al., 1966).

2.4 Transfer Factor

Thisis the parameter used to describe the translocation of aradionuclide among different environmental matrices; and it is defined as the ratio between thespecific activity in the destination matrix and that in the departure matrix (International Commission on Radiation Units and Measurements (ICRU); 1998). This factor is used to illustrate the transfer of radionuclides from soil to the plant. Generally, this concept refers to root

uptake and there are strict protocols to follow when obtaining the data to calculate soil to plant transfer factors as described by the International Union of Radioecology (IUR, 1989). The prime use of soil to plant transfer factors is for environmental transfer modelling or simple radiological dose assessments, where the knowledge of the transfer of radionuclides from soil to plants and subsequently animal products is very important. There are many parameters to consider in order to determine soil to plant transfer factors. The most important studies to date are; the type of plant, soil characteristics, chemistry of the radionuclide present, climate, cultivation practice and also how long the radionuclide has been in contact with the soil (Golmakani et al, 2008; Savinkov et al, 2007). Once uptake via the roots has taken place, the radionuclide will be distributed throughout the plant in both the edible and inedible parts. Thetransfer factor depends sensitively on chemical, physiological and ecological conditions and,for this, the large data dispersion present in the literature do not allow a clear interpretation(Whicker et al., 1999). The large data dispersion is also due to the fact that some of the ratiosbetween two specific activities are in fact time-dependent, so that the assumption of anequilibrium model is not always valid. In particular, for the soil-plant system, usually plantscropped on a contaminated soil, the transfer factor is determined by harvesting the plants at afixed growth stage and by measuring the specific radionuclide activity.The calculation of the transfer factor based on this methodology is implicitly based on the assumption that the ratio between specific activities in plant and soil has reached an equilibrium value. In other words, the soil to plant transfer factor (TF) is the ratio of the concentration of a radionuclide in the plant to the concentration of the radionuclide in the soil at equilibrium, usually measured at the time of harvest. However, thereare indications that uptake of radionuclide by plant is enhanced in the initial growth stage(Whicker et al., 1999).

The transfer factor (TF) depends on radionuclide, crop, or vegetation type, soil type, soil TF values have been considered in compliance with the definition proposed by theInternational Union of Radioecology(IUR; 1989), which is:

$$TF = \frac{Concentration\ \ of\ radionuclide\ \ in\ plant\ \ (Bqkg^{-1}\ \ dry\ crop\ \ mass\ )}{Concentration\ \ of\ radionuclide\ \ in\ soil\ (Bqkg^{-1}\ \ dry\ soil\ mass\ in\ upper\ \ 20cm)} \qquad (2.1)$$

In this study, the soil to plant transfer factors (TFs) will be reported on a dry mass basis in order to avoid inaccuracies associated with different moisture contents of crops, butalso to make comparisons with previous data obtained using the lysimeters and thecurrent parameter values used in the farmland model (Brown and Simmonds,1995).

However, it is important at this point to take a good look at detector performance in general in other to have a better understanding of the important criteria necessary in the choice of a detector.

2.5Detector Performance

Gamma spectroscopy systems are selected to take advantage of several performancecharacteristics. Two of the most important include detector resolution and detector efficiency.

(a) Detector Resolution

Gamma rays detected in a spectroscopic system producepeaks in the spectrum. The width of the peaks is determined by the resolution of the detector, a very importantcharacteristic of gammaspectroscopic detectors, and high resolution enables thespectroscopist to separate twogamma lines that are close to each other. Gamma spectroscopysystems are designed and adjusted to produce symmetrical peaks of the best possible resolution. The peak shape is usually a Gaussian distribution. In most

spectra the horizontal position of the peak is determined by the gamma ray'senergy, and the area of the peak isdetermined by the intensity of the gamma ray and the efficiency of the detector.

The resolution of a detector is a measure of its ability to resolve two peaks that are close together in energy. The parameter used to specify the detector resolution is the full width at half maximum (FWHM). This is the width of the gamma ray peak at half of the highest point on the peak distribution. If astandard Gaussian shape is assumed for the photopeak, the FWHM is given by(Fano, 1946);

FWHM = $2\sigma\sqrt{In2}$ (2.2)

Where σ is the width parameter for the Gaussian.

High resolution (small FWHM)not only makes individual definition of close-lying peaks easier but also makes thesubtraction of the Compton continuum less uncertain because it is a smaller fraction of the total activity in the peak region. The more complex a gamma-ray spectrum is,the more desirable it is to have the best energy resolution possible.

Resolution figures are given with reference to specified gamma ray energies. Resolution can be expressed in absolute (i.e., eV or MeV) or relative terms. For example, a sodium iodide (NaI) detector may have a FWHM of 9.15 keV at 122 keV, and 82.75 keV at 662 keV. These resolution values are expressed in absolute terms. To express the resolution in relative terms, the FWHM in eV or MeV is divided by the energy of the gamma ray and usually shown as percentage. Using the preceding example, the resolution of the detector is 7.5% at 122 keV, and 12.5% at 662 keV. A germanium detector may give resolution of 560 eV at 122 keV, yielding a relative resolution of 0.46%(Muggleton; 1972).

There are both natural and technological limits to how precisely the energy of agamma-ray detection event can be registered by the detection system. The natural limiton the energy precision arises primarily from the statistical fluctuations associated withthe charge production processes in the detector medium. The voltage integrity of thefull-energy pulses can also be disturbed by electronic effects, such as noise, pulsepileup, improper pole-zero settings, etc. Theseelectronic effects have become less important as technology has improved, but their potential effects on the resolution mustbe considered in the setup of a counting system.

The two types of detectors most widely used in gamma-ray nondestructive assay (NDA) applications are the NaI(Tl) scintillation detector and the germanium solid-state detector. The NaI(TI) detector generates full-energy peaks that are much wider than their counterparts from the germanium detector.

By considering the statistical limit on the energy precision, it is possible to understandthe origin of the difference in the energy resolution achievable with various types of detectors. Ideally, the number of electron charges (n) produced by the primary detection event depends upon the total energy deposited (E) and the average amount of energy required to produce an electron-ion pair (δ), (*Fano, 1946*):

$$n = {}^{E}/_{\delta} \qquad (2.3)$$

The random statistical variance in n is the primary source of fluctuation in the fullenergypulse amplitude. However, for some detector types, this statistical variance is observed to be less than (that is, better than) the theoretical value by a factor known as the Fano factor (Fano, 1946):

$$\sigma^2(n) = Fn = {}^{FE}/_{\delta} \qquad (2.4)$$

This effect comes from the fact that pulse marginof the energy lost by the incident photon goesinto the formation of ion pairs and part goes into heating the lattice crystal

structure (thermal energy). The division of energy between heating and ionization is essentiallystatistical. Without the competing process of heating, all of the incident energy would result in ion-pair production, and there would be no statistical fluctuation in n (F = 0).

By contrast, if the probability of ion pair production is small, then the statistical fluctuations would dominate (F ≅1). For scintillators, the factor F is approximately unity; for germanium, silicon, and gases, it is approximately 0.15 (Knoll, 1979;Adams and Dams, 1975). Since the number of charge carriers (n) is proportional to the deposited photon energy (Equation 2.2), the ***statistical portion*** of the relative energy resolution is given by(Fano, 1946);

$$\Delta E_{stat}/_{E} = 2.35\sigma(n)/_{n} = 2.35[F\delta/_{E}]^{1/2} \qquad (2.5)$$

The electronic contribution to the energy fluctuations (ΔE_{elect}) is essentially independent of photon energy and determined largely by the detectorcapacitance and the preamplifier. Thus, the total energy resolution can be expressedas the combination of the electronic and statistical effects (Fano, 1946):

$$\Delta^2 E_{tot} = \Delta^2 E_{elect} + \Delta^2 E_{stat} = \alpha + \beta E \qquad (2.6)$$

In Figure 2.5, the energy resolutions of scintillation, gas, and solid-statedetectors are compared in the low-energy x-ray region(Muggleton, 1972).

The argument presented here assumes that the scintillation efficiency is the mainfactor influencing the number of electrons produced at the photocathode of a scintillationdetector. Other factors, such as scintillator transparency, play important roles. Towork effectively as a detector, a scintillating material must have a high transparencyto its own scintillation light. In a similar vein, factors such as charge carrier mobility play an important role in determining the resolution of a solid state detector.

This discussion is simplified of necessity, but it illustrates the primary reason why germanium detectors resolve so much better than scintillation detectors.

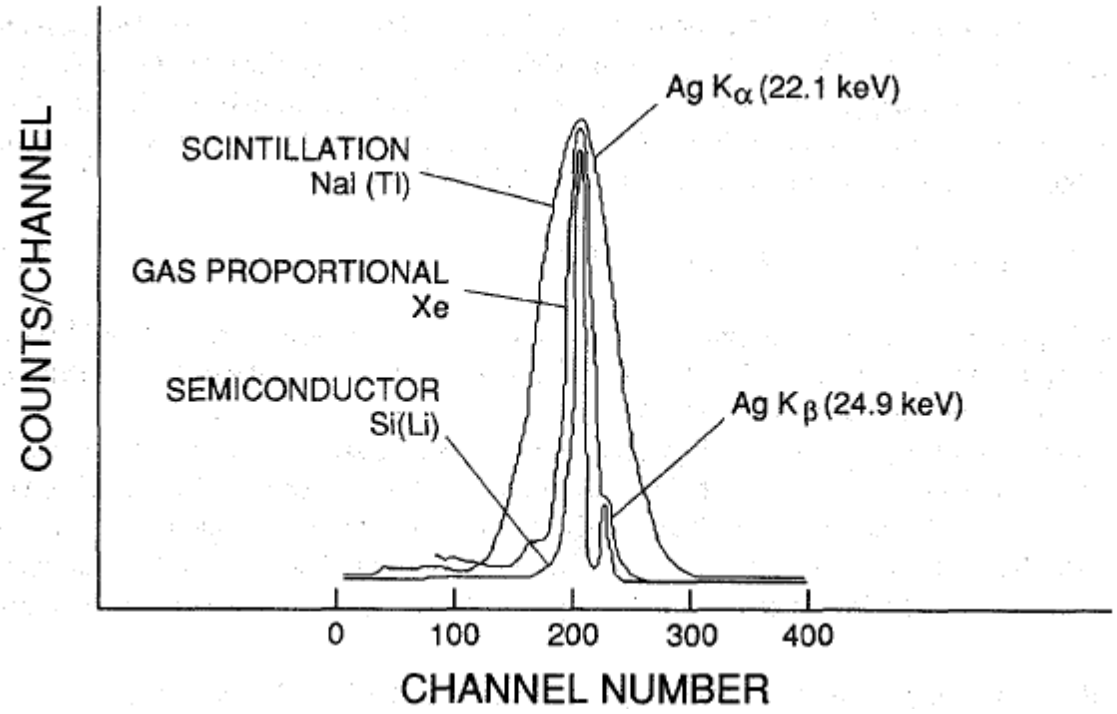


Fig. 2.1: Resolution comparison among NaI(TI) scintillation, gas proportional, and Si(Li) semiconductor detectors for the primmy x rays of silver. (Adapted from Muggleton; 1972).

(b) Detector Efficiency

According to Muggleton (1972), the basic definition of absolute photon detection efficiency is:

$$\varepsilon_{tot} = \frac{total\ number\ of\ detected\ photons\ in\ the\ full-energy\ peak}{total\ number\ of\ photons\ emitted\ by\ the\ source} \qquad (2.7)$$

Not all gamma rays emitted by thesource that pass through thedetector will produce a count inthe system. The probability that anemitted gamma ray will interactwith the

detector and produce acount is the efficiency of thedetector. High-efficiency detectorsproduce spectra in less time thanlow-efficiency detectors.

In general,larger detectors have higherefficiency than smaller detectors,although the shielding propertiesof the detector material are alsoimportant factors. Detectorefficiency is measured bycomparing a spectrum from asource of known activity to thecount rates in each peak to thecount rates expected from theknown intensities of each gammaray.

For the discussion to follow, we will be concerned with only full-energy events and thus with the full-energy detection efficiency. This total efficiency can be expressed as the product of four factors (Muggleton; 1972):

$$\varepsilon_{tot} = \varepsilon_{geom}\, \varepsilon_{absp}\, \varepsilon_{sample}\, \varepsilon_{int} \qquad (2.8)$$

According to Muggleton (1972), the geometric efficiency ε_{geom} is thefraction of emitted photons that are interceptedby the detector. For a point source, this is given by

$$\varepsilon_{geom} = {}^{A}/_{4\pi r^2} \qquad (2.9)$$

where A is the cross-sectional area of the detector and r is the source-to-detector distance. This factor is essentially independent of photon energy. It manifests the well-known inverse-square law for counting rates as a function of source-to-detector distance.

The absorption efficiencyε_{absp} takes into account the effects of intervening materials(such as the detector housing, special absorbers, etc.) that absorb some of theincoming radiation before it interacts with the detector volume. This term is especiallyimportant (it should be <<1) for low-energy photons for which absorption effects aremost pronounced. It has the mathematical form (Muggleton; 1972):

$$\varepsilon_{absp} = \exp\left[- \Sigma\, \mu_i(E_\gamma)\rho_i X_i \right] \qquad (2.10)$$

Whereμ_i , ρ_i and X_i are the mass absorption coefficient, density, and thickness of the ith intervening material, and the summation is over all types of intervening materials.

The sample efficiencyε_{sample} isthe reciprocal of the sample self-absorption correction(CF_{atten}). This quantity is the fraction of emitted gamma rays that actually emerge from the sample material. For example, in a slab of thickness x and transmission T equal to $\exp[-(\mu\rho x)_s]$, the sample efficiency is(Muggleton; 1972):

$$\varepsilon_{sample} = \frac{1-\exp[-(\mu\rho X)_s]}{(\mu\rho X)_s} = \frac{T-1}{In\ T} \qquad (2.11)$$

This factor clearly depends on the composition of each sample (*Muggleton; 1972).*

The intrinsic efficiency ε_{int} is the probability that a gamma ray that enters thedetector will interact and give a pulse in the full-energy peak. In simplest terms, this efficiency comes from the standard absorption formula(Muggleton; 1972):

$$\varepsilon_{int} = 1 - \exp(-\mu\rho X) \qquad (2.12)$$

whereμ is the photoelectric mass attenuation coefficient, and ρ and x are the densityand thickness of the sensitive detector material. This simple expression underestimatesthe true intrinsic efficiency because the full-energy peak can also contain events frommultiple Compton scattering interactions. In general, ε_{int} is also a weak functionof r because of the detection of off-axis incident gamma rays. According toMuggleton; (1972) empirically, ε_{int} canusually be approximated by a power law of the form:

$$\varepsilon_{in\ t} \propto aE_\gamma^{-b} \qquad (2.13)$$

Efficiency, like resolution, can beexpressed in absolute or relativeterms. The same units are used(i.e., percentages); therefore, thespectroscopist must take care todetermine which kind of efficiencyis being given for the detector.

Absolute efficiency valuesrepresent the probability that agamma ray of a specified energypassing through the detector willinteract and be detected. Relativeefficiency values are often used forgermanium detectors, and comparethe efficiency of the detector

at1332 keV to that of a 3 in × 3 inNaI detector (i.e., 1.2×10^{-3}cp s/Bq at 25 cm). Relative efficiencyvalues greater than one hundredpercent can therefore beencountered when working withvery large germanium detectors.

Detector efficiencies are usually measured and quoted as absolute photopeak efficiencies for detection of gamma rays from unattenuating point sources. Therefore, their energy dependence is dominated by ε_{int} at the higher energies and by ε_{absp} *at* the lower energies; the geometrical factor ε_{geom}establishes the overall magnitude of the efficiency.

The energy of the gamma raysbeing detected is an importantfactor in the efficiency of thedetector. An efficiency curve canbe obtained by plotting theefficiency at various energies. Thiscurve can then be used todetermine the efficiency of thedetector at energies different fromthose used to obtain the curve.

The field instruments commonly used for detecting radiological contaminants relies on the detection of gamma-ray emissions from the radionuclides of interest such as 238U, ^{232}Th and ^{40}K which are eminent in the soil. Sodium Iodide (NaI) scintillators; an inorganic type of scintillator is an above-ground gamma-ray detector typically employed to interact with gamma rays to produce a detectable signal. In view of this, the Sodium Iodide (NaI) scintillators is specifically used in this work to analyze the ginger and soil samples from Jabi Local Government Area of Kaduna state and will be described in Chapter Three and its advantages and disadvantages described below.

2.6 Advantages and Disadvantages of Sodium Iodide Scintillators

Thallium-doped sodium iodide (NaI(Tl)) detector has two principal advantages:

1. It can be produced in large crystals, yielding good efficiency, and

2. It produces intense bursts of light compared to other spectroscopic scintillators. NaI(Tl) is also convenient to use, making it popular for field applications such as the identification of unknown materials for law enforcement purposes.

The disadvantages are as follows:

1. NaI(TI) is very hygroscopic and needs to be housed in an airtight enclosure.
2. Because of the poor resolution of NaI-based detectors, they are not suitable for the identification of complicated mixtures of gamma ray-producing materials. Scenarios requiring such analyses require detectors with higher resolution.
3. Sodium iodide systems, as with all scintillator systems, are sensitive to changes in temperature. Changes in the operating temperature caused by changes in environmental temperature will shift the spectrum on the horizontal axis. Peak shifts of tens of channels or more are commonly observed. Such shifts can be prevented by using spectrum stabilizers.

2.7 Previous Works

The medicinal, chemical, and pharmacological properties of ginger have been extensively reviewed (Surhet al, 1998; Ernst and Pittler 2000 ; Afzal et al. 2001 ; Bode et al, 2004; Boone and Shields 2005; Chrubasik and Pittler 2005; Chrubasik et al, 2005; Grzanna, Lindmark, and Frondoza 2005 ; Thompson and Potter 2006; Eliopoulos 2007 ; Shukla and Singh 2007 ; White 2007; Ali et al. 2008 ; Nicoll and Henein 2009).

Surh, et al. (1998), carried out study on chemoprotective properties of some pungent ingredients present in red pepper and ginger. The recent studies reveal substantial antigenotoxic and anticarcinogenic effects of capsaicin, suggesting this compound as another important dietary phytochemical with a potential chemopreventive activity. Some pungent constituents present in ginger and other zingiberaceous plants have

potent antioxidant and anti-inflammatory effects, and some of them exhibit anti-tumor promotional activity in experimental carcinogenesis.

Ernst, et al., (2000), studied the efficacy of ginger for nausea and vomiting: a systematic review of randomized clinical trials. Six studies met all inclusion criteria and were reviewed. The report shows that three on postoperative nausea and vomiting were identified and two of these suggested that ginger was superior to placebo and equally effective as metoclopramide. The pooled absolute risk reduction for the incidence of postoperative nausea, however, indicated a non-significant difference between the ginger and placebo groups for ginger 1 g taken before operation (absolute risk reduction 0.052 (95% confidence interval -0.082 to 0.186)). One study was found for each of the following conditions: seasickness, morning sickness and chemotherapy-induced nausea. These studies collectively favoured ginger over placebo. Hence, this goes to show that ginger has an utmost value to subside the effect of nausea and vomiting.

Boone, et al. (2005), carried out a research on; treating pregnancy-related nausea and vomiting with ginger. It was reported that while data are insufficient to recommend ginger universally and there are concerns with product quality due to limited regulation of dietary supplements, ginger appears to be a fairly low-risk and effective treatment for nausea and vomiting associated with pregnancy. In low doses, this may be appropriate for patients not responding to traditional first-line therapies.

Nicoll, et al. (2009), investigated the use of ginger as a hot remedy for cardiovascular disease. This letter reviews the more recent trials, which suggest that ginger shows considerable anti-inflammatory, antioxidant, anti-platelet, hypotensive and hypolipidemic effect in in vitro and animal studies. It was observed that although human trials have been few and generally used a low dose with inconclusive results,

however dosages of 5 g or more demonstrated significant anti-platelet activity. More human trials are needed using an appropriate dosage of a standardized extract. Should these prove positive, ginger has the potential to offer not only a cheaper natural alternative to conventional agents but one with significantly lower side effects.

White (2007), studied the overview of ginger and it was reported that ginger *(Zingiberofficinale)* is one of the more commonly used herbal supplements. Although often consumed for culinary purposes, it is taken by many patients to treat a variety of conditions. Ginger has been shown to be effective for pregnancy-induced and postoperative nausea and vomiting. There is less evidence to support its use for motion sickness or other types of nausea and vomiting. Mixed results have been found in limited studies of ginger for the treatment of arthritis symptoms.

Over the last few years, interest in ginger or its various components as valid preventive or therapeutic agents has increased markedly, and scientific studies focusing on verification of ginger's pharmacological and physiological actions have likewise increased (Ali et al. 2008).

There are many studies about the concentration of radioactivity in medicinal plants from different countries. However, (Abdulhussein*et al* 2016) carried out a research on the measurement of natural radioactivity in selected samples of medical plants in Iraq. One of the medical plants investigated is ginger out of 40 plants investigated.

Natural levels of radiation in some selected medical plants existing in the Iraqi stores were estimated to determine any activity concentration, radium equivalent and internal hazard indexdue to radionuclide, of ^{238}U, ^{232}Th as well as ^{40}K, which occurs naturally. This activity concentrationwas identified by gamma-ray spectroscopy (NaI(TI)). The findings indicate that, the rate of activity concentration for Uranum-238, Thorium-232

and Potasium-40 in the medical plants were (4.953 ±0.37)Bq.kg^{-1}, (2.916 ± 0.12) Bq.kg^{-1}and (219.13 ± 2.24) Bq.kg^{-1}respectively. The values of the radium equivalent ranged from (6.08 ± 0.09) Bq.kg^{-1}to (44.608 ± 0.46) Bq.kg^{-1} with the rate of (20.278 ±0.38) Bq/kg. The natural radionuclides and activity of the radium equivalent in the medical plant sampleswere far below the world for the ingestion of naturally occurring radionuclide provided in UNSCEAR 2000 report. As one of the medicinal plants studied, ginger crop to be specific, was analyzed to have an activity concentration of (3.13 ± 0.23) Bq.kg^{-1}, (3.17 ±0.14) Bq.kg^{-1} and (213.77 ± 2.00) Bq.kg^{-1}for Uranum-238, Thorium-232 and Potasium-40 respectively. The radium equivalent value was found to be (24.12 ± 0.59) Bq.kg^{-1}. These values obtained were far below the world standard values as provided in UNSCEAR2000 report. The results for ginger was singled out and used as a basis for comparison with the NORMs under investigation in this work.

There are many studies about the concentration of radioactivity in medicinal plants from different countries. However, it is pertinent to know that no concrete study had been conducted on the radionuclide uptake of ginger from the soil. Hence, this research is a first of its kind to intensively look into ginger with the sole aim of estimating the level of radionuclide content in ginger grown inSambamGida, Jaba Local Government, Kaduna State, Nigeria; by determining the rate of transfer from soil to the crop; and to intimate other researchers on the need to carry out a similar research in this area.

CHAPTER THREE

MATERIALS AND METHOD

3.1 Materials

The following materials were used in this work:

- Weighing balance
- Sieve
- Sodium Iodide Thallium doped (NaI(TI)) detector.
- Ginger grown in SambamGida Village, Jaba Local Government Area, Kaduna State.
- Mortar and pestle for grinding and homogenizing the sample.
- Candle and Petroleum Jelly for sealing the sample container
- Use of natural drying such as shade as well as electric oven to dry sample

3.2 Methodology

3.2.1 Study Area

SambamGida is a village in Jaba Local Government Area in Kaduna State, Nigeria. The headquarters of Jaba local government are in the town of Kwoi (HarKwain) in Hyam. The people know themselves as the Ham and speak Hyam but are called 'Jaba' by the Hausa. Almost the entire inhabitants of the local area speak the same language.

Jaba local government has an area of 368 km^2 and a population of 155,377 at the 2006 census. It is inhabited predominantly by Ham people. There are three Districts/Areas in Jaba Local Government Area which are Ankung, Kwoi and Nok.

Jaba Local government could be reached by road from the southern parts of the country from Abuja,through Keffi a town in Nassarawa state or through Kafanchan, which lies roughly 40Km away from the Headquarters of the Ham in Kaduna State, Nigeria.

From the Plateau State capital, Jos, it is a journey by road through Kafanchan, linking Sambang Shang, Kwoi (HarKwain), Nok, and to all other villages.

From Kaduna town, SambamGida village in Jaba local government can be reached through Kachia, Ngboodub, Ghikyaar and HarKwain. These are routes connecting Jaba local government from the southern part of Kaduna state situated close to Jos Plateau and Abuja region in the central part of Nigeria in West Africa.

Jaba has a farming population and rated one of the highest locations where ginger is produced in the state.

Ginger and soil samples used for this work were obtained from SambamGida village situated in Jaba Local Government Area of Kaduna State. The SambamGida falls within the coordinate of latitude 9˚27′08″N & 9˚28′33″N and longitude 8˚02′48″E & 8˚03′23·54″E.It is a small settlement in between high lands, specifically rocks each with a depth of 2920ft and 2890ft.Each sampling points was marked using global positioning system (GPS)as shown in figure 3.1.

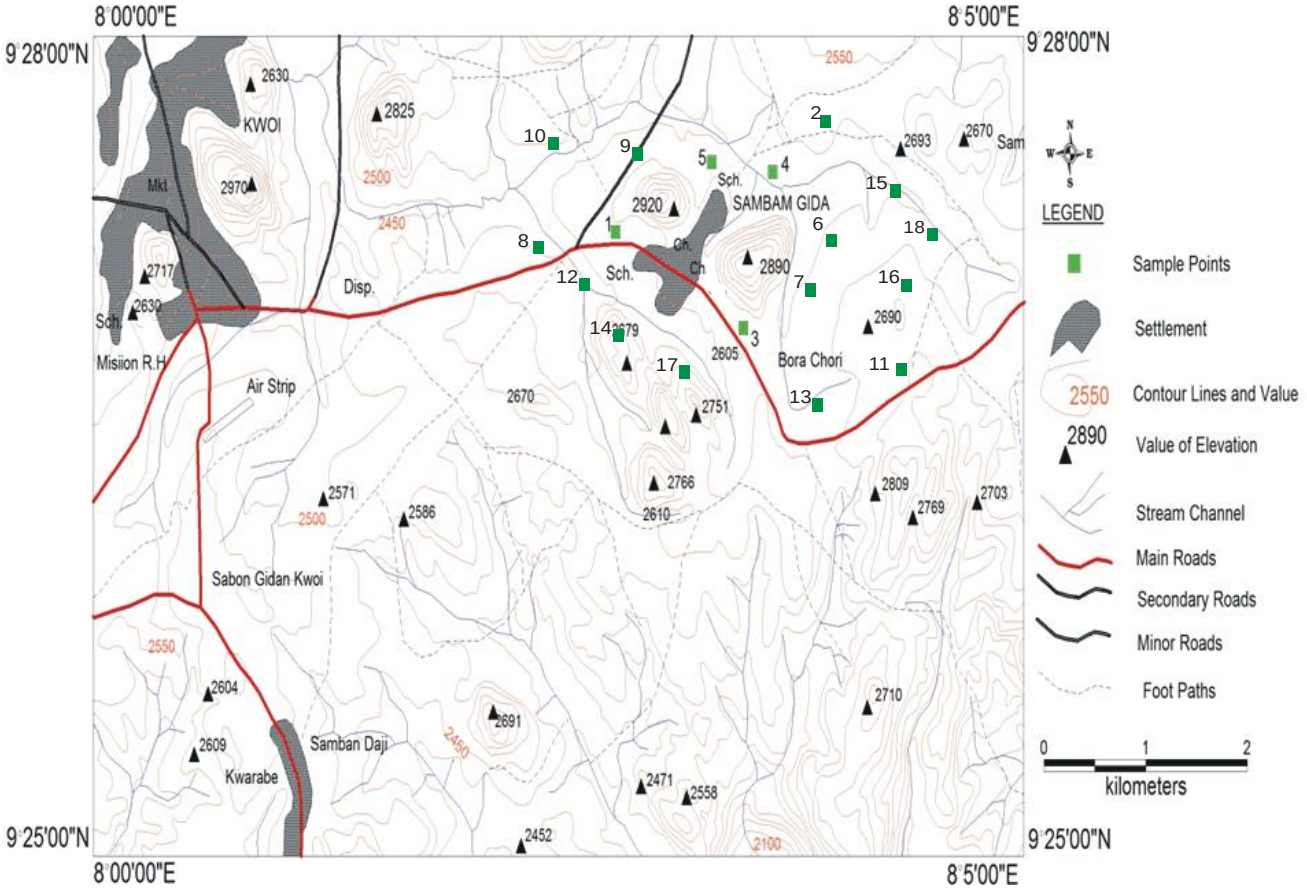


Fig. 3.1: Topographical map of Sambam Gida and its environs; part of sheet 188, Jama'a NW.

Within Sambam Gida village in Jaba local government, eighteen farmlands were mapped out for sample collections. On each of these eighteen farmlands,twenty samples comprising of ginger and the host soil were obtained from twenty different sampling spots to give a total of 360 sampling points in all.Anda different farmland, the control samples were collected from the eighteen farmlands but just at a spot to make a total of 378 samples.

The exact locations of the samples collected falls within eighteen geographical points from9^{o}27'40" N and 8^{o}01'30" Efor farmland one to 9^{o}26'45" N and 8^{o}04'06" E for farmland eighteen with slight variations in minutes and seconds as show in Table 3.1.The samples were transferred into the laboratory after which they were labelled

accordingly as shown also in Tables3.1.The fertilizer specifically used by the farmer in cultivating the ginger crop is Stallion Magic NPK 15:15 and was gotten from the local market.

Table 3.1: Soil & Ginger Sample Data from 18 farmlands(Sample Point)

SAMPLE POINT	DESCRIPTION	Longitude	Latitude
Farmland 1	Soil& Ginger	9°27’40” N	8°01’30” E
Farmland 2	Soil& Ginger	9°27’58” N	8°01’45” E
Farmland 3	Soil& Ginger	9°27’32” N	8°02’59” E
Farmland 4	Soil& Ginger	9°27’20” N	8°00’48” E
Farmland 5	Soil& Ginger	9°27’29” N	8°01’59” E
Farmland 6	Soil& Ginger	9°27’20” N	8°03’48” E
Farmland 7	Soil& Ginger	9°26’20” N	8°02’22” E
Farmland 8	Soil& Ginger	9°26’20” N	8°01`32” E
Farmland 9	Soil& Ginger	9°26’48” N	8°01’43” E
Farmland 10	Soil& Ginger	9°25’20” N	8°00’00” E
Farmland 11	Soil& Ginger	9°25’20” N	8°03’15” E
Farmland 12	Soil& Ginger	9°25’18” N	8°03’41” E
Farmland 13	Soil& Ginger	9°25’30” N	8°03’43” E
Farmland 14	Soil& Ginger	9°25’06” N	8°01’20” E
Farmland 15	Soil& Ginger	9°27’20” N	8°03’52” E
Farmland 17	Soil& Ginger	9°27’38” N	8°01’59” E
Farmland 18	Soil & Ginger	9°26’45” N	8°04’06” E
CONTROL	Soil & Ginger	9˚27′17·08″N	8˚02′48·1″E

3.2.2 SamplingProcedure

Eighteen farmlands were mapped out for use.Another farmland aside the eighteen earlier mapped separately was marked as control sample point where soil sample was obtained too making a total of nineteen. The farmlands were a small piece of land measuring about 14x6.5m eachwith very few unharvested crops. Samples from each of these farmlands were proportioned into20 parts per land in such way that from each assigned portion of land, twenty soil samples were obtained from a different sampling spot; same goes for the other apportioned land called the control.

3.2.3 Sample Collection

3.2.3.1 Soil Sample

The surface soil samples of 1kg weight were collected (20 cm deep) from Sambam Gida village in Jaba Local Government Area from the rooting area of the host plant. Eachsample was transferred into labeled polythene bag from the field. The control soil sample was room dried to avoid contamination of radionuclides from sun light while the other soil samples were sun dried for a period of one week before crushing and sieving to obtain a homogenous mixture. The samples were properly dried to ensure that moisture is completely removed. The samples werelater transferred into the labelled polythene bags and sent to laboratory at the Centre for Energy Research and training, Ahmadu Bello University, Zaria.

3.2.3.2 Ginger Sample

Ginger crop of 1kg weight werecollected from Sambam Gida village in Jaba Local Government Area and were dug out from the corresponding point where the soil sampleswerecollected. Each samplewas packedin a labelled polythene bag right from

the field. The control ginger samples were rinsed with distilled water to get rid of contaminants and they were grated and then room dried on trays for a period of one week, while the other ginger samples were washed with tap water and grated and subsequently sun dried for a period of one week to ensure it is properly driedbefore pounding and sieving to obtain a homogenous mixture.

The samples were properly dried to ensure that moisture is completely removed. This isto ensure that the moisture content doesn't interfere with the radioactivity concentration results obtained. They were later transferred into the labeled polythene bags and taken to the laboratory at the Centre for Energy Research, Ahmadu Bello University, Zaria.

3.2.4 Sample Preparation Procedure

Each of the soil samples collected were dried and crushed to fine powder with the use of mortar and pestle. They were sieved and mixed for homogenization, and the large pieces were removed.

The samples were then filled into plastic containers of known weight. The weight of the sample and the container were measured using the weighing balance. The weight of the sample was obtained by subtracting the weight of the empty container from the weight of the sample and the container.

To prevent radon-222 escaping, the packaging in each case was triple sealed.The sealing process includes smearing of the inner rim of each container lid with petroleum jelly, filling the lid assembly gap with candle wax to block the gaps between lid and container, and tight-sealing lid-container with masking adhesive tape.The sealed containers were kept for a period of one month to make sure the samples attained secular radioactive equilibrium between Ra-226 and its decay products in the uranium

series, and Ra-228 and its decay products in the thorium series (Lordford et al, 2013; Tahir and Alaamer, 2009).

In a nutshell, the samples were stored for 30 days prior to gamma spectrometry measurements to allow Radon and its short-lived progenies to reach secular radioactive equilibrium.

3.2.5 Sample Analysis

3.2.5.1 Equipment Used for Analysis

Gamma ray spectrometry was employed for the activity concentration measurements. The analysis was carried out using a 76x76mm **NaI (Tl)** detector crystal optically coupled to a photomultiplier tube (PMT). The assembly has a preamplifier incorporated into it and a 1kilovolt external source. The detector is housed in a 6cm thick lead-shield, cadmium-lined assembly with copper sheets for the reduction of background radiation. The data acquisition software is **Maestro** by Canberra Nuclear Products with a Model No. 727 and Serial No. 1914167. The samples were measured for a period of 29000 seconds, for each sample. The peak area of each energy in the spectrum was used to compute the activity concentrations in each sample by the use of the following equation:

$$C\ (Bqkg^{-1}) = \frac{C_n}{C_{fk}} \tag{3.1}$$

where;

C = activity concentration of the radionuclides in the sample in $Bqkg^{-1}$

C_n = count rate;Count per second (cps)= $\frac{Net\ Count}{live\ Time}$

C_{fk} = Calibration factor of the detecting system.

(a) Sodium Iodide Thallium Doped (NaI(TI)) Scintillators

Sodium iodideactivated with thallium, NaI(Tl), when subjected to ionizing radiation, emits photons (i.e., scintillate) and is used in scintillation detectors. Traditionally used in nuclear medicine, geophysics, nuclear physics, and environmental measurements, NaI(Tl) is the most widely used scintillation material.

The crystals are usually coupled with a photomultiplier tube, in a hermetically sealed assembly, as sodium iodide is hygroscopic. Fine-tuning of some parameters (i.e., radiation hardness, afterglow, transparency) can be achieved by varying the conditions of the crystal growth. Crystals with a higher level of doping are used in X-ray detectors with high spectrometric quality. Sodium iodide can be used both as single crystals and as polycrystals for this purpose. The wavelength of maximum emission is 415 nm.

Sodium iodide detectors are well-suited for detection of photon radiation. Energy-compensated sodium iodide detectors may also be cross-calibrated for assessment of exposure rates. Unlike ZnS(Ag), sodium iodide crystals can be grown relatively large and machined into varying shapes and sizes. Sodium iodide crystals are activated with trace amounts of thallium (hence the abbreviation NaI(Tl)), the key ingredient to the crystal's excellent light yield (Knoll, 1979). These instruments most often have upper- and lower-energy discriminator circuits and when used correctly as a single-channel analyzer, can provide information on the photon energy and identify the source radionuclides. Sodium iodide detectors can be used with handheld instruments or large stationary radiation monitors.

(b) Principle of operation of the Detector

The Sodium iodide doped with thallium is a scintillator that converts the energy from incident gamma radiation into light in the visible spectrum that is then detected with a photomultiplier tube.

The gamma rays interact with sodium iodide crystal in mainly two ways known as the photoelectric effect and Compton scattering.

The purpose of the Gamma-Spec as shown in plate I below is to identify and quantify the gamma emitting radionuclides in the plant and soil samples. The gamma-ray energy pulse first goes through a preamplifier before reaching an amplifier, where the current pulse is converted into a voltage pulse made possible by power supply source. This is done by performing an energy calibration resulting in the pulse height being proportional to the gamma-ray energy. Next the pulse travels through an Analog to Digital Converter (ADC as its used is shown in plateII) where the voltage pulse is transformed into a number. Finally, the number is reported using a spectrum by the Multi-Channel Analyzer (MCA).

By performing an energy calibration, a relationship between channel number and gamma ray energy is determined. Each radionuclide has one or more identifying energy levels. Each peak produced and measured by the Gamma-Spec analyzer is matched to a radionuclide energy level. The detected nuclides activity levels are reported in Becquerel/kg.

(c)Experimental Set-up

Experimental set-up of NaI(TI) detector employed in analyzing the sample are shown in Plate I and Plate II shows pictorial illustration of analyzing through a digital display.



Plate I: A Gamma Spectroscopy Set-up (Centre for Energy Research and Training, ABU Zaria 2017).



Plate II: Analyzing the samples via the digital display to determine the peak area of each energy in the spectrum (Centre for Energy Research and Training, ABU Zaria 2017)

3.2.5.2 Equipment Calibration

The standards used to check for the calibration are the IAEA gamma Spectrometric reference materials RGK-1 for K-40, RGU-1 for Ra-226 (Bi-214 peak) and RTG-1 for Th-232 (Ti-208)

(a) Efficiency Calibration

Calibration of the system for efficiency was done with two calibration point sources, Cs-137 and Co-60. These were done with the amplifier gain that gives 72% energy resolution for the 66.16Kev of Cs-137 and counted for 30minutes.

The absolute detection efficiency of the NAI(TI) detector was determined using the standard sources shown in Table 3.2 (Varier, 2009). The absolute efficiency of the detector for the γ-ray energies were calculated from Equation (3.2),

$$\varepsilon = \frac{n}{tP_{\gamma}(E)N_o e^{-\lambda t_d}} \qquad (3.2)$$

where n is the net area under the full energy peak of gamma-ray energy E, t is the counting time, $P_{\gamma}(E)$ is the gamma-ray emission probability at energy E, N_o is the activity of the source (Becquerel), λ is the decay constant = ln $2/T_{1/2}$ where $T_{1/2}$ is the half- life of the radionuclide, and t_d is the decay time. The efficiency calibration curve for the NaI (Tl) detector is shown in Figure 3.2.

Table 3.2: Standard gamma-ray sources (Varier, 2009).

Source	Half-life ($_{T1/2}$)	Gamma energy (MeV)
60Co	5.26 years	1.1732 and 1.3323
137 Cs	30 years	0.6616
54 Mn	312.5 years	0.8348
133 Ba	10.52 years	0.340 and 0.081
22 Na	2.6 years	0.511 and 1.275

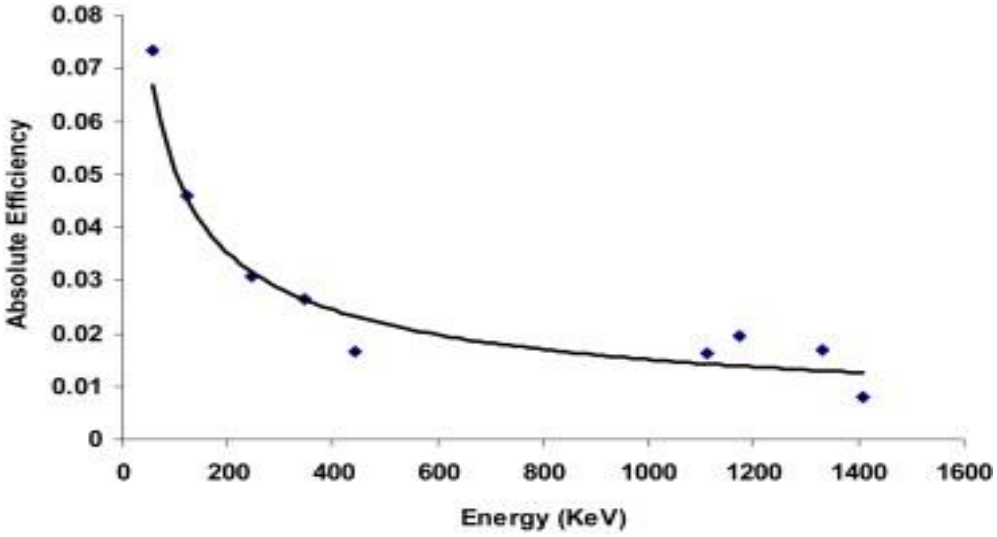


Fig. 3.2: The efficiency calibration curve for the NaI(TI) detector.(International Atomic Energy Agency; (IAEA), 1989).

(b) Energy Calibration

Energy calibration involves identifying the locations of standard photo-peaks in the raw spectrum, then creating an adjusted (or calibrated) spectrum by interpolation from the raw positions to the standard (or ideal) positions displaced by the MAESTRO software. For a standard spectrum measured from 0.0 to 3.0 MeV and digitized into 256 channels

(0–255) each channel has a range of 11.72 keV. This defines the standard channel range for each IAEA defined energy window. The calibration of the system for energy was done with two calibration point sources, Cs-137 and Co-60 using the amplifier gain that gives 72% energy resolution for the 66.16kev of Cs-137 and counted for 30minutes.

The analyzer was calibrated with the IAEA supplied reference materials for the quantitative determination of ^{40}K, ^{238}U and ^{232}Th in the plant and soil samples. The system was set at a working energy range of 0–3000 keV, which accommodated the energy range of interest in the study. An energy resolution of 7.2% (661.6 keV 137 Cs) was obtained. Each sample was counted for 29,000 s (≈8 h) in the set geometry. The activity concentration of ^{238}U, ^{40}K, and ^{232}Th was determined by the γ- lines of their decay products.

Table 3.3: Spectral energy windows used in the Analysis(International Atomic Energy Agency; (IAEA), 1989).

Isotope	***Gamma Energy (keV)***	***Energy Window (keV)***
R-226	1764.0	1620 – 1820
Th-232	2614.5	2480 – 2820
k- 40	1460.0	1380 – 1550

Table 3.4: Energy Calibration for Quantitative Spectral Analysis(International Atomic Energy Agency; (IAEA), 1989).

IsotopeCalibration FactorsConversion Factors($Bq^{-}kg^{-1}$)Detection Limits   ***10^{-3} (cps/ppm)10^{-3} (cps/ppm)ppm Bq/kg***
^{40}K0.0266.4310.032454.5414.54
^{226}Ra10.500 8.63212.200 0.323.84
^{232}Th3.612 8.7684.1202.279.08

(c) Background Calibration

This was also the bases upon which calibration of the system for energy was done with two calibration point sources, Cs-137 and Co-60. The background count rate was done for 29000 seconds just as those of the samples.

3.2.5.3 Sample Counting Parameters

The samples were measured for a period of 29000 seconds, for each sample. The peak area of each energy in the spectrum was used to compute the activity concentrations in each sample.

3.2.6 Sample Analysis Computation

3.2.6.1 Transfer Factor

This factor is used to illustrate the transfer of radionuclides from soil to the plant.

TF values have been considered in compliance with the definition proposed by the International Union of Radioecology (IUR), 1989, which is:

$$TF = \frac{Concentration\ \ of\ radionuclide\ \ in\ plant\ \ (Bqkg^{-1}\ \ dry\ crop\ mass\ )}{Concentration\ \ of\ radionuclide\ \ in\ soil\ (Bqkg^{-1}\ \ dry\ soil\ mass\ in\ upper\ \ 20cm)} \qquad (3.3)$$

3.2.6.2 Assessment of Radiological Health Hazards

The following radiological parameters were calculated from the activities. They are radium equivalent index, representative gamma index, absorbed dose, annual effective dose rate, external hazard index, and internal hazard index. These parameters are factors or limits which define health status of a radiated or irradiated environment or food and human being.

3.2.6.2.1 Radium equivalent activity index (Raeq): This is a radiological index which represents the activity levels of ^{226}Ra, ^{232}Th and ^{40}K by a single quantity and also takes into account the radiation hazards associated with them (Diab *et al*., 2008). It is mathematically defined by (UNSCEAR, 2000) as

$$Raeq = CRa + 1.43CTh + 0.077CK \quad (3.4)$$

where CRa, CTh and CK are the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K respectively. In the above relation, it has been assumed that 10 $Bqkg^{-1}$ of ^{226}Ra, 7 $Bqkg^{-1}$ of ^{232}Th and 130 $Bqkg^{-1}$ of ^{40}K produce equal gamma dose. The maximum value of Raeq in soil must be less than 370 $Bqkg^{-1}$ (UNSCEAR 2010) otherwise it is regarded as being above standard.

3.2.6.2.2 Absorbed dose rate (D): Absorbed dose rate is a measure of energy deposited in a medium by ionizing radiation. It is equal to the energy deposited per unit mass of the medium, and so has the unit J/kg, which is given by special name Gray (Gy). Absorbed dose rate therefore is absorbed dose divided by the time it takes to deliver that dose unit Gy/s. The absorbed dose rates in outdoor (D) due to gamma radiations in air at 1m above the ground surface for the uniform distribution of the naturally occurring radionuclides (^{226}Ra, ^{232}Th and ^{40}K) were calculated based on guidelines provided by (UNSCEAR, 2000). The conversion factors used to compute absorbed - dose rate (D) in air per unit activity concentration in Bq/kg (dry weight) corresponds to 0.462 nGh^{-1} for 226Ra (of U – series), 0.621 nGh-1 for 232Th and 0.0417 nGh-1 for 40K (UNSCEAR, 2000).

$$D\ (nGh\text{-}1) = 0.462CRa + 0.621CTh + 0.0417CK \quad (3.5)$$

3.2.6.2.3 Annual effective dose rate: To estimate the annual effective dose rates outdoor, the conversion coefficient from absorbed dose in air to effective dose (0.7$Sv.Gy^{-1}$) and outdoor occupancy factor (0.2) proposed by (UNSCEAR, 2000) are used. Therefore, the annual effective dose rate ($mSvy^{-1}$) was calculated by the formula (UNSCEAR, 2000):

Effective dose rate ($mSvy^{-1}$) = D (nGh-1) x 8760h. y^{-1} x 0.7 x (103 mSv/109) nGh x 0.2

$$Eff\ dose = D \times 1.2264 \times 10^{-3} \quad (3.6)$$

UNSCEAR(2000), stated that the worldwide annual effective dose from the natural sources of radiation in areas of normal background ionizing radiation is estimated to be $1mSvy^{-1}$.

3.2.6.2.4 External hazard index (Hex): External hazard index is a widely used hazard Index which represents the external exposure and it is defined by UNSCEAR, 2000 as

$$Hex = CRa/370 + CTh/259 + CK/4810 \quad (3.7)$$

3.2.6.2.5 Internal hazard index (Hin): In addition to external hazard index, radon and its short-lived products are also hazardous to the respiratory organs. The internal exposure to radon and its daughter progenies is quantified by the internal hazard index Hin, which is given by the equation;

$$Hin = CRa/185 + CTh/259 + CK/4810 \quad (3.8)$$

The values of the indices (Hex, Hin) must be less than unity for the radiation hazard to be negligible (UNSCEAR, 2000).

Using the above equations, the results of analysis were computed. The various graphsshowing the comparisonof activity concentration of ^{40}K, ^{226}Ra and ^{232}Th in ginger crops and soil samples as well as the radiological parameters and the soil to plant factors (TF) were presented for a better understanding of the result of study.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

The activity concentration of naturally occurring radionuclides and the radiological hazard parameters in various ginger and their respective soil samples, with the fertilizer commonly applied in Sambam Gida, Jaba Local Government Area, Kaduna State, Nigeria have been determined.

The background radioactivity of these sampled areas were also measured using a survey meter as shown in Table 4.1 to check if the presence of parent granite rocks would influence a higher reading with respect to activity concentration of samples collected. In this case, about 65% of the soil on this sample area (Sambam Gida village) are traceable to rocks (sedimentary) fragments over the years.

The activity concentration due to ^{40}K, ^{226}Ra and ^{232}Th for the NPK 15:15 fertilizer used in the cultivation of ginger crop in Sambam Gida village is also shown in Table 4.2, while that of the soil and ginger crops are shown in Tables 4.3 and 4.4 respectively. The calculated radiological hazard indices for both soil and ginger crops are also detailed in Tables 4.5 and 4.6 correspondingly.

4.1 Results of Background Radiation Measurement of Sample Areas

Table 4.1: Background Radiation Measurement of Sample Areas using surveymeter.

S/N	SAMPLE POINTS	Long.	Lat.	RADIATION DOSE (µSv/hr)
1	FARMMLAND 01	9°27'40"N	8°01'30" E	0.05
2	FARMMLAND 02	9°27'58"N	8°01'45" E	0.07
3	FARMMLAND 03	9°27'32"N	8°02'59" E	0.43
4	FARMMLAND 04	9°27'20"N	8°00'48" E	0.09
5	FARMMLAND 05	9°27'29"N	8°01'59" E	0.13
6	FARMMLAND 06	9°27'20"N	8°03'48" E	0.15
7	FARMMLAND 07	9°26'20"N	8°01'32" E	0.36
8	FARMMLAND 08	9°26'20"N	8°01'32" E	0.28
9	FARMMLAND 09	9°26'48"N	8°01'43" E	0.20
10	FARMMLAND 10	9°25'20"N	8°00'00" E	0.32
11	FARMMLAND 11	9°25'20"N	8°03'15" E	0.21
12	FARMMLAND 12	9°25'18"N	8°03'41" E	0.08
13	FARMMLAND 13	9°25'30"N	8°03'43" E	0.23
14	FARMMLAND 14	9°25'06"N	8°01'20" E	0.26
15	FARMMLAND 15	9°27'20"N	8°03'53" E	0.11
16	FARMMLAND 16	9°27'38"N	8°01'59" E	0.28
17	FARMMLAND 17	9°26'45"N	8°04'06" E	0.09
18	FARMMLAND 18	9°27'17.08"N	8°02'48" E	0.19
19	CONTROL AREA	9°27'17"N	8°02'48" E	0.11

Sampling points and radiation dose varied as shown in Table 4.3,using a survey meter.It can be seen that Farmlands closer to parent rock have higher radiation dose readings than farmlands afar off.This alsocontribute to the reason for higher concentration of ^{40}K on farmlands closer to parent rocks as shown on map; for instance, farmland **3** to be specific was tested for a high concentration of ^{40}K inginger samples.

4.2 Results of Activity Concentration in Fertilizer

The results of the stallion Magic NPK 15:15 fertilizer used in cultivating ginger crop in Sambam Gida, Jaba Local Government Area, Kaduna State, Nigeria have been analysed and shown below. This information will form a basis to compare reasons as to whether or not the ginger cultivated could take up more radionuclides besides the presence of massive rocks situated on both sides of the geographical locations of the study area.

Table 4.2 Activity concentration of radionuclides of NPK fertilizer

Sample ID	K-40 (Bq/kg)	Ra-226 (Bq/kg)	Th-232 (Bq/kg)
NPK (F)	2024.19±12.44	19.26±3.19	62.05±1.26
World Standard	420	32	45

4.3 Results of Activity Concentration in Soil Samples

Table 4.3:Average Activity concentration of radionuclides of ^{40}K, ^{226}Ra, and ^{232}Th, inthe soil samples collected from 18-farmlands and Control.

FARM LOCATION	NO. OF SOIL SAMPLES COLLECTED	GPS LOCATION Long. Lat.	K-40 (Bq/kg)	R-226 (Bq/kg)	Th-232 (Bq/kg)
			MEAN ACTIVITY CONCENTRATYON		
Farm 01	20	9°27'40"N	8°01'30" E	401.30 ± 10.08	46.59 ± 6.03	121.26 ± 2.99
Farm 02	20	9°27'58"N	8°01'45"E	313.24 ± 10.14	30.81 ± 3.28	68.77 ± 0.87
Farm 03	20	9°27'32"N	8°02'59" E	290.40 ± 7.94	38.84 ± 3.92	83.71 ± 3.26
Farm 04	20	9°27'20"N	8°00'48" E	232.53 ± 7.19	21.42 ± 3.84	41.13 ± 1.26
Farm 05	20	9°27'29"N	8°01'59" E	310.99 ± 5.65	19.54 ± 3.87	72.26 ± 1.43
Farm 06	20	9°27'20"N	8°03'48" E	280.48 ± 9.53	23.65 ± 6.65	52.73 ± 3.43
Farm 07	20	9°26'20"N	8°02'22" E	261.28 ± 9.79	28.65 ± 4.65	38.54 ± 2.76
Farm 08	20	9°26'20"N	8°01`32" E	350.74 ± 9.03	35.35 ± 4.57	60.65 ± 4.42
Farm 09	20	9°26'48"N	8°01'43" E	232.71 ± 5.86	28.93 ± 5.58	65.44 ± 3.57
Farm 10	20	9°25'20"N	8°00'00" E	283.49 ± 5.65	38.26 ± 6.96	94.77 ± 0.60
Farm 11	20	9°25'20"N	8°03'15" E	203.50 ± 5.75	25.42 ± 6.66	90.67 ± 0.11
Farm 12	20	9°25'18"N	8°03'41" E	399.01 ± 8.89	33.53 ± 4.35	08.57 ± 2.99
Farm 13	20	9°25'30"N	8°03'43"E	301.29 ± 8.77	38.98 ± 6.61	45.77 ± 2.79
Farm 14	20	9°25'06"N	8°01'20" E	315.98 ± 8.77	27.77 ± 3.76	43.72 ± 2.77
Farm 15	20	9°27'20"N	8°03'52" E	243.64 ± 4.68	30.36 ± 3.86	48.55 ± 1.99
Farm 16	20	9°27'38"N	8°01'59" E	295.43 ± 4.65	44.54 ± 5.87	110.65 ± 3.3
Farm 17	20	9°26'45"N	8°04'06" E	307.38 ± 6.67	22.54 ± 5.65	84.78 ± 2.49
Farm 18	20	9˚27′17·08″N	8˚02′48·1″E	405.15 ± 10.66	45.09 ± 2.46	103.86 ± 2.00
Control Soil	20	9˚27′17·08″N	8˚02′48·1″E	295.87 ± 8.63	34.20 ± 5.07	113.95± 3.03
Mean				301.59 ± 7.76	32.24 ± 4.92	74.21 ± 2.39
World Standard			420	32	45	

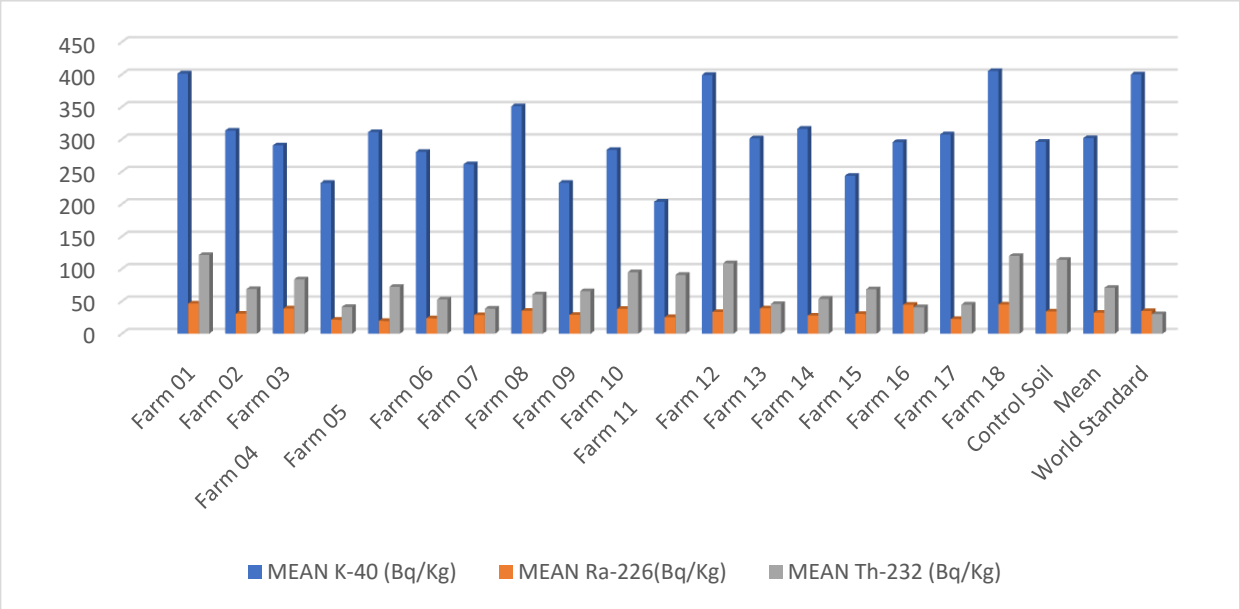


Fig. 4.1: Comparison of activity concentrations of soil samples with the standard value.

As seen in Table 4.3, the activity concentration of 40K in all the soil samples obtained from 18 farmlands and 'Control' ranges from 203.50 Bq/kg as the lowest concentration to 405.15Bq/kg as the highest concentration with a mean value of 301.59Bq/kg. The lowest activity concentration of ^{40}K was recorded for sample11, whilesample 18, sample 12 and Sample 1as shown on table 4.3 had the highest activity concentration. For ^{226}Ra, it ranges from 19.54Bq/kg to 46.59 Bq/kg, with a mean value of 32.42 Bq/kg. Sample 5 has the lowest activity concentration of ^{226}Ra, while Sample 1 has highest activity concentration.

For the activity concentration of ^{232}Th, activity concentration varies from 30.58 Bq/kg to 121.26 Bq/kg, with a mean value of 74.21Bq/kg. The lowest activity was recorded for sample 7 while the highest activity was recorded for sample 1.

By comparing the values in Table 4.2 (Activity concentration of radionuclides in NPK fertilizer) and those of Table 4.3 (Activity concentration of radionuclides in the soil samples collected from farmland 1 to 18 and Control), with the world

standardrepresented diagrammatically in Fig. 4.1, of course the fertilizer has the highest value of ^{40}K amounting to 2024.19 Bq/kg and its presence in all the soil samples experimented was negligible.On the average, the level of ^{40}K across the soil samples are within the standard recognized limit of 420 Bq/kg.It is also important to note that the value of ^{40}K in sample1 and sample 18farm lands are 401.30 Bq/kg and 405.15Bq/kg are higher values which is probably because of the composition of the soil and other soil management practices like fertilizer application on that particular part of the soil but its effect is negligible since on the average, all other soil sample that was experimented was far below the standard limit.

Also, the level of ^{226}Ra on the average in all the soil samples and the fertilizer applied are also within the standard limit of 32Bq/kg, except for samples 1,3,8,10,12,13,16,18 and control soil with values 46.59, 38.84, 35.35, 38.26,38.98, 44.54, 45.09 and 34.20Bq/kgrespectively which are above the standard limit. ^{232}Th in the fertilizer is higher than the standard limit and its presence in all the soil samples also reflects a high ^{232}Th content on the average which is also attributable to the composition of the soil and fertilizer application.

4.4 Results of Activity Concentration in Ginger Samples

Table 4.4: Activity concentration of radionuclides of ^{40}K, ^{226}Ra, and ^{232}Th, in the ginger samples collected from 18 farmland and Control.

FARM LOCATION	NO. OF GINGER SAMPLES COLLECTED	GPS LOCATION Long.	Lat.	MEAN ACTIVITY CONCENTRATION K-40 (Bq/kg)	R-226 (Bq/kg)	Th-232 (Bq/kg)
Farm 01	20	9°27'40"N	8°01'30" E	107.10 ± 2.84	10.51 ± 0.96	10.38 ± 3.54
Farm 02	20	9°27'58"N	8°01'45"E	248.40 ± 10.35	38.20 ± 4.24	40.58 ± 1.42
Farm 03	20	9°27'32"N	8°02'59" E	1962.94 ± 11.91	41.83 ± 3.88	48.24 ± 1.97
Farm 04	20	9°27'20"N	8°00'48" E	205.98 ± 3.32	51.50 ± 0.80	72.23 ± 0.63
Farm 05	20	9°27'29"N	8°01'59" E	405.35 ± 1.05	17.54 ± 0.77	62.26 ± 1.88
Farm 06	20	9°27'20"N	8°03'48" E	285.42 ± 4.52	28.45 ± 4.25	42.73 ± 0.36
Farm 07	20	9°26'20"N	8°02'22" E	272.08 ± 12.19	22.65 ± 3.15	18.54 ± 1.76
Farm 08	20	9°26'20"N	8°01`32" E	251.04 ± 8.01	55.35 ± 2.50	10.65 ± 3.48
Farm 09	20	9°26'48"N	8°01'43" E	242.70 ± 10.16	22.93 ± 4.58	55.84 ± 1.57
Farm 10	20	9°25'20"N	8°00'00" E	383.29 ± 2.65	18.26 ± 8.96	64.77 ± 0.55
Farm 11	20	9°25'20"N	8°03'15" E	203.20 ± 6.75	23.42 ± 0.98	92.67 ± 0.11
Farm 12	20	9°25'18"N	8°03'41" E	270.81 ± 9.89	10.53 ± 5.34	48.57 ± 3.99
Farm 13	20	9°25'30"N	8°03'43"E	221.13 ± 12.77	40.98 ± 1.68	42.73 ± 0.99
Farm 14	20	9°25'06"N	8°01'20" E	235.18 ± 9.80	36.12 ± 4.76	53.72 ± 3.77
Farm 15	20	9°27'20"N	8°03'52" E	248.54 ± 7.98	26.36 ± 6.76	68.55 ± 0.69
Farm 16	20	9°27'38"N	8°01'59" E	395.23 ± 11.10	43.54 ± 6.71	40.65 ± 0.65
Farm 17	20	9°26'45"N	8°04'06" E	387.32 ± 8.67	19.58 ± 3.15	44.78 ± 1.06
Farm 18	20	9˚27′17·08″N	8˚02′48·1″E	105.12 ± 2.96	34.04 ± 6.66	119.85 ± 1.01
Control	20	9˚27′17·08″N	8˚02′48·1″E	110.15 ± 7.56	49.51 ± 0.84	119.18 ± 2.44
Mean				357.27 ± 7.61	30.10 ± 3.90	52.10 ± 1.63
World Standard				420	32 --	45 --

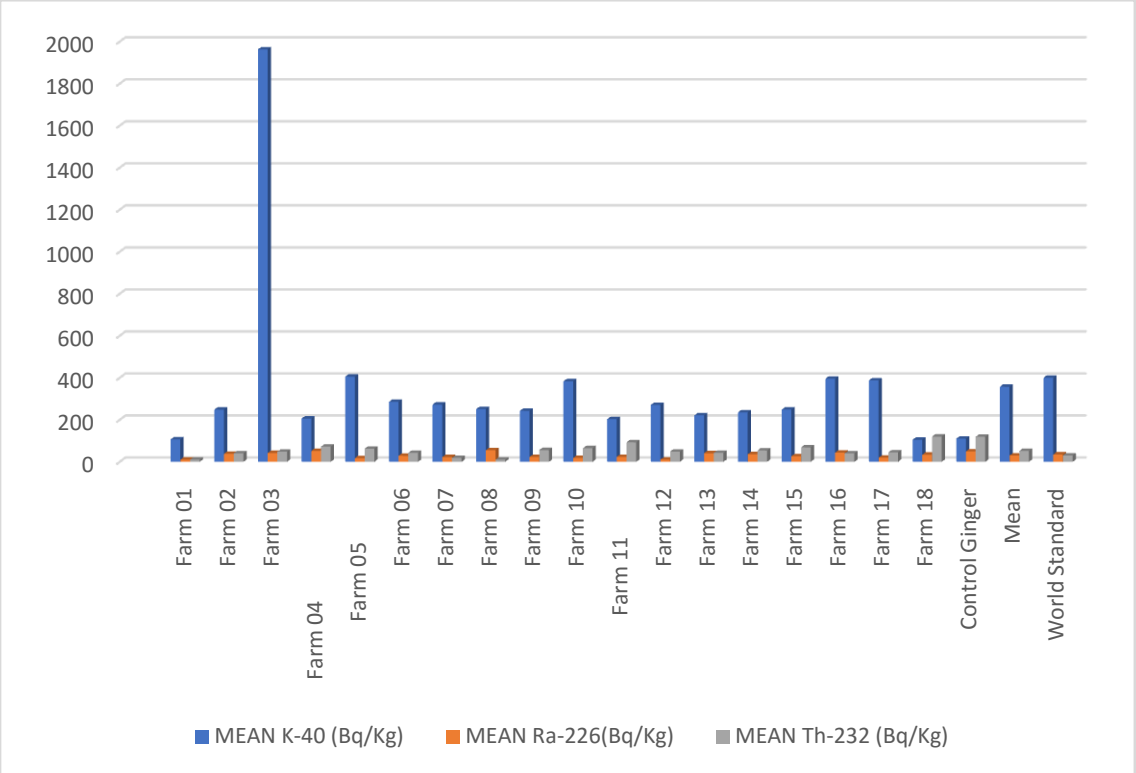


Fig. 4.2: Comparison of activity concentrations of ginger samples with the standard value.

As seen in Table 4.4, the activity concentration of 40K in all the ginger samples obtained from farmland 1 to 18 and 'Control' ranges from 105.12 Bq/kg to 1962.94 Bq/kg, with a mean value of 357.21 Bq/kg. The lowest activityconcentration of ^{40}K was recorded for Sample 18, while Sample 3had the highest lowest activity concentration. ^{226}Ra activity concentration varies from 10.51 Bq/kg to 55.35 Bq/kg, with a mean value of 30.10 Bq/kg. Sample 1 has the lowest activity concentration of ^{226}Ra, while Sample 8 has highest activity concentration.

For the activity concentration of ^{232}Th, it ranges from 10.38 Bq/kg to 119.85 Bq/kg, with a mean value of 52.10 Bq/kg. The lowest activity was recorded for Sample 1 while the highest activity was recorded for Sample 18.

Also, comparing the figures in table 4.2 (Activity concentration of radionuclides in NPK fertilizer) and those of table 4.4 (Activity concentration of radionuclides in the ginger samples collected from farmland 1 to 18 and Control), and illustrating it diagrammatically in Fig. 4.2, it is noted that the fertilizer has the highest value of ^{40}K worth 2024.19 Bq/kg and its presence in the soil is negligible even though all other samples of ginger are below the standard recognized limit, a particular sample, sample 3; with figure 1962.94 Bq/kg gave a rise of 357.21 Bq/kg to the average mean owing to fertilizer distribution on plant ridges and other ecological factors like water, wind, erosion, etc. On the other hand, the mean value of ^{226}Ra across the ginger samples is 30.10 Bq/kg which is slightly lower than the standard limit of 32 Bq/kg. ^{232}Th in the fertilizer is higher than the standard limit of 45 Bq/kg and its presence in the all the soil samples also reflects a high soil content on the average. This is also attributable to the rise in the mean value worth 52.10 Bq/kg across the ginger samples. The increase in the ^{232}Th as seen in the ginger samples could also be as a result of soil type, soil weathering process and chemical characteristics on which the crops were planted.

4.5 Results of Transfer Factor Computed

The transfer factor which illustrates the rate at which radionuclides are transferred from soil to the plant is as shown in Table 4.5.

The mean transfer factor (TF) computed for the samples obtained from farmland 1 tofarmland 18 and 'CONTROL' for ^{40}K, ^{226}Ra and ^{232}Th respectively are as shown on Figure 4.3.This simply implies that the ginger crop obtained from these farmlands take up more Potassium and Radium than it does for Thorium, with the transfer rate of Potassium from the soil to ginger being the highest.

Table 4.5: Transfer Factors for the samples collected from farmland 1 to farm land 18 and 'CONTROL'.

FARM LOCATION ID	Long.	Lat.	K-40	Ra-226	Th-232
Farm 01	9°27'40"N	8°01'30" E	0.27	0.23	0.09
Farm 02	9°27'58"N	8°01'45" E	0.79	1.24	0.59
Farm 03	9°27'32"N	8°02'59" E	6.76	1.08	0.58
Farm 04	9°27'20"N	8°00'48" E	0.89	2.40	1.76
Farm 05	9°27'29"N	8°01'59" E	1.30	0.90	0.86
Farm 06	9°27'20"N	8°03'48" E	1.02	1.20	0.81
Farm 07	9°26'20"N	8°02'22" E	1.04	0.79	0.48
Farm 08	9°26'20"N	8°01`32" E	0.72	1.57	0.18
Farm 09	9°26'48"N	8°01'43" E	1.04	0.79	0.85
Farm 10	9°25'20"N	8°00'00" E	1.35	0.48	0.68
Farm 11	9°25'20"N	8°03'15" E	0.51	0.92	1.02
Farm 12	9°25'18"N	8°03'41" E	0.68	0.31	0.45
Farm 13	9°25'30"N	8°03'43"E	0.73	1.05	0.93
Farm 14	9°25'06"N	8°01'20" E	0.74	1.30	1.23
Farm 15	9°27'20"N	8°03'52" E	1.02	0.87	1.41
Farm 16	9°27'38"N	8°01'59" E	1.34	0.98	0.37
Farm 17	9°26'45"N	8°04'06" E	1.26	0.87	0.53
Farm 18	9˚27'17·08"N	8˚02'48·1"E	0.26	0.75	1.15
CONTROL	9˚27'17·08"N	8˚02'48·1"E	0.37	1.45	1.05
MEAN			**1.20**	**1.06**	**0.83**

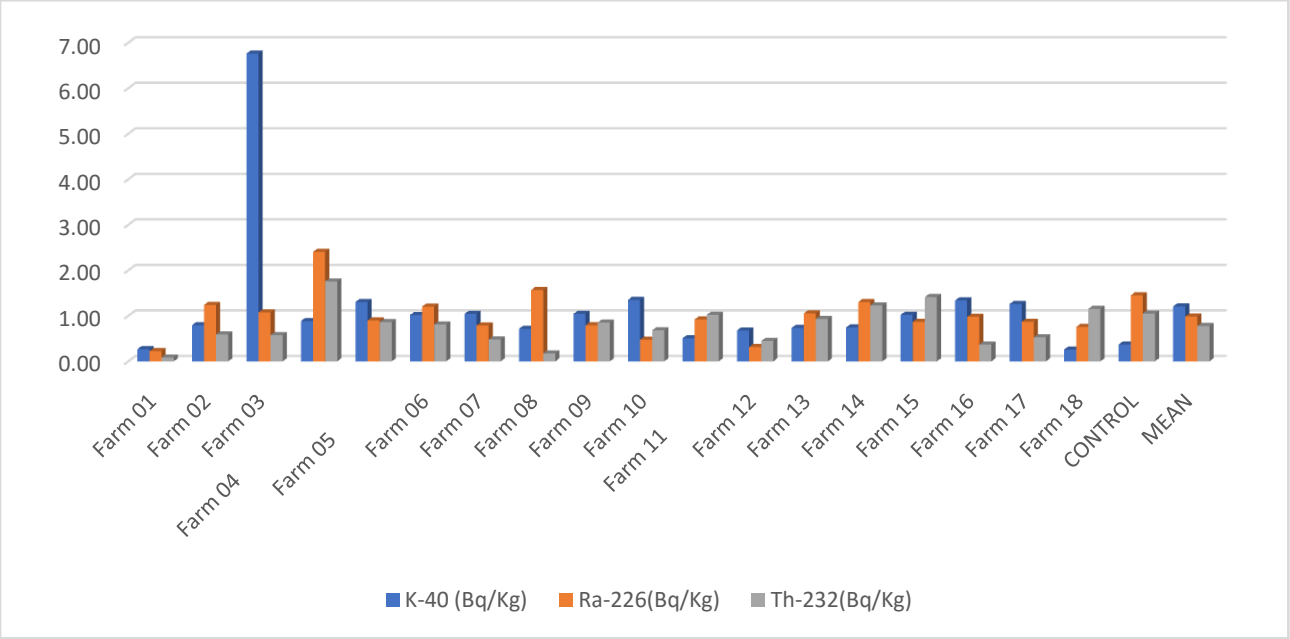


Fig. 4.3: Comparison of Transfer Factor of radionuclides from Soil to Ginger Sample.

From Fig 4.3 as illustrated, it is obvious that out of the various samples analyzed, ^{40}K was the highest transferred radionuclide in sample location 3; meaning that the ginger sample 3 from soil sample 3 absorbed the highest potassium more than the other ginger samples. It can also be seen that ^{40}K, ^{226}Ra and ^{232}Th were the least transferred in sample 1 when compared with the other samples analyzed.

Again, as shown in Fig 4.3, the mean transfer factor (TF) computed for the samples obtained across the various farmlands, shows that the rate at which radionuclides are transferred from the soil to the crop is highest for Potassium, followed by Radium with Thorium being the least transferred.

The implication is that on the average, the ginger plant cultivated in Sambam Gida, Jaba Local Government Area, Kaduna State, Nigeria; takes up more Potassium and Radium than it does for Thorium, with the transfer rate of Potassium from the soil to ginger being the highest.

4.6 Calculated Radiological Hazard Indices for Soil Samples

Table 4.6: Calculated Radiological Hazard Indices for the soil samples collected from farmland 1 to farmland 18 and 'CONTROL'

Farmland LOCATION	Long.	Lat.	Raeq (Bq/kg)	D ($nGy.h^{-1}$)	AEDR ($mSvy^{-1}$)	Hex	Hin
Farm 01	9°27'40"N	8°01'30" E	250.89	113.56	0.14	0.68	0.80
Farm 02	9°27'58"N	8°01'45" E	153.27	70.00	0.09	0.41	0.50
Farm 03	9°27'32"N	8°02'59" E	180.90	82.04	0.10	0.49	0.59
Farm 04	9°27'20"N	8°00'48" E	98.13	45.13	0.06	0.27	0.32
Farm 05	9°27'29"N	8°01'59" E	146.81	66.87	0.08	0.40	0.45
Farm 06	9°27'20"N	8°03'48" E	120.65	55.37	0.07	0.33	0.39
Farm 07	9°26'20"N	8°02'22" E	103.88	48.06	0.06	0.28	0.36
Farm 08	9°26'20"N	8°01`32" E	149.09	68.62	0.08	0.40	0.50
Farm 09	9°26'48"N	8°01'43" E	140.43	63.71	0.08	0.38	0.46
Farm 10	9°25'20"N	8°00'00" E	195.60	88.35	0.11	0.53	0.63
Farm 11	9°25'20"N	8°03'15" E	185.91	84.75	0.10	0.50	0.57
Farm 12	9°25'18"N	8°03'41" E	219.51	99.55	0.12	0.59	0.68
Farm 13	9°25'30"N	8°03'43"E	127.62	58.99	0.07	0.34	0.45
Farm 14	9°25'06"N	8°01'20" E	114.62	53.15	0.07	0.31	0.38
Farm 15	9°27'20"N	8°03'52" E	118.55	54.34	0.07	0.32	0.40
Farm 16	9°27'38"N	8°01'59" E	225.52	101.61	0.12	0.61	0.73
Farm 17	9°26'45"N	8°04'06" E	167.45	75.88	0.09	0.45	0.51
Farm 18	9°27′17·08″N	8°02′48·1″E	224.81	102.22	0.13	0.61	0.73
CONTROL	9°27′17·08″N	8°02′48·1″E	219.93	98.9	0.12	0.59	0.69
MEAN			162.42	74.01	0.09	0.44	0.53
WORLD STANDARD			≤370	60.00	1.00	1.00	1.00

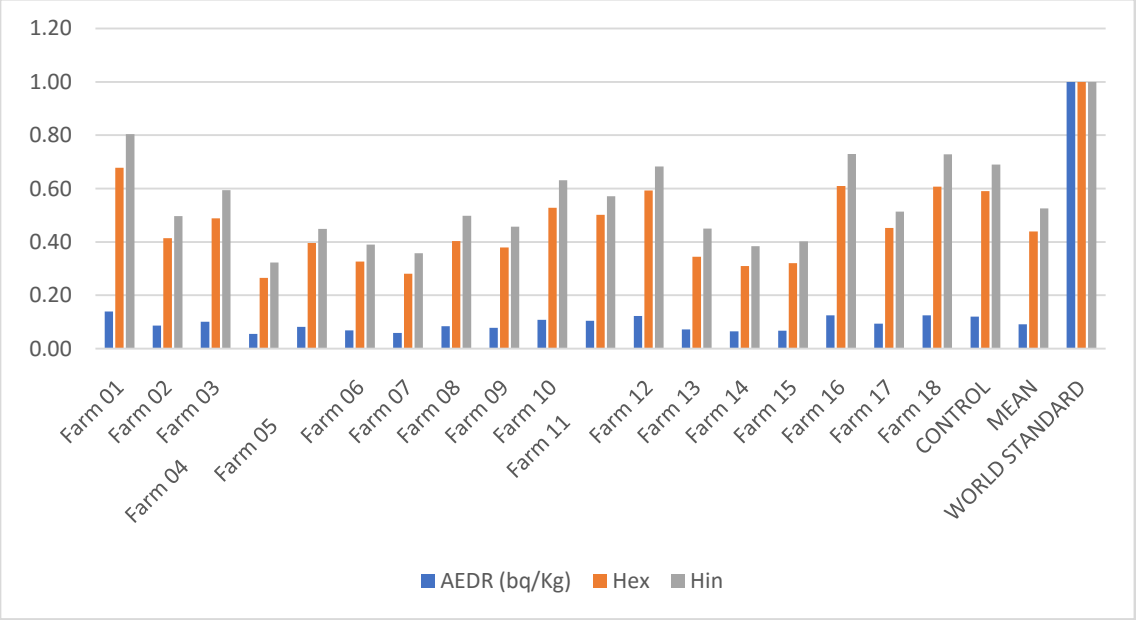


Fig.4.4: Comparison of calculated radiological Hazard indices of the soil samples with standard value.

As illustrated in Table 4.6 above, the radium equivalent $Ra_{(eq)}$ dose in all the soil samples obtained from farmland 1 to 18 and 'CONTROL' ranges from 98.13 to 250.89 $Bqkg^{-1}$, with a mean value of 162.42 $Bqkg^{-1}$. Sample 4 had the lowest radium equivalent $Ra_{(eq)}$ dose, while the highest radium equivalent $Ra_{(eq)}$ dose was recorded for sample 1. The absorbed dose rate (D) varies from 45.13 to 113.56nGy.h^{-1} with a mean value of 74.1 nGy.h^{-1}. The lowest absorbed dose rate (D) was recorded for sample 4 while the highest activity was recorded for sample 1. The Annual Effective Dose Rate (AEDR) ranges from 0.06 to 0.14mSvy^{-1} with a mean value of 0.09 mSvy^{-1}. The lowest Annual Effective Dose Rate (AEDR) was recorded for sample 7 whilesample 1 has the highest value. The external hazard index varies from 0.28 to 0.68 with a mean value of 0.44. The lowest external hazard index was recorded for sample 7 and the highest was recorded for sample 1. The internal hazard index varies from 0.32 to 0.80 with a mean value of 0.53. The lowest internal hazard index was recorded for Sample 4 and the highest was recorded for Sample 1.

As shown in Fig. 4.4, it could clearly be seen that all the parameters calculated for the hazard indices like the Annual Effective Dose Rate (AEDR), external hazard (H_{in}) and internal hazard (H_{ex}) never exceeded the standard value.

4.7 Calculated Radiological Hazard Indices for Ginger Samples

Table 4.7: Calculated Radiological Hazard Indices for the ginger samples collected from farmland 1 to farmland 18 and 'CONTROL'.

SAMPLE ID	Long.	Lat.	Raeq (Bq/kg)	D ($nGy.h^{-1}$)	AEDR ($mSvy^{-1}$)
Farm 01	9°27'40"N	8°01'30" E	33.60	15.77	0.02
Farm 02	9°27'58"N	8°01'45" E	115.35	53.20	0.07
Farm 03	9°27'32"N	8°02'59" E	261.97	131.14	0.16
Farm 04	9°27'20"N	8°00'48" E	170.65	77.24	0.09
Farm 05	9°27'29"N	8°01'59" E	137.78	63.67	0.08
Farm 06	9°27'20"N	8°03'48" E	111.53	51.58	0.06
Farm 07	9°26'20"N	8°02'22" E	70.11	33.32	0.04
Farm 08	9°26'20"N	8°01`32" E	89.91	42.65	0.05
Farm 09	9°26'48"N	8°01'43" E	121.47	55.39	0.07
Farm 10	9°25'20"N	8°00'00" E	140.39	64.64	0.08
Farm 11	9°25'20"N	8°03'15" E	171.58	76.84	0.09
Farm 12	9°25'18"N	8°03'41" E	100.84	46.32	0.06
Farm 13	9°25'30"N	8°03'43"E	119.10	54.68	0.07
Farm 14	9°25'06"N	8°01'20" E	131.05	59.86	0.07
Farm 15	9°27'20"N	8°03'52" E	143.53	65.11	0.08
Farm 16	9°27'38"N	8°01'59" E	132.10	61.84	0.08
Farm 17	9°26'45"N	8°04'06" E	113.44	53.01	0.07
Farm 18	9˚27′17·08″N	8˚02′48·1″E	213.53	94.54	0.12
CONTROL	9˚27′17·08″N	8˚02′48·1″E	219.62	101.47	0.12
MEAN			132.11	61.16	0.08
WORLD STANDARD			≤370	60.00	1.00

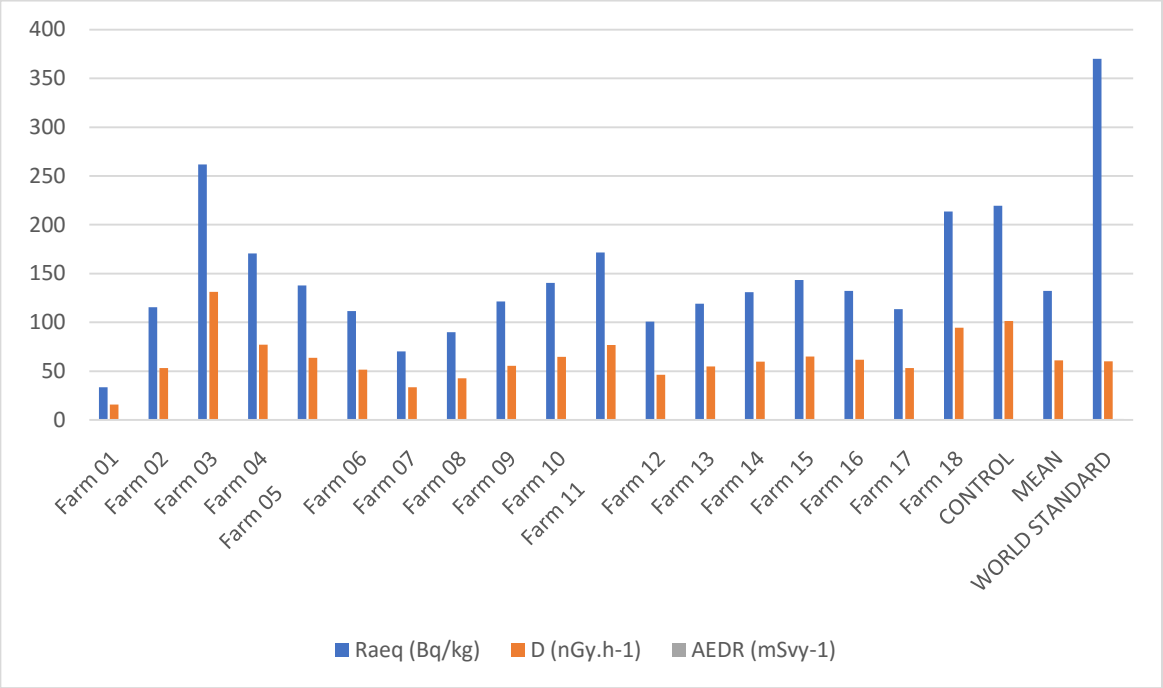


Fig.4.5: Comparison of calculated radiological Hazard indices of the ginger samples with standard value.

As shown in Table 4.7 above, the radium equivalent $Ra_{(eq)}$ dose in all the ginger samples obtained from farmland 1 to farmland 18 and 'CONTROL' ranges from 33.60 to 261.97 $Bqkg^{-1}$, with a mean value of 132.11Bq/kg. Sample 1 had the lowest radium equivalent $Ra_{(eq)}$ dose, while the highest radium equivalent $Ra_{(eq)}$ dose was recorded for sample 3. The absorbed dose rate (D) varies from 15.77 to 131.14$nGy.h^{-1}$ with a mean value of 61.16$nGy.h^{-1}$. The lowest absorbed dose rate (D) was recorded for sample 1 while the highest activity was recorded for sample 3. The Annual Effective Dose Rate (AEDR) ranges from 0.02 to 0.16 $mSvy^{-1}$ with a mean value of 0.08$mSvy^{-1}$. The lowest Annual Effective Dose Rate (AEDR) was recorded for sample 1 whilesample 3 has the highest value.

It is pertinent to note that, for radium equivalent activity index (Raeq), all the samples parameters analyzed are within the UNSCEAR standard; while for the Absorbed dose rate (D), only sample 1, 2,7,8,12,13,14, & 17 are less than the UNSCEAR standards while the others are above.

Fig. 4.5 clearly illustrates that all the parameters calculated for the hazard indices like the Radium equivalent $Ra_{(eq)}$ dose,and Annual Effective Dose Rate (AEDR)are within world standard limit. This affirms the safety of consumption of ginger grown in Sambam Gida, Jaba Local Government Area, Kaduna state, Nigeria.

4.8 Comparison of Ginger Results with a Previous Work

Abdulhussein *et al*(2016) carried out a research on the measurement of natural radioactivity in selected samples of medical plants in Iraq. One of the medical plants investigated was ginger out of 40 plants investigated.The results for ginger was singled out and used as a basis for comparison with the NORMs under investigation in this work.

Table 4.8 below shows the comparison of the results obtained in this work and that of ginger which was one of the medicinal plants used in the measurement of natural radioactivity in selected samples of medical plants in Iraq. The average values of ginger crop and the control samples excluding fertilizer and soil samples were computed and used for comparison with respect to activity concentration and radiological hazard indices.

Table 4.8: Comparison of Ginger Results

Country	Activity concentration (Bq/kg)			Radiological Hazard Indices Raeq (Bq/kg)	References
	K-40	Ra-226	Th-232		
Nigeria	357.27	30.10	52.10	132.11	This Study
Iraq	213.77	-	3.17	24.12	Abdulhussein et al., (2016)
World Standard	420	32	45	370	UNSCEAR, 2000

The average ^{40}K content in all the ginger samples experimented in this work is 357.27 $Bqkg^{-1}$ and is less than the recommended maximum permissible limit of 420 $Bqkg^{-1}$ as shown in Table 4.8. This is in agreement with the ^{40}K value of 213.77$Bqkg^{-1}$ reported by Abdulhussein *et al*., (2016). The mean value of radium in ginger reported in this work is30.10 $Bqkg^{-1}$, which is less than the standard limit of 32 $Bqkg^{-1}$, although Abdulhussein *et al*., (2016) did not analyze for ^{226}Ra in his samples. The mean value of Thorium in ginger sample was52.10 $Bqkg^{-1}$, which is higher than the standard limit of 45 $Bqkg^{-1}$, whereas Abdulhussein *et al*., (2016) obtained a value of 3.17 $Bqkg^{-1}$. This variance may be attributed to difference in plant species,composition of the soil elements, as well as the soil management practices and fertilizer application.

The radium equivalent (Raeq) of ginger cultivated in Sambam Gida village, Jaba Local Government; Kaduna state is within the world standard limit of 370 $Bqkg^{-1}$, with a mean value of 132.11 $Bqkg^{-1}$, which is higher than the result obtained by Abdulhussein *et al*., (2016) in Iraq which reported a value of 24.12 $Bqkg^{-1}$. Although, both results are still within the world standard limit of 370 $Bqkg^{-1}$.

Generally, the results computed in this work for the radiological health hazards (radium equivalent, Annual Effective Dose Rate (AEDR), and the external and internal hazard indices) with respect to the soil were within the world standard (UNSCEAR, 2000). The same is also true for ginger in which the radium equivalent (Raeq) agrees with UNSCEAR as well as the results obtained by Abdulhussein *et al*., (2016).

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Summary

This study aimed to determine the radionuclide levels ofGinger grown in Sambam Gida, Jaba Local Government Area, Kaduna State, Nigeria. The research was carried out using handheld (RADOS – 120) survey meter for the measurement of the radiation dose level of the area and Sodium Iodide Thallium doped (NaI(TI)) detector for determining the activity concentration of ^{40}K,^{226}Ra, and ^{232}Th present in the fertilizer used in cultivation, the soil and ginger grown. Eighteen farmlands and a control farmland were mapped out for experiment, with twenty samples collected from each farmland. Stallion Magic NPK fertilizer 15:15 was the dominant fertilizer used by the farmers in the study area and its activity concentration also determined. The transfer factor computed shows that ginger crop from these farmlands takes up more K-40 and Ra-226 than it does for Th-232. The radiological hazardsfor the soil and ginger crop were calculated to determine the safety of growing these crops in the study area as well as the crop consumption and theresults obtained inferred the general safety of the ginger crops grown in Sambam Gida village, Jaba Local Government Area, Kaduna State.

5.2 Conclusion

The assessment of the radionuclide levels by ginger grown in Sambam Gida, Jaba Local Government Area, Kaduna State,have been carried out and the values of the background dose, activity concentrations and radiological hazards were also obtained.

From the survey meter readings, it can be seen that farmlands closer to parent rock have higher radiation dose readings than farmlands afar off. This also contribute to the reason

for higher concentration of ^{40}K on farmlands closer to parent rocks as shown on map; for instance, farmland 3 to be specific was tested for a high concentration of ^{40}K for ginger samples.

From the values obtained, it is also evident that ^{40}K is significantly large in the fertilizer and in sample 3 (ginger) compared to other radionuclides in the other samples, although the average value calculated for all the ginger is not above the world standard limit of 420 Bq/kg. It is always expected that the content of ^{40}K in fertilizer should be high no doubt, but another reason for the high concentration of ^{40}K in sample 3 is probably because of the type of parent weathering rock, the soil management practices and fertilizer applied during planting.

Also, it is worth noting that the rate of transfer of radionuclides from soil to ginger plant is highest for ^{40}K followed by ^{226}Ra and the least for ^{232}Th. This suggests selective and preferential uptake of ^{40}K and ^{226}Ra by these plants. This is attributed to the fact that; plant physiology, soil characteristics, nuclide and plant kind are important parameters which influence absorption (Coughtrey & Thorne, 1983).

^{40}K is an isotope of potassium, and it is an important nutrient of the plants in their metabolic activities. Since ^{40}K is highly absorbed by ginger in the study area, it is also important to note that a number of potassium channels are involved in the treatment of health problems related to the respiratory system such as asthma, cough, and chronic obstructive pulmonary diseases (Malerba *et al*, 2010).

Since Potassium channels are involved in the treatment of health problems related to the respiratory system such as asthma, cough, and chronic obstructive pulmonary diseases, higher concentrations of ^{40}K in sample 3 and averagely in the other ginger crops

sampled in this work support their medicinal use in the treatment of the above said ailments.

Again, it is pertinent to also note that in all the samples studied, none exceeded the threshold for the standard values of radium equivalent, Annual Effective Dose Rate, and the internal and external hazard indices, except for the absorbed dose and activity concentration of Thorium which was slightly above the world standard limit.Thus, the study suggests that there is no radiological health risk in using these medicinal plants to treat the diseases, but the application of fertilizer to grow these crops should be minimized and further research on this area carried out to further determine and affirm the safety of consuming these crops. Since the value of the external hazard indices in all the soil samples were less than a unity, it suggests that ginger grown on this geographical area can safely be used as beauty products in cosmetics. The same is also true for its internal hazard indices which are lower than International permissible value of a unity, which indicates that ginger grown in Sambam Gida village situated in Jaba Local Government Area of Kaduna State is safe for human consumption, but the use of fertilizer during cultivation of this crop should be optimally minimized to reduce the amount of radionuclides absorbed by the crop from the soil.

5.3 Recommendations

Based on the research carried out; it suggests that there is no radiological health risk whatsoever associated in using these medical plants to treat diseases. The results obtained in this work can also be used as baseline data for other similar studies on ginger that follow suite. However, to provide a compelling argument as to the reasons behind the safety of consumption of these crops, this study recommends for further research in other geographical study areas within Kaduna State and other parts of the

country that are predominately known for ginger cultivation in other to draw a logical conclusion that will ultimately help to ensure the dietary safetyof the society as attributed to in this study.

This study also suggests, that other radiation detectors like the High Purity Germanium (HPGe) radiation detector be used to detect wide range of radionuclides present in the samples collected aside ^{40}K, ^{226}Ra, and ^{232}Th in other to ascertain if other radionuclides present is also safe for consumption.

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