ACTIVITY CONCENTRATION OF RADIONUCLIDES PRESENT IN SOME TROPICAL WOOD SAMPLES

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CERTIFICATION

This is to certify that this research work was carried out by **OJUOLAPE AMINAT OLATUNDUN,** with Matriculation Number **11/06/1736** under the supervision of Mr. A.A Okusanya, in the Department of Science Laboratory Technology, Abraham Adesanya Polytechnic, Ijebu-Igbo, Ogun State.

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25/3/14

DATE

DEDICATION

This report is dedicated to the Almighty ALLAH who spared my life and gave me the grace needed in the scheme and to all those who love me.

ACKNOWLEDGEMENT

My deepest gratitude goes to the Almighty ALLAH. The Alpha and Omega of my life. I adore His Holy name for his grace, innumerable support, protection and guide that count me among the living and giving me the power to complete the National Diploma successful despite all odds.

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To all others who in one way or the other assisted me but not mention, should not fell offended. I SAY BIG THANK TO YOU ALL.

ABSTRACT

The Radionuclide concentration levels have been determined using gamma ray spectrometer consisting of a lead-shielded 76mm x 76mm Nal(TI) of the detector crystal coupled to Canberra series 10 plus multichannel analyzer method was used in tropical wood samples widely used for furniture, building and soon. Each of the samples was counted for a present conunting time of 7 hours (25200s).

The photo-peaks observed with reliable regularity belong to the naturally occurring series decay radionuclide headed by 238U and 232Th, as well as non-series decay Mpe, ^{40}K. Caesium 139 as essential elemental indicator of radioactive contamination was not detected in any of the wood samples in view of the possible ecosystematic transfer through the soil to plant's stem which will be inert cut down to form woods.

The mean activity concentration of ^{40}K, ^{238}U, ^{232}Th for the woods samples obtained were 3119.61 ± 6.198 Bqkg^{-1}, 81.122 ± 2.468 Bqkg^{-1}, 159.888 ± 12.076 Bqkg^{-1} respectively. Potassium 40 recorded the highest activity concentration in all the wood samples analysed than Thorium and Uranium.

The result which attributed to the fact that potassium was released in the soil during the application of fertilizers to crops especially when applied at rates well above crop requirement. And also, minerals occurring in rocks such as mica and feldspar as they slowly release potassium into the soil slowly through weathering.

Since 40K is an essential biological element and its concentration in human tissue is under woods analysed in rooting of houses and furniture works have no the human body.

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INTRODUCTION

1.1 THE CONCEPT OF RADIOACTIVITY

Everything in the World, and everybody in the World, is composed of different types matter (chemical elements). The smallest part of each element is called the "Atom". An atom is so small that it can be seen only with the most powerful microscope. But the atom is the core of every substance in the universe.

Sometimes the centre of an atom (its nucleus) has too much energy in it. An atom cannot hold this energy forever. Sooner or later, the atom must get rid of the excess energy and return to its normal (stable) state. Atoms with too much energy in their nuclei are called "radioactive" they get rid of their excess energy by emitting radiation.

All elements consist of atoms which are made up of a central and positively charged nucleus surrounded by series of shells containing negatively charge electrons. The nucleus is made up of protons (Z) and neutrons (N), which are collectively referred to as nucleons. Any specific combination of neutrons and protons is called nuclei.

Many nuclei are stable while a significant numbers are not. The stability of nucleus depends on the N to Z ratio. An unstable nucleus will tend towards stability by changing the N to Z ratio to a more stable configuration through the emission of nuclear particles with some accompanying energy.This process of emitting nuclear particles and energy from the unstable nucleus in order to attain stability is called radioactivity.

The radioactive decay process is largely insensitive to conditions outside the nucleus and therefore for a given nuclide, it may be characterized by a fixed decay probability as well as by the mode and energy of decay. It is a statistical process such that although the decay probability is constant, the time of decay of a particular atom of an unstable cannot be predicted.

A radioactive decay is independent at all physical and chemical conditions but obeys the exponential law described by the equation:

$$N = N_0 e^{-\lambda t} \quad \text{---} \ (1.1)$$

Where N and N_0 are the number of radioactive atoms at time, t and t=0 respectively and λ is the decay constant, which is the probability that the atom will decay in unit time. The decay constant λ has a characteristics value for each radionuclide and is related to the half life ($t^1/_2$) of the radionuclide through the equation:

$$t^1/_2 = \frac{In2}{\lambda} = \frac{0.693}{\lambda} \quad \text{---} \ (1.2)$$

For naturally occurring radionuclide, $t^1/_2$ ranges from fraction of second to billions of years.

The number of atoms decaying in unit time is referred to as the activity A and is given by:

$$A = \frac{-dN}{dt} = N\lambda \tag{1.3}$$

The decay law equation given in equation 1.1 may be rewritten in terms of activities of the radionuclide by:

$$A_t = A_0 e^{-\lambda t} \tag{1.4}$$

The SI unit of activity is the Becquerel (Bq). 1Bq corresponds to one decay or disintegration per second. The activity of the radionuclide to be measured in this work will be based on activity per unit mass of the wood samples. This is termed specific activity or activity concentration.

1.2 TYPES OF NUCLEAR RADIATION

The particles emitted in natural radioactivity include the heavy alpha particles (α) and the light-particles (β±) with the accompanying neutral and much lighter particles, called neutrinos. The particles are often accompanied by the emission of gamma – rays (γ). During an α-decay, an atom with atomic mass A and atomic number Z is transformed into a new atom with atomic mass (A-4) and atomic number (Z-2) as described by the equation:

$${}^{A}_{Z}X \rightarrow {}^{A-4}_{Z-2}Y + {}^{4}_{2}He + \gamma + Q_{\alpha} \tag{1.5}$$

β- Decay would transform the same atom into a new one with essentially no change in A but a change of Z to (Z ± 1) as described below:

$${}^{A}_{Z}X \rightarrow \frac{A}{Z-1}Y + \beta^{+} + \gamma + v + Q_{B}^{+} \text{ ------------------------------------- } (1.6)$$

$${}^{A}_{Z}X \rightarrow \frac{A}{Z+1}Y + \beta^{-} + \gamma + v^{-} + Q_{B}^{-} \text{ ------------------------------------- } (1.7)$$

Gamma radiation is a form of electromagnetic radiation, which originates within the nucleus of an atom after excitation. As a result of either alpha or beta decay to the ground state usually with the emission of gamma radiation. Gamma radiation is very penetrating and van only be shielded by dense materials such as lead and steel. It can cause both external and internal health hazard when one is expose to it.

Environment radiation in wood samples, which is the main concern of the work, is due mainly to gamma radiation from radionuclide: ^{238}U, ^{232}Th series and ^{40}K, or from artificial ones such as ^{137}Cs and ^{60}Co that may be in the environment due to radioactive contaminations.

1.3 DECAY SERIES AND CONCEPT OF EQUILIBRIUM

In a number of radioactive transformations, the daughter products are also unstable and the process of emission of radiation continues until stable daughter end products are formed. All nuclides products in a chain through the activity of a parent radionuclide constitute a decay series. There are four naturally occurring radioactive decay series. These are ^{232}Th, ^{238}U, ^{237}Np, and ^{235}U – series each with atomic mass A that can take the form 4n, 4n+2, 4n+1 and 4n+3 respectively, where n is an integer.

Table 1.1 summarizes these series. From Table 1.1, the half-life $2.2\text{x}10^6$y of the longest – lived member in the Neptunium series is three orders of magnitude shorter than the age of the earth and as a result, this series is not observed in nature. Unlike the Neptunium series, ^{238}U and ^{235}U series are sufficiently long lived to survive till the present time and are still found in the Earth. Each of the three naturally occurring series has a gaseous member, which is a different isotope of the element radon.

In this case of Uranium series, the gas ^{222}Rn is called radon, in the thorium series the gas, ^{220}Rn, is called thorium, and while in the actinium series it is called action, ^{219}Rn. The intervention of these gaseous members is the main cause of disequilibrium observed in the three series.

Table 1.1: The Natural Radioactive series

Name of series	Types	Stable Nucleus	Longest Lived	Half-Life (years)
Thorium	4n	$^{208}_{82}$Pb	^{232}Th	$1.3\text{x}10^{10}$
Neptunium	4n+1	$^{209}_{83}$Bi	^{237}Np	$2.2\text{x}10^{6}$
Uranium	4n+2	$^{206}_{82}$Bi	^{238}U	$4.47\text{x}10^{9}$
Actinium	4n+3	$^{207}_{82}$Pb	^{235}U	$7.1\text{x}10^{8}$

Radioisotopes that are found in nature are not restricted to the thorium, uranium and actinium series. Several elements with lower atomic numbers also have radioactive isotopes (Table 1.2)

Table 1.2: Selection list of Primordial Radionuclide

Nuclide	Isotopic abundance (%)	Decay Mode	Half-Life (year)
^{40}K	0.0117	β^-, EC	$1.28x10^{9}$
^{50}V	0,250	β^-, EC	$1.5x10^{17}$
^{87}Rb	27.83	β^-	$4.8x10^{10}$
^{115}Ln	95.72	β^-	$4.4x10^{14}$
^{123}Te	0.905	EC	$9.99x10^{12}$

The most important of these low – atomic numbered natural emitters is the radioactive potassium isotope, ^{40}K. byvirtue of the widespread distribution of potassium in the environment, ^{40}K like ^{232}Th is very important from health physicals point of view. It has a half-life of $1.28x10^{9}$y and an isotopic abundance of 0.0117% in natural potassium.

The decay law may be extended to the case of successive decays where the parent nuclei 1 decay to a daughter 2, which then decays to a grand-daughter 3, and so on until a stable end product is achieved. For a daughter, which is itself not stable, the rate of change in the number of nuclei per unit time, that is, $\left(\frac{dN_2}{d_t}\right)$ is given by the difference between its rates of formation and its rate of decay the parent 1. This can be summarized by the differential equation:

$\frac{dN_2}{d_t} + \lambda_2 N_2 = \lambda N_o e^{-\lambda 1^t}$ -- (1.8)

Where λ_1 and λ_2 are the decay constants of the parent and the daughter, respectively and N_0 is the number of parent nuclei at time t=0 when the number of daughter nuclei N_2=0. Solving equation 1.8 gives the number N_2 of daughter nuclei present at time t as:

$N_{2=} \, N_2 \, \frac{\lambda 1 \, (e^{\lambda 1t} - e^{\lambda 2t})}{\lambda_2 - \lambda_1}$ -- (1.9)

$\frac{\lambda_2 N_2}{\lambda_1 N_1} = \frac{\lambda_2(1-e^{-(\lambda_2-\lambda_1)t})}{\lambda_2-\lambda_1}$ -- (1.10)

Where $\lambda_2 \gg \lambda_1$ for sufficiently long time (t→α), the value of the daughter/parent activity ratio in equation 1.10 reduces to unity, assuming as usual that N_2=0 at t=0

That is:

$\lambda_2 N_2 = \lambda_1 N_1$ -- (1.11)

Equation 1.11 express the state of secular equilibrium when the activity of the daughter nuclide is equal to that of parent. An example of this is the relationship between radon gases ^{222}Rn ($t^{1}/_{2}$ = 3.8d) and its immediate parent radium ^{226}Rn ($t^1/_2$ 160_{2y}) in U-series when radon is confined for about 4 weeks. In nature, radon is not confined, which leads to a state of disequilibrium in U and Th series.

That is, the radionuclides in the Uranium and thorium decay chain are not in radioactive equilibrium. The isotopes ^{238}U and ^{234}U are in approximate equilibrium, as they are separated by too much shorter – lived solid nuclides, ^{234}Th and ^{234}Pa. the decay process itself may however allow some dissociation of the decay radionuclide from the source material, facilitating subsequent environment transfer. Thus ^{234}U may be slightly deficient relative to ^{238}U in soils and enhanced in rivers and the sea.

The radionuclide ^{226}Ra in this chain may have slightly different concentration from ^{238}U, because separation may occur between is parent ^{230}Th and Uranium and because radium has greater mobility in the environment. The decay products of ^{226}Ra include the gaseous element radon, which diffuses out of the soil, reducing the exposure rate from the ^{238}U series as well as introducing marked disequilibrium in the series.

The radon nuclide in this series, ^{222}Rn, has a half life of only 3.8 days, but it has two longer- lived decay products, ^{210}Pb and ^{210}Po, which are important in dose evaluation. For the ^{232}Th series, similar considerations apply. The gaseous element of the chain, ^{220}Rn, has a very short half-life of 55.6s and on long-lived decay product.

In this work, this activity of ^{238}U has been measured using the γ - activity of Bi -214(1.76MeV) while that of ^{232}Th has been measured using the γ activity of TI-208 (2.61MeV). In both cases, equilibrium was achieved by confining radon gas emitted for a period for four weeks. The activity of ^{40}K a non-series decay element was measured using activity of 1.460MeV gamma line.

1.4 SOURCES RADIATION IN THE ENVIRONMENT

In an environment, human beings are exposed to some forms of ionizing radiation emanating from two main types of source; those that are natural and manmade (artificial). A brief discussion of each is given below:

1.4.1 Natural Radiation

Natural sources of radiation can be classified into group. The first group is due to highly penetrating cosmic radiation of galactic origin. The prominent radionuclides, which result from the interaction of cosmic rays with atom and molecules of the upper layers of the atmosphere, are ^{14}C, ^{7}Be, and ^{3}H.

The intensities of these secondary radiations at any location depend on the altitude. Cosmic radiation according to Lin *et al.*, (1986) and Weng and Chen (1987) are the dominant sources of ionizing effect in the atmosphere from altitude 70km-100km. below this altitude, its ionization effect is comparable to that from airborne and terrestrial radioactivity.

The second group is due to terrestrial radiation from the primordial radionuclides, which have survived since the time of formation of the earth. There are no fewer than 20 natural radionuclides remaining at present for which ^{238}U and ^{232}Th with their progenies and ^{40}K from the bulb. They easily combine with oxygen to form oxides of reduced densities and crystallized on the earth surface as litho pile elements during the formation of the earth.

They therefore, constitute sources of direct radiation exposure in the environment. Radiations from these primordial sources are now known to constitute about 85% of natural background radiation and the remaining 15% is from cosmic rays (IAEA, 1986). Radioactivity in air is due mainly to the gaseous component of the daughter product ^{222}Rn ($t^1/_2 = 3.8d$) and ^{220}Rn ($t^1/_2 = 55.6s$) from the U-238 and Th-232 series, respectively.

They emanate readily from the soil and they are dispersed in the air at concentrations, which depend on meteorological conditions.

1.4.2 Artificial Radioactivity

Apart from natural radionuclides, there are a number of artificial radioactive sources which are produced through nuclear weapon tests, nuclear power plant accidents, (Chernobyl nuclear power) and the controlled release of small amounts of radioactive waste to the environment mainly by the nuclear power industry.

In addition, there is also an input from the use of radionuclides in medicine and industry. The man-made contribution to the radiation exposure of the World population originated from the testing of nuclear weapons in the atmosphere that took place from 1980 (Bouville *et al.,* 2002; Beck and Bennette, 2002).

Each nuclear test result in unrestrained release into the environment of substantial quantities of radioactive materials including the prominent ones such as ^{90}Sr, ^{137}Cs and ^{131}I, which were widely dispered in the atmosphere and deposited on the earth`s surface (NRPB, 1989).

Radiation (UNSCEAR) evaluated the average annual dose from combined effects of both natural and artificial sources. The result of the evaluation shows that about 82% comes from the terrestrial and cosmic sources, 17% from medical application, 0.9% from radioactive element and 0.04% from production of nuclear energy.

1.5 BIOLOGICAL EFFECT OF RADIATION

Whenever radiation is absorbed, chemical changes are produced immediately, and subsequent molecular damage follows in a short span of time (seconds to minutes). It is after this, during a much longer time span of hours to decades that the biological damage becomes evident. The chain of events is illustrated in fig 1.3.

During radiation exposures, it is the ionization process that cause the majority of immediate chemical changed in tissue. The photon energy creates a fast-moving electron, resulting in ionization. The critical molecules for radiation damage are believed to be the protein (such as enzymes) and nucleic acid (principally deoxyribonuclide acid (DNA)).

The damage occurs in two basic ways: (1) by producing lesions in solute action molecules directly, e.g. by rupturing a covalent bond (2) by an indirect action between the solute molecules and the free radicals produced during the ionization of cellular water.

Indirect damage arises more commonly because living is about 70-90% water. If water molecule is irradiated, it irradiated, it emits a free electron and produces a positively charged water ion, which immediately decomposes.#

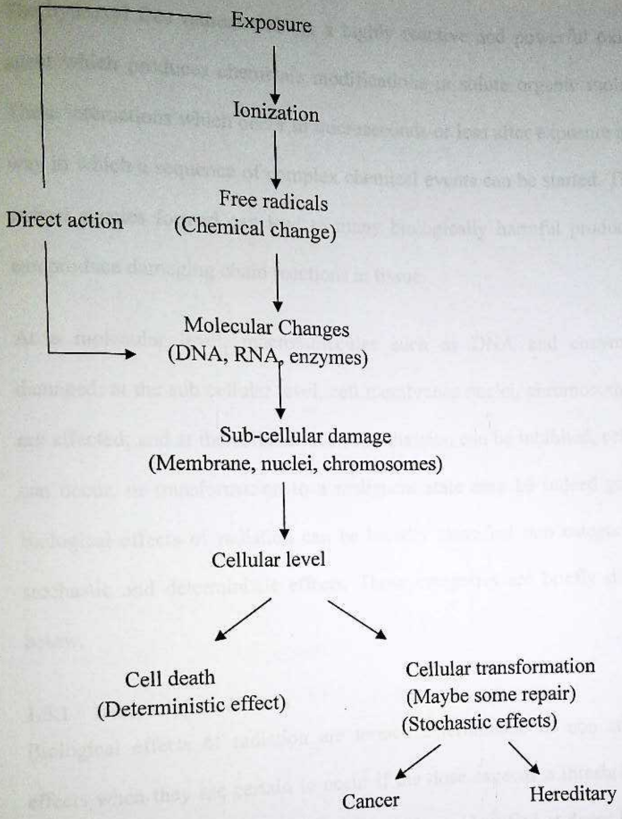


Fig 1.1: Chain of events following exposure to ionizing radiation

The hydroxyl free radical OH* is a highly reactive and powerful oxidizing agent which produces chemicals modifications in solute organic molecules. These interactions which occur in microseconds or less after exposure are one way in which a sequence of complex chemical events can be started. The free radical species formed can lead to many biologically harmful products and can produce damaging chain reactions in tissue.

At a molecular level, macromolecules such as DNA and enzymes are damaged: at the sub cellular level, cell membranes nuclei, chromosomes, etc, are affected; and at the cellular level, cell division can be inhibited, cell death can occur, or transformation to a malignant state may be indeed generally biological effects of radiation can be broadly classified into categories, viz stochastic and deterministic effects. These categories are briefly discussed below.

1.5.1 Deterministic Effects

Biological effects of radiation are termed deterministic or non stochastic effects when they are certain to occur if the dose exceeds a threshold level. Biological damage due to radiation has not been identified at doses less than 50mSv and in general, most health effects occur at doses greater than 500mSv.

For instance, cataracts are produced above a threshold of about 5Sv to the lens. For skin damage, the threshold for erythema and dry desquamation is about 4Sv. Impairment of fertility varies with age, but a dose of 1Sv to the gonads has a measurable effect while a doses of as 4Sv will cause permanent sterility in both sexes. The severity of radiation damage does not increase with the rate at which the dose is given.

Generally, the threshold doses (>500mSv) for deterministic effects can be incurred only in accidents where the doses are acutely delivered to an individual and hence, this category of radiation effect is of little or no relevance to the present study, which is concern with low – level radiation doses in the natural environment.

1.5.2 Stochastic Effects

Stochastic effects are those radiation effects that occur without a threshold level of dose. The probability of a stochastic an effect occurring increases with dose but its severity is independent of the dose. Whenever the frequency of occurrence of stochastic effects is plotted against the size of dose, a linear relationship is usually observed. In the context of radiation protection, the main stochastic effects are cancer and effects that result from low-level chronic exposure to radiation, the type that can be incurred over a long time in an environment.

Cancer is a disorder in which differentiated body cells undergo changed at the molecular level resulting in loss of normal cell regulation, characteristics and functions. It is a disease of the cell that is characterized by abnormal growth and spread of affected cells. If cancer is not treated, it can progress to the extent that vital physiologic functions are disrupted, leading to the death of affected individual. If an irradiated cell is not killed but only modified by radiation damage, the damage in the viable cell can be repaired. If the repair is not perfect, the modification will be transmitted to daughter cells and may eventually lead to cancer in the tissue or organ of the exposed individual.

The probability of occurrence of cancer is higher doses, but the severity of any cancer that may result from irradiation is independent of dose. Some organs are more vulnerable to cancer induction than others. Among the vulnerable tissues for tumours are female breast, the lungs, thyroid and the skin in that order (IAEA, 1995).

Cancer induction actually has a latent period, which ranges from two years for leukaemia and between 15 and 40 years for solid cancers. The effect of the radiation damage may therefore not be expressed within the lifetime of the recipient, depending on the age at exposure.

It should be quickly added that radiation is one of the very many causes of cancer, all of which are collectively referred to as carcinogens. The list of carcinogens include, genetic disposition, cigarette smoking, consumption of certain food with additives, alcoholic drinks etc. (WHO, 1997).

1.6 RADIOACTIVITY IN WOOD

Wood in a contaminated environment they may contain both natural and radionuclide that, after inhalation and direct (external) exposure, contribute to both internal and external dose.

Exposure by the inhalation pathway occurs when people breathe radioactive material like wood dust (sawdust) into the lungs. The chief concerns are radioactively contaminated dust or gaseous radionuclides of exposure depend on how the source is arranged whether the source is concentrated in one place or more evenly distributed.

Apart from the naturally occurring radionuclides, artificial radionuclides such as ^{137}Cs and ^{60}Co have also been measured in soil and as well as in atmosphere aerosols. Woods can easily provide possible routes for these artificial radionuclides from the soil to human bodies.

1.7 PURPOSE OF THE STUDY

The radioactive fallouts may be taken up by crops via soil in which they were planted. Radioactive particles can lodge in the lungs and remain for a long time as longs as it remain and continues over a very long time. The emission of ^{137}Cs with half life of 30.2y pose a greater problem to the health of the human populace since this isotope will persist in the environment for many years and even in human bodies. This can damage tissues, DNA or other cellular material. This damage can eventually lead to cancer or other diseases and mutations called radiation poisoning.

The purpose of this study is therefore to:

1. Identify the types of radionuclide present in some tropical wood samples.
2. Determine gamma activity concentration of ^{40}K, ^{238}U, and ^{232}Th in some tropical wood samples.
3. Determine the highest gamma activity concentration between ^{238}U, and ^{232}Th.

1.8 STATEMENT OF THE PROBLEM

The main focus of this study is to identify the radionuclide content present in the tropical wood samples which causes damage of the tissues and other disease like cancer.

1.9 SIGNIFICANCE OF THE STUDY

This topic of discussion will be very useful and important to everyone that uses wood for furniture and in building and especially people working in saw-mill in protecting them from long term effect of radiation that might eventually grow into nausea, muscle weakness, cancer and slow hearth beat which can be accompanied by an irregular heart that can lead to death in some cases.

1.10 SCOPE OF THE STUDY

The study centred on the radionuclide content in some tropical wood samples, samples were collected for Ejinrin road sawmill, Ijebu-Ode, Ogun State, Nigeria.

1.11 DEFINITION OF TERMS

1. Electromagnetic radiation: Is a radiation that take the form of a self-propagating wave of electric and magnetic fields including such phenomena as radio waves and visible light.

2. Excited state: These are the arrangements that are so unstable that they have only transient existence before transforming into other states.
3. Ground state: This is the most stable arrangement of nucleus.
4. Ionizing radiation: Radiation that is of high enough energy to cause atoms to lose or gain electrons, rendering molecules, such as protein, incapable of functioning.
5. Isotopes: Are nuclides that belong to the same chemical properties and have the same atomic number but have different neutrons.
6. Meta stable state: These states are also unstable but they have vey long-life time before transforming into another state.
7. Nuclear radiation: Radiation especially ionizing radiation that emanates from nuclear processes such as radioactive decay.
8. Radiation poisoning: This is a form of damage to organ tissue due to excessive exposure to ionizing radiation.
9. Radioactive decay: This is the process by which an atomic nucleus of an unstable atom loses energy by emitting ionizing particles.
10. Radio isotopes: Is a measure of the tendency of the nucleus to decay or disintegrate

CHAPTER TWO

RADIATION DETECTION AND MEASUREMENT

2.1 INTRODUCTION

An understanding of the interaction of charged particles and photons with matter is of great significant to the understanding of detection methods of radiation. The charges particles and photons can only be observed when they interact with matter through excitation and ionization effects they produce in a medium where they are absorbed. The ways in which these effects they produce in a medium where they are absorbed.

They ways in which these effects are used for radiation detection depend on the mode and efficiency of interaction, which in turn, depend on the type and energy of radiation. The different modes of γ-radiation with matter will be discussed in this chapter as this is the basic of the γ-spectrometric method employed in this work.

2.2. INTERACTION OF PHOTONS WITH MATTER

In the energy region of 0.01 – 10MeV, which is the energy range usually encountered in an ordinary environment, gamma and x – ray photons may interact with matter to produce high – speed electrons by three distinct processes. These are the Compton scattering, photoelectric absorption and pair production.

2.2.1 Photoelectric Absorption

Photoelectric effect is an interaction between a photon and a tightly bound electron whose binding energy is equal to or less than the energy of the photon. In this process, a photon energy Eγ is absorbed by a bound electron ejecting it from its orbit with T given by:

$T = E_\gamma - E_b$ -- (2.1)

Where E_b is the binding energy of the electron. The primary ionizing particle resulting from this interaction is the photoelectron. Equation 2.1 shows that photoelectron production occurs only when E_γ is equal or greater than the binding energy of the electron in the absorbing material. A vacancy is created mostly from the tightly bound shell (e.g. k - shell) due to the production of photoelectrons.

This is promptly filled by electrons from the higher shells with the emission of characteristic x – rays. The probability τ, which photoelectric absorption will occur is expressed by the equation:

$\tau = \frac{kpZ^3}{E^3}$ -- (2.2)

Where k = a constant

Z = the atomic number of the absorbing materials

ρ = the density of the absorbing material

E = photon energy

Equation 2.2 shows that low-energy photons and high atomic numbered absorbers favour the photoelectric effects. It is this very strong dependence of photoelectric absorption on the atomic number Z that makes Pb a good material for shielding against x-rays and γ-rays. Sodium iodide crystal has high photoelectric absorption efficiency because of its high density. This explains its popular choice as a scintillation detector as employed in the work.

2.2.2 Compton scattering:

Compton scattering is an elastic collision between a photon and a "free" or loosely bound electron. After the collision, the photon is scattered at angle θ to its initial direction and with less energy or longer wavelength than the incident photon. The photon transfers the rest of its energy to the electron (assumed to be initially at rest), which thereafter moves away at some other angle. The amount of energy transferred in the collision can be calculated by applying the laws of conservation of energy and momentum. The Eγ energy of scattered photon has been shown to given by:

$$E^{1}_{\gamma} = \frac{E_{\gamma}}{1+\frac{E_{\gamma}}{M_{o}c^{2}}(1-\cos\theta)} \qquad \text{-------------------------------------- (2.3)}$$

Where ***E*γ** is the initial photon energy and ***Mo*** is the electron rest mass. The scattered electron is the channel by which energy from the scattered photon is transferred to the absorbing medium. The kinetic energy T of the resoil electron is given by:

$$T = \frac{E_\gamma}{1+\frac{E_\gamma}{Moc^2}(1-\cos\theta)-1} \text{ -- } (2.4)$$

Photon energy and it corresponds to a head – on collision in which the photon is scattered backwards, that is θ = 180°. in this case,

$$E_c = E\gamma \left[\frac{2E_\gamma}{Mec^2 + 2E_\gamma}\right] \text{ -- } (2.5)$$

Equation 2.4 shows that a continuum of energies can be transferred to the electron ranging from zero up to the maximum given by equation 2.5. This explains the continuous distribution of pulse heights termed Compton plateau in gamma spectroscopy.

2.2.3 Pair Production

When a photon of energy greater than 1.2 MeV, passes near the nucleus of an atom, it is subjected to the strong field to the nucleus. It may disappear and become a positron and an electron. The energy equation of the process is given by:

$$hv = E_{e^-} + E_{e^+} + 2M_oC^2 \text{ -- } (2.6)$$

Where E_{e^-} and E_{e^+} are the kinetic energies of the emitted electron and positron, respectively. Equation 2.6 implies that pair production can take place only if $hv \geq 2M_oc^2$ (1.022, MeV). The positron produced is a very unstable particle. One its kinetic energy becomes zero, it interacts with an electron almost immediate thereby annihilating each other to from two 0.511 MeV photons which travel in opposite directions. These may escape from the medium or interact with it in Compton or photoelectric processes.

This usually leads to a photo peak at 0.511 MeV, which can be confused with the gamma peaks of the source being measured especially if the source has gamma energy close to 0.511 MeV.

Unlike the other two photon interactions, pair production has a cross section σ_{pp} which increases, although slowly, with photon energy Eγ and the interaction tends to be dominant at high energies. The cross-section can be written as:

$$\sigma pp = cZ^2 \rho \, \boldsymbol{In} E\gamma \quad \text{------------------------------------} (2.7)$$

Where c = a constant. The net effect of the above three processes is an exponential attenuation in the intensity of a beam of gamma rays passing through a thickness X of an absorbing material. This is described by the equation:

$$I = Ioe^{-\sigma x} \quad \text{------------------------------------} (2.8)$$

Where I_o = the initial intensity at x=0, σ= the linear absorption co-efficient due to all the effects described above.

2.3. SCINTILLATION DETECTION

A scintillation detector is a transducer that changes the kinetic energy of an ionizing particle into a flash of light. Crystals of organic and inorganic compounds exhibit this phenomenon.

The modern-day photomultiplier (PM) tube converts the light into an electrical pulse, which may be amplified, sorted by size and counted. Scintillation detectors are widely used for the detection and spectroscopy of gamma-rays and low energy beta-rays.

The detector most frequently used for gamma ray measurement is a sodium iodide crystal activated with thallium (Na1(TI)) optically coupled to the photomultiplier tube. This is because is its density (higher probability for photoelectric interaction as shown in equation 2.2 and high effective atomic number due to iodide). Sodium iodide crystal is highly hygroscopic which result in the crystal deteriorating when expose to moisture. Therefore, the crystal is hermetically sealed in a light proof covering, usually ny a light metal, with an optical window through which it is then coupled to a photomultiplier tube. A Canberra 76mm x 76mm NaI(TI) detector (Model No:802 - series) was used for the radioactivity measurements of the wood samples in this work. The systematic detection processes by the NaI(TI) detector assembly is described below.

2.3.1 Scintillation Detection by NaI(TI)

A schematic representation of the sequence of events on the detection of a gamma ray photon by a scintillation detection system is shown in Fig 2.1. When an energetic charge particle is incident on the crystal, the primary ionizing particles resulting from the gamma-ray interactions dissipate their kinetic energy by exciting and ionizing atoms in the crystal. The excited atoms return to the ground state by emitting N light photons given by:

$$N = \frac{E_q}{w_o} \quad \text{------------------------------------} \ (2.9)$$

Where q is the luminescence quantum efficiency, which is probability of photoelectric interaction of the incident, w_o is the average of a single photon, which is about 3eV for NaI(TI)

These N photons impinge on the photocathode of the photomultiplier tube and are converted into photoelectrons, which are directed to incident on the first dynode of the photomultiplier tube. The total number N_c of photoelectrons at the first dynodes is given:

$$N_c = \frac{E_q}{w_o} mc_{p.e^{g}c^{G}} \quad \text{------------------------------------} \ (2.10)$$

Where G is the light collection efficiency of the photocathode, which gives the fraction of photons that impinge on the photocathode and converted into photoelectrons, $C_{p.e}$ is the photo-quantum efficiency of the window – cathode system, m is a factor between 0 and 1 depending on the degree of spectral matching between the scintillation spectrum and the spectral responses of the photocathode; is g_c the efficiency with which the first dynode collects the number of electrons arriving these efficiencies are affected by number of factors.

Factors, G, is determined by self-absorption, reflection loses, light trapping optical flaws and the optical geometry of the photocathode. In NaI(TI), G is usually nearly by self – absorption, reflection loses, light trapping, optical geometry of the photocathode. In NaI(TI), G is usually nearly unity by coating the detector with a reflector like MgO thereby making self-absorption very small. The term $mC_{p.e}g_c$ depends in a complex manner, on the wavelength and the point of incident of the photons on the photocathode.

Factor, $C_{p.e}$, depends on the cathode material and its thickness while g_c depends on the structure of the dynode and the applied voltage. The total number of electron Q at the last dynode collected at the anode is given as:

$$Q = MN_c \qquad \text{------------------------------------} \qquad (2.11)$$

Where M is the overall gain resulting from K successive multiplications of N_c electrons at each dynode and is given by:

$$M = \Pi_i^k \, m_i \qquad \text{------------------------------------} \qquad (2.12)$$

Where m_i is the multiplication at the i^{th} is roughly proportional to the voltage between the dynodes. It can be observed from equation 2.9 and 2.10 that Q is a linear function of the energy E of the initial incident photon. All the electrons produced are collected at the output terminal of the photomultiplier tube.

The size of the current pulse, which is proportional to the energy of the primary ionizing particle, can be further amplified and counted.

Apart from the number of electrons give by equation 2.10, there are a number of electrons produced due to thermionic emission in the photomultiplier tube. According to Birks (1964), the number of electrons with thermal energy greater than the work function of photocathode which are emitted as thermionic electrons is a function of temperature as give by the equation.

$$n_T = ATe^{-}\left[\frac{Qe}{KT}\right] \quad \text{--------------------------------------- (2.13)}$$

Where T is the absolute temperature, e is the electronic charge, k is the Boltzmann constant, A and Q are characteristics of the cathode material.

2.3.2 Pulse Shaping and Height Analysis

The number of electrons that reach the anode (or collector) decays according to the equation:

$$N = Qe - \left[\frac{t}{T_d}\right] \quad \text{--------------------------------------- (2.13)}$$

Where T_d is the modified decay time of the scintillate which is about 0.25µsec NaI(TI). Because of the short lifetime of the pulses, they may be subjected to a pile up and as such, it is important to collect information about a pulse as quickly as possible.

A pulse shaping RC circuit whose function is to preserve maximum information while reducing to the pulse duration usually used to achieve this. The RC circuit as shown in Fig 2.2 is usually placed after the amplifier.

The number of electrons N (t) in the shape output is given by (1964) as:

$$N(t) = Q\left[\frac{RC}{RC-T_d}\right]\left(\frac{e^{-t}}{RC}-\frac{e^{-t}}{TT_d}\right) \qquad \text{------------------------} \; (2.14)$$

The voltage is, thus given by:

$$V(t) = \frac{Q_e}{C_s}\left[\frac{RC}{RC-T_d}\right]\left(\frac{e^{-t}}{RC}-\frac{e^{-t}}{TT_d}\right) \qquad \text{---------------------------------} \; (2.15)$$

Equation 2.14 shows that the amplitude of the pulse depends on C, T_d and RC (time constant) of the circuit. The RC must be greater than T_d to ensure that V(t) peak is proportional to the energy dissipated by the primary radiation in the scintillator. In essence, the pulse height is maximized and subsequent noise will have minimum degrading effect. The amplitude distribution V(t) is therefore related to the energy spectrum through Q defined by equation 2.10.

2.4. RESOLUTION

As a result of statistical fluctuations in the various factors leading to its production, a photo peak is usually a Gausian spread around the peak energy. It is therefore possible for the spread of one photo peak to overlap with that of another if they are too close. The ability of a detector assembly to distinguish between two energies that close is termed resolution R. it is quantified as the full width at half maximum of the speak (FWHM) divided by the peak energy E_o, That is

$$R = \frac{FWHM}{E_o} \text{X } 100\% \quad \text{-----------------------------------} (2.16)$$

It has been shown (Fari, 1989) that R^2 is inversely proportional to the gamma energy and a system must conform to this rule for its performance to be reliable. The typical resolution of 3" x 3" NaI(TI) detector is 5 – 10% depending on the energy of gamma radiation (Thompson *et al.*, 1999).

It has been determined by counting a reference ^{137}Cs source that the resolution of the NaI(TI) actual used for this work is 9.6% at 0.662MeV. The photo peak of ^{137}Cs used for the determination is shown in Fig 2.3. To show that this adequate for our purpose, the spectra of K, Th and U were obtained separately using IAEA standard calibration sources RGK-1(K_2SO_4), RGU – 1(U-ore) and RTh – 1 (Th-ore) respectively.

The three spectra were therefore superimposed on the same graph as shown in Fig 2.4. From the figure 40K, ^{238}U and ^{232}Th can be identified from the

1.460MeV peak, 1.760MeV peak of ^{214}Bi and 2.614MeV peak of ^{208}Th respectively. The other photo peaks of the ^{238}U and ^{232}Th, especially at the lower energy regions overlap and cannot be resolved by the detector crystal. The evaluation wood radioactivity concentrations of ^{40}K, ^{238}U and ^{232}Th carried out in this work was done using these distinguished photo peaks.

2.4.1 DETERMINATION OF AREA UNDER PHOTO PEAK

The energy spectrum of environmental radiation comprises of a mixture of peaks from different natural and man-made radionuclide. The area under a photo peak due to a particular γ-energy is often difficult to determine accurately because of the number of events such as electronic noise of the system, Compton plateaux of higher peaks, etc. which contributes to the spurious counts under the photo peak.

The actual count due to photoelectric absorption is equal to the integral count in the region of the photo peak minus the total background count in the region. The method adopted for the computation of the net area, which has been programmed in the memory of the analyzer system used in this work is illustrated in Fig 2.5.

A region of interest (ROI) is defined around a photo peak that is bounded systematically by channels *d* and *g* on either side of the photo peak. The average count B due to the background event in each channel of this region has been estimated by considering 3 channels at the tail of the Gausian curve on either side. This consideration of 3 channels is only applicable to the photo peaks of the three natural radionuclide of the interest in this study, because their photo peaks are well defined with very low continuum. The average count B is given by:

$\bar{B} = \frac{B_1 + B_2}{2(3)}$ -- (2.17)

Where $B_1 = {}^{a=c}_{a=d} X_{a,}\ B_{a=}\ {}^{a=c}_{a=f} X_a$

Where X_a is the content of each channel. The integral count I in the whole region given by\;

$I = I_p + B_1 + B_2$ -- (2.18)

Where I_p is the sum of the contents of N channels actually under the photopeaaak and not in B_1 and B_2. Ip is given by:

$I_p = {}^{a=c}_{a=b} X_a$ --- (2.19)

The net area, which is the area due to actual photoelectric absorption, is equal to the total count I_p minus the total background, $N\bar{B}$ in all the N channels.

That is: $A = I_p - N\bar{B}$ -- (2.20)

Equation 2.18-2.20 are stored as computation algorithms in the memory of the MCA system used in this work. Data are processed automatically and the result displayed whenever the region of interest is judiciously created around the photo-peak due to a particular Y-ray energy of a radionuclide.

From equation 2.20, the accuracy of reproducing the net count A depends on the statistical errors in the actual photoelectrical event and also the background events. That is, standard deviation OĀ in the net count A is given by (caberra MCA Operation Manual) as:

$$\sigma_A^2 = \sigma_p^2 + \sigma_B^2 \left[\frac{N}{6}\right]^2 \tag{2.21}$$

Also the percentage standard deviation error, E in A is given by:

$$E = \frac{F}{A}\,\sigma_A X\ 100\% \tag{2.22}$$

These algorithms also have been stored in the memory of the system with F=1.645. That is, the error statement is at 90% confidence limit. This error statement is usually displayed along with the net count A whenever analysis is made in the various region of interest.

2.6 GAMMA-RAY SPECTROMETRY

Gamma-spectrometry is a technique of analyzing the energy of the gamma radiation emitted by a nuclide, to permit conclusion to be drawn on type of nuclide or nuclide mixture. A gamma spectrometer consists of a detector, preamplifier and detector bias supply, pulse-height analyzer system, data readout capability and shielded sample enclosure. The pulse height analyzer system consists of a linear amplifier, an analogue-to-digital converter (ADC), memory storage and a logic control mechanism.

The logic control capabilities allow data storage in various modes and display or recall of data. All spectrometry measurements made to date use either Nal(TI) or germanium (Ge) detectors (Thompson, *et al.,* 1999).

The common processes of energy transfer by gamma-rays have been discuses in section 2.2. The fast electrons, which result from three processes, provide very useful information on energy and intensity of the incident gamma-rays. The system for the conversion of these fast electrons into flash of light, detected by optically matched electronic system to yield useful information concerning the primary Y-photon contrite scintillation Y-ray spectroscopic system. The ability of the system to differentiate between radiation energies and hence, identify source in the environment is the basis of its application in this work.

CHAPTER THREE

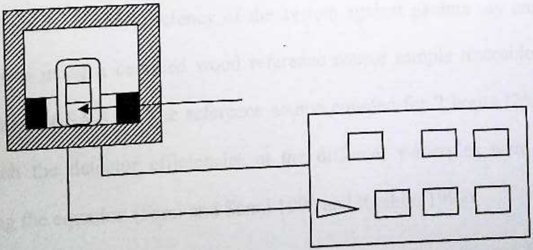
MATERIALS AND METHODS

3.1 CALIBRATION

Radioactivity counting in the work was carried out using a lead-shielded 76mm x 76mm Nal(Ti) detector crystal (Model No:802 series) by Canberra Inc; which is coupled to a Canberra 10plus Multichannel Analyzer (MCA) (Model No:1104) through a preamplifier base. Fig 3.1 shows a schematic diagram of the measuring assembly.

The first was carried out in order to convert the channel numbers to gamma-ray energy in MeV and the second was determine detector efficiencies at different γ – energies to enable quantitative and qualitative determination of the γ – counts to be related to enable to activity concentration n $Bqkb^{-1}$.

The description of these steps is this section.



3.1.1 Energy Calibration

The calibration of the detector system to determine the equation relating to channel number was carried out using a set of standard gamma emitters from IAEA with energies in the range 0.662-2.614 MeV. After a preset counting time of 1000s, the channel numbers of the photo-peaks corresponding to the different gamma energies were identified. Using energy calibration (ECAL) function of the MCA, the linear relationship fitting the graph is given as;

$$E(MeV) = 4.646 \times 10^{-3} C - 1.858 \times 10^{-3} \quad \ldots\ldots\ldots\ldots \quad (3.1)$$

Where C is the channel number corresponding to gamma energy (E) in MeV. With equation 3.1, the defection system could therefore be used to identify an unknown source from he channel number corresponding to the gamma energy is emits.

3.1.2 Efficiency Calibration

Calibration of the efficiency of the system against gamma ray energies was achieve using a certified wood reference source sample traceable to source number IAEA-152. The reference source counted for 7 hours (25200s) after which the detector efficiencies at the different γ-energies were calculated using the equation (Farai and Sanni 1992 and Ibrahim 1999).

$$\Sigma_{\gamma} = \frac{C_{net}}{A_s \gamma_{\gamma} M_s} \quad \text{--------------------} \quad (3.2)$$

Table 3.1. Detector efficiencies at different γ-energies.

Radionuclide	Energy (MeV)	Gamma yield (γ)	Efficiency ($\times10^2$cps/Bq)
^{137}Cr	0.662	0.852	1.99
^{40}K	1.460	0.107	0.96
^{238}U	1.760	0.159	0.85
^{232}Th	2.615	0.358	0.60

3.2 SAMPLE COLLECTION AND PREPARATION

A wood sample (sawdust) was collected from the Popoola Sawmill located at Oru road in ijebu-Igbo (Ogun State).

A total amount of five samples were collected for this study. The containers used were weighed to be 24 g and each sample collected was transferred in to containers. The mass of the container with wood sample to determine the actual mass of the sample in each container as shown in the table 3.2 and they were all scaled for over 30days to allow the random and its progenies to reach secular equilibrium prior to gamma counting.

Wood samples	Mass of sample with container	Mass of wood sample (g)
Poroporo	87.5	63.5
Araba	84.2	60.2
Arere	61.7	37.7
Aire	117.6	93.6
Ahun	76.9	52.9

The counting of each sample was 25,200s after which the area (A) under each photo-peak of the radionuclide was computed using the equation, the algorithm of the MCA (equation 3.2).

The net area under the photo-peaks after background subtraction of each of the three primordial radionuclide in the wood sample was related to activity concentration AC (in $Bqkg^{-1}$) using equation 3.3

$$Ac = \frac{C}{t_{\varepsilon}\gamma_{\gamma}M_{s}} \text{ -- } (3.3)$$

Where C = the net area under the photo-peak of each radiation

ε = the detector efficiency at the γ-energy

t = time of counting (25,000)

Ms = mass of the sample

γ_{γ} = intensity of the gamma at the particular energy

The Gross Area obtained from the photo-peaks due to each radionuclide of interest after the present times are give in the table while the area due to background radiation is in table 3.4. Using 3.3 after background subtraction was used to calculate the activity concentrations of radionuclide in each sample.

CHAPTER FOUR

4.0 RESULT AND DISCUSSION

The three primordial radionuclides ^{40}K, ^{238}U, ^{232}Th have been detected and measured in all the 5 wood samples. Table 4.1 present the result of radioactivity concentrations in wood samples.

Caesium 137 and cobalt 60, index for the presence of any artificial radioactive contamination of environment were not detected in any of the sample

Table 4.1 Gross γ count in the wood samples for each radionuclide

S/N	Wood sample	K-40	U-238	Th-232
01	Araba	2098.24 ± 6.35	51.50 ± 2.41	142.53 ±1 5.80
02	Poroporo	2177.12 ± 6.81	68.26 ± 3.00	275.96 ± 27.26
03	Arere	2013.43 ± 5.26	80.68 ± 2.70	227.41 ± 17.96
04	Ahun	3161.52 v 8.37	74.54 ± 2.94	133.85 ± 14.18
05	Aire	1841.52 ± 7.46	49.03 ± 3.00	115.89 ± 17.64

4.1 ACTIVITY LEVEL IN WOOD SAMPLES

The five wood samples were analysed and results were presented in Table 4.1as shown above, ^{40}K was detected from all the wood samples with Ahun that has the highest radioactivity concentration of 3161.52 ± 83.37 $Bqkg^{-1}$ while the lowest were Aire which has 1841.52 ± 7.46. ^{238}U was detected from all the wood samples with Arere which has the highest radioactivity concentration of 80.68 ± 2.70 $Bqkg^{-1}$ while the lowest is Aire which has 49.03 ± 3.00. ^{232}Th was also detected from all the wood samples with Poroporo which has the highest radioactivity concentration of 275.96 ± 27.26 $Bqkg^{-1}$. The mean activity concentration in wood samples for ^{40}K, ^{238}U and 232Th were 2,258.37 ± 6.85 $Bqkg^{-1}$, 64.80 ± 2.81 $Bqkg^{-1}$, 179.13 ± 18.57 $Bqkg^{-1}$ respectively.

Generally, a comparism of the table 4.1 shows that there is highest radioactivity concentration of ^{40}K followed by ^{232}Th and 238U the least. Potassium 40 recorded the highest activity concentration in all the wood samples analyzed than Thorium and Uranium. Zach *et al* (1989) observed thesame.

This result could be attributed to the fact that potassium was released in the soil during the application of fertilizers to crops especially when applied at rates well above crop requirement. And also, minerals occurring in rocks such as mica and feldspar as they slowly release potassium into the soil slowly through weathering.

The primary cause is over application of potassium in manure. Famer applying manure at rates targeted to meet the nitrogen requirement of a crop will generally be applying potassium is excess. In one long-term manure application study, soil potassium levels in manure treatments increases by 35% in only 3years. (Karunakara *et al.*, 2001).

When soil potassium concentration become elevated plants will take up this potassium in direct proportion to its concentration in the soil, far beyond the amount required for normal growth of the crop. This process is often referred to as “luxury consumption.”

CHAPTER FIVE

5.0 CONCLUSION

This study provided primordial radionuclide activities in some tropical wood samples which were ^{40}K, ^{238}U and ^{232}Th. From the result it shows that there was highest radioactivity concentration of 40K in the wood samples analyzed than Thorium and Uranium.

^{40}K is essential biological element and its concentration in human tissue is under close metabolic (homeostatic) control, its means that the use of wood analyzed in roofing of houses and furniture works will have no harmful effects on the human body.

The work was carried out within the limited scope of the academic research. Further work can be carry out by determining the close rates of the radionuclides. The number of wood sample can be increase and samples ca be taken from different local government or different states.

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