INVESTIGATIONS OF NORM AND POSSIBLE CONTAMINATION OF WATER AROUND GOLD MINING SITES OF BIRNIN GWARI, NORTH WESTERN NIGERIA USING NaI(Tl) AND AAS

By

MOHAMMED SANI ABDULKARIM

DEPARTMENT OF PHYSICS

AHMADU BELLO UNIVERSITY, ZARIA

NIGERIA.

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By

Mohammed Sani ABDULKARIM, PHYSICS (MAIDUGURI) 2001

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DEPARTMENT OF PHYSICS,
FACULTY OF SCIENCE
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NIGERIA

OCTOBER, 2014

DECLARATION

I declare that the work in this Thesis titled" Investigation of Natural Radioactivity and Possible Contamination of Water Around Gold Mining Sites In Birnin Gwari North Western Nigeria, has been carried out by me in the Department of Physics under the Supervision of Dr Sadiq Umar and Dr Zakari I. Yusuf.

The information derived from the literature has been dully acknowledged in the text and a list of references provided .No part of this project was previously presented for another Degree or diploma at this or any other institution.

Mohammed Sani Abdulkarim **……..……..** **…….**
signature **Date**

CERTIFICATION

This thesis titled INVESTIGATION OF NORM AND POSSIBLE CONTAMINATION OF WATER AROUND GOLD MINING SITES IN BIRNIN GWARI NORTH WESTERN NIGERIA by MOHAMMED SANI ABDULKARIM meet the regulations governing the award of the degree of Masters of Physics of the Ahmadu Bello University ,Zaria and is approved for its contribution to knowledge and literary presentation.

Chairman, Supervisory Committee	**…….**	**……..**
(Dr Sadiq Umar)	**(Signature)**	**date**
Member, Supervisory Committee	**……**	**…….**
(Dr Zakari I Yusuf)	**(Signature)**	**date**
Head of Department	**……**	**……**
(Dr Sadiq Umar)	**(Signature)**	**date**
Dean School of Postgraduate Studies	**……**	**……**
(Prof. A .Z. Hassan)	**(Signature)**	**date**

DEDICATION

The research work is dedicated to the entire members of my family most especially my father Alhaji Sani Abdulkareem , my brothers ,sisters and beloved wife Hauwa Hambali to whom I will for ever remain grateful.

ACKNOWLEDGEMENT

I would like to acknowledge the entire management and staff of Ahmadu Bello University, Zaria most especially the Vice Chancellor Professor Abdullahi Mustapha for giving me the opportunity to study in this famous institution.

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ABSTRACT

Thirty six soil and thirty six water samples from gold mining sites of Birnin- gwari in Kaduna state were analyzed for potassium (K-40), thorium (Th-232), Radium (Ra-226) and Heavy Metals (Hg, Cu, Ni, Mn, Cr, Zn, Pb, Fe)activity. The activity of soil was determined using NaI Tl detector and Atomic Absorption Spectrophotometer for heavy metals concentration in water. Most of these mining sites were discovered to have a combined Th-232 and K-40 activity in excess (Th-232 18.13±3.1 to 102.62±1.9 Bq/kg with mean value of 51.95 Bq/kg and K-40 19.75±6.2 to 862.20±13.9 Bq/kg with mean value of 464.65 Bq/kg) which are against world health organization (WHO) regulations. Most of these samples contained insignificant amounts of Ra-226. The activity of radium found in all of the samples was below world health organization (WHO) standard Ra-226(0.1506±.03 to 5.67±.03 Bq/kg with mean value of 2.31 Bq/kg) . In water samples Fe has higher concentration (0.69mg/l to 72.12mg/l with average of 12.21mg/l. mg/l). The concentrations of Mercury, copper, Nickel, Manganese, Lead and Iron metals were found to be above World Health Organization and Nigeria Standard for Drinking water Quality (NSDWQ) *limit in these samples, while Chromium and Zinc was found to be below the permissible limit.*

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ABBRIVIATIONS

BG	Birnin Gwari
NORM	Natural Occurring Radioactive Material
UV	Ultra Violet
GPS	Global Positioning System
PPM	Part Per Million
UNSCEAR	United National Science Committee on the effect of Atomic Radiation
IAEA	International Atomic Energy Agency
WHO	World Health Organization
EPA	Environmental Protection Agency
NSDWQ	Nigeria standard for drinking water quality
MMSD	Ministry of Mine and Steel Development
NGSA	Nigeria Geological Survey Agency

CHAPTER ONE

1.0 INTRODUCTION

1.1 General Introduction

Gold production is associated with contribution to hazardous pollution (Peoples gold summit 2012). The ore generally containing less than one ppm gold metal, is ground and mixed with sodium cyanide or mercury to react with gold in the ore for gold separation. Cyanide is highly poisonous chemical, which can kill living creatures when exposed in minute quantities. Many cyanide spills (Deseret news.com 2000) from gold mines have taken place worldwide both in developed and poor countries which killed the marine life in long stretch of affected rivers. Environmentalists consider these pollution as major environmental disasters80 (Death of a river 2000 and Cyanide spill second only to Chernobyl 2000). When mercury is used in gold production, minute quantity of mercury compounds enters water bodies causing heavy metal contamination of water. Mercury enters human food chain in the form of methyl mercury through fish, etc. Mercury poisoning in humans causes incurable severe retardation of brain functions.

Heavy metal contamination is a major environmental concern because of their toxicity. They can cause damage to practically all the organs in the body. Though in physiochemical terms, heavy metals are defined as metals with a density at least five times greater than water. In medicine they are all toxic metals irrespective of their atomic weight. (John H.D. 2002)

Thirty tones of used ore is dumped as waste for producing one finger ring of gold, (New York Times 2005) . Gold ore dumps are the source of many heavy elements such as Mercury, copper, Nickel chromium, Manganese, Zinc, lead, Iron. Water is unsuitable for human consumption if these heavy metals are found in more than one ppm concentration.

When sulfide bearing minerals in these ore dumps are exposed to air and water, the sulfide transforms to sulfuric acid which in turn dissolves the heavy metals facilitating their passage to surface water and ground water. This process is called acid mine drainage. The gold ore dumps are considered as long term man made hazardous waste next only to nuclear waste dumps83(Norgate and Nawshad ,2012) Billions of dollars need to be spent to mitigate the heavy metals pollution from worldwide gold ore dumps which are increasing every year. (Wikipedia, the free encyclopedia 2012)

Uranium is a silver-colored metal that is radioactive. Small amounts of uranium occur naturally in rocks, soil, and water. Natural uranium is composed of three forms (also known as *isotopes*): uranium-234, uranium-235, and uranium-238. Uranium- 238 is the most predominant form. Over 99 percent of the uranium found in nature is uranium-238. Uranium is not stable but breaks down into other elements including radium and radon. This process is called decay, and alpha radiation is released. Both radium and radon are also unstable, and decay to other elements, releasing additional radiation. The total amount of radioactivity emitted is combined and often referred to as *gross alpha*. The gross alpha results are measured using the term pico Curies per liter (pCi/l). Uranium-238 decays very slowly. Uranium-238 is not the same form of uranium used in nuclear power plants or weapons. Depending on the type of analysis, uranium results are measured in terms of micrograms per liter (g/l), or Pico Curies per liter (pCi/ l).

(Fact-sheet 2006)

Most drinking water sources have very low levels of radioactive contaminants ("radionuclide's"), most of which are naturally occurring, although contamination of drinking water sources from human-made nuclear materials can also occur. Most radioactive

contaminants are at levels that are low enough to be considered for a public health concern. At higher levels, long-term exposure to radionuclides in drinking water may cause cancer. In addition, exposure to uranium in drinking water may cause toxic effects to the kidney.

Water is a liquid of ambient condition, but it often co-exists on earth with its solid state, ice and gaseous state, water vapor or stream water which covers seventy percent of the earth's surface and it's vital for all forms of life. Ninety-five percent of all fresh water on earth was found in natural rock formation. These formations, called aquifers are vital natural sources with many uses. Naturally fifty three percent of the populations rely on ground water as source of drinking water; in rural area this figure is even higher. Man uses water for domestic and industrials supply, transportation, irrigation, power generation, fish farming, sports, drainage and waste management. Water pollution is the contamination of water bodies such as lakes, rivers, ocean and underground water by human or natural activities which can be harmful to organism and plants, which lives or uses the water. Waste product like industrial waste, mining wastes, agricultural wastes and toxic wastes often contain some amount of pollutants as a result of the material used in generating the waste, thereby adding to the level of water pollution.

Another form of water pollution is naturally occurring Radioactive Materials (NORM) that emits alpha, beta and gamma radiation, these usually have elements in the Uranium and Thorium series whose radioactive gaseous daughter (radon and thoron) in particular cause an appreciable airborne particulate activity and contribute to the radioactivity of rain and ground water, this also affect drinking water . Furthermore, spring or flowing water passes through rocks that contains many radioactive materials as a result, the flowing water that leaches and migrates affects the soil and plants on its way, and it could also be transported into wells,

boreholes and tap water through burst pipes. The most important radionuclide's in drinking water are tritium, potassium – 40, radium and radon, which are alpha beta, and gamma emitters. (Sa'idu et al 2012)

The Hungarian Nobel Prize winner Albert Szent-Gyorgyi once said, "Water is life's matter and matrix, mother and medium. There is no life without water." If the water resources are contaminated, so is life. Providing clean drinking water for the growing population of the world is one of the most pressing issues we all stand to support in the 21th century. Both Anthropogenic and natural processes can affect the water quality. Except from the metals, Man has created through nuclear reactions; the rest has been on earth since the planet was formed. There are a few examples of local metal pollutions through natural weathering but in most cases metals become an environmental and health issue because of anthropogenic activity. Mainly mining and smelting plant release metals from the bed-rock (Walker & Sibly 2001).

This study is focused on an area in north western Nigeria that has a long history of mining activity. There are fears that the mining activity is causing serious metal pollution to the water resources such metals as mercury, lead, Iron, copper, Zinc, chromium, Manganese and Nickel.

1.2 Statement of the problem

In many cases, NORM producing industries such as mining companies have been in operation for long periods with little knowledge of the radiological aspects of the mining activities.

The potential hazard occurs when the operator of the practice or the regulatory authority are not aware of the problems associated with the enhanced levels of NORM in raw materials products, mine tailings and also no protective actions are put in place so that doses to workers and the public do not exceed the prescribed dose limits. The relevant route of exposure of the public is internal, via inhalation of dust and aerosols and ingestion of water and food. Mining results in large volumes of mine tailings that may contain enhanced levels of natural radionuclides. Leaching of radionuclide's can result in contaminated ground and surface water bodies and thereby expose members of the public to danger. Radionuclides, such as ^{226}Ra and ^{228}Ra are known to have high mobility in the environment due to their high comparative solubility in water. Most of these radionuclides are predominantly alpha emitters and alpha particles tend to cause more internal hazard. (Faanu et al 2011)

Tsofon Gwari Goldmine is one of the largest gold mining companies in Nigeria and has been in operation since 1930. The mine currently undertakes only surface mining and the process produces large volumes of tailings and waste that may contain NORM and heavy metals. Some of the NORM are soluble in water and have the tendency for leaching into water bodies and farm lands. The mine operates within the Tsofon-Gwari and the communities whose inhabitants depend on surface and ground water as their source of their drinking water. Farming is also an important activity within the mine's operational area. The soil, water bodies, dust and crops could be potential sinks for these radionuclides.

The above reasons are the bases for the choice of the Birnin Gwari Goldmine for this study. It is also important to note that NORM is identified as the major source of human exposure to ionizing radiations and it is important to conduct studies in all NORM industries to establish reference data which will be useful for all stakeholders in the NORM industries in Nigeria. (Faanu et al 2011)

1.3 AIM AND OBJECTIVES

1.3 AIM

The aim of this study is to assess the risk to members of the public living in the vicinity of the Birnin-Gwari Goldmine area due to NORM and heavy metals as a result of the gold mining activities.

1.4 The study has the following specific objectives;

1) To determine the activity of the radionuclide's *potassium (K-40), thorium (Th-232) `and Radium (Ra-226)* in the soil.

2) To assess the hazard and risk to the public associated with radionuclides activity and heavy metal concentrations.

3) To determine heavy metals concentration in water samples within the mines areas.

1.5 JUSTIFICATION OF THE STUDY

In many developing countries including Nigeria, mining activities have not been subjected to radiological regulatory control. Data on radionuclide concentrations in raw materials, residues and waste streams and data on public exposure are scanty. Consequently, there is general lack of awareness and knowledge of the radiological hazards and exposure levels by legislators, regulators and operators.

Mining has been identified as one of the potential sources of exposure to naturally occurring radioactive materials (NORM). Some of the NORM and Heavy metals are soluble in water and have the tendency to leach into water bodies and farm lands. Na(Tl)I and AAS techniques were used to analyse for *potassium (K-40), thorium (Th-232) and Radium (Ra-226)* in the soil and Heavy metal in water samples from the mining environment. There are some human activities which can enhance radioactivity from NORM indirectly, such as the use of building materials that contain elevated levels of activity concentration in building dwellings and workplace.

There is therefore, the need for more studies to be carried out to cover all the gold and other mines in Nigeria so that a concrete decision can be taken to ascertain the NOR situation in Nigeria as the process of formulating guideline on setting standards for the regulations of NORM in the mining industry has started. The available of data from such studies is very vital to all stakeholders involved since it will add to the data required for the development of this guideline. (Darko et al., 2005; Darko and Faanu, 2007)

1.6 Review of Similar work

Many researchers have carried out soil and water analysis using Thallium Activated sodium iodide Detector NaI(Tl) and Atomic Absorption Spectrophotometer (AAS).

- A radiological survey and assessment was carried out at selected sites (Osiri, Mikei, Masara and Macalder) in the Migori gold mines of southern Nyanza, Kenya to determine the levels of exposure of the artisanal miners to the naturally occurring radioactive materials (NORM) and dust. The activity concentrations of (40)K and the decay products of *thorium (Th-232) and Radium (Ra-226)* were obtained using an innovative method in single channel NaI(Tl) gamma-ray spectrometry. (oduma et al 2011)

- Radiological survey and assessment of associated activity concentration of the naturally occurring radioactive materials (NORM) in the Migori artisanal gold mining belt of southern Nyanza, Kenya .A study explores the possibility of converting an abandoned dredged mine paddock into a fish pond. The aim of the study is the assessment of the water quality conditions of nine surface water sampling points including paddocks/impoundments created by the operations of defunct dredged gold mine operations more than a decade for conversion into a fish pond. The concentrations of twenty water quality parameters (major ions, physicochemical and trace metals) were determined and compared with threshold values for protection of aquatic life to evaluate the suitability of the paddocks for development into a fish pond Using NaI Th (Apori . et al, 2012)

- The activity concentrations of potassium, uranium and thorium in minerals and soil samples from a mining site in Ibadan, Southwestern Nigeria were measured using gamma ray spectroscopy method. (Ademola et al 2009)

- gamma spectroscopy was used for analysis of Soil samples collected from 10 different mine sites in Zamfara State, northwest-Nigeria.(Innocent et al 2013)
- Tiimub B N conducted a research conducted in the Akantansu stream of Tutuka in Kenyasi in the Brong Ahafo Region of Ghana from October 2010 to January 2011. An AAS 220 atomic absorption spectrometer was used for the analyses of heavy metals (lead, chromium and arsenic).(Tiimub et al, 2012)
- A study conducted at the Osprey and Fumani gold tailings dams indicated high concentrations of, Zn-96.4, Cu-64.2, and Cr-269.3. High concentrations of these metals have toxicity potential on plants, animals and humans Using Atomic Absorption Spectrometer.
- (Ogola et al ,2010)
- Mining of solid minerals has been identified as an entry point of heavy metals into the environment consequently polluting various components of the environment such as water and air. Five water samples and a kilogram each of selected solid minerals (Gold, tantalite and columbite) from one of the gold mines of Zamfara state were analyzed for mineral and heavy metals (Mn, Zn, Pb, Mg, Al, Cd, Cr, Ni, Co and Cu) using Atomic Absorption Spectrophotometer and Energy Dispersive X-Ray.The results revealed high concentration of Heavy metals in water which indicate significant contamination. The study concluded that there was pollution of water body especially for toxic metals like Pb and Cd.(Tsafe et al 2012)

CHAPTER TWO

2.0 Literature Review

2.1 Gold

Gold is a dense, soft, shiny, malleable and ductile metal and is a chemical element with the symbol **Au** and atomic number 79. Pure gold has a bright yellow color and luster traditionally considered attractive, which it maintains without oxidizing in air or water. Chemically, gold is a transition metal and a group 11 element. It is one of the least reactive chemical elements solid under standard conditions. The metal therefore occurs often in free elemental (native) form, as nuggets or grains in rocks, in veins and in alluvial deposits. Less commonly, it occurs in minerals as gold compounds, usually with tellurium. Gold resists attacks by individual acids, but it can be dissolved by the aqua regia (nitro-hydrochloric acid), so named because it dissolves gold. Gold also dissolves in alkaline solutions of cyanide, which have been used in mining. Gold dissolves in mercury, forming amalgam alloys. Gold is insoluble in nitric acid, which dissolves silver and base metals, a property that has long been used to confirm the presence of gold in items, giving rise to the term *the acid test.*(Dexter 2007)

Besides its widespread monetary and symbolic functions, gold has many practical uses in dentistry, electronic, and other fields. Its high malleability, ductility, resistance to corrosion and most other chemical reactions, and conductivity of electricity led to many uses of gold, including electric wiring, colored-glass production and even gold leaf eating. (From Wikipedia, the free encyclopedia 2012)

2.2 Gold Occurrence and Mineralization in Nigeria

Gold in Nigeria is found in alluvial/eluvial placers and primary veins from several parts of upracrustal (schist) belts in the Northwest and Southwest of Nigeria. The most important occurrences are found in the Maru, Anka, Malele, Malendo, Sofon Birnin Gwari-Kwaga, Gurrara, Bin Yauri, Okolom- Dogondaji, Ijero - Ekiti and Iperindo areas, all associated with the schist belts of Northwest and Southwest Nigeria. There are also a number of smaller occurrences beyond these major areas. (NGSA, 2010)

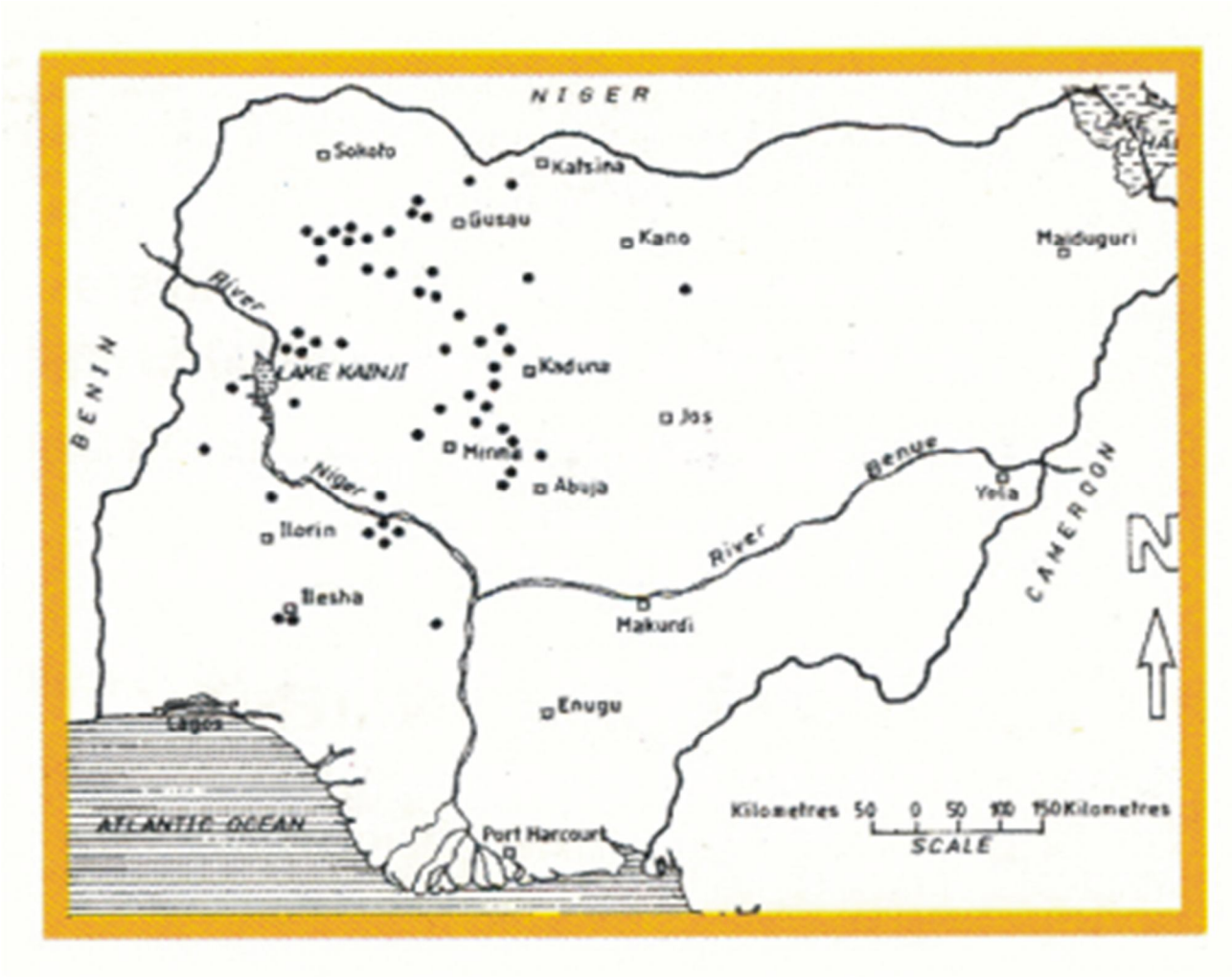


Plate 2.1 Location of Gold Occurrences in Nigeria (source: MMSD, 2010)

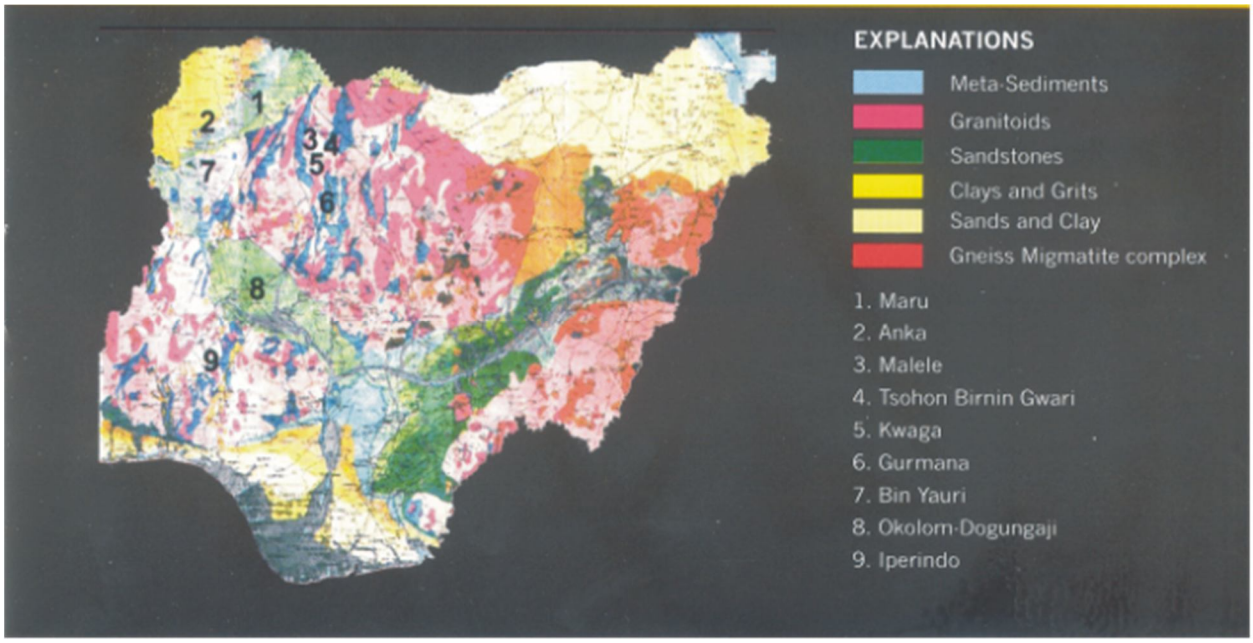


Plate 2.2 (MAJOR AREAS OF GOLD MINERALISATION IN NIGERIA SOURCE NGSA 2010)

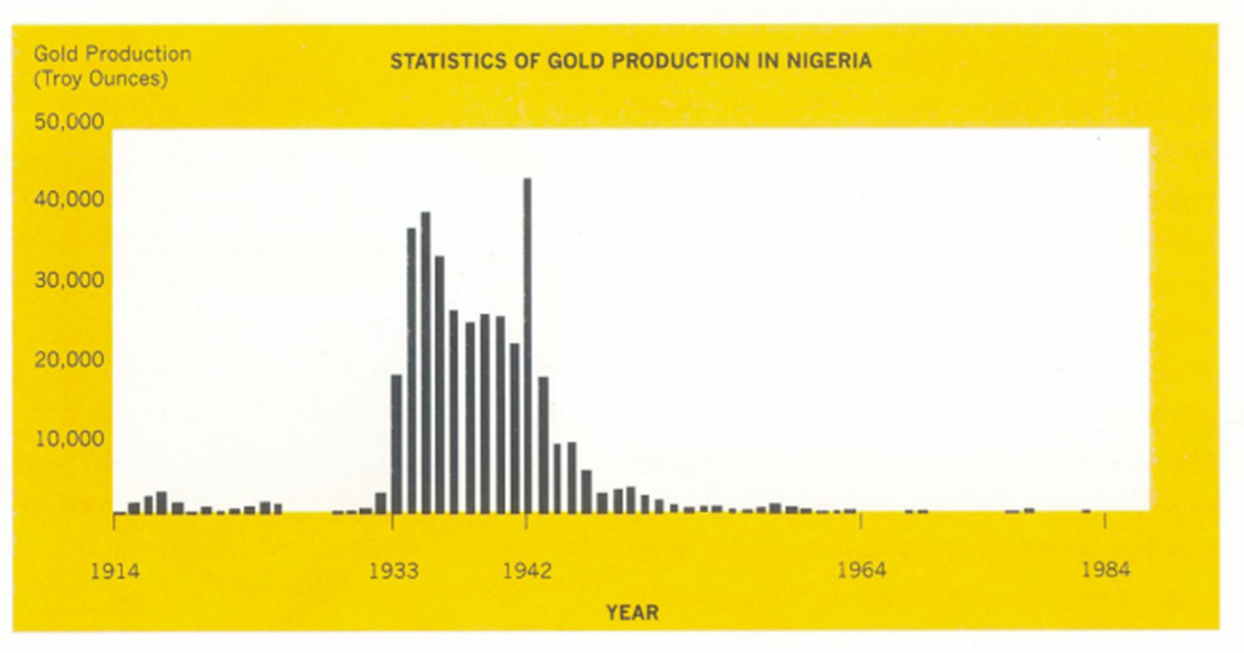


Plate 2.3 Statistics of gold production in Nigeria (NGSA)

2.3 Basic Radioactivity

Among about 2500 known radionuclides, fewer than 300 are stable. The others are unstable structures that decay from other nuclides by emitting particles and electromagnetic radiation, a process called radioactivity. The time scale of these decay processes ranges from a small fraction of a microsecond to billions of years.

(Young and Freedman, 2008)

Natural radioactivity is due to one or more of three types of radiation emitted from heavy elements such as uranium whose nuclei are unstable. These are originally called α-, β-and γ-rays but α and β 'rays' were soon shown to be particles.(Nelkon and Parker, 1995)

. α and β-particles and γ-rays all produce ionization as they move through gas. An average α – particles produce about 1000 times as many ions per unit length of their path as β-particles, which in turn produce about 100 times as many ions as γ-rays.

(Nelkon and Parker, 1995)

2.31 Alpha – Particles

It is found that α – particles have a limited range in air at atmospheric pressure. This can be shown by slowly increasing the distance between a pure α- source and a detector. The count rate is observed to fall rapidly to zero at a separation greater than a particular value, which is called the 'range' of the – particles. The range depends on the source and on the air pressure. Using the apparatus charge on an – particle, it can be shown that α –particles have positive charges.

Nature of α – particle

Lord Rutherford and his collaborators found by deflection experiments that an α – particle had a mass about four times that of a hydrogen atom He, and carried a charge + 2e, where is was the numerical value of the charge on an electron. The relative atomic mass of helium is about four. It was thus fairly certain that an α – particle was a helium nucleus, that is, a helium action which has lost two electrons. Experiment by Rutherford and Royds showed conclusively that α – particles were helium nuclei. Radon, a gas given off by radium which emits α – particles, was collected above mercury in a thin – walled tube.(Nelkon and Parker, 1995)

2.3.2 Beta and Gamma - Rays

By deflecting β-particles with perpendicular magnetic and electric fields, their charge mass ratio could be estimated. This is similar to Thomson's experiment. These experiments showed that β–particles are electrons moving at high speeds. Generally, β-Particles have a greater penetrating power of materials than α – particles. They also have a greater range in air than α – particles, since their ionization of air is relatively smaller, but their path is not so well defined.

Using a strong bar magnet, it can be shown that β– particles are strongly deflected by a magnetic field. The direction of the deflection corresponds to a stream of negatively – charged particles, that is, opposite to the deflection of α – particles in the same field. This is consistent with the idea that β– particles are usually fast moving electrons.

The nature of γ-rays has shown by experiments with crystals. Diffraction phenomena are obtained in this case, which suggest that γ – rays are electromagnetic waves. Measurement of their wavelengths, by special techniques with crystals, show they are shorter than the wavelengths of X – rays and of the order of 10^{-11}m or less. γ –rays can penetrate large thicknesses of metals, but they have far less ionizing power in gases than β – particles.

If a beam of γ-rays is allowed to pass through a very strong magnetic field no deflection is observed. This is consistent with the fact that γ –rays are electromagnetic waves and carry no charge.

The mass of an α – particle, a helium particle, is about 800 times the mass of a β – particle, an electron. The α – particle is therefore massive compared with the β- particle , the ratio of their masses is similar to that of the mass of a small elephant compared to the mass of a new

born baby. The mass of the γ-ray is negligibly small compared with α – and β – particles. (Nelkon and Parker, 1995)

2.4. Half – Life and Decay Constant

2.4.1 Rate of disintegration.

Considering the laws governing the rate of disintegration of radioactive atoms. These laws lead to the identification of atoms and to useful applications.

Radioactivity, or the emission of – α or β – particles and γ –rays, are due to disintegrating nuclei of atoms. The disintegrating obeys the statistical law of chance. Thus although we cannot tell which particular atom is likely to disintegrate next, the number of atoms, N, present at that instant will tell.

A statistical analogy is to say that with many cars on the roads on a national holiday, more accidents per hour will occur in proportion to the number of cars on the road. So

$\frac{dN}{dt} = -\boldsymbol{\lambda N}$----------> (2.2.1)

Where λ is a constant characteristic of the atom concerned called the radioactivity decay constant?

The negative sign indicates that N becomes smaller when t increases. So if No is the number of radioactive atoms present at a time t = o, and N is the number at the time t, we have, by integration;

$$\int_{NO}^{N} \frac{dn}{N} = -\lambda \int_{\mathrm{o}}^{\mathrm{t}} \mathrm{dt}$$

$\therefore (\ln) N \int_{N}^{N} = -\lambda t$ …….2.2.2

$N(t) = Noe^{-\lambda t}$ ---> (2.2.3)

So, the number N of un-decayed atoms left decreases exponentially with the increase in time t,

From equation (2.2.1)

$, \lambda = \frac{-1}{N} \frac{dN}{dt} = \frac{no\ of\ disintergrating\ atom\ per\ second}{total\ no.of\ atoms}$

So λ is the fraction per second of the decaying atoms or the probability of an atom decaying in the next second, Since the rate of disintegration, or activity A, is proportional to the number N of disintegrating atoms, and $N = Noe^{\lambda t}$, then $A = A_0\ e^{-\lambda t}$, where A_0 is the initial rate of disintegration or activity, of the atom at time t = 0.

2.4.2 Half – Life

The half – life $T_{½}$ of a radioactive element is defined as the time taken for the atoms to disintegrate to half their initial number, that is, in a time $T_{½}$ the radioactivity of the element diminishes to half its value. So, if No is the initial number of atoms, from equation (2.2.3),

$\frac{No}{2} = Noe^{-\lambda}T_{½}$ ……………………………………………………..> (2.2.4)

$\frac{1}{2} = 2^{-1} = e^{-\lambda}T_{½}$ ……………………………………………………………> (2.2.5)

Taking logs to the base on both sides of the above equation we get,

$-1 \ln 2 = -\lambda T_{½}$ ………………………………………………………..>. (2.2.6)

$\therefore\ T_{½} = \frac{\ln 2}{\lambda} = \frac{0.693}{\lambda}$ ……………………………………………….> (2.2.7)

(Nelkon and parker, 1995)

2.5 Natural Radioactivity

Many radioactive elements occur in nature for example, one is very slightly radioactive because of unstable nuclides such as carbon – 14 and potassium – 40 that are present throughout your body. The study of natural radioactivity began in 1896; one year after Rontgen discovered X-rays. Hermi Becquerel discovered a radiation from uranium salts that seemed similar to X – rays. Intensive investigation in the following two decades by Marie and pierce curie, Ernest Rutherford, and many others revealed that the emissions consist of positively and negatively charged particles and neutral rays; they were given the names alpha, beta, and gamma because of their differing penetration characteristics.

The decaying nucleus is usually called the parent nucleus; the resulting nucleus is the daughter nucleus. In this case a series of successive decays occurs until a stable configuration is reached. Several such series are found in nature. The most abundant radioactive nuclide found on earth is the uranium isotope ^{238}U, which undergoes a series of 14 decays, including eight α emissions and six β^- emissions, terminating at a stable isotope of lead, ^{206}Pb.

Radioactive decay series can be represented on a Segre chart. The decay in an equation form is as thus

$$^{238}\text{U} \longrightarrow {}^{234}\text{Th} + {}^{4}_{2}He$$

$$^{234}\text{Th} \longrightarrow {}^{234}\text{Pa} + \beta^{-1} + \overline{\nu e}$$

Or more briefly as

$$^{238}\text{U} \xrightarrow{\alpha} {}^{234}\text{Th}$$

$$^{234}\text{Th} \xrightarrow{\beta} {}^{234}\text{Pa}$$

In the second process, the beta decay leaves the daughter nucleus ^{234}Pa in an excited state, from which it decays to the ground state by emitting a gamma – ray photon. An excited state is denoted by an asterisk, so the gamma emission can be represented as thus

$$^{234}Pa^* \longrightarrow {}^{234}Pa + \gamma$$

or $$^{234}Pa^* \xrightarrow{\gamma} {}^{234}Pa$$

An interesting feature of the ^{238}U decay series is the branching that occurs at ^{214}Bi. This nuclide decays to ^{210}Pb by emission of an α and a β^-, which can occur in either order. It was also noted that the series includes unstable isotopes of several elements that also have stable isotopes, including thallium (Tl), lead (Pb), and bismuth (Bi). The unstable isotopes of these elements that occur in the ^{238}U series all have too many neutrons to be stable. Many other decay series are known. Two of these occur in nature, one starting with the uncommon isotope ^{235}U and ending with ^{807}Pb, the other starting with thorium (^{232}Th) and ending with ^{208}Pb. [Young and freedman, 2008]

2.6 Radiation in the Home

A series of health hazard in some areas is the accumulation in houses of ^{222}Rn, an inert, colorless, odorless radioactive gas. The ^{238}U decay chain shows that the half-life of ^{222}Rn is 3.82 days. ^{222}Rn is continuously being produced by the decay of ^{226}Ra, which is found in minute quantities in the rocks and soil on which some houses are built. It's a dynamic equilibrium situation, in which the rate of production equals the rate of decay. The reason ^{222}Rn is a bigger hazard than the other elements in the 238U decay series is that it's a gas. During its short half-life of 3.82 days it can migrate from the soil into the house. If a ^{222}Rn nucleus decays in the lungs, it emits a damaging particle and its daughter nucleus ^{218}Po, which is not chemically inert and is likely to stay in your lungs until it decays, emits another damaging particle and so on down the ^{238}U decay series.

Reports indicates that the hazard value of radon is as high as 3500 PCi/L, the average activity per volume in the air inside American homes due to ^{222}Rn is about 1.5PCi/L (over a thousand decays each second in an average sized room. If one's environment has this level of activity, it has been estimated that a lifetime exposure would reduce the life expectancy by about 40 days. (Young and Freedman, 2008)

2.7 Radiation Hazards

Here are a few numbers for perspective. To convert from Sv to rem, simply multiply by 100. An ordinary chest X-ray exam delivers about 0.20-0.40m Sv to about 5kg of tissue. Radiation exposure from cosmic rays and natural radioactivity in soil, building materials, and so on is of the order of 2-3m Sv per year at sea level and twice that at an elevation of 1500m (5000ft). A whole- body dose of up to about 0.20Sv causes no immediately datable effect. A short-

term whole body dose of 5Sv or more usually causes death within a few days or weeks. A localized dose of 100 Sv causes complete destruction of the exposed tissues.

The long-term hazards of radiation exposure in causing various cancers and genetic defects have been widely publicized, and the question of whether there is any "Safe" level of radiation exposure has been hotly debated. U.S. government regulations are based on a maximum yearly exposure, from all except natural resources, of 2 to 5mSv. Workers with occupational exposure to radiation are permitted 50mSv per year. Recent studies suggest that these limits are too high and that even extremely small exposures carry hazards, but it is very difficult to gather reliable statistics on the effects of low doses. It has become clear that any use of X-rays for medical diagnosis should be preceded by a very careful estimation of the relationship of risk to possible benefit.[Young and Freedman, 2008]

2.8 Gamma Spectroscopy

The detection method for gamma rays depends on the interaction of gamma-ray photons with the detector material. Each of the (main) types of gamma-ray interactions can occur within the detector volume, but the most significant types which play important roles in photon detection are the photoelectric effect and Compton scattering. For these interactions, the primary gamma-ray photons and/or the secondary scattered photon interact with the detector atoms and generate fast electrons within the detector volume that an energy proportional to that of the primary photon. These fast electrons can then generate secondary electrons as they travel through the detector volume. These secondary electrons can be collected to generate electrical pulses. The charges can be converted via a preamplifier to a voltage, whose magnitude is proportional to the original gamma-ray energy deposited in the detector.

There are two distinct functions required in a workable gamma spectroscopy detector. First, the detector must work as a radiation converter medium with a reasonable probability of interaction to produce fast electrons, which themselves must be able to travel easily through the detector; second, the background noise in the detector must be low enough to collect only those electrons which represent the energy of the detected gamma-ray photons. These can be achieved if the detector can support a high electric field (Krane, 1988 and Knoll, 2000)

2.9. Scintillators (NaI)

Gamma spectroscopy systems that use NaI as a detector material are considered as

Practical, in-situ measurement systems (Knoll, 2000)

Due to their room temperature operation. The electrons generated by the radiation interaction are transferred into photoelectrons indirectly to generate the electrical pulses (Krane, 1988). The gamma-ray photons deposit their energy in the scintilator (a florescence material) resulting in the raising of atoms to exited states. The energy of the excite electrons from the valence band, which is generally full, to the empty conduction band across the energy gap is about 4 eV in NaI.(Krane, 1988)

Eventually, the excited atoms lose their energy by emitting visible photons and the

electrons drop back into the valence band. The visible photons emitted following this deexcitation hit a photosensitive surface and photoelectrons are generated. Electrical pulses are formed by multiplying and accelerating the photoelectrons using a photomultiplier tube.

Self absorption of visible photons in a pure NaI crystal can occur. In order to reduce this effect, and to increase the probability of transmission of visible photons, small amount of impurities, called "activators" are added to the crystal such as the element thallium (Tl).

Adding activators to a pure NaI crystals to form NaI(Tl) increases the wavelength of the maximum emission of visible photons from 303 nm to 410 nm and reducing the self absorption of the scintillation light within the crystal.(Krane, 1988)

2.10 System Components

A gamma spectroscopy system consists of a detector, electronics to collect and process the signals produced by the detector, and a computer with processing software to generate, display, and store the spectrum. Other components, such as rate meters and peak position stabilizers, may also be included.

Gamma spectroscopy detectors are passive materials that wait for a gamma interaction to occur in the detector Volume. The most important interaction mechanisms are the photoelectric effect, the Compton Effect, and pair production. The photoelectric effect is preferred, as it absorbs all the energy of the incident gamma ray. Full energy absorption is also possible when a series of these interaction mechanisms take place within the detector volume without being absorbed, the background rate in the spectrum is increased by one count. This count will appear in a channel below the channel that corresponds to the full energy of the gamma ray. Larger detector volumes reduce this effect.

The voltage pulse produce by the detector (or by the photomultiplier in a scintillation detector) is shaped by a multichannel analyzer (MCA). The multichannel analyzer takes the very small voltage signal produced by the detector, reshapes it into a Gaussians or trapezoidal shape, and converts that signal into a digital signal. In some systems, the analogue –to- digital conversion is performed before the peak is reshaped. The analogue –to-digital converter (ADC) also sorts the pulses by their height. ADC's have specific numbers of "bins" into which the pulses can be sorted; these bins represent the channels in the

spectrum. The number of channels can be changed in most modern gamma spectroscopy systems by modifying software or hardware settings. The number of channels is typically a power of two common value include 512, 1024, 2048, 4096, 8192, or 16384 & channels. The choice of number of channels depends on the resolution of the system and the energy range being studied. The multichannel analyzer output is sort to a computer, which stores displays, and analyses the data. A variety of software packages are available from several manufacturers, and generally include spectrum analysis tools such as energy calibrations, peak area and net area calculations, and resolution calculation.

Mining and Toxic Metals

Mining encompasses the extraction of metals and minerals from the ground (Weber-Fahr and Andrews, 2002; Downing, 2002; Cernea, 2000) .

A case study of the proposed Donlin Creek mine Mining activities are known to release significant amounts of toxic metals into the surrounding environment.

Some toxic metals frequently associated with mining include mercury, arsenic and lead. These substances are present at low concentrations in soil, rock and water, but the process of mining may release quantities harmful to the health of people and the environment.

How Mining Releases Toxic Metals

Large amounts of waste rock and tailings contaminated with toxic metals can be produced by mine sites. In the case of the Donlin Creek mine, there are only 0.072 ounces of gold for every ton of ore, a figure that does not take into account the waste rock. Toxic substances contained within the rock and tailings are more easily released once these substances are processed/milled and left in mine pits, underground workings, waste rock piles, and tailings impoundments where they are exposed to the environment. (Engle et al. 2001).

Mercury can be released from waste rock and mine tailings directly into the atmosphere even at normal environmental temperatures because mercury evaporates at a much lower temperature than other metals, once in the atmosphere, it can later be deposited in soils and waters miles from the mining site.

(National Atmospheric Deposition Program. 2008)

Dust emissions from the mine site during blasting and mining operations could contain any toxic metals. For example, dust emissions at Alaska's Red Dog mine are responsible for severely contaminating the surrounding environment with lead and cadmium. (Hasselbach , 2005)

Rain water leaches toxic substances from waste rock and mine tailings into soil and waterways. Additionally, rain can deposit toxic metals from the air, present as vapors or attached to dust particles, into waterways. (Lawson and Mason. 2001)

One of the major sources of toxic metals associated with mining is acid mine drainage. When waste rock excavated from the mine is exposed to air (oxygen) and water, it chemically reacts to form several acids, including sulfuric acid. This acid leaches toxic metals from the rock and surrounding environment. Acid mine drainage is known to have very high concentrations of metals including iron, mercury, arsenic and antimony. Acid mine drainage may contaminate both surface and ground water. (Corkhill and Vaughan . 2009).

Once acid mine drainage begins to form it is usually impossible to stop and is difficult and costly to remedy (Johnson and Hallberg . 2005). . According to the Environmental Protection Agency, the variable size and mineral composition of waste rock makes accurate prediction of AMD difficult. (US EPA. 1994)

The massive amounts of fossil fuels needed for large scale mining operations also contribute to the release of toxic metals into the atmosphere. Burning coal and petroleum releases toxic metals, specifically mercury, and other hazardous substances into the air. These toxic emissions are associated with cardiovascular problems, reproductive effects, cancer and other health problems. (Lewtas . 2007) It is estimated that mining consumes 7-10 percent of the world's energy production. (Dirty Metals: Mining, Communities and the Environment. 2004) Additionally, seasonal variations in precipitation and temperature can have a significant impact on the concentrations of toxic metals and the effects on wildlife. Snowmelt from or through a mine site can potentially introduce considerable amounts of toxic metals and acidic water into ecosystems in a short period of time. The increased stresses of an arctic winter make arctic organisms more vulnerable to toxic exposures. (Moiseenko . 1999)

Effects of Toxic Metals

Different toxic metals produce different symptoms in the people and animals that are exposed to them.

Effects in Humans

Mercury is toxic to the central and peripheral nervous systems. Health problems associated with mercury include personality changes, deafness, changes in vision, loss of muscle coordination or tremors, loss of sensation, and difficulties with memory. Mercury can be passed from pregnant mothers to unborn children and also to babies through breast feeding. Because they are still developing, fetuses and children are especially sensitive to the harmful effects of mercury. (Agency for Toxic Substances and Disease Registry 1999).

Bacteria within the environment transform inorganic mercury into methyl-mercury, a more toxic form of mercury that is best known as being the form that accumulates in fish.

Indigenous populations that rely on subsistence fishing are especially susceptible to the effects of methyl-mercury, because they are disproportionately exposed through their traditional diet. (Wheatley. 2000). One study found that prenatal methyl-mercury exposure due to consumption of marine mammals and fish by the mother resulted in attention, language, and memory deficits in children. (Grandjean , et,al. 1997). Not only does presence of methyl-mercury present a danger to health, it also presents a danger to the livelihood of anyone who relies on healthy stocks of fish.

Lead is neurotoxic, which means it destroys brain and nerve cells. Children exposed to lead can suffer from abnormal and reduced physical and mental growth, and may also have lower intelligence. Lead can be passed from mother to child during pregnancy and breast feeding. Developing children are much more sensitive to lead exposure than adults. (Agency for Toxic Substances and Disease Registry(ATSDR). 2007).

There is evidence that lead can cause health problems at much lower levels than previously thought, and that no level of exposure to lead is safe for developing fetuses or children. (Canfield, 2003). Lead exposure has also been associated with attention deficit hyperactivity disorder and antisocial behavior.

(Bellinger, 2008)

Lead has been determined to be a probable human carcinogen by the Environmental Protection Agency.(US EPA.2007).There is also evidence that lead is an endocrine disrupting chemical, with the potential to alter hormone function.(Wide . 1980).(Dearth . 2002)(ACAT.Mining and Toxic Metals . A case study of the proposed Donlin Creek mine.2007)

CHAPTER THREE

3.0 MATERIAL AND METHOD

3.1 Study Area

The Study area is located at Tsohon-Gwari and its surrounding community where artisanal gold mining activity are taking place in Birnin-Gwari Local Government area of Kaduna State. The Local Government was created in September , 1978. The Local Government is situated in the western part of Kaduna State between latitude 12^{o} 20'N and longitude 90^{o} 0' E and According to National Population Commissiion Birnin-Gwari local has a population of 253,363 (NPC 2006).Birnin Gwari has 14 districs , namely Birnin Central Saminaka, Kuyello,Dogon Dawa, Tabanni, Kakagi, Randagi, Kazage, Kungi, Maganda, Saulawa,Gayin, Bugai and Kutemeshi. The main Ethnic group are Hausa ,Fulani,Gwari, and Kamuku .

3.2 Sample Collection

Soil samples were collected from the following locations within the mines and the surrounding communities which include; Farin-ruwa, Jan-ruwa, Kano Tsofon-Gwari ,Katsina Tsofon-Gwari , Abuja Tsofon-Gwari , Colonial ,Yankan Dutse and Jiniya located on the Kushaka north-east of Birnin-Gwari. In order to ensure representative, samples were taken from the area for the analysis; initial survey was carried out in the area to determine the sampling points. The selection of the sampling locations was based on the accessibility to the public and proximity to the mine. In addition, the geological map of the area was used to identify the locations where samples will be taken. Based on these criteria, 36 locations were identified for the soil and water samples analysis. Within the mines, soil and water samples

were collected at ore stockpiles, tailings dams, heap leach pads, wastes dumps and open pits. The sampling locations were marked using a Geographical Positioning System (GPS), Geo Explorer II. The sampling strategy that was adopted for the soil samples was random [ASTM, 1983, 1986; IAEA, 2004].

At each identified location samples were arbitrary collected within defined boundaries of the area of concern. The soil samples were taken using a coring tool to a depth of 5-10 cm. At each sampling location, samples of soil were taken from different sections of the area into labeled plastic bags. One kilogram (1 kg) of each sample was collected for analysis. The samples were transported to the laboratory for preparation and analysis with Sodium Iodide Thallium NaI(Tl) detector. The site from which the sample were collected are listed in table 3.1 below

Table.3.1 Soil Samples Coordinates

Sample (Soil)	Number	Northern	Eastern	Elevation
BGK	1	11° 10’ 27.3”	006° 59’ 04.3”	686m
BGK	2	11° 10’ 22.2”	006° 59’ 04.1”	676m
BGK	3	11° 10’ 26.8”	006° 59’ 09.6”	678m
BGK	4	11° 10’ 31.4”	006° 59’ 13.0”	684m
BGK	5	11° 00’ 43.3”	006° 48’ 48.0”	533m
BGJ	6	11° 00’ 41.0”	006° 48’ 15.3”	530m
BGJ	7	11° 00’ 37.5”	006° 48’ 16.7”	528m
BGJ	8	11° 00’ 34.2”	006° 48’ 09.5”	535m
BGJ	9	11° 00’ 33.1”	006° 48’ 04.4”	531m
BGJ	10	11° 00’ 33.0”	006° 48’ 04.6”	531m
BGJ	11	11° 00’ 37.9”	006° 48’ 23.8”	543m
BGJ	12	11° 00’ 41.1”	006° 48’ 23.3”	541m
BGJ	13	11° 00’ 44.4”	006° 48’ 23.8”	539m
BGJ	14	11° 00’ 47.0”	006° 48’ 22.7”	543m
BGJ	15	11° 00’ 15.2”	006° 48’ 15.0”	525m
BGJ	16	11° 01’ 14.6”	006° 48’ 20.4”	539m
BGJ	17	11° 01’ 15.8”	006° 48’ 20.2”	544m
BGJ	18	11° 01’ 15.5”	006° 48’ 23.5”	552m
BGJ	19	11° 01’ 15.1”	006° 48’ 22.0”	550m

BGJ	20	11° 01' 14.6"	006° 48' 13.3"	534m
BGJ	21	10° 01' 14.4"	006° 48' 07.0"	525m
BGJ	22	10° 01' 16.2"	006° 48' 09.5"	534m
BGJ	23	11° 01' 16.5"	006° 48' 08.9"	532m
BGJ	24	11 ° 00' 33.9"	006° 48' 25.3"	546m
BGJ	25	11° 00 33.0"	006° 48' 26.2"	549m
BGJ	26	10° 59' 23.8"	006° 48' 31.9"	558m
BGJ	27	10° 59' 23.1"	006° 48' 34.5"	560m
BGJ	28	10° 59' 26.4"	006° 48' 47.4"	533m
BGJ	29	10° 59' 17.2"	006° 48' 33.7"	561m
BGJ	30	10° 59' 18.3"	006° 48' 32.6"	560m
BGJ	31	10° 59' 19.3"	006° 48' 31.9"	554m
BGJ	32	10° 59' 20.8"	006° 48' 31.6"	554m
BGJ	33	10° 59' 22.2"	006° 48' 32.7"	557m
BGJ	34	10° 59' 22.5"	006° 48' 30.8"	560m
BGJK	35	10° 59' 23.6"	006° 48' 30.0"	555m
BGJK	36	10° 59' 22.3"	006° 48' 30.1"	565m

Key

1.Birning Gwari Kakini water
2.Birning Gwari Farin Ruwa water
3.Birning Gwari Tsofon Gwari water
4.Birning Gwari Jiniya water

3.3 Collection of Water samples

Samples which are representatives of the water bodies were collected at random from different location of Farin-ruwa, Jan-ruwa, Kano Tsofon- Gwari ,Katsina Tsofon-Gwari , Abuja Tsofon-Gwari , Colonial ,Yankan-Dutse and Jiniya located on the Kushaka north-east of Birnin-Gwari gold mining site and examined. These samples were collected at designated areas as shown in Table 3.2 Water samples were collected by lowering pre-cleaned plastic bottles into the bottom of the water body, 30cm deep, and allowed to overflow before withdrawing. Thirty six sampling points were used and the sampling points are approximately 100m away from each other. Two liters of each water sample was taken at each sampling point. A total of 36 samples were collected, Samples were collected in the year 2012. The sampling names were shown in Table 3.2 Northern, Eastern , Elevation ,Temperature and pH of the samples were measured while collecting the samples .The samples were transported to the laboratory for preparation and analysis with atomic absorption spectroscopy. (Mendham *et al* 2002).

Table 3.2 Water Samples Coordinates

SITE.ID (Water)	Northern	Eastern	Elevation	Temp	Ph
BGKW 1	11 10’ 27.3”	006 59’04.3”	686m	18	6.63
BGKW 2	11 10’ 31.5”	006 59’3.0”	684m	21	6.74
BGKW 3	11 00’ 54.9”	006 48’9.1”	531m	29	6.90
BGKW 4	11 00’ 52.6”	006 48’ 8.8”	531m	25	6.77
BGKW 5	11 00’ 47.9”	006 48’ 2.0”	528m	28	6.82
BGKW 6	11 00’ 43.6”	006 48’ 3.3”	529m	32	6.92
BGKW 7	11 00’ 41.2”	006 48’ 5.2”	528m	26	6.68
BGKW 8	11 00’ 37.5”	006 48’ 6.7”	527m	32	6.78
BGKW 9	11 00’ 37.1”	006 48’ 3.4”	529m	29	6.71
BGKW 10	11 00’ 37.1”	006 48’ 2.5”	531m	44	6.75
BGKW 11	11 00’ 32.6”	006 48’ 3.3”	529m	29	6.68
BGKW 12	11 00’ 32.8”	006 48’ 2.9”	527m	28	6.77
BGFW 13	11 04’ 04.0”	006 47’ 6.5”	593m	29	6.68
BGSGW14	11 01’ 06.8”	006 47’ 5.7”	527m	37	6.92
BGSGW15	11 01’ 08.8”	006 47’ 2.4”	522m	26	6.83
BGSGW16	11 01’ 05.7”	006 47’28.8”	521m	28	6.87
BGSGW17	11 01’ 06.5”	006 47’ 0.2”	522m	28	6.92
BGSGW18	11 01’ 06.4”	006 47’32.8”	526m	28	6.75
BGSGW19	11 01’ 00.5”	006 47’18.7”	543m	28	6.78

BGSGW20	11 00’ 56.7”	006 47’12.0”	545m	28	6.55
BGJW 21	10 58’ 46.1”	006 47’35.9”	582m	29	6.64
BGJW 22	10 59’ 46.4”	006 48’30.2”	546m	26	6.71
BGJW 23	11 01’ 15.1”	006 48’05.8”	526m	29	6.69
BGJW 24	11 01’ 16.8”	006 48’04.9”	530m	29	6.68
BGJW 25	11 01’ 14.1”	006 48’05.8”	521m	29	6.67
BGJW 26	11 01’ 13.1”	006 48’06.3”	526m	29	6.88
BGJW 27	11 01’ 12.0”	006 48’07.1”	532m	29	6.77
BGJW 28	11 00’ 02.5”	006 48’29.0”	531m	29	6.63
BGJW 29	10 59’ 27.4”	006 48’48.7”	534m	27	6.80
BGJW 30	10 59’ 26.0”	006 48’47.2”	533m	28	6.78
BGJW 31	10 59’ 25.6”	006 48’47.6”	533m	27	6.89
BGJW 32	10 59’ 18.0”	006 48’45.8”	553m	27	6.68
BGJW 33	10 59’ 16.8”	006 48’45.6”	523m	28	6.77
BGJW 34	10 59’ 17.4”	006 48’33.9”	556m	28	6.72
BGJW 35	10 59’ 18.4”	006 48’ 6.9”	558m	27	6.82
BGJW 36	10 59’ 17.4”	006 48’ 3.7”	554m	28	6.60

Key

1.Birning Gwari kakini water

2.Birning Gwari Farin ruwa water

3.Birning Gwari tsofon gwari water

4.Birning Gwari jiniya water

3.4 ANALYSIS OF SAMPLES FOR BACKGROUND ACTIVITY

The major nuclear technique employed in the analysis of sample for background activity is the Gamma spectrometry using NaI (Tl) detector

LABORATORY MEASUREMENTS

Soil Samples Preparation

The collected samples (i.e. soil) brought into the laboratory were left open (if wet) for a minimum of 24hrs to dry under ambient temperature. They were ground into a fine powder with the use of a table ceramic mortar and pistil and then a pulverizer. The process was followed by packaging into radon impermeable cylindrical plastic containers of height 7cm by 6cm in diameter. This satisfied the selected optimal sample container height i.e. the detector geometry. Each container would accommodate approximately 300g of sample.

A 3–stage sealing system was made for each of the packaging to prevent ^{222} Ra – from escape. This include, smearing of the inner rims of each container lid with Vaseline, filling the lid assembly gap with candle wax to block the gaps between lid and container and tight – sealing lid – container with a masking adhesive tape. The prepared sample were then stored for a period of about 30 days to allow for radon and its short – lived progenies to reach secular radioactive equilibrium prior to gamma spectroscopy measurements. (Girgisu et al 2012)

Sample Analysis

Gamma ray spectrometry technique was employed in the spectral collection of the prepared samples using the higher energy region of the γ – line as indicated below: Samples filled into the plastic container of uniform size geometry of the Thallium Activated Sodium Iodide Detector NaI (Tl) detector.

Table 3.3 Gamma ray spectrometry technique

ELEMENT ANALYZED	ISOTOPE USED	GAMMAENERGY(KeV)	ENERGY WINDOWS(KeV)
K	40_K	1460.0	1380 – 1510
Ra	214_{Bi}	1764.0	1690 – 1820
Th	208_{Tl}	2614.5	2590 – 2710

Table3.4. Samples measurement

S/N	Sample ID	Weight of Empty Container (g)	Weight of Sample + Container (g)	Weight of Sample (g)	Date Sealed
1	BGK1	25.00	300	275	19/12/12
2	BGK2	25.00	325	300	19/12/12
3	BGK3	25.00	300	275	19/12/12
4	BGK4	25.00	325	300`	19/12/12
5	BGK5	25.00	300	275	19/12/12
6	BGJ 6	25.00	300	275	19/12/12
7	BGJ 7	25.00	300	275	19/12/12
8	BGJ 8	25.00	325	300	19/12/12
9	BGJ 9	25.00	325	300	19/12/12
10	BGJ 10	25.00	300	275	19/12/12
11	BGJ 11	25.00	300	275	19/12/12
12	BGJ 12	25.00	300	275	19/12/12
13	BGJ 13	25.00	325	300	19/12/12
14	BGJ 14	25.00	300	275	19/12/12
15	BGJ 15	25.00	325	300	19/12/12
16	BGJ 16	25.00	325	300	19/12/12
17	BGJ 17	25.00	325	300	19/12/12
18	BGJ 18	25.00	275	250	19/12/12
19	BGJ 19	25.00	300	275	19/12/12
20	BGJ 20	25.00	325	300	19/12/12

21	BGJ 21	25.00	325	300	19/12/12
22	BGJ 22	25.00	300	275	19/12/12
23	BGJ 23	25.00	300	275	19/12/12
24	BGJ 24	25.00	275	250	19/12/12
25	BGJ 25	25.00	300	275	19/12/12
26	BGJ 26	25.00	300	275	19/12/12
27	BGJ 27	25.00	300	275	19/12/12
28	BGJ 28	25.00	325	300	19/12/12
29	BGJ 29	25.00	325	300	19/12/12
30	BGJ 30	25.00	325	300	19/12/12
31	BGJ 31	25.00	325	300	19/12/12
32	BGJ 32	25.00	225	200	19/12/12
33	BGJ 33	25.00	300	275	19/12/12
34	BGJ 34	25.00	325	300	21/12/12
35	BGJK 35	25.00	325	300	21/12/12
36	BGJK36	25.00	225	200	21/12/12

Key

1.Birning Gwari kakini

2.Birning Gwari Farin ruwa

3.Birning Gwari tsofon gwari

4.Birning Gwari jiniya

3.5 Energy Calibration of Sodium Iodide Thallium Gamma Spectroscopy System

Before the counting commenced the two gamma standard sources (^{137}Cs and $^{60}C_0$) were placed into a graded 16cm lead shield of NaI(Tl) detector chamber and closed to exclude laboratory background interference. The Acquire display was clicked on from the MAESTRO window. The limit was preset and the live time typed (i.e. 1024). The micro ace amplifier gains was set at (15,002) on the adjust control. The sample description/name was typed on the service display and counting commenced. The spectra acquired were saved at the end of the counting time of 100 seconds.

3.6 The Measurement System

This consists of a 7.62cm x 7.62cm NaI (Tl) detector housed in a 6cm thick lead shield and lined with cadmium and copper shields. The shield assisted in the reduction of the background radiation. The samples were mounted on the detector surface and each counted for 29,000 seconds in reproducible sample – detector geometry. The configuration and geometry was maintained through out the analysis. A computer based multichannel analyzer (MCA) Maestro program from Ortec was used for data acquisition and analysis of gamma spectra. The 1764keV γ- line of ^{214}Bi for ^{234}U was used in the assessment of the activity concentration of ^{226}Ra where 2614.5keV γ-line of ^{208} Tl was used for ^{232}Th. The single 1460keV r – line of ^{40}K was used in its content evaluation.

All the obtained raw data were then converted to conventional unit using calibration factors to determine the activity concentrations of ^{40}K, ^{226}Ra and ^{232}Th

Table 3.5 Energy calibration for quantitative spectra analysis

ISOTOPE	Calibration Factors			DETECTION Limit	
	$x10^{-3}$(cps/ppm)	x10^{-4}cps/Bq-kg^{-1}	Conversion factors Bq/kg(ppm)	Ppm	Bq/kg
^{40}k	0.026	6.431	0.032	454.54	14.54
^{214}Bi	10.500	8.632	12.200	.32	3.84
^{208}Tl	3.612	8.768	4.120	2.27	9.08

3.7 Water Samples Preparation

For preparation of heavy metals, acidification with 2M HNO_3 was done because this tends to keep the required species, of cations in solution, and slows down or stops biological changes. Typically addition of 1ml of concentrated HNO3, to 100ml sample was done.(Faanu et al 2011)

First take 100ml in to a beaker and put 10ml of HNO_3, Heat on a hot plate until it remains about 5ml then allow it to cool and add about 30ml of distilled water, Filter the solution and make it 60ml with distilled water.

3.8 METHODS OF ANALYSIS

Atomic absorption spectroscopy

Atomic absorption spectroscopy (AAS) determines the presence of metals in liquid samples. Metals determined include Fe, Cu, Pb, Cr, Zn,Hg,Ni, Mn . It also measures the concentrations of metals in the samples. Typical concentrations range in the low mg/L range.

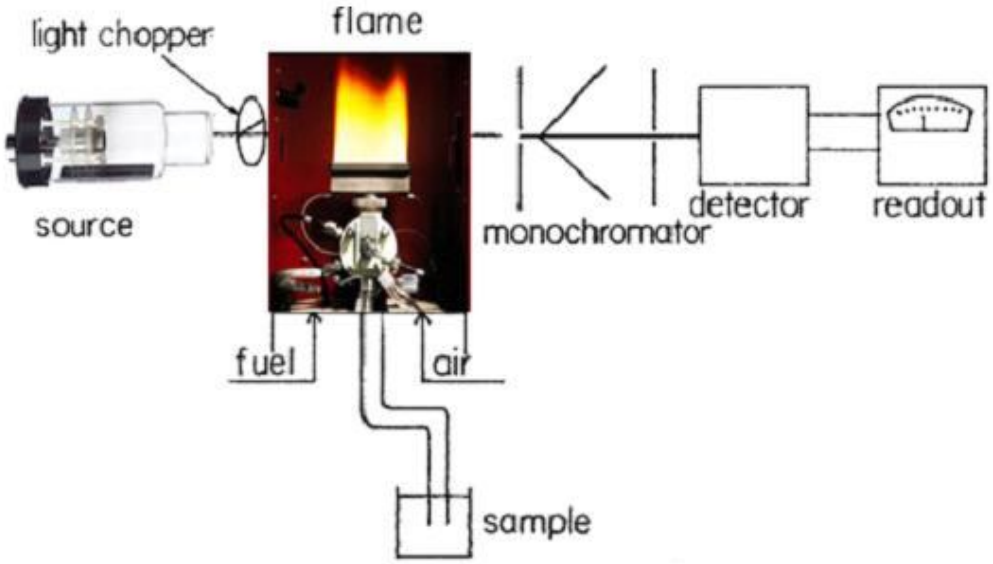


plate .3a **Atomic absorption spectrometer**

In their elemental form, metals will absorb ultraviolet light when they are excited by heat. Each metal has a characteristic wavelength that will be absorbed. The AAS instrument looks for a particular metal by focusing a beam of uv light at a specific wavelength through a flame and into a detector. The sample of interest is aspirated into the flame. If that metal is present in the sample, it will absorb some of the light, thus reducing its intensity. The instrument measures the change in intensity. A computer data system converts the change in intensity into an absorbance.

As concentration goes up, absorbance goes up. Calibration curve is constructed by running standards of various concentrations on the AAS and observing the absorbance's .The computer data system will draw the curve for you! Then samples can be tested and measured against this curve. (Welz, et al, 1999)

3.9 DATA ANALYSIS

Data obtained were subjected to statistical analysis and results were presented as mean ± SD.

CHAPTER FOUR

4.0 RESULTS

Table 4.1 Result of Analysis Using Atomic Absorption Spectrometer

		CONCENTRATION OF ELEMENTS(mg/l)							
S/No	SAMPLES ID	Hg	Cu	Ni	Mn	Cr	Zn	Pb	Fe
1	BGKW 1	BDL	12.1316	1.1050	8.5431	0.1084	9.5123	0.1118	72.1299
2	BGKW 2	BDL	3.5526	0.1050	0.2326	0.0181	BDL	1.1211	39.0714
3	BGKW 3	0.6006	BDL	0.1271	0.2118	BDL	5.7629	0.0062	3.4156
4	BGKW 4	0.2619	BDL	0.0110	4.3603	BDL	0.1063	0.0280	3.8312
5	BGKW 5	0.2519	1.9474	BDL	0.2482	0.0301	BDL	BDL	3.2857
6	BGKW 6	0.2992	0.3421	BDL	0.1765	BDL	1.1444	0.0093	3.5065
7	BGKW 7	0.0864	0.2368	0.0497	0.1225	0.0181	2.0490	0.0155	3.8052
8	BGKW 8	0.2924	0.0526	0.0884	0.2617	0.0181	BDL	0.0062	8.1364
9	BGKW 9	BDL	0.6579	0.1934	4.0582	0.0181	6.3134	0.0124	36.9610
10	BGKW10	0.3897	48.6316	0.1326	1.1049	BDL	0.9264	0.0280	15.1883
11	BGKW11	BDL	5.1315	0.5470	5.1225	0.0843	4.4060	0.0807	63.5974
12	BGKW12	0.1062	1.2895	0.1436	0.8764	0.0482	5.4850	0.0093	35.1948
13	BGFW13	0.4026	1.1053	0.0829	0.1402	0.0241	2.1090	0.0031	2.3182
14	BGSGW14	0.0418	0.4474	BDL	0.2762	0.0120	BDL	0.0093	4.1104
15	BGSGW15	BDL	BDL	0.0387	0.4133	BDL	2.0163	0.0031	5.5649
16	BGSGW16	0.2938	0.0789	0.2210	0.2939	BDL	0.7602	0.0248	3.5130
17	BGSGW17	0.2448	0.4474	0.1160	0.2866	0.0120	BDL	0.0342	2.9286
18	BGSGW18	0.1348	0.3684	BDL	0.3531	0.0181	1.5395	0.0151	4.1364
19	BGSGW19	0.1028	1.4474	BDL	0.1194	0.0181	BDL	0.0248	1.0065
20	BGSGW20	0.3091	8.8158	0.0884	0.0924	0.0181	4.3025	6.6025	1.0519

21	BGJW 21	0.0643	BDL	0.1160	0.1360	0.0181	2.7902	0.0093	0.8247
22	BGJW 22	0.2877	1.8684	0.0663	0.0862	BDL	2.8093	0.1615	0.8312
23	BGJW 23	0.2986	3.4737	BDL	0.0623	0.0060	1.2343	0.5497	2.0260
24	BGJW 24	0.2838	1.8421	0.0331	0.3167	BDL	1.3243	0.0807	14.2208
25	BGJW 25	0.3807	0.4211	0.0331	0.3167	BDL	1.34200	0.0124	12.5325
26	BGJW 26	0.5039	0.3158	0.1657	0.3489	0.0181	2.80210	0.0124	13.5519
27	BGJW 27	0.2818	1.6316	BDL	0.3842	BDL	0.9809	0.0217	16.9545
28	BGJW 28	0.1246	0.9211	0.0552	0.3385	BDL	BDL	0.0124	29.8506
29	BGJW 29	0.1557	1.1579	0.1547	0.1796	0.0060	5.4496	0.0870	1.2403
30	BGJW 30	0.4720	3.8158	0.0718	0.4756	0.0241	1.6458	0.0217	5.3182
31	BGJW 31	0.0414	1.3947	0.0442	0.0363	0.0061	BDL	0.0404	0.8312
32	BGJW 32	0.3719	1.0263	0.0773	0.3562	0.0301	BDL	0.0155	7.0195
33	BGJW 33	0.5544	2.6316	0.0884	0.3385	BDL	1.3869	BDL	6.3442
34	BGJW 34	0.2073	0.3158	BDL	0.9678	0.0120	BDL	0.0093	13.6948
35	BGJW 35	0.3670	BDL	0.0773	0.0415	0.0241	2.0191	0.0373	0.6948
36	BGJW 36	0.6234	6.2368	0.0166	0.0862	0.0301	BDL	BDL	1.1429

Key

1.Birning Gwari kakini water

2.Birning Gwari Farin ruwa water

3.Birning Gwari tsofon gwari water

4.Birning Gwari jiniya water

Table 4.2.Statistical Analysis for water samples

Metals	N	Minimum concentration	Maximum concentration	Mean concentration
Hg	**31**	**0.04**	**0.62**	**0.28**
Cu	**31**	**0.05**	**48.63**	**3.66**
Ni	**28**	**0.01**	**1.10**	**0.14**
Mn	**36**	**0.03**	**8.54**	**0.88**
Cr	**24**	**0.006**	**0.10**	**0.02**
Zn	**25**	**0.10**	**9.51**	**2.80**
Pb	**33**	**0.003**	**6.60**	**0.27**
Fe	**36**	**0.69**	**72.12**	**12.21**

Table4.3 Nigeria Standard for Drinking water Quality (NSDWQ)(2013)

S/No	Parameter	Unit	Maximum Level	Permitted
	Chemical			
1	Iron (Fe2+)	mg/L	0.3	
2	Manganese (Mn2+)	mg/L	0.2	
3	Chromium(Cr6+)	mg/L	0.05	
4	Copper (Cu)	mg/L	1	
5	Lead (Pb)	mg/L	0.01	
6	Mercury (Hg)	mg/L	0.001	
7	Nickel(Ni)	mg/L	0.02	
8	Zinc (Zn)	mg/L	3	

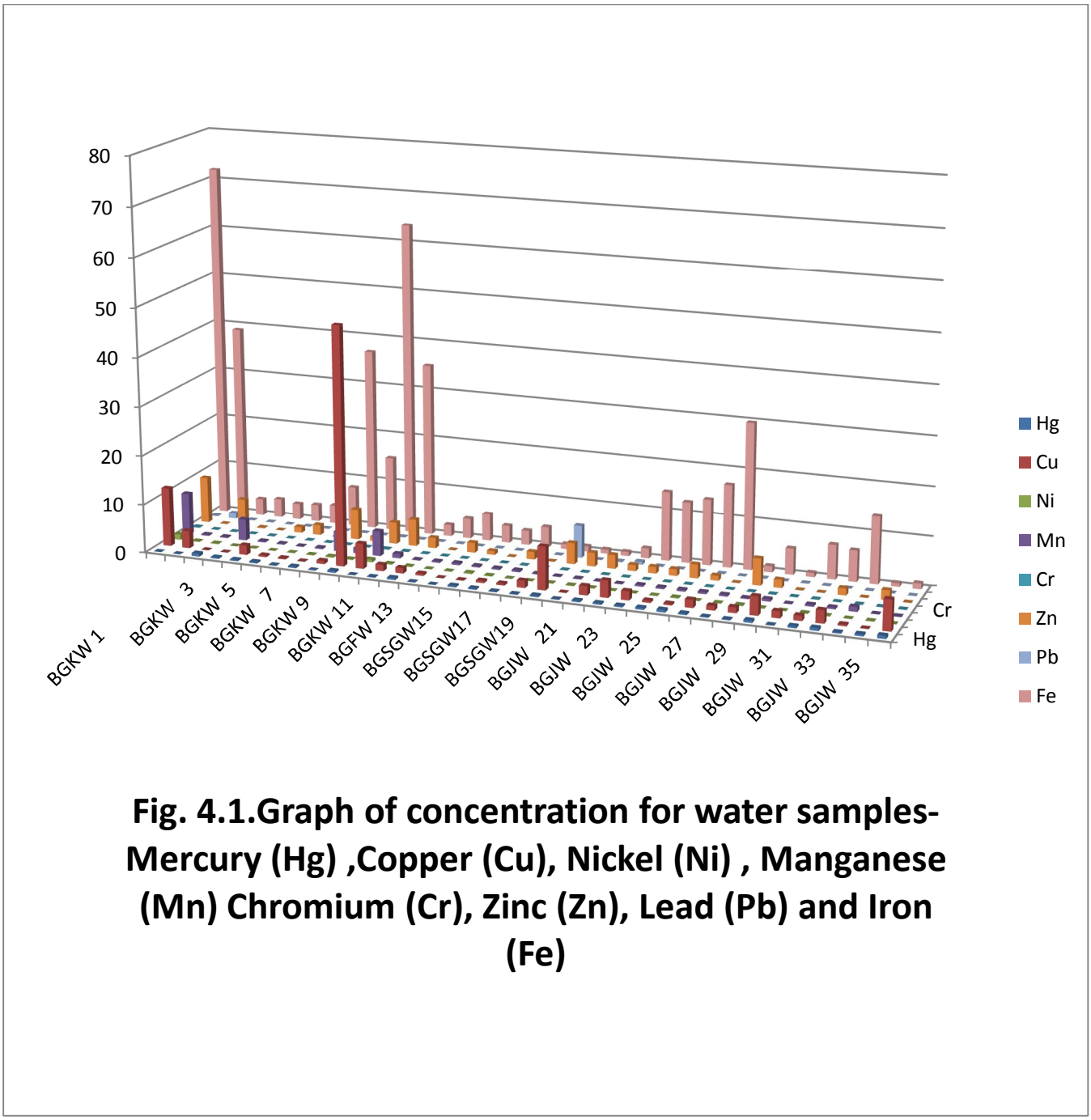


Fig. 4.1.Graph of concentration for water samples- Mercury (Hg) ,Copper (Cu), Nickel (Ni) , Manganese (Mn) Chromium (Cr), Zinc (Zn), Lead (Pb) and Iron (Fe)

Table 4.4 RESULT FOR ANALYSIS USING NaI(Tl) DETECTOR ACTIVITY CONCENTRATION OF K-40,Ra-226 and Th-232

Site Name	K-40 (Bq/kg)	Ra226 (Bq/kg)	Th-232 (Bq/kg)
1 BG	524.88 ± 12.44	5.67 ±0 .03	65.45 ± 1.14
2 BG	553.03 ± 1.08	3.78 ± 0.16	63.28 ± 1.59
3 BG	447.90 ± 6.84	1.36 ± 0.04	20.06 ± 1.25
4 BG	509.02 ± 1.04	3.32 ± 0.38	56.78 ± 0.79
5 BG	333.74 ± 9.33	2.45 ± 0.05	52.79 ± 0.45
6 BG	196.11 ± 2.02	1.74 ± 0.15	23.37 ± 0.34
7 BG	207.62 ±0 .77	1.72 ± 0.03	18.13 ± 3.19
8 BG	239.03 ± 3.11	1.59 ± 0.11	22.00 ± 0.34
9 BG	398.28 ± 10.10	0.40± 0.12	70.92 ± 0.57
10 BG	488.18 ± 8.08	0.15± 0.03	57.24 ± 1.14
11 BG	419.90 ± 9.33	0 .44±0.08	73.09 ± 1.59
12 BG	266.40 ± 9.33	2.34 ± 0.03	43.67 ± 1.36
13 BG	402.33 ± 9.95	1.55 ± 0.04	59.06 ± 1.25
14 BG	524.88 ± 12.44	5.67 ± 0.03	65.45 ± 1.14
15 BG	264.85 ± 10.88	1.40 ± 0.02	35.80 ± 1.14
16 BG	196.11 ± 6.22	0.77 ± 0.11	50.85 ± 3.42
17 BG	169.51 ± 10.88	1.04 ± 0.09	44.12 ± 0.68
18 BG	303.42 ± 9.33	1.69 ± 0.26	41.27 ± 1.82
19 BG	207.77 ± 4.66	2.66 ± 0.46	38.76 ± 1.14
20 BG	862.20 ± 13.99	4.28 ± 0.39	84.83 ± 14.82
21 BG	419.44 ± 7.77	1.46 ± 0.01	51.31 ± 2.28
22 BG	19.75 ± 6.22	1.15 ± 0.11	69.55 ± 1.14
23 BG	673.40 ± 7.77	3.87 ± 0.34	49.48 ± 1.36
24 BG	647.74 ± 11.04	3.15 ± 0.69	33.29 ± 2.28
25 BG	738.88 ± 18.81	3.22 ± 0.39	74.57 ± 3.64
26 BG	593.93 ± 9.33	2.02 ± 0.19	58.15 ± 1.14
27 BG	860.34 ± 15.39	2.63 ± 0.15	51.88 ± 4.50
28 BG	788.33 ± 13.68	2.89 ± 0.38	102.62 ±1.93
29 BG	538.72 ± 2.02	1.49 ± 0.46	30.78 ± 1.36
30 BG	797.97 ± 10.88	3.59 ± 0.39	90.30 ± 2.28
31 BG	601.39 ± 6.53	2.72 ± 0.18	29.98 ± 1.14
32 BG	218.04 ± 3.26	2.23 ± 0.32	32.26 ± 2.28
33 BG	533.59 ± 7.46	1.94 ± 0.42	63.85 ± 2.39
34 BG	738.88 ± 18.81	3.23 ± 0.40	75.71 ± 2.50
35 BG	593.93 ± 9.33	2.14 ± 0.20	49.48 ± 1.36
36 BG	447.90 ± 6.84	1.36 ± 0.04	20.06 ± 1.25

Table 4.5 Statistical Analysis for Soil Samples

	N	Minimum	Maximum	Mean	Std Deviation
K-40	36	19.75	862.20	464.65	216.87
Ra-226	36	0.15	5.67	2.31	1.31
Th-232	36	18.13	102.62	51.95	20.93

Table 4.6: Comparison of activity concentration of ^{238}U, ^{232}Th and ^{40}K in soils in the study area and published data (UNSCER, 2000, Muhammad et al., 2010, Faanu et al., 2010 and Darko et al., 2007).

Concentration in soil Bq/Kg						
	^{226}Ra		^{232}Th		^{40}K	
	Range	Mean	Range	Mean	Range	Mean
This work	0.15-5.67	2.31	18.13-102.62	51.95	19.75-862.20	464.65
Nigeria (Zaria)*	4-12	8	15-47	34	317-985	641
Ghana (1)+	8-26	15	9-67	27	60-249	157
Ghana (2)++		29		25		582
Ghana (3)++		35		21		682
Algeria	2-10	30	2-140	25	66-1150	370
Egypt	6-120	37	2-96	18	29-650	320
U.S.A	4-140	35	4-130	35	100-700	370
India	7-81	29	14-160	64	38-760	400
Malaysia	49-86	66	63-110	82	170-430	310
Lithaunia	3-30	20	9-46	25	350-850	600
UK	2-330		1-180		0-3200	
Hungary	12-66	29	12-45	28	79-570	370
Spain			2-210	33	25-1650	470
WorldAverage		33		45		420

Legend - UNSCER, 2000 Report,++ Darko et al., 2007, +, Faanu et al., 2010 and Muhammad et al., 2010

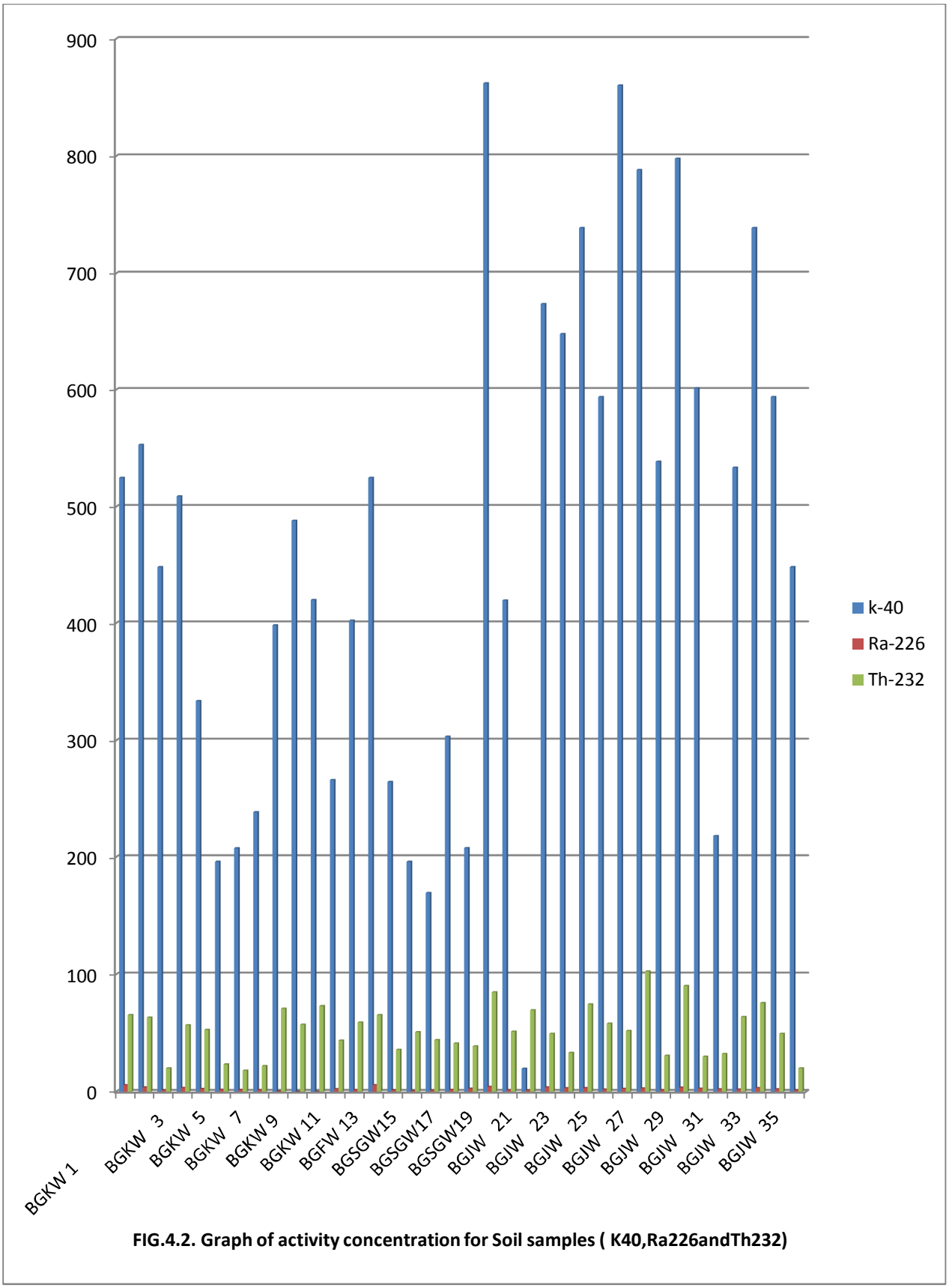


FIG.4.2. Graph of activity concentration for Soil samples (K40,Ra226andTh232)

5.0 CHAPTER FIVE

DISCUSSION

In this work, seventy-two (72) composite samples were randomly within selected areas of the mines. This included 36 soil samples and 36 water samples taken from the mines and the surrounding communities. The results obtained from the Atomic Absorption Spectrophotometer and NaI (TI) laboratory measurements are summarized in Tables 4.1 to 4.5. Figures 4.1 are the bar chart concentration of metals in water and Figure 4.2 is the bar chart for activity concentration of soil samples in gold mining site around Birnin-Gwari respectively.

In water samples Fe was found to have higher concentration which ranged between 0.69mg/l to 72.12mg/l with average of 12.21mg/l. Other metals have the following concentrations, Hg 0.04 mg/l to 0.62mg/l with average of 0.28mg/l,Cu 0.52mg/l to 48.63mg/l with average of 3.66 mg/l ,Ni 0.01 mg/l to 1.10 mg/l, with average of 1.46 mg/l, Mn 0.36mg/l to 8.54mg/l with average of 0.88 mg/l, Cr 0.006mg/l to 0.10mg/l with average of 0.02 mg/l, Zn 0.10mg/l to 9.51mg/l with average of 2.8 mg/l, Pb 0.003mg/l to 6.60mg/ with average of 0.27 mg/l.

Results from the thirty six field soil samples analyzed also indicated that the activity concentration due to ^{40}K with the highest values ranged from 19.75±6.2 to 862.20±13.9 Bq/kg with mean value of 464.65±37.13, thorium 18.13±3.19 to 102.62±1.9 Bq/kg with mean value of 51.95±1.99. And Radium 0.15±.03 to 5.67±.03 Bq/kg with means value of 2.31±.20. As shown in the Tables 4.5. Generally, there was higher activity concentration in both ^{40}K and ^{232}Th but lower in ^{226}Ra in the soil.

Atomic absorption spectrometric analysis of untreated water samples from Birnin-Gwari gold mine revealed varying detectable concentrations of the different heavy metals studied. This study showed that the concentrations of Mercury ,copper ,Nickel, Manganese , Lead and Iron metals were found to be above World Health Organization and Nigeria Standard for Drinking water Quality(NSDWQ) except Zinc and Chromium of the water sources which contained heavy metals in concentrations below the World Health Organization and Nigeria Standard for Drinking water Quality(NSDWQ) and Environmental Protection Agency specified mg/L. There is a need for adequate treatment of this water sources to appropriate quality before use as these concentrations could result in severe damage of body organs over varying periods of consumption times.

CHAPTER FIVE

6.0. CONCLUSION AND RECOMMENDATIONS

6.1. CONCLUSION

Water is of growing importance in a world where climate change impacts, including droughts, are increasingly noticeable and human population will likely reach 9 billion people by 2050. Freshwater resources are critical to human and ecosystem survival but are increasingly threatened by depletion and pollution. The ocean and its resources are also under unprecedented and unsustainable pressure from direct contamination such as oil spills, overharvest, and through climate change and acidification from greenhouse gas emissions.

If indeed the extent of "… problems related to mining waste may be rated as second only to global warming and stratospheric ozone depletion in terms of ecological risk" (EEB, 2000), then the Tsofon-Gwari gold mining area of Kaduna north west Nigeria is at serious risk.

The mining industry must share the collective responsibility to protect water and aquatic ecosystems, and the communities that rely on them, especially since mining produces such large quantities of toxic waste. Tailings have destructive impacts on natural water bodies and the ecosystems and people dependent on them. Companies and governments must adopt a precautionary approach to disposal of tailings and ensure that mining operations do not place tailings or other mine waste into natural bodies of surface water, including rivers, stream, lakes, wetlands, and intertidal, estuarine, and marine ecosystems.

In this study, data on the activity concentrations ^{40}K, ^{226}Ra and, ^{232}Th have been established. The activity concentrations ^{40}K, ^{226}Ra and, ^{232}Th which members of the public could be exposed were quantified using direct gamma spectroscopic analysis .The mean activity concentrations of ^{40}K in the soil samples were estimated to be

464.65±37.13, For ^{226}Ra the mean activity concentrations is2.31±.20 and The mean activity concentrations of ^{232}Th in samples were 51.95±1.99.Bq/Kg respectively. The results in this study compared well with other studies carried out in other countries and with the worldwide average which show that the activity concentrations for ^{232}Th and ^{40}K is high but for ^{226}Ra the activity concentration is below the world wide average and the result for concentration of heavy metal in water sample has also been established .

6.2.0 RECOMMENDATION

1. There is need for gross alpha gross beta analysis of water samples to be carried out around gold mining sites of Birnin-Gwari .

2. Internal exposure resulting from drinking water ingestion of food and inhalation of radon gas and dust containing U, Th, K should be undertaking

3 determination of ^{238U}, 232Th, ^{226}Ra, 210Po and^{210} pb in drinking water from the study area should be carried out.

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