

**DETERMINATION OF CONCENTRATION OF NATURALLY  
OCCURRING RADIONUCLIDES AND OTHER ELEMENTS IN  
NASARAWA MUNICIPALITY/MINING AREAS**

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**A THESIS SUBMITTED TO THE POSTGRADUATE  
SCHOOL IN PARTIAL FULFILMENT OF THE  
REQUIREMENTS FOR THE DEGREE OF MASTER OF  
SCIENCE IN RADIATION BIOPHYSICS**

DEPARTMENT OF PHYSICS  
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## DECLARATION

I hereby declare that;

- (1) the report presented in this thesis is the result of my original research work.
- (2) this thesis at any time has not been submitted to any institution or organisation or body for an award of any degree other than Ahmadu Bello University, Zaria.
- (3) all the inclusions from others have been duly acknowledged.



DANSUMA SAID AUDU

25-9-2000  
DATE

## CERTIFICATION

This thesis entitled "Determination of Concentration of Naturally Occurring Radionuclides and Other Elements in Nasarawa Municipality/Mining Areas" by Dansuma Said Audu meets the requirements governing the award of a degree of Master of Science of Ahmadu Bello University, Zaria and is approved for its contribution to knowledge and literary presentation.



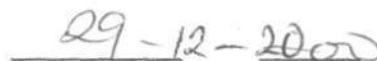
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## **DEDICATION**

Dedicated to my Mother - Aishatu and my daughter - Fatima.

## ACKNOWLEDGEMENT

I'm so much indebted to Dr. I.M Umar for his helpful suggestions, constructive criticisms and also I am indebted to Dr. T.C Akpa for his excellent suggestion, constructive criticism and supervision.

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I will not forget my parents, Sisters, brothers and friends praying for my successful completion of my studies. I am so grateful to them.

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## ABSTRACT

Soil and water samples were collected from two principal areas within Nasarawa municipality at two different locations; Ung. Habibu and Tama. All the sample materials were counted in the laboratory by NaI (TI) (7.5cm by 7.5cm) detector for a period of two hours at 1000V. The efficiency of the detector was determined by using standard point resources. Later on, this efficiency was used in the calculation of the activity of each of the radionuclide present in the sample. Total mean specific activity of the radionuclide in the soil ranges from 9.1Bq/kg to 34.2Bq/kg and the specific activity of radionuclide present in water samples ranges from 0.0045 to 0.235 Bq/cm<sup>3</sup>. K, U and Th concentration in soil ranges from 0.11 - 0.82%, 0.043 - 4.32ppm and 0.33 - 6.66pprn respectively. Potassium concentration in water (well-water) falls between 0.23% to 1.24% and that of stream within the town is 0.231%). Total means dose rate of the soil samples calculated is 68.34 x10<sup>-4</sup> mSv/y which is below the dose limit for occupational and non-occupational workers in radiation fields. The ICRP does limit is 5mSv/y and 50mSv/y for non-occupational and occupational workers respectively. Energy Dispersive X-ray fluorescence (ED-XRF) was used to determine concentration either in % or ppm of major, minor and trace elements in the soil. Ten elements were identified and their range of concentration are Ti (0.234 - 0.748%), Mn (0.0239 - 0.093%), Fe (0.392 - 6.55%), Zn (0.34ppm - 0.759ppm), Rb

(<0.107ppm - 0.0297%), Sr (0.103ppm - 0.92ppm), Th (<0.122ppm - 0.325ppm), Y (<0.220ppm - 0.396ppm), Zr (0.0163ppm to 0.21 lppm) and Nb (<6.3ppm - 9.99ppm). From the results obtained that is the activity of the soil and water one can say that Nasarawa Municipality is not an area with high natural radioactivity. In addition to that, environmental impact of mining activities has not introduced high concentration of toxic elements into the environment.

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# CHAPTER ONE

## INTRODUCTION

### 1.1 OCCURENCE OF RADIONUCLIDES IN THE ENVIRONMENT

Nasarawa State is rich with natural resources like tantalite, coulumbite, zinc, tin and manganese. Also present within the environment are primordial radionuclides from which external gamma radiation arises.

Usually these radionuclides comprise mainly of the following K-40, Th-232 decay series and U-238 decay series. In terms of specific radionuclide contributing to the gamma radiation Tl-208, Ac-228 from Th-232 decay chain, Pb-214 and Bi-214 from U-238 decay series give rise to about 99% (Guy, 1999). The depth to which these radioactive substances emit radiation are expected to be in the range of 0-30cm (Guy 1999).

Typical world average specific activity and ranges in normal soil for U-238 is 25 Bq/kg (0.01 - 0.05) and for Th-232 is 25Bq/kg ( 0.007 - 0.05), (Guy, 1999 ). The dose rate varies according to the geology of an area and the radionuclide composition of the rock and soils. The highest concentration comes from igneous rock for example granite and this is related to the quantity of silicates, being the highest in acidic rock.

Where naturally elevated levels of uranium or thorium exist close to the surface, significantly higher radiation level can be found. This can result to higher effective doses to the individual living in the area. Elevated gamma radiation are

found in a number of regions of the world for example Italian provinces of Lazio in Campania, Brazil, France, India, Iran, Madagascar and Nigeria. (UNSCEAR, 1982). In these areas, they are significantly high concentration of uranium or thorium associated with certain types of mineral deposits.

## **1.2 STATEMENT OF THE PROBLEM**

Radiation and radioactivity in the environment provides the major source of human exposure to ionizing radiation (i.e natural and artificial sources). A distinguishable problem of natural radioactivity is the irradiation of the whole population.

Problem of irradiation in particular, from the study area are ;

1. Open pit mining that is being carried out by individual and cooperate bodies.  
This introduces radiation sources into the environment and enhances the radiation level. There are no data or record to show the amount of radiation that has been introduced into the area.
2. Pollution of water and farm land as a result of these mining activities and the extend of pollution is not known since there are no data for it.
3. There is every possibility for plants to take in these radionuclide present in the soil and when man and animal feed on them, and by bioaccumulation, the level of radioactive content of such food materials can become very high. The level of radioactivity in the food eating and sold from this area is also not known.

### **1.3 OBJECTIVES**

This research work was initiated with the following objectives:-

1. Determination of natural radioactivity level in soil and water samples from Nassarawa municipality using NaI (TI) detector.
2. Estimation of dose rate to individuals from soil and water in the area.
3. Determination of the elements in the soils, major, minor or trace using XRF technique.

### **1.4 JUSTIFICATION OF THE PROJECT WORK**

The people living in this area have to know the existence of natural radionuclide. Not only that, they should know the side effects on taking these radionuclides. The effects on plants and animal should be emphasized. Plants and animals from such places could take in these radionuclide which will have adverse effect on man depending on the nature of the irradiation in the body tissue that is after feeding on them. The effect could be genetic or somatic. Such places where these radionuclides are found in high doses is not fit for human inhabitation, thus the community is advised to take adequate measures. Siting of industrial houses, the usage of water and soil from such places should be discouraged. Control of mining activity, such that radioactivity released into the environment is in accordance with I.C.R.P.( International Commission On Radiological Protection) recommendation. The level of trace elements in the soil and water could be of epidemiological importance since it may be above toxilological levels.



## **1.5 LOCATION OF THE STUDY AREA**

### **1.5.1 NASARAWA TOWN**

Nasarawa town is the headquarter of Nasarawa L.G.A of Nasarawa State. The town is bounded on North by Keffi, on the South by Benue State, on the West by Doma L.G.A and on the East by Toto L.G.A.

The town has a stream that runs across her from North East to the South West and mouthed into River Benue.

Nasarawa L.G.A is found within latitude  $8^{\circ}$  and  $9^{\circ}$  North and longitude  $7^{\circ}$  and  $8^{\circ}$ E and belongs to Southern Guinea Savannah of annual rainfall of 1000-1200mm. Vegetation here is mostly grassland, herbs and trees usually scattered. The grasses die during the long dry seasons and come back when the season is wet.

Nasarawa is mostly granite, old granite and undifferentiated basement complex. The granite and old granite exist at the South East and North East respectively while the undifferentiated basement complex is located almost at the center of the town. The undifferentiated basement complex is believed to contain granites. The granites contain quartz, feldspars, and mica. The main type of soil here is ferruginous tropical soils as classified in the CCTA ( Commission for Technical Co-operation in Africa ) system of the soils from Northern Nigeria. The soil is rich in quartz and less than 150cm deep. The cultivated soil has a sandy surface a compact clayed subsoil and dark brown loamy material which is 10.16 - 22.8cm (4" - 9") deep (Ahn , 1970).

tin in the 1996 and 1994 respectively. The method of mining is by open pit and the mineral concerned is removed by mechanical means.

## CHAPTER TWO

### LITERATURE REVIEW

#### 2.1 RELATED WORKS

It is a regrettable fact that as a consequence of various sources of contamination in many areas, our environment has become polluted to such an extent that there is no chance of its natural cleaning. Therefore, active intervention, development of the technologies protecting the environment and decrease of the contamination level will be necessary (Andras,1993). There remains the concentrations of the contamination components and among them the several micro-elements and radioisotope present in different segments of the air, water, soil, plants, foods, animals and man.

With food, drink and partly by inhalation, radioactive isotopes enter our bodies, where they can accumulate and depending on their concentration, physical and biological half-lives may cause deleterious changes (for example, gene mutation and chromosomal aberrations). Since there is no threshold dose for a genetic effect, a small dose of radiation can give rise to a mutation ( This an alteration in genetic information or chromosomal changes in DNA- deoxyribo nucleic acid). For our present and future ,it is a decisively important task to reduce the radiation level affecting mankind to the lowest possible level (ICRP, 1977).

Radioactivity in soil and water has been studied extensively over the years. The concentration of Rn-222 range in water has been found to be from 1.85 x

$10^{-3}$  to  $1.998 \text{ Bq/cm}^3$  and that of Ra-226 ranges from  $7.4 \times 10^{-7}$  to  $7.4 \times 10^{-6} \text{ Bq/cm}^3$ . Also K-40 has a concentration of  $1.11 \times 10^{-5} \text{ Bq/cm}^3$  (Keifer, 1958 and Kautsky, 1961).

Specific activity of soil around Jos Tin Mines and Mills ranges from 0.1-2.5Bq/g. Some wastes such as monazite and zircon from the same area have specific activity as 95.9Bq/g and 77.4Bq/g respectively (Rabiu, 1993).

Though the activity of some soil taking from Niger State within the geographical zone of Nassarawa municipality was not measured probably due to lack of equipment by National Cereal Research Institute Bida Niger State. However, concentration of major, minor and trace elements in the soil from some areas (Niger state) were measured. These elements are iron, zinc, copper and manganese at a depth of 0 - 22cm. The concentration of elements as mentioned above were obtained by using Atomic Absorption Spectroscopy (AAS). The concentration of these elements are Zn (0.42ppm), Cu (0.10ppm) and Mn (7.14ppm) at 0 - 22cm depth (Oyediran,1990). Also concentration of these elements were obtained in Yampere. There are Zn (0.78ppm), Fe (3.12ppm), Cu (0.06ppm and Mn 2.98ppm) at the depth of 0 - 21cm. In Kulfo area. The concentration of these elements are as follows; 1.08ppm-Zn, 1.32ppm-Fe, 0.12ppm-Cu and 8.52ppm-Mn.

## **2.2 CHOICE OF THE EQUIPMENT**

Before measuring radioactivity, some factors must be born in mind as regards to radiation energy being emitted from the radioactive source or research sample materials. These are; the type of radiation , the energy of radiation , the time of the particle arriving at the detector , the amount of energy in deposited in the detector and the number of particle per unit time emitted by the source (relative or absolute). Measurement of activity by relative method could be used on all samples by applying the same condition so that there is a comparison of activity of each sample to the other. It implies that the type of radiation to be detected and activity would be important in chosing the type of detecting equipment for the experiment.

Sodium iodide scintillation detector was used throughout this experimental work. NaI(Tl) is preferred over some other scintillation detectors. Detectors such as gas counters are not the ideal counters for gamma radiation because gamma radiation are very penetrating and cannot be stopped by gas detectors. Semi conductors counters have very good energy resolution but are very expensive. Scintillation detector is chosen because of its high intrinsic efficiency and less expensive.

## **2.3 SCINTILLATOR COUNTER**

Sodium iodide is the most commonly used scintillator for gamma rays. It has been produced in single crystals of up to 0.75m (-30in) - diameter and

considerable thickness (0.25cm = 10cm). Its relatively high density ( $3.67 \times 10^3$  kg/m<sup>3</sup>) and high atomic number combined with large volume make it a  $\gamma$  ray detector with very high efficiency.

The emission spectrum of NaI(Tl) peaks at 410nm and the light conversion efficiency is the highest (100%) for all inorganic scintillators. As a material NaI(Tl) has many undesirable properties. It is brittle and sensitive to temperature gradients and thermal shocks. It is also hygroscopic that it should be kept encapsulated all the times. NaI(Tl) has a decay constant of 0.25  $\mu$ s with a dead time of the order of 1-5  $\mu$ s. Thallium (Tl) in NaI(Tl) is an activator or impurity which has a relatively small concentration. It is  $10^{-3}$  on a per mole basis - it is the agent that is responsible for the luminescence of the crystal.

#### **2.4 MECHANISM OF SCINTILLATOR DETECTOR**

Scintillation detector produces sparks or a small flash of light (scintillations) when ionizing radiation passes through them. When a gamma-ray photons is partially or totally absorbed in the scintillation crystal, the gamma-photons interact with the atoms of the crystal by the usual mechanism of photoelectric absorption or Compton scattering or pair-production. At least one fast electron is liberated which could be either a photoelectron, a Compton electron or positron-electron pairs. This fast electron dissipates their energy which causes the excitation and ionization of the atoms in the crystal. The excited atoms return to the ground state by the emission of light photons. The total number of light photons emitted will be

proportional to the amount of the gamma-photon energy that is absorbed by the crystal.

These light photons on striking the photo sensitive cathode of the photomultiplier tube cause photoelectron to be ejected from the photocathode by the photoelectric effect. The number of these photoelectron again is proportional to the gamma-photons energy originally absorbed in the crystal.

These photoelectrons are being accelerated by electrical voltage impressed upon each dynode and each photo electron that strikes the dynode causes two or more secondary electrons to be ejected from the surfaces of the dynodes, thereby multiplying the original photo-current. This process is being repeated several times and at the end of ten or more stages about a large number of electrons will arrive at the anode. The size of the electrons will be proportional to the original gamma-ray energy lost in the crystal which can be amplified and counted.

The crystal is attached intimately or connected by an efficient light pipe to a photomultiplier tube and then to the amplification unit. The amplification unit consist of several fundamental components.

#### **2.4.1 GAMMA RADIATION OR RAYS**

In contrast to  $\alpha$ - and  $\beta$ - particles,  $\gamma$ -rays are a form of electromagnetic radiation that is photons.

Photons are electrically neutral particle. When they travel with velocity of light their rest mass is zero and so in their charge. They penetrate matter readily. This characteristic of  $\gamma$ -ray allows it to have an effective range in matter that is

much greater than of  $\alpha$  - and  $\beta$  - particles of comparable energy. For example whereas the range in air of  $\alpha$  particles is 2 to 8cm and the range of  $\beta$  - particle in air is 0 to 10cm, the distance travelled by a typical  $\gamma$ -radiation is from 0cm to 100cm. (Actually, the spread in distance travelled in matter for  $\gamma$ -rays is so large that the concept of a finite range is not valid). Light and X-rays are all form of electromagnetic radiation.

The spectrum of electromagnetic radiation shown indicates the relationship between  $\gamma$ - radiation to other forms of electromagnetic radiation. All form of electromagnetic radiation differ in frequency and wavelength. The relationship between energy  $E$ , frequency  $f$ , and wavelength  $\lambda$ , is given as  $E = hf$ ; ( $h$  = Plank's constant).

There is clear distinction between x-ray and  $\gamma$ - rays though both are photons. The term x-ray is applied generally to photons with energy  $E$  less than 1 MeV while  $\gamma$ -ray are photons with energy  $> 1$  MeV. Gamma rays are most frequently emitted immediately following  $\alpha$  or  $\beta$ - particle emission from a nucleus. In the case of certain nuclide  $^{131}\text{I}$  for example, the excess energy is carried off by series or "cascade" of  $\gamma$ -rays within a time of  $10^{-13}$  second. It therefore follows that  $\gamma$ - rays represent the readjustment of energy content in the radionuclide from excited states to more stable state (i.e unstable atomic nucleus releases energy to regain its stability).



## **2.5 COMPONENT OF SCINTILLATION DETECTOR**

### **2.5.1 DETECTOR HOUSING**

The entire scintillation detector is housed in a light tight thin metal cylinder. The cylinder gives mechanical protection to all components and also prevents spray light from reaching the photocathode while it is in operation. Also since inorganic crystal, such as NaI are hygroscopic prevents moisture from attacking the crystal. The inside of the detector is coated with a light reflecting materials such as  $\text{Al}_2\text{O}_3$  or MgO. Protection against the effect of exterior magnetic fluxes on the photo-multiplier is offered by a mu-metal shield. Where directional sensitivity is desired a lead collimator may be fitted over the scintillation crystal. Incident radiation must pass through the light tight enclosure around the fluor in order to interact and be detected. In the case of  $\gamma$  rays the thin aluminum of about 0.08 cm thick to prevent absorption.

### **2.5.2 PHOTO COUPLING**

In order to direct the maximum of photons from the scintillator crystal to the photocathode certain optical features must be included in the detector. The side of the crystal housing facing the photocathode is formed by an optical window of clear glass quartz. All other surfaces of the crystal are covered with a light-reflecting layer, usually  $\text{Al}_2\text{O}_3$  or aluminum foil. Good optical contact between the crystal and the photomultiplier tube is obtained by means of transparent viscous medium in such as dow-coating "200" silicone fluid. In application where it is desirable to have the scintillation in probe form so as to reach less-accessible

positions, a light pipe of lucite or quartz is used to connect it with the photomultiplier tube.

### **2.5.3 PHOTOMULTIPLIER TUBE**

A photomultiplier tube consists of a photosensitive cathode, a series of dynodes maintained at increasingly positive potentials to the cathode, and an electron-collecting anode, all sealed in a glass envelope. Both the photocathode and the dynodes have sensitive surfaces that are capable of emitting electrons when struck by incident photons or electrons. It is the property of secondary emission that allows electron multiplication to occur through the dynode as previously noted.

### **2.5.4 AMPLIFICATION UNIT**

The amplification unit consists of preamplifier, amplifier, discriminator and scaler.

The processing of signals produced by the detector consists of some combination of three basic operations namely, amplification, shaping and analysis done by the associated electronic equipment. Most counting system's failure and malfunction occur in the electronic component which together with the geometry, size and quality of the crystal determine the shape of the gamma-ray spectrum and hence the overall counting efficiency of the system.

The preamplifier is located very close to the crystal to minimize distortion of signal from the detector system by electrical noise originating in the cable. In the preamplifier, preliminary shaping and amplification of signal occur. Then the amplifier acts on the signal to improve on its size and shape and passed on to the discriminator. The discriminator level is set to exclude electrical noise

pulses unit to trigger on all detector pulses above the discriminator level, regardless of size. The discriminator output are counted by a scaler.

## 2.6 EFFICIENCY OF A DETECTOR

Total detector efficiency ( $\epsilon_T$ ) is the probability that any  $\gamma$ -ray of a given energy striking the detector will produce a measurable pulse height. There are two type of detector efficiency; (1) Intrinsic and Absolute efficiency.

### 2.6.1 Intrinsic efficiency

Intrinsic efficiency is the probability that a gamma of a given energy which strikes the detector will be recorded.

$$\text{i.e } \epsilon_{\text{int}} = \frac{\text{Number of pulse recorded}}{\text{Number of radiation quanta incident on a detector}} \dots\dots\dots 2.1$$

$$\implies \epsilon_{\text{int}} = \frac{I_0 - I_0 e^{-\mu x}}{I_0}$$

$$\epsilon_{\text{int}} = 1 - e^{-\mu x} \dots\dots\dots 2.2$$

where  $I_0$  = Incident intensity

$I$  = Transmitted intensity

$\mu$  = Linear absorption coefficient

$X$  = Thickness of the absorber

### 2.6.2 Absolute detector efficiency

Absolute detector efficiency is the probability that a gamma emitted from a specific source will be recorded in the detector.

$$\epsilon_{\text{abs}} = \frac{\text{Number of pulse recorded}}{\text{Number of quanta incident on detector.}} \dots\dots\dots 2.3$$

The two efficiency are related by isotropic source by

$$\epsilon_{\text{int}} = \epsilon_{\text{abs}} \frac{4\pi}{\Omega} \dots\dots\dots 2.4$$

$$\Omega = \frac{\text{area of a detector}}{4\pi r^2}$$

r = radius

where  $\Omega$  = solid angle

### 2.6.3 Counting efficiency

Counting efficiency is the ratio of observed counts per seconds to disintegration per second.

$$\text{efficiency} = \frac{\text{measured activity (c/s)(\%)}}{A_t \times \text{fg.}} \dots\dots\dots 2.5$$

where fg is the branching ratio

## 2.7 NATURAL RADIOACTIVE SERIES OR CHAINS

All natural radioisotopes undergo spontaneous disintegration of their unstable nuclei to release energy in the form of  $\alpha$  - and  $\beta$ - particles and  $\gamma$  - rays

(radiations). This phenomenon is called natural radioactivity.

There are three natural radioactive series. There are uranium - radium series, Uranium - Actinium series and Thorium series.

The characteristics common to all the three natural radioactive series are:-

- (a) Each first member is very long lived.
- (b) Each has a gaseous member and the radioactive gas in each case is a different isotope of the element radon. These are  $^{222}_{86}\text{Rn}$ ,  $^{220}_{86}\text{Rn}$  and  $^{219}_{86}\text{Rn}$
- (c) Each has an end stable product of lead - There are  $^{206}_{82}\text{Pb}$ ,  $^{207}_{82}\text{Pb}$  and  $^{208}_{82}\text{Pb}$

These three radioactive series are often designated as  $4n + 2$  (uranium 238 series),  $4n+3$  (Uranium- Actinium - 235 series) and  $4n+0$  (Thorium - 232 series).  $^{238}\text{U}$  has a half-life of  $4.468 \times 10^9$  years and natural abundance of 99.28%  $^{232}\text{Th}$  has a half-life of  $1.429 \times 10^9$  years and natural abundance of 100%.

Potassium-40 is one of the natural radioisotopes in nature. It has a half-life of  $1.27 \times 10^9$  years with natural abundance of 0.0119%. Other elements which are naturally radioactive include vanadium, lanthanum, samarium, platinum and some of the rare earths.

## **2.8 Hazardous effect of enhanced Radiation in the Environment**

The general public and open pit workers shared the risk of radiation exposure, inhalation of dust particles and injection. Workers at the open pit mining are at high risk because they do not use any of the principle of radiation protection which are time, distance and shielding and they do not take any protective

measures. Not only that the waste and pit water constitute a hazard to the public. Dust particles blow from this area to another place could cause radiation exposure. Food grown or water from such area will seriously affect the public.

The net effect of radiation exposure could be cancer induction, genetic damage, leukemia and some other long term effects which are not shown immediately but could not appear in one's life time or in later generations.

In some cases the effect is not so pronounced because the amount of radiation produced by radionuclide is not up to a threshold dose to cause acute radiation damage. Such doses will be overcome by repair process going on in the body.

## 2.9 X-RAY FLUORESCENCE

X-ray is a form of electromagnetic wave of shorter wave length of high frequency. It is a radiation originating outside the nucleus of the atom. An alpha particle for example is used to bombard the inner most shell of the atom and consequently dislodging it (electron) thereby creating a vacancy. The vacancy created is being filled up by one of the outer electrons thus a radiant energy is produced called x-ray. The magnitude of the energy of x-ray is given by this relationship,  $E=h\nu = hc/\lambda$ .

Where       $h$       =      Planck constant  
                  $\nu$       =      Frequency of the wave form  
                  $c$       =      Speed of light in vacuum

$\lambda$  = Wave length in metres

### 2.9.1 TYPE OF X-RAY FLOURESCENCE

There are two types of X-ray spectrometer:

#### 1. **WD-XRF (Wavelength disperse) and ED-XRF (Energy dispersive).**

##### **ED - DISPERSIVE**

ED-Dispersive is cheaper and differs from WD-spectrometer because instead of being based on a Bragg-diffraction crystal the spectrometer always uses the solid state lithium drifted silicon Si (Li) detector for spectrum analysis. The solid detector main advantage is its ability it has to detect many elements with a complete well-resolved spectrum that is to detect incident x-rays of all energies emitted from an excite sample. In this spectrometer (ED-XRF), there is an excellent pulse resolution near 150keV at 6keV for Si (li) detectors (Leo, 1987; Kahn and Lyon, 1953), and exhibit excellent linearity and sensitivity of wide energy range. K-lines excitation of higher Z-elements are very much accomplished with selective radioisotopes for samples that are heterogeneous in nature due to particle size or compositional differences which is very beneficial or gainful. The peripheral temperature effects are avoided because the detector and amplifier system are maintained at the liquid nitrogen (77<sup>0</sup>k) temperature which is very low.

The main disadvantage of Si(Li) detector is the application of liquid nitrogen for its operation. Because of this, an x-ray transparent window made of beryllium which limit the instrument performance on the low energy side of the spectrum is needed for the detector chamber. The detector damage due a vacuum

loss and temperature is feasible and the system count rate is limited since higher count rates come in and there is loss of resolution and low count rates will need longer counting times.

### 2.9.2 THE Si(Li) DETECTOR

The detector consists of a lithium drifted silicon crystal mounted at the end of a copper cold finger in a vacuum housing, X-ray enters the spectrometer through the beryllium window. The other end of cold finger is connected to an adjacent liquid nitrogen reservoir. The detected signals are fed to a preamplifier, the first stage of which (a field effect transistor) is mounted adjacent to the detector crystal. The Si(Li) detector for XRF in mineral exploration came into use in 1967 (Langheirich et al, 1973) in the United States by Copper Industrialists. The Silicon crystal is normally manufactured in cylindrical form, usually 10 to 16mm in diameter. The starting material is p-type silicon, which is made up of boron impurities in small amount. Lithium atoms were first of all diffused into the inner part of the crystal so that the boron atoms that have few electrons available could coordinate very well with the four adjacent silicon atoms.

The detector housing must be maintained under very high vacuum to reduce the heat conduction from the surrounding to the detector and to prevent the deposition of contaminants on the crystal surfaces which would otherwise promote the breakdown of high voltage bias. The detector housing must also be able to remove noise induced by light photons striking the detector crystal. A beryllium window is provided to reduce attenuation of low energy x-ray photons. Standard



detectors are supplied with 8 $\mu$ m window to allow adequate sensitivity down to NaK $_{\alpha}$  at 1.04keV.

## 2.10 INTERACTION OF X - RAYS WITH THE SILICON DETECTOR

The three principle interactions involved are photoelectric absorption, Compton Scatter and Rayleigh scatter.

Photoelectric absorption is the most probable interaction for photons of energy below about 50KeV. In this process, the whole energy of the photons is absorbed within the detector, usually by interaction with an inner (K-shell) electron of a silicon atom. This electron is ionized from the atom and rapidly losses its excess kinetic energy by collision with other silicon atoms causing further ionization. The original atom de-excites by emitting either a characteristic Si fluorescence  $\gamma$ -ray or Augger electrons. Both have the high probability of being absorbed within the active volume of the detector. If this occurs the full energy of the incident is detected.

Compton scatter occurs when part of the photon energy is absorbed normally in ionization of outer orbital electron of a silicon atom, the remainder being re-irradiated as secondary x-rays which escapes from the detector. Only part of the incident photon energy is deposited in the detector.

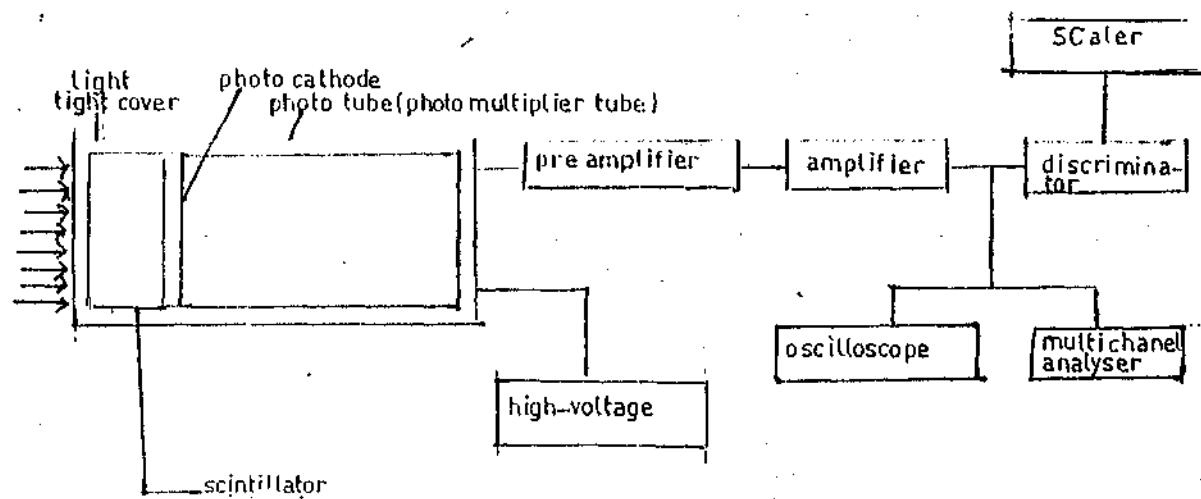
Rayleigh scatter occurs when a small fraction of the entirely x-ray tube spectrum will be scattered off the sample into the detector as well as any characteristic x-ray arising from the photoelectric absorption within the sample

Itself.

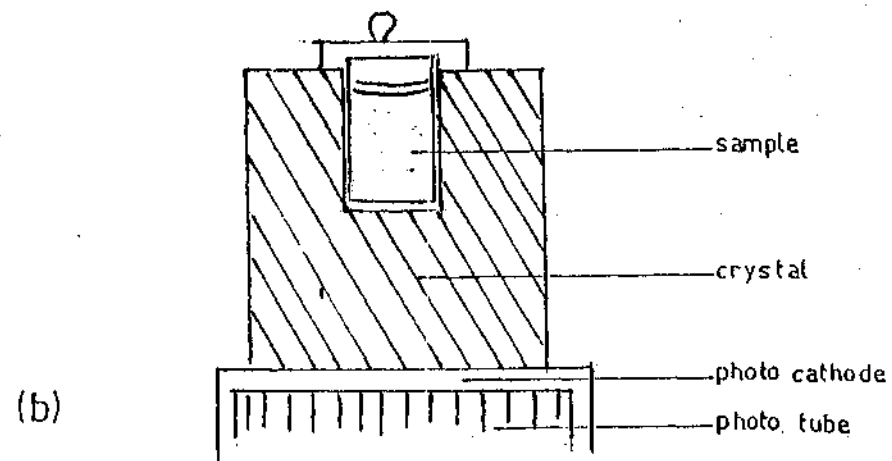
## 2.11 RADIOISOTOPE EXCITATION

Usually the x-ray tube is replaced by radioactive source for ED-XRF analysis. In many respect the usage of radioisotope source is similar to secondary target excitation but does not change the source emission characteristics. There is one important feature of XRF, and that is it has a variety of possible sources for the analysis thus there is the need for careful selection of radioisotopes for a particular analysis.

In most cases, x-ray tube source is used which incorporates six (6) selectable targets, magnesium (for k-lines of O,F and Na), aluminum (O,Na and Mg), silicon (O, Na, Mg, Al), silver (Al, Si, P, S and Cl), titanium (Si, Cl, K, Ca), nickel (Cl, K, Ca, Si, Ti, V, Cr, Mn, Fe). These target materials were bombarded with electron to 7kV (10kV for Ni) and the resultant emission spectra are filtered with a foil containing the same element as the target. Samples were excited with the radiation from each target in turn to optimize fluorescence of individual elements (Herbert and Street, 1974).



(a)



(b)

Fig. 2.2 A block diagram of (a) scintillation detector and (b) NaI (TI) crystal <sup>cross-section</sup> on the photo cathode

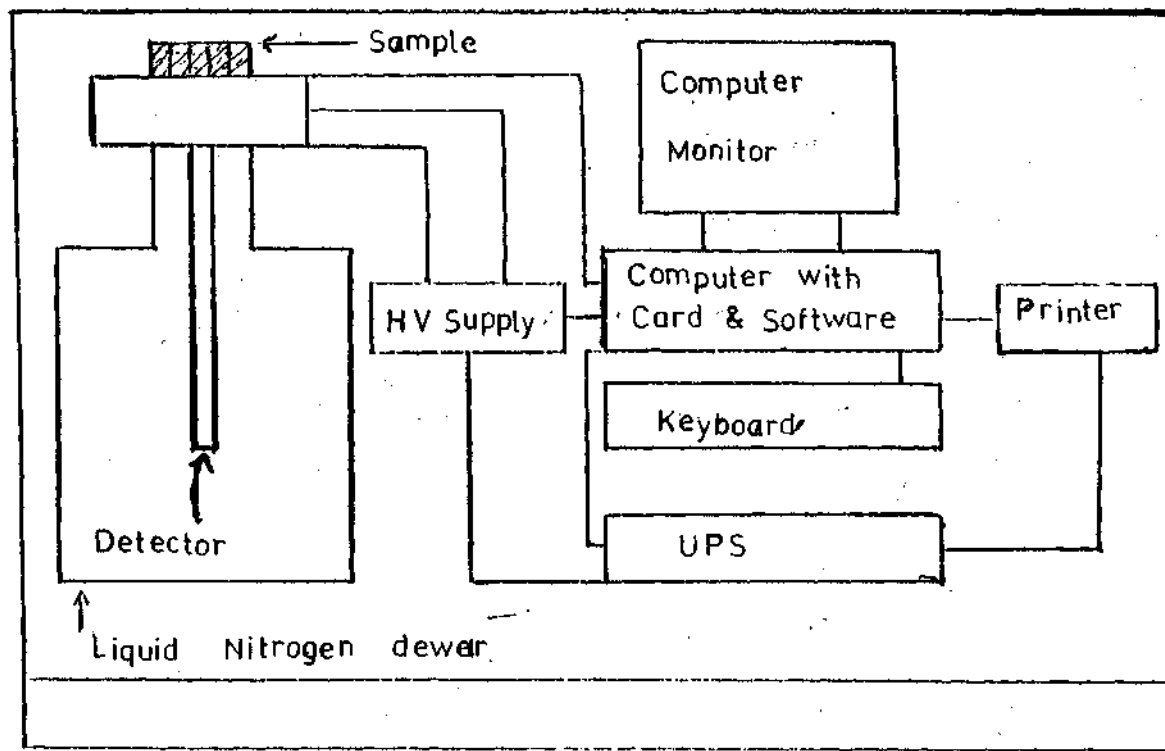


Fig. 2.3

A diagram showing energy dispersive detector.

## 2.12 ABSORPTION RELATIONS

### 2.12.1 Linear absorption coefficient

Since the absorption of  $\gamma$ -radiation is exponential in nature,  $\gamma$ -radiation have no clear-cut range. This situation is in contrast to  $\alpha$ - and  $\beta$ - particles.

As the incident  $\gamma$ -rays beam passes through the absorber with thickness  $x$  and intensity  $I_0$ , some of the gamma rays are absorbed. Consider that each photon is independent of all photons and that the average probability that one photon will be taken out of the beam per unit path length is a constant,  $\mu$  the linear absorption coefficient.

The rate of decrease of intensity of a beam of photons  $-dI/dx$ , will be equal to (the average probability per photon per unit length of beam being absorbed)  $\times$  (the number of photon in the beam) in order words.

$$-dI/dx = \mu I \dots \dots \dots 2.6$$

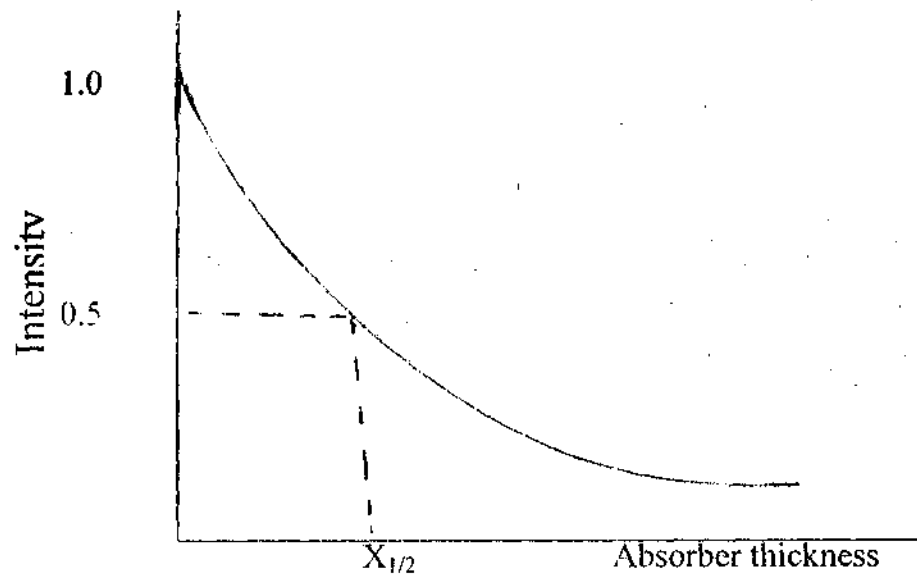


Fig. 2.1 Exponential absorption of  $\gamma$  - radiation

The  $\gamma$ -ray intensity decreases exponentially with absorber thickness as shown in figure 2.1.

The table 2.1 : Linear absorption coefficient of selected absorbers

Incident $\gamma$ -ray E(MeV)	H <sub>2</sub> O	Al	Fe	Pb
1.0	0.071	0.168	0.44	0.79
1.5	0.057	0.136	0.40	0.590
2.0	0.050	0.117	0.33	0.504

### 2.12.2 Mass absorption coefficient

As one can see from table 2.1 (Linear absorption coefficient) the linear absorption coefficient varies considerably for different absorber materials. since the absorption of  $\gamma$ -rays is primarily a function of the mass of the absorber by taking the density of the absorbing materials into account, more comparable values of the absorption coefficients for the different absorber materials are obtained. Thus one can define the mass absorption coefficient ( $\mu_m$ ) as the linear absorption coefficient,  $\mu_l$  divided by the density  $\rho$  of the absorber, or

$$\mu_m = \frac{\mu_l}{\rho}, \rho\mu_m = \mu_l \dots\dots\dots 2.7$$

Thus the basic absorption equation becomes  $I = I_0 e^{-\mu_m P} \dots\dots\dots 2.8$

The mass absorption coefficients are nearly the same for  $\gamma$ -rays of the energies listed in different absorbers as shown in Table 2.2.

**Table 2.2: Mass absorption coefficient in  $\text{cm}^2/\text{g}$**

Incident $\gamma$ -ray Energy(MeV)	H <sub>2</sub> O	Al	Fe	Pb
1.0	0.071	0.162	0.062	0.070
1.5	0.057	0.050	0.056	0.052
2.0	0.050	0.043	0.046	0.046

## **CHAPTER THREE**

### **MATERIALS AND METHODS**

#### **3.1 SAMPLE COLLECTION AND PREPARATION**

Sample materials brought from Nasarawa for this work comprises of soil and water.

#### **3.2 SOIL SAMPLE**

Soil samples as shown on Topographical map (map 3.1) were collected from those areas; Tama and Ung/Habibu. Each quantity was dogged out (depth 2 to 20cm) and kept in the white polythene bag. By this method fourteen samples were collected and allowed to stand for some days so that secular equilibrium is attained. Then the soils were filled into empty washed cleaned plastic containers after they have been dried. The masses of the soil samples were noted and ready for counting.

#### **3.3 WATER SAMPLE**

Eight well-water (underground water) were sampled out and about 400ml of water were collected into white polythene bags. Additional underground water from open pit mining was collected from two different locations at U/Habibu. Also collected is the stream water passing through the area (U/Habibu) and a tap-water from Nasarawa municipality (Tama). In the laboratory, 200cm<sup>3</sup> of water was



measured and filled into the washed cleaned dry plastic bottle. Also the water samples were allowed to stay for some days before counting.

### 3.4 MEASUREMENT BY NaI (TI) DETECTOR

All the samples were counted by 6.7cm x 6.7cm NaI(Tl) detector coupled to a computer which has ACCUSPEC 2086k card used for gamma spectroscopy via power supply and amplifier unit. The amplifier gain was well adjusted then each sample was counted for 2 hrs and store in the computer. Before the samples were worked on (counted) energy calibration was done by using point sources namely; Cs-137, Co-60, Na-22 and Mg-24. Energy spectra were printed out after counting and the efficiency curve was obtained for NaI(Tl) as 8.08% which falls within the range of 0 to 30% (Knoll, 1979).

The counting of the point sources and the samples were registered in counts per seconds (c/s). This counts/second was converted to activity (disintegration/second) by relating it (count/second) to the detector efficiency and the branching ratio (B.R) of the radionuclide concerned. By the method of the interpolation efficiency  $\epsilon$ , for a particular energy of the radionuclide was obtained from the curved graph of the point sources which was later used in calculating the activity in Bq. The specific activity (Bq/kg) was calculated when the activity was related to the mass of the sample in kg.

Before any counting is done with NaI(Tl) detector background radiation will be counted for two hours at 1000V which shall be subtracted from any counts performed on the sample.

### **3.5 ENERGY DISPERSIVE X-RAY FLOURESCENCE**

#### **MEASUREMENT**

For each of the fourteen soil sample brought from Nasarawa, a pallet was formed by grinding the soil into fine powder (micro) to attain homogeneity. And later the powdered samples formed were machined into pallet after a binder has been applied.

The radiation from the pallets were measured by using Si(Li) detector for fifty minutes coupled to a source of power supply and amplification unit. The programme for silicate was checked in the computer and this programme was entered for the soil samples analysis because soil contains a lot of silicate. Then Cd-109 source was used as a radioisotope source for the excitation of the soil samples at the amplification gain of 240volts. The quantitative analysis was performed by using AXIL programme which eliminates the elements whose standard deviation is higher than the reading already measured (fitting). This allows for correction of spectra overlaps of emission and absorption edges of intervening elements.

TOPOGRAPHICAL MAP OF NASARAWA TOWN

( MUNICIPALITY ) OF NASARAWA STATE

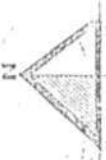


LEGEND

1	road and rail
2	well
3	pond
4	water (containing)
5	water (not containing)
6	marsh
7	swamp
8	marsh
9	marsh
10	marsh
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## CHAPTER FOUR

### RESULT AND DISCUSSION

#### 4.1 Soil Samples

The total mean specific activity measured for the soil samples is shown in table 4.1.

**Table 4.1: Soil Samples**

Sample code	Location of sample	Mass (kg)	Mean count (c/s)	Mean Specific activity (Bq/kg)
N S5	Ung/Habibu	0.475	0.0758	29.4
NS13	"	0.700	0.0355	10.3
N S4	"	0.575	0.0397	17.8
NS12	"	0.525	0.0763	17.7
NS14	"	0.675	0.05583	10.9
N S3	"	0.525	0.0896	34.2
N S1	"	0.675	0.0407	28.2
N S2	"	0.525	0.05118	24.3
N S6	Tama	0.550	0.0330	14.8
N S7	"	0.700	0.0573	9.1
N S8	"	0.600	0.0447	14.1
NS10	"	0.700	0.0332	9.4
N S9	"	0.600	0.0462	23.9
NS11	"	0.700	0.0422	11.6

Total mean specific activity of soil sample ranges from 9.1 - 34.2 Bq/kg. The highest specific activity was found in soil No.3, while the least activity

was registered in soil No.7. Actually a lot of mining activities were carried out around soil No. 3, No. 5, No. 1, N4, No.2

#### 4.2 Water Samples

The result of specific activity of water samples is contained in Table 4.2.

**Table 4.2: Water Samples**

Sample code	Location of sample	Volume (cm <sup>3</sup> )	Mean count (c/s)	Mean Specific activity (Bq/cm <sup>3</sup> )
Nw10	U/Habibu	200	0.0545	0.086
Nw11	"	"	0.0435	0.1033
Nw12	"	"	0.0393	0.072
Nw 1	"	"	0.0434	0.087
Nw 4	"	"	0.0467	0.075
Nw33	"	"	0.0519	0.0785
Nw 6	Tama	"	0.058	0.182
Nw 5	"	"	0.0272	0.044
Nw 8	"	"	0.0298	0.148
Nw 9	"	"	0.0607	0.235
Nw 2	"	"	0.048	0.1089
Nw 7	"	"	0.0277	0.0045

Mean specific activity of water samples ranges from 0.075 - 0.087 Bq/cm<sup>3</sup>.(U/Habibu).That of Tama has a range of 0.044 to 0.235 Bq/cm<sup>3</sup>. Water from the open pit mining (Nw11) has the highest activity of 0.1033 Bq/cm<sup>3</sup> with Nw12 having the least value of 0.072 Bq/cm<sup>3</sup> (stream water). The highest activity

in Tama comes from well No.9 i.e 0.235 Bq/cm<sup>3</sup>. Actually the specific activity of underground water (well water) from Tama has a higher activity compared to that from U/Habibu. As expected, the activity of tap-water is the least of all the water activities from Nasarawa municipality i.e 0.0045 Bq/cm<sup>3</sup>.

#### 4.3 Concentration of K-40 in the soil Sample

For every potassium - 40 peak energy its concentration was calculated ( as shown in the appendix). The K - concentration measured is shown in table 4.3.

**Table 4.3: Concentration of K-40 in the Soil Samples at 1460.0KeV**

Sample code	Mass (g)	(c/s/g)	Concentration (%)
N S5	475	0.000363	0.62
NS12	700	0.000095	0.16
N S4	575	0.000222	0.37
NS12	525	0.000148	0.25
NS14	675	0.000065	0.11
N S3	525	0.00048	0.82
N S1	350	0.000262	0.52
N S2	325	0.000191	0.32
N S6	550	0.00012	0.20
N S7	700	0.0000665	0.113
N S8	600	0.000104	0.18
NS10	700	0.0000895	0.15
N S9	600	0.000193	0.33
NS11	700	0.000111	0.19

The K concentration measured in the soil samples ranges from 0.11 - 0.82% with NS14 having the least and NS3 having the highest.

K - concentration measured in the soil seems to be small ie. the concentration is less than 1%. This is so because there are other ways in which K could be lost in the soil. (a) K could be lost in the water drainage ie. leaching (b) it is converted to less available form, (c) to some extent microorganism in the soil make use of it (K). In such an area K is so depleted except it is being replenished by any method. Moreso, K-uptake by plants help in reducing the K-concentration in the soil. K is a major element in most igneous rocks and K-values were converted to  $K_2O$  and the Clarke value for granite is 5.46% range of values of  $K_2O$  in all rock samples is 3.44 - 7.65% (Funtua,1992).

#### 4.4 K - Concentration in Water Sample

The potassium (K) concentration in water sample is shown in table 4.4.

**Table 4.4: Concentration of K - 40 in Water Sample at 1460.0 keV**

Sample code	Mass (g)	( c/s/ g )	Concentration ( % )
Nw10	200	0.000534	0.91
Nw11	"	0.0639	1.09
Nw12	"	0.0136	0.231
Nw 1	"	0.0137	0.234
Nw 4	"	0.0463	0.79
Nw33	"	0.0639	0.109
Nw 6	"	0.0563	0.98
Nw 5	"	0.0135	0.23
Nw 8	"	0.0457	0.78
Nw 9	"	0.0727	1.24
Nw 2	"	0.0699	1.14
Nw 7	"	0.0135	0.22

The concentration of potassium (K) in ground water (well-water vary from 0.23% to 1.24%. The highest concentration of the K comes from well water - No. 9 in Tama area, and also the least comes from Tama of well water No. 5.

The stream that passes through the U/Habibu has a concentration of 0.231% (Nw12) while the two open pit has K concentration as 0.91% (Nw10) and 1.09% (Nw11) respectively. Also in U/Habibu is 0.234%K (Nw1). Tap-water has concentration of 0.22% almost equal to that of well-water Nw5.

K - concentration in Tama is comparatively the same with that of U/Habibu. Other K concentration recorded in Tama are 1.09% (Nw33), 0.98% (Nw6) and 0.78%, (Nw8).

#### 4.5 U - Concentration in Soil

The result of U-238 in the soil samples is contained in the table 4.5.

**Table 4.5: Concentration of U in the Soil Samples at 1764.5KeV**

Sample code	Mass (g)	(c/s/g)	Concentration (ppm)
N S5	475	0.000046	1.25
NS13	700	0.00000157	0.043
N S4	575	0.0000313	0.085
NS12	525	0.000139	3.78
NS14	675	0.0000528	1.43
N S3	525	0.0000108	0.295
N S1	350	0.0000914	2.48
N S2	325	0.000159	4.32
N S6	550	0.0000221	0.60
N S7	700	0.0000357	0.97
N S8	600	0.000084	2.28
NS10	700	0.00003129	0.85
N S9	600	0.000058	1.57
NS11	700	0.000032	0.87



The concentration of  $^{238}\text{U}$  in the soil ranges from 0.043 - 4.32 ppm. Soils from U/Habibu have the highest concentration of U namely NS2, 4.32 ppm, NS1, 2.4 ppm, NS12, 3.78 ppm. Those from Tama have very low concentration of U. The highest concentration is 0.60 ppm in soil No.6 and the least comes from soil No.9, 1.23 ppm.

The above result agrees with the Clarke value of U in the crust i.e 2 ppm and in the granites the U-concentration is 4 ppm (Vinogradov, 1962).

#### 4.6 Th Concentration in the Soil

The result of Th concentration in soil samples is contained in table 4.6.

**Table 4.6: Concentration of Th in the soil samples at 2614.6 KeV**

Sample code	Mass (g)	(c/s/g)	Concentration (ppm)
N S5	475	0.0000362	3.29
NS13	700	0.0000457	4.16
N S4	575	0.00000366	0.33
NS12	525	0.0000510	4.64
NS14	675	0.0000601	5.46
N S3	525	0.0000548	4.98
N S1	350	0.0000368	3.35
N S2	325	0.0000578	5.26
N S6	550	0.0000366	3.332
N S7	700	0.0003767	3.42
N S8	600	0.000733	6.66
NS10	700	0.0000328	2.98
N S9	600	0.000072	0.65
NS11	700	0.0000457	4.15

Thorium concentration in the soil ranges from 0.33 (NS4) to 6.46ppm (NS14) (U/Habibu). From the result, there is a high distribution of Th-232 in U/Habibu because other results like 4.64ppm, (NS12), and 4.98ppm (NS3) were fairly high.

At Tama the concentration of Th is equally high. Values like 6.66ppm and 3.42ppm were observed in NS8 and NS7 respectively. The least concentration of Th in Tama is 2.98ppm (NS10).

#### **4.7 Concentration of Major, Minor and trace elements in the Soil by using XRF Technique**

ED-XRF method was used to determine the concentration of various elements present in the soil samples after the formation of the pallets.

The following results were contained in table 4.7.

##### **4.7.1 Ti (Titanium)**

The concentration of Ti varies from 0.234% to 0.748%. Soil No.4 from Z/Habibu has the highest percentage with the least coming from NS6 of concentration 0.234% (Tama soil). There is a general low concentration in Tama as shown in NS 11 (0.411%), NS 8 (0.407%) and NS7 (0.342%).

From U/Habibu we have NS5, NS 2, NS14, and NS12 recording a concentration of 0.636%, 0.634%, 0.411%, and 0.408% respectively. As shown in table 4.7.

Table 4.7: Elemental concentration of soil samples

S/No	Ti (con. %)	Mn (con. %)	Fe (con. %)	Zn (con. ppm)	Rb (con. ppm)	Sr (con. ppm)	Th (con. Ppm)	Y (con. ppm)	Zr (con. ppm)	Nb (con. ppm)
NS5	0.62	0.075	6.55	0.0125	0.0297	0.402	0.235	0.517	0.211	0.160
NS13	0.235	0.0263	0.450	<0.357	8.10	0.149	<0.133	0.396	0.0328	<7.12
NS4	0.748	0.0932	3.85	<0.924	0.526	0.366	<0.189	<0.189	0.232	0.110
NS12	0.408	0.0295	0.424	0.450	0.128	0.131	<0.173	<0.258	0.036	7.50
NS14	0.411	0.036	0.593	0.354	0.173	0.166	<0.193	<0.272	0.033	<6.30
NS3	0.435	0.032	1.23	0.749	0.160	0.759	<0.136	<0.228	0.0208	7.52
NS1	0.391	0.0345	1.4	0.618	0.358	0.920	<0.122	<0.220	0.0163	<6.49
NS2	0.639	0.0917	3.11	0.759	0.485	0.771	<0.154	<0.287	0.0219	6.33
NS6	0.234	<0.0242	4.17	0.340	0.133	0.103	<0.158	<0.271	0.0343	<6.73
NS7	0.342	<0.0261	0.449	4.406	<8.41	0.15	<0.133	<0.286	0.0360	<7.43
NS8	0.407	<0.0297	0.428	<0.398	0.180	0.230	<0.127	<0.340	0.0404	9.99
NS10	0.266	<0.0345	0.308	0.378	0.183	0.106	<0.181	<0.367	0.0380	<7.33
NS9	0.466	0.0369	0.926	0.565	0.132	0.136	<0.139	<0.247	0.0293	0.125
NS11	0.411	<0.0239	0.0512	<0.345	<0.107	0.0196	<0.162	<0.229	0.0306	9.05

The above result is in line with the finding of Taylor (1964a) which recorded 0.44% for Ti concentration and Funtua (1992) has the range of 0.10 - 0.56% of Ti concentration in rock samples. It is observed that Tama result agreed with Taylor's with few soil samples from U/Habibu and same with that of Funtua.

#### **4.7.2 Zn (Zinc)**

Zn concentration vary from 0.34ppm to 0.759ppm. Soil from U/Habibu No.2 has the highest concentration and the least are <0.345 ppm, soil No.11 from Tama and soil No.4 (<0.924 ppm). Soil No.2 (0.751ppm), Soil No 3 (0.749ppm) and Soil No. 9 (0.565 ppm) are appreciably high. Low concentration were recorded mostly in Tama for example NS8; <0.398 ppm and NS10; <0.378 ppm. As shown in table 4.7.

The Clarke value for Zn concentration is 8ppm (Vinogradov, 1962) while that of Funtua (1992) rock samples is from 46ppm - 379ppm.

#### **4.7.3 Mn (Manganese)**

The concentration of Mn vary from <0.0239 - 0.0932%. The highest concentration was recorded in U/Habibu of NS4 while the least comes from Tama NS11. Tama has a very low concentration of Mn in the soil compared to that of U/Habibu. Values from Tama are <0.024% (NS8), <0.0345% (NS12), <0.0261%(NS7) and (<0.0305%). Some of the values from U/Habibu are 0.0917%, 0.075% 0.036%, 0.032% 0.0295% of soil No. 2, 5,14, and 3 respectively. As shown in table 4.7. According to Funtua (1992) Mn0 concentration in rock samples ranges from 0.02 - 0.17%

#### **4.7.4 Fe (Iron)**

The concentration of Fe vary from 0.392 - 6.55%. U/Habibu has the highest concentration of Fe of soil No.5 while Tama has the least of soil No.10. Soil No.4 (3.85%), No.2 (3.11%) No.1 (1.43%) and No.3 (1.23%) are fairly high compared to that of Tama which are mostly very low e.g. NS9(0.926%), NS8 (0.428%) and NS7 (0.409%) However, low concentration were equally recorded in U/Habibu in some soil samples like NS14 (0.693%), NS12 (0.424%) and NS13 (0.45%). As shown in table 4.7.

Concentration of Fe found in rock samples of Funtua (1992) is from 1.00 - 7.97%. U/Habibu concentration of Fe (1.23 - 6.55%) falls within the range of Funtua.

#### **4.7.5 Rb (Rubidium )**

Rb's concentration varies from <0.107 ppm to 0.0297%. U/Habibu recorded the highest concentration of Rb while Tama has the least value. There are other high concentration of Rb recorded in U/Habibu soil. There are 8.1 ppm of NS13, 0.526 ppm of NS4, 0.485 ppm of NS2, 0.358ppm of NS1, 0.173ppm of NS14 and 0.160ppm of NS3. The highest concentration in Tama is 0.18ppm of NS8 followed by NS10 at 0.183ppm. The rest are very low e.g NS9 - 0.132 ppm, and Ns7 - 8.41ppm. As shown in table 4.7.

#### **4.7.6 Sr (Strontium )**

The concentration of Sr vary from 0.103 ppm to 0.920 ppm. The highest concentration comes from NS1 in U/Habibu while the least was recorded in NS6

also in U/Habibu. The concentration of NS6 in Tama is first being moderate notably among them are 0.23 ppm - NS8, 0.196 ppm - NS11, 0.106 ppm - NS10 . As shown in table 4.7.

300ppm was recorded in Vingradov (1962) samples while that of Funtua (1992) are in the range of 311 - 1400ppm.

#### **4.7.7 Th (Thorium )**

Th concentration vary from <0.122ppm to 0.235ppm. The least concentration comes from NS1(U/Habibu) while the highest concentration of Th in soil from both U/Habibu and Tama are within the limit of detection. Some of them are < 0.193ppm - NS14, <0.173 ppm-NS12, <0.154ppm NS2, <0.122ppm - NS1 (Z/Habibu) and <0.139 ppm - NS9 (Tama Soils). As shown in table 4.7. From Rabi (1993), the concentration of Th vary from 1.04 ppm - 2.7% mostly in monazite waste.

#### **5.7.8 Y (Yttrium )**

Concentration of Y vary from <0.220 ppm to 0.396 ppm. Soil No.13 recorded the highest concentration from U/Habibu also the lowest concentration comes from U/Habibu (NS.1), NS13 and NS5 showed a high concentration of 0.396ppm and 0.317ppm all from U/Habibu. Low concentration, we expect from U/Habibu are from soil No. 12, <0.258 ppm, 1:<0.220 ppm, 3; <0.228ppm and 6; <0.271ppm. That of Tama are <0.34ppm -NS8, <0.367ppm NS10, <0.247ppm-NS9, and <0.229ppm; NS11. As shown in table 4.7. According to (vinogradov

(1962), Y's concentration is 34 ppm and that of Funtua (1992) vary from 31 - 1400ppm.

#### **4.7.9 Zr (Zirconium )**

The concentration of Zr vary from 0.0163ppm to 0.211ppm. Tama recorded the highest concentration of Zr in soil No,8 with the least coming from U/Habibu of NS1. Other concentration observed in Tama are 0.038 - NS 10 and 0.036ppm - NS7. Z/Habibu also recorded 0.036% in soil No.12. 0.04040ppm - NS8, 0.033mm - NS14, 0.0208 NS3, 0.0219ppm - NS2 are the low concentration of these element in U/Habibu. As shown on Table 4.7.

The range of value of concentration of Zr in Nasarawa municipality is within the range of Funtua (1992) which was 97 - 498ppm.

#### **4.7.10 Nb (Niobium )**

The concentration of Nb vary from <6.3ppm to 9.99ppm. The highest concentration of Nb comes from Tama of soil No 8 while the least comes from U/Habibu soil No.14. Other high concentration in Tama are NS11, 9.06 ppm and 0.125 ppm. At U/Habibu only few cases (high concentration were noticed i.e NS3, 7.52 ppm, N2, 6.33ppm and 7.5ppm-NS12.

The low concentration observed in both areas are almost the same. As shown on Table 4.7.

**Table 4.8: Summary (point sources)**

Radion -uclide	$T_{1/2}$	$A_o$ (Bq)	Fg	Energy (keV)	C/S	Chn	$A_t$ (Bq)	$\epsilon$ (%)
$^{60}\text{Co}$	5.27yo	48.27	0.99	1172	845.43	168.2	25.007	3.42
"	"	"	1.00	1331	274.21	171.8	"	3.18
$^{137}\text{Cs}$	30.14yr	37.92	0.92	662.2	3630.29	95.1	33.80	11.67
$^{54}\text{Mn}$	3.125d	41.28	0.95	833.4	74.93	118.8	0.7178	10.9
$^{22}\text{Na}$	2.6 yr	48.48	0.99	508.4	2277.94	69.6	14.36	16.02
"	"	"	0.92	1279.47	467.44	185.4	"	3.28



### A graph of Efficiency vs Energy

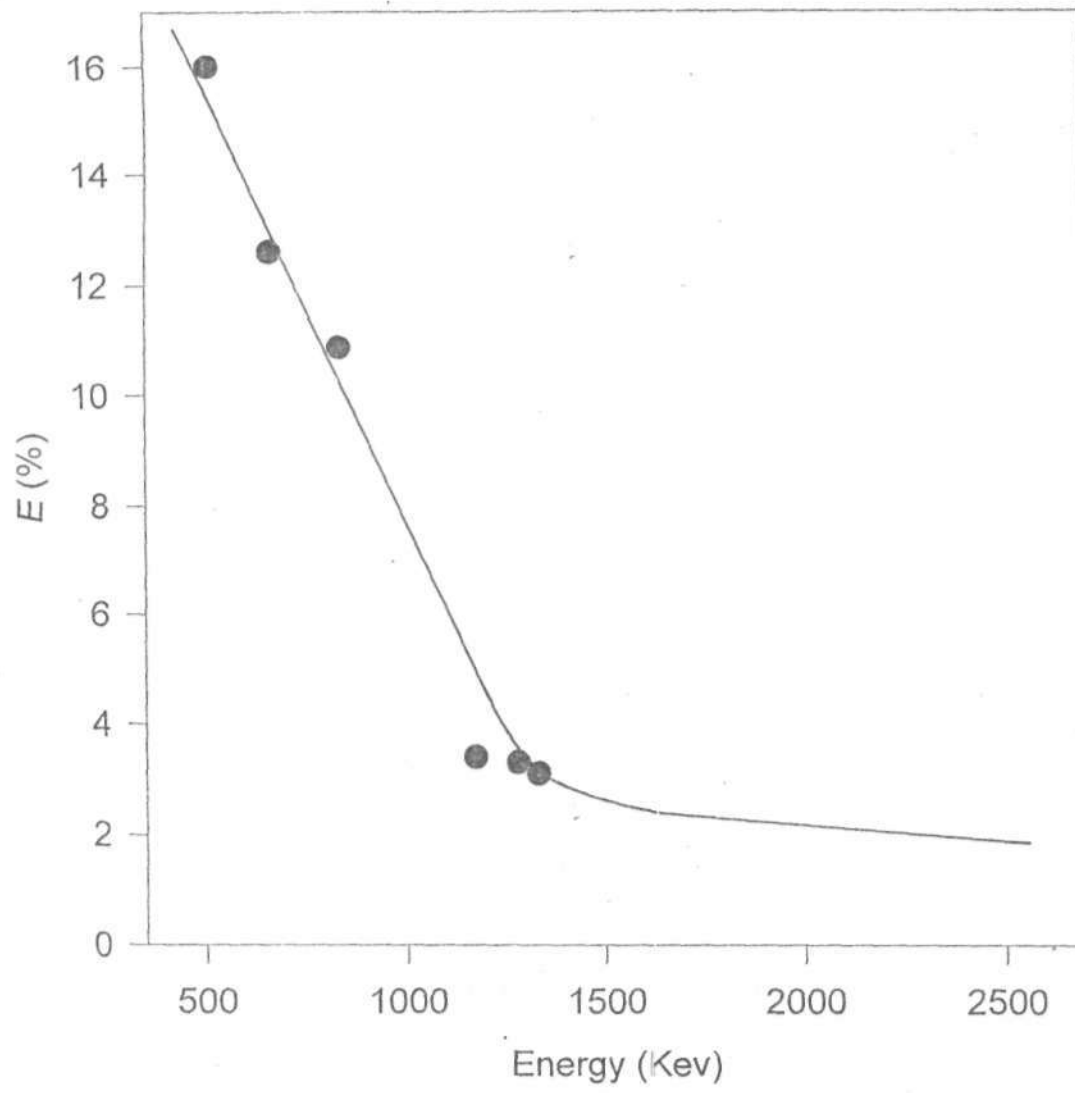


fig. 4.1

## CHAPTER FIVE

### CONCLUSION AND RECOMMENDATION

#### 5.0 CONCLUSION

The specific activity of soil samples determined in Nasarawa municipality by experiment ranges from 10.3 - 34.2 Bq/kg all from U/Habibu. And at Tama, the range is from 9.4 - 23.9 Bq/kg. This showed that the soil activity in U/Habibu is higher than that of Tama. Water activity ranges from 0.0045-0.235 Bq/cm<sup>3</sup> (all from Tama). U/Habibu recorded 0.1033 Bq/cm<sup>3</sup> as the highest in one of the open pits.

U/Habibu recorded a high concentration of U and Th in the soil, U concentration in Nasarawa municipality soil generally has a range from 0.043 - 4.32ppm and that of Th is from 0.33 to 5.46 ppm. The range of K concentration in the soil vary from 0.32 - 0.82%. Both readings were obtained from U/Habibu soil.

K in water vary from 0.23% to 1.24% all from Tama. The stream water has 0.231% K and open pit water has 1.09%K. (highest). The mean absorbed dose per year in air for a height of 1 metre above the ground surface for each location from the activity of the natural radionuclides (K, U, Th) were calculated from Gamma-ray. Flux - to Dose Rate conversion factors<sup>7</sup>

The mean absorbed dose per year calculated from U/Habibu soil is 35.32 x 10<sup>-5</sup> mSv/y and that of Tama is 33.02 x 10<sup>-5</sup> mSv/y. The two sets of reading is below the dose rate meant for the general public and occupational workers. The

maximum permissible dose for general public (non-occupational workers) is 5 mSv/y and occupation workers is 50 mSv/y (I.C.R.P. 1977).

Some elements were equally found in Nasarawa municipality. There are Ti, Mn, Fe, Nb and Zr. These elements have the highest concentration in U/Habibu while Zr and Nb have theirs at Tama. Th is within the detection limit from both sides. This is so because the soil so collected maybe from a shallow depth.

Among the elements found in Nasarawa municipality, Fe is the most prominent one with concentration of 6.5% in soil No. 5 far ahead Mn with 0.0932% in NS4 and Ti with 0.639% in NS2. The rest have a very low concentration in ppm.

Then this work revealed (a) the amount of K concentration level in soil and water, (b) the concentration of U, Th, Fe, Zn and a host of others in the Nasarawa municipality soil and the depth to which these radionuclides and other elements could be found. (c) Nasarawa municipality soil have more trace elements (Co,Cu,Zn,Ga,Rb,Sr,Y,Nb,Zr,Pb) than major (Al,Si,Fe,Ti) and minor (P,K,Ca,Mn,V) elements.

Above all, the dose rate of the natural radionuclide in the soil is below the dose limit recommended by ICRP and as such Nasarawa is not an area with high natural radioactivity.

In terms of exposure, the exposure rate of the soil samples calculated vary from  $2.09 \times 10^{-5}$  mR/h to  $5.8 \times 10^{-3}$  mR/h This is below the dose limit and there is no need for radiation monitoring.

## 5.1 RECOMMENDATION

The following recommendations were made as follows:

1. The finding of radionuclide concentration and its activity should be extended to the leaves, stem and root crop most especially the edible food plants and equally grasses.
2. Soil should be collected from the compound where people are inhabiting to ascertain the radioactivity level.
3. If possible one should collect some soil from mud houses (not plastered) and do the counting to know the radiation background dose within the room.
4. The research work should be extended to the neighbouring villages to account for the radioactivity level within Nasarawa L.G.A.
5. At any time the research work is being carried out most especially the one involving open pit mining, it is advised that protective lab coat should be worn. Also finger-dosimeters or film badges should be put on to know the amount of radiation dose absorbed into the body.
6. During further research work into concentration of major and minor elements including natural radionuclides, it is recommended that the depth in which the soil are collected should be increased since this present research work had some of the elements including Th that is mined openly are within the limit of detection. The depth have to be

## APPENDIX

### METHOD OF DETERMINATION OF TOTAL DETECTOR EFFICIENCY

Total detector efficiency or counting efficiency,  $\epsilon$  is the ratio of observed counts per second to disintegration per seconds

$$\Rightarrow \epsilon = \left[ \frac{C/S}{A_t \times B.R.} \right] \times 100 \% \text{-----(1)}$$

$$A_t = A_0 e^{-\lambda t} \text{.....(2)}$$

Where C/S = Counts per second

$A_t$  = Activity at time t.

also

$$\lambda = 0.693 / T_{1/2} \text{-----(3)}$$

$A_0$  = Initial activity

$\lambda$  = decay constant

$T_{1/2}$  = Half-life

B.R. = Branching ratio

#### Secondly, activity of the sample

$$\text{Activity, } A \text{ (d/s)} = \frac{C/S}{\epsilon \times B.R.} = \text{(Bq)} \text{-----(4)}$$

Note that standard point sources were used to determine the efficiency, of the detector.

The point sources are Cs - 137, Na - 22, C0 - 60 and Mn - 54,

Now let us look at equation (2)

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

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6. During further research work into concentration of major and minor elements including natural radionuclides, it is recommended that the depth in which the soil are collected should be increased since this present research work had some of the elements including Th that is mined openly are within the limit of detection. The depth have to be

increased because Th is not among the exchangeable cations that exist between 0cm to 22.2cm as sited in this research work.

7. There should be enough funds for this type of work so that the researcher could include more areas as recommended (No.4)

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The point sources are Cs - 137, Na - 22, C0 - 60 and Mn - 54,

Now let us look at equation (2)

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



Given  $A_0 = 37.92 \text{ KBq}$

$$\lambda = 0.693 / T_{1/2}$$

$$(3) \Rightarrow \lambda = 0.693 / \{950.81 \times 10^6 \text{ sec}\} = 0.729 \times 10^{-9} \text{ sec}^{-1}$$

$$T_{1/2} = 950.81 \times 10^6 \text{ (30.144)}$$

Elapse time = 5 yrs

$$= 0.15768 \times 10^9 \text{ sec.}$$

$$\Rightarrow \lambda = 0.729 \times 10^{-9} \text{ sec}^{-1}$$

$$(2) \Rightarrow A_t = A_0 e^{-\lambda t}$$

$$\text{Therefore } A_t = 37.92 e^{(-0.114949)} = 3792 \text{ (0.8541)}$$

$$A_t = 33.80 \text{ KBq.}$$

Similarly, activity A, at time t of other point sources were calculated.

There are  $^{22}\text{Na} = 14.36 \text{ KBq}$

$$^{60}\text{Co} = 25.007 \text{ KBq.}$$

$$^{94}\text{Mn} = 0.7178 \text{ KBq.}$$

Efficiency calculation, for instance  $^{137}\text{Cs}$

$$(1) \Rightarrow \varepsilon = \frac{C/S}{A_0 \times \text{B.R.}} \times 100\%$$

$$(1) \Rightarrow C/S = 360.9$$

$$A(t) = 33.80 \text{ kBq.}$$

$$\text{B.R.} = 0.92$$

$$(1) \Rightarrow \varepsilon = \{36309 \times 100\} / \{33.80 \times 0.92 \times 100\} = 11.67\%$$

$$E_{\gamma} = 662.21 \text{ keV}$$

$$\text{Others are } ^{22}\text{Na} (1279.47 \text{ KeV}) = 3.28\%$$

$$\text{" } (508.4 \text{ keV}) = 16.02\%$$

$$^{60}\text{Co} (1172 \text{ KeV}) = 3.42\%$$

$$\text{" } (1332 \text{ KeV}) = 3.13\%$$

$$^{54}\text{Mn} (833.43 \text{ KeV}) = 10.98\%$$

$$\text{Mean efficiency} = 8.08\%$$

A graph of efficiency  $\epsilon$  against Energy  $E$  of the standard point sources was plotted, from the energy of the radionuclide present in the samples,  $\epsilon$  of each of the radionuclide in the sample was determined by method of interpolation from the graph. This  $\epsilon$  is now, being used in the calculation of activity  $A$ , of the samples i.e disintegration per second (Bq)

$$(4) \implies A, (\text{d/s}) = \{C/S (\text{sample})\} / \{ \epsilon \cdot \text{B.R} \} = \text{Bq}$$

For example NS5 (Soil)

(a)  $\Lambda$  of k - 40, at 1460.41keV.

$$c/s = 0.1678$$

$$\epsilon = 2.95\%$$

$$\text{B.R} = 10.7\%$$

$$A = \{C/S\} / \{\epsilon \cdot \text{B.R}\} = \{0.1678\} / \{0.0295 \times 0.107\} = 53.15 \text{ Bq}$$

(b)  $\Lambda$  of  $^{238}\text{U}$  (Bi - 214) at  $E = 1781.9 \text{ keV}$

$$C/S = 0.0219$$

$$\varepsilon = 2.75\%$$

$$B.R = 15.9\%$$

$$A = \frac{C/S}{\varepsilon \cdot B.R}$$

$$A = \{0.0219\} / \{0.0275 \times 0.159\} = 5.008 \text{ Bq}$$

(c)  $\Lambda$  of  $^{232}\text{Th}$  (Tl - 208) at  $E = 2599.05 \text{ KeV}$

$$C/S = 0.0172$$

$$\varepsilon = 2.5\%$$

$$B.R = 99.8\%$$

$$A = \{0.0172\} / \{0.025 \times .998\} = 0.689 \text{ Bq}$$

(d)  $\Lambda$  of Tl - 208 at  $E = 537.05 \text{ keV}$

$$A = \frac{C/S}{\varepsilon \cdot B.R} \quad C/S = 0.065$$

$$\varepsilon = 15\%$$

$$B.R = 21.6\%$$

$$A = \{0.065\} / \{0.152 \times 0.216\} = 2.006 \text{ Bq}$$

$$\text{Mean Activity} = \underline{13.95 \text{ Bq}}$$

Similarly others and water, as contained on the tables.

### Specific Activity (Bq/kg)

Specific activity (S.A) is the activity per mass.

e.g Ns.5 (soil) knowing the activity to be 13.95Bq

the weight to be 475g.

$$\Rightarrow S.A = \frac{13.95}{475} \quad \frac{Bq}{g} = 0.0294 \text{ Bq/g.} = 29.4 \text{ Bq/kg}$$

Similarly others including water as contained on the tables.

### **Natural radionuclide concentration in the soil and water by Activity method**

From IAEA GK - 1, K concentration is 44.8%.

$$\text{weight} = 335.8\text{g}$$

Expressed on dry weight basis constant weight at 130°C

At significance level of 0.05

Firstly, the calibration value (CV) of the standard is determined and this is related to the C/S of the sample. The end result will give the concentration either in part per million (ppm) or percentage(%)

$$\Rightarrow KCV = \frac{{}^{40}\text{K C/S/g in the standard}}{\text{Concentration (\%)} \text{ of k - 40}}$$

$$[{}^{40}\text{K}] \text{ sample} = \frac{40\text{K c/s/g sample}}{KCV}$$

For example soil No.5

$$\text{K - Standard counts} = 0.0263 \text{ C/S/g}$$

$$\text{K - Weight} = 3358\text{g.}$$

$$\text{K - sample counts} = 0.0000363 \text{ C/S/g}$$

$$KCV = \{0.0263\} / \{0.448\} = 0.0587 \text{ C/S/g}$$

$$[^{40}\text{K}] \text{ sample} = \{0.00036\} / \{0.0587\} = 0.0061 \times 100 \% = 0.61\%$$

$$[^{40}\text{K}] \text{ sample} = 0.61\%$$

For K-concentration in water sample

For example Nw10

But Kcv = 0.0587 c/s/g

$$[^{40}\text{K}] = \frac{0.000534 \text{ c/s/g}}{0.0587 \text{ c/s/g}} = 0.91\%$$

$$[^{40}\text{K}] \text{ sample} = 0.91\%$$

### Uranium concentration

Uranium concentration = 400  $\mu\text{g/g} \pm 2\mu\text{g/g}$

IAEAGU - 1 significance level = 0.05 weight = 304.2g.

UCV =  $^{238}\text{U}$  c/s/g in the standard concentration (ppm)

$$[^{238}\text{U}] \text{ sample} = \frac{\text{c/s/g in the sample}}{\text{UCV}}$$

e.g. soil No. 5.

U Standard counts = 0.0147 c/s/g

U sample counts = 0.0000461 c/s/g

UCV =  $\{0.0147 \text{ c/s/g}\} / \{400 \mu\text{g/g}\} = 0.00003675 \text{ g/ug/c/s/g}$

$[^{238}\text{U}] \text{ sample} = \{0.0000461 \text{ c/s/g}\} / \{0.00003675 \text{ g/ug/c/s/g}\}$

$[^{238}\text{U}] \text{ sample} = 1.25 \mu\text{g/g} = 1.25 \text{ ppm}$

### Th - 232 concentration

Th - 232 concentration is 800  $\mu\text{g/g}$  - 16  $\mu\text{g/g}$ .

mass = 292.2g.

ThCV =  $\frac{\text{Th c/s/g in the standard}}{\text{con. ppm}}$

[Th-232] sample =  $\frac{{}^{232}\text{Th c/s/g in the sample}}{\text{Thcv}}$

e.g Ns 5

Th - standard count = 0.008792 c/s/g

Th - sample counts = 0.0000362 c/s/g.

ThCV =  $\frac{0.0008792}{800\mu\text{g/g}} = 0.0000109$

Therefore, ThCV = 0.000011c/s/g.

[<sup>232</sup>Th] sample =  $\frac{0.0000262}{0.000011\text{g}/\mu\text{g}}$

= 3.29  $\mu\text{g/g}$  = 3.29 ppm.

Therefore [Th-232] sample = 3.29 ppm

Similarly others.

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