RADIOLOGICAL ASSESSMENT OF WATER AND SEDIMENTS OF ZOBE DAM DUTSINMA IN KATSINA STATE FOR NATURAL RADIONUCLIDES

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BY

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Declaration

I declare that the work in this Thesis entitle "RADIOLOGICAL ASSESSMENT OF WATER AND SEDIMENTS OF ZOBE DAM DUTSINMA IN KATSINA STATE FOR NATURAL RADIONUCLIDES" has been carried out by me in the Department of Physics. The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this thesis was previously presented for another degree or diploma at this or any other Institution.

…….. **……...**

Najib Mannir, USMAN **Date**

M.Sc/Scien/01909/2010-2011

Certification

This thesis entitle "RADIOLOGICAL ASSESSMENT OF WATER AND SEDIMENTS OF ZOBE DAM DUTSINMA IN KATSINA STATE FOR NATURAL RADIONUCLIDES" by NAJIB MANNIR USMAN meets the regulations governing the award of the degree of Master of Science (Nuclear Physics) of the Ahmadu Bello University, Nigeria and is approved for its contribution to the knowledge and literary presentation.

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ABSTRACT

A radioactivity measurement was carried out in water and sediments of Zobe Dam. Samples of sediments from Zobe Dam were collected, prepared and analysed using NaI(Tl) gamma ray spectrometer for the activity concentrations of the primordial ^{226}Ra, ^{232}Th and ^{40}K. The results obtained show average activity concentrations of 49.67±3.07 (35.89-75.75), 127.29±4.42 (47.21-112.91) and 443.43±9.51 (338.88-638.40) in Bq/kg for ^{226}Ra, ^{232}Th and ^{40}K respectively. To assess the radiological hazard of Dam sediments, the radiological hazard indices such as absorbed dose rate, annual effective dose equivalent (AEDE), hazard indices (H_{ex} and H_{in}) were calculated and found to be comparable with the world average values. The mean absorbed dose rate obtained is124.52 nGy/ h, and is higher than the world average of 55 nGy/h. The measured average annual effective dose rate 0.152mSv/y, and is lower than the world average value of 1 mSv/y (ICRP, 1991). The measured average values of external and internal hazard index is 0.717 and 0.851 and are lower than unity set by ICRP,2000, which indicate that the sediments in all the sampling sites can be used for safety construction of buildings.

The gross alpha and beta radioactivity of water samples were measured using gas proportional counter. The result show that the gross alpha and beta radioactivity in water samples is higher than the maximum contaminant levels of 0.1 and 1.0Bq/L set by WHO. The ranges of the measured alpha and beta activity were found to be between 0.595±0.26 to 9.547±0.37Bq/L with mean of 6.18±0.30 Bq/L and 2.837±0.77 to12.119±0.46 Bq/L with mean of 8.332±0.44 Bq/L and this indicate that the water in all the sampling sites is not safe for livestock and domestic consumption if compared with WHO values.

CHAPTER ONE

INTRODUCTION

1.1 General Introduction

Naturally occurring radioactive materials (NORMs) contain insignificant amounts of radionuclides in the environment. Geological materials when disturbed or altered from natural settings, present technologically enhanced concentrations of NORMs above the background radiation levels due to human activities this may result in a relative increase in radiation exposures and risks to the public and the environment. Radioactivity in the environment is mainly due to the presence of long-lived radionuclides; of the ^{238}U, ^{235}U and ^{232}Th series and ^{40}K. Their distribution in the earth crust depends on the type of rock formation under the earth's crust (Mujahid and Hussain, 2010).

When rocks are disintegrated through natural processes, radionuclides are seep to the soil and are carried to the rivers by rain and flows (Taskin, *et al*., 2009). Soil radionuclide activity concentration is one of the main determinants of the natural background radiation. The knowledge of the distribution of these radionuclides in soil, water, sediment, rock and building materials plays an important role in the protection, measurement, geoscientific research and guidelines for the use and management of these materials (Ravisankar, *et al*, 2011).

Radioactivity present in surface continental waters is mainly due to the presence of radioactive elements in the earth crust. Human activities (mining, milling and processing of uranium ores and mineral sands, manufacture of fertilizers, burning of fossils fuels, metal refining, farming, etc.) have raised natural radioactivity concentrations in the environment. These Radioactive materials can reach surface continental waters by different pathways from each of the processes or activities. Rivers and Dam water can be contaminated by surface runoff of rainwater

transporting leached radionuclides from cities, mine waste, soil weathering, agricultural areas (Pujol and Sanchez, 2000). In the long term, radioactivity in a water body can remain at significant levels as a result of secondary contamination processes. Due to gravitational settling and other depositional phenomena, the highest proportion of the radioactive materials is mainly found in the sediment compartment of the aquatic ecosystem (Olatunde, *et al*, 2011). Thus river sediment is considered as a durable and reliable register of the river pollution by radionuclides (Bikit et al, 2005). Knowledge of natural radioactivity present in aquatic sediments enables one to assess any possible radiological hazard to mankind, by the uses of such materials especially in building and construction material (Ramasamy, *et al*, 2011).

1.2 The Study Area

1.2.1 Area of Study and Location

The Zobe Dam is located between latitude 12^0 20' 34.62□ □ N to 12^0 23□ 27.48□ □ N and between longitude 7^0 27□ 57.12□ □ E to $7^0$34□ 47.68□ □ E, in Dutsinma Local Government Area of Katsina State.

The reservoir formed by the Dam cover 4500 hectares of rocky land and during the rainy season stores 177 million cubic metres of water which is released downstream for irrigation and town water supplies.

The Zobe Dam has only two tributaries; these include river Karaduwa and river Gada in which river Gada drains to river Karaduwa.

The Dam is constructed in river Karaduwa and the Dam over Karaduwa is about 2.7 kilometres long and flowing north westward to the Sokoto Basin. Along the river course, there are no large cities, no mining cites, no nuclear enterprises such as chemical and phosphate industries. Farmers' lives in the area generally rear animals, raise crops and some vegetables. Therefore,

agrochemical such as fertilizers and pesticides, herbicides are the main contaminant of the Dam reservoir. Fishing is another major activity in the area.

1.2.2 Geology

In general, the bedrock geology of Katsina State can be subdivided into two main formations; the basement complex throughout the south and central areas, and the sedimentary formations in the north (Ktstgov., 2001).

The study area is covered by the basement complex or crystalline basement. This unit is comprised mainly of granitic rock, but includes migmatte, gneiss and schists of sedimentary origin. These rocks have been fractured in places and are cut by quartz and aplite veins and pegmatite dikes. They have also been extensively decomposed in some area. The depth of this decomposed zone varies considerably over short distance and is often greats where there are fractures, veins and dike features (Ktstgov., 2001).

1.2.3 Climate

The area is hot and dry, characteristic of the Sudan Savannah climate (Ileoje, 1981). The temperature in this area is high throughout the hottest months when the noon temperature frequently exceeds 37^0C and it is low when the dry dust laden winds (Hammatan) blow south from the desert. The rainfall is light, variable and erratic with a single maximum throughout; it begins and ends with heavy showers and thunderstorm that are associated with unstable condition. The highest amount of rainfall is recorded in the month of August. The mean annual rainfall here is low and is below 700mm. It occurs usually in 3 – 4 months of the year and the other 7 – 8 months being dry (Ileoje, 1981).

Humidity depends on the season. It is low during the hottest months when the relative humidity is not more than 20% and is high in the raining season when it can reach up to 60% (Ileoje, 1981).

Generally, the climate in the area varies with month and season and is as a result of these climatic controls and the temporal variation in rainfall and temperature conditions that Max lock Group (1978), identified four different climatic regimes in the area.

(a) **A Cool and Dry Season** otherwise known locally as "*RANI*" begins from December and ends in February. This is characterized by cool and dry weather condition with occasional dusty hammatan haze (*Hazo*) and a predominantly northerly wind.

(b) **A Hot and Dry Season** known locally as "*BAZARA*" begins in March to end in May. This is a transitional period between the hammatam and wet season. It is also the hottest period of the year when mid-day temperatures can reach up to 40^0C. Dust devil is also a characteristic of this season.

(c) **Warm Wet Season** known locally as "*DAMINA*" begins from June and ends in late September. This is the proper wet season in the area when the whole rain fall is recorded. Line squall occurs in this season.

(d) **A Less Marked Season** after the rain characterized by decreasing rainfall and gradual lowering of temperature known locally as "*KAKA*". This begins in September and ends early November with the onset of hammatan.

1.2.4 Vegetation

Dutsinma and environs have northern Sudan savannah type of vegetation. This vegetation consists of grasses with a variety of scattered trees on the plains. The grasses are shorter and feathery and are hardly taller than one metre in the wet season during maturity, in the dry season they wither and dry off.

1.3 Research Problem

Determination of radionuclides in drinking water, biota, and the general environment has become increasingly important during the past few years. This may particularly be due to most communities acknowledging the fact that elevated levels of radionuclides in drinking water and environment can be harmful to humans, especially babies and children (Rabi'u, 2013).

Zobe Dam has only two tributaries; these include river Karaduwa and river Gada in which river Gada drains to river Karaduwa. The Dam is greatly used for irrigation, fishing, household activities and source of drinking water for livestock.

Uses of agrochemicals, fertilizers are some of the human activities that are very common in the area. These may contribute to the inducement of radionuclide contaminations in the Dam reservoir.

High concentration of radioactive substance in the Dam reservoir may endanger the health of human, animals and plants and also may affects the suitability of crops and water for human consumption (Thornton, 1983).

Therefore there is need to probe the radiological hazard of the biosphere (biota, soil and drinking water sources) of the people living in this important area. Gross alpha and beta activity survey or gamma spectroscopy is the first step for natural radionuclide probe. It will provide information

on the environment for assay of the radiological safety of the area. Gamma spectroscopy which is the mostly used analytical method in natural environmental studies of radionuclide was employed to determine the quality and quantity of the natural radionuclide activity of the sediment samples collected at the Dam and gross alpha and beta activity is used to ascertain the presence of radionuclides in the Dam reservoir. This is to ensure that the reference dose level (RDL) of committed effective dose of $0.1mSv$ annually is not exceeded from consumption of water for drinking.

1.4 Aims and Objectives

The aim of this study is to measure the radiological concentrations and activity levels of water and sediments of Zobe Dam and ascertain the radiological side-effect on the populace and the environment.

Objectives of the study are:

- To determine the concentration of the radionuclides ^{238}U, ^{232}Th and ^{40}K in the sediment samples.
- To evaluate the gross alpha and beta radioactivity in water of the Dam reservoir.
- To estimate the radiation dose due to the activities in the samples so as to assess the radiological impact on the populace.
- To identify possible elevated area**s.**

1.5 Justification

Radionuclides in water can have serious effect on biological system through the emission of radiation at various energies which will have molecular interaction with the cellular composition of the organism, (Stephen, *et al.*, 2004). Alpha and beta radiations are high Linear Energy transfer (LET) radiations. Alpha-radiation, for instance was recognized to be the most hazardous type of radiation when incorporated in the human body. The determination of their concentration and dose level will therefore help the health workers in tracing the history of the recent prevailing health cases of renal failure and kidney diseases (Waziri, *et al*., 2009). This will consequently be in better position to respond to them appropriately and go a long way in reducing the loss of lives as a result of environmental contamination related diseases hence bursting the socio- economic activities in that geographical location.

Since there is no data in terms of radioactivity measurement in the area, the result of this investigation will be used by Katsina State government and other stakeholders in putting good environmental protection strategic planning as well as protection of human health. This can be achieved by educating the settlers and farmers in that area of environmental and most importantly radiological and toxicological risk involved by their activities. Useful information will also be provided in protecting the public against diseases especially those which could be as a result of ingestion of food contaminated with radioactive substances from agrochemicals and other wastes. My work will also establish a base line data in term of radioactivity measurement in the area.

1.6 The scope of the research

The scope of this research is limited to Dutsinma Zone metropolis in Katsina State. The survey of alpha and beta concentration in water ideally should involve proportional counter, alpha spectrometry and liquid scintillation methods. However, because of the non- availability of the certain equipments in the Centre for Energy Research and Training Zaria the researcher limited the methods to proportional counter only.

The Measurements of ^{238}U, ^{232}Th and ^{40}K in the sediment samples carried out using a γ-ray spectrometry system, comprising NaI(Tl) detector coupled with PC based multi-channel analyzer, the measurement carried out in Centre for Energy Research and Training Zaria.

CHAPTER TWO

LITRERATUE REVIEW

2.1 Water pollution

Water pollution means the contamination of water by discharge of noxious substances. As defined by the International Oceanographic Commission (IOC) for the United Nation Educational and Scientific Commission (UNESCO), water pollution is the introduction by man, directly or indirectly, of substances into the water body resulting, in such deleterious effects as harm to living resources, hazards and to human health, or hindrance to marine activities and reduction of amenities (Williams, 1926). This supposes that man is a major contributor of water pollution, even though there are natural sources of water pollution. Sources of water pollution can therefore be classified as: Natural sources and man-made sources.

Natural sources of water pollution can arise either from rocks or NORMS. Igneous rock formed by the solidification of melts, are the major component of the earth's crust. These rocks are mainly silicic and basaltic types in the ratio of 2:1 (Johnston, 1976). The major component minerals of these rocks determine fairly predictably the trace elements that solidified out of them. For instance magnesium rich rocks yield chromium ores together with nickel. Basaltic rocks yield copper and zinc granite rocks yield potassium, beryllium and lead. The weathering of these rocks produces sedimentary rock and unconsolidated sediments (Johnston, 1976). Rivers, streams and lakes encounter these sedimentary and igneous rocks and consequently the water is contaminated by the trace elements present in the rocks.

The naturally occurring radioactive materials (NORMS) in the earth's crust comprise of Uranium, Thorium, Radium, with their radon-gas progeny and potassium-40. These materials seep into the ground water, introducing radioactivity into the water body.

Some of the major water pollutants introduced by man's activities include chemicals, radionuclide from radioactive wastes, acids and bases among others. Chemical pollutants are introduced into the water through two different pathways, first by direct drain of rain run off into the water. Secondly is by accumulation of these chemicals as industrial impurities in the atmosphere in which they are dispersed with air masses and are deposited on water surfaces through atmospheric precipitation. Of these chemicals is the petroleum, hydrocarbon, which accounts for 50 to 90 millions tonnes per year of manmade hydrocarbons in the forms of atmospheric currents (Patin, 1982).

Fertilizers constitute a serious pollutant as they are washed by flood or rain into various rivers and streams. Most fertilizers contain phosphate, potassium and nitrate products. These substances are nutrients to the plants, but some of them constitute serious health risk especially to infants, due to interference of the chemical with the blood oxygen transport (Ruesel, 1966). Some of these substances in the fertilizer are radioactive and constitute radiological hazards to man when they contaminate water sources.

Furthermore, radionuclides from radioactive waste find their ways into water bodies. Radioactive wastes are generated from radioactive ore, mines, nuclear reactor operations, hospitals and industries where radioactive sources are used. When these radioactive wastes are disposed, especially through ground repository and water disposal the containment can give way after sometime. The radionuclides from the radioactive waste can seep into water body and consequently contaminating water supplies leading to man's exposure to ionizing radiation (Winn, 1995).

2.2 Natural Radiation in the Environment

Radiation comes from outer space, from the ground and even from within our own bodies. Radiation is all around us and has been present since the birth of this planet. This kind of radiation is called Background Radiation.

Background radiation (which scientists call "ubiquitous background radiation") is emitted from both natural and human-made radioactive chemicals (*radionuclides*). Some naturally occurring radionuclides are found in the earth beneath our feet, while others are produced in the atmosphere by radiation from space. Human-made radionuclides have entered the environment from activities such as medical procedures that use radionuclides to image the body and electricity generation that uses radioactive uranium as fuel (NCRPM, 2009).

Humans are continuously irradiated by sources outside and inside their bodies. Outside sources include *space radiation* and *terrestrial radiation*. Inside sources include the radionuclides that enter our bodies in the food and water people ingest and the air they breathe. Whatever its origin, radiation is everywhere (or "ubiquitous") in the environment (Duval, *et al.*, 2009).

2.2.1 Radiation from the Space

Radiation that enters the Earth's atmosphere from space can come from as close as the Earth's radiation belts and the sun or as far away as beyond the boundaries of the solar system and even beyond the Milky Way galaxy. Radiation from beyond the solar system has enough energy to generate additional radiation as it passes through Earth's atmosphere, creating either radionuclides in the air or secondary particles. Some secondary particles reach the Earth's surface most readily near the magnetic poles where the Earth's magnetic field is weakest and at high altitudes where the Earth's atmosphere is thinnest. Radionuclides created by space radiation

are called *cosmogenic* radionuclides. They include tritium (hydrogen-3), beryllium-7, carbon-14, and sodium-22 (Grasty and Lamarre, 2004).

2.2.2 Terrestrial Radiation

Radiation that originates on Earth is called terrestrial radiation. *Primordial* radionuclides (radioactive chemicals that were present when the Earth formed about 4.5 billion years ago) are found around the globe in igneous and sedimentary rock. From rocks, these radionuclides migrate into soil, water, and even air. Human activities such as uranium mining have also redistributed these radionuclides. Primordial radionuclides include the series of radionuclides produced when uranium and thorium decay, as well as potassium-40 and rubidium-87.

In the past, one human activity that contributed to terrestrial radiation was production of nuclear weapons. Today, atmospheric weapons testing are not a significant contributor to background radiation because fallout has decayed since weapons' testing was stopped (in the United States, testing ended in 1963). The reactor accident at Chernobyl in 1986 is also not a significant source of background radiation in the United States (Duval, *et al.*, 2009).

2.2.3 Radionuclide in the Body

Terrestrial and cosmogenic radionuclides enter the body through the food we eat, water we drink, and air we breathe. As with all chemicals, radionuclides are used and eliminated by the body during normal metabolism. Some radionuclides decay away quickly but are replaced through fresh ingestion or inhalation. Other radionuclides decay more slowly and may concentrate in specific body tissues (such as radium in bone); others are not readily absorbed by the gut and are quickly eliminated (Duval, *et al.*, 2009).

The most important radionuclides that enter the body are terrestrial in origin. Primary among them are the radon gases (and their decay products) that a person constantly inhales. Radon levels depend on uranium and thorium content of the soil, which varies widely across the United States. The highest levels are found in the Appalachians, the upper Midwest, and the Rocky Mountain states (Grasty and Lamarre, 2004).

Other radionuclides in the body include uranium and thorium and their decay products, as well as potassium-40. These terrestrial radionuclides are in the soil where food grows and eventually find their way into the water supply.

Most drinking-water sources have very low levels of terrestrial radionuclides, including radium-226, radium-228, and uranium. These radionuclides may be higher in some areas of the United States than in others for example, radium levels are higher in some Midwestern states, while uranium levels are higher in some Western states. Typically these levels are less than the limits set by the United States Environmental Protection Agency (NCRPM, 2009).

2.3 Radioactive Decay Law

The instability of a nucleus describes a statistical phenomenon hence; the associated transformation process is probabilistic (random in nature). The random behaviour of a particular radioactive sample is expressed in the radioactive decay law which state that if N represents the number of atoms radionuclides in a given sample at a time, then the change in the number of nuclides dN during a time interval dt is proportional to N thus;

$$\frac{dN}{dt} = -\lambda N \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2.1)$$

where λ is called the decay or transformation constant. The negative sign show that N decreases as time, t increases.

$$\frac{dN}{N} = -\lambda dt \quad \ldots\ldots\ldots\

2.3.2 Activity

The activity of a radionuclide is the number of atoms of the radionuclide that decays per unit time. It describes the rate of transformation of a radionuclide. The activity of radionuclides increases as in the sample increases; and decreases exponentially with time. It is given by

$$A_t = A_0 e^{-\lambda t} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2.6)$$

where A_0 is the activity at time t=0 and A_t is the activity at time,t.

2.3.4 Specific Activity

Although, the activity is used as a measure of the quantity of radionuclide present, it does not consider mass or volume of the radioactive material. The relationship between the activity and the mass of the radioactive material is called the specific activity; which is the activity per unit mass of the radioactive material (Cember, 1996). Specific activity is the measure of activity concentration of radioactive material; expressed as.

$$A_{sp} = \frac{A_{ct}}{A} = \frac{\lambda N_A}{A} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2.7)$$

where N_A is the Avogadros' number and A is the atomic mass of the radionuclide.

2.4 Sources Radionuclide in Water

A radionuclide is an atom with an unstable nucleus which, to become more stable, emits energy in the form of rays or high speed particles.

Most of the radionuclides present in drinking water are from natural sources. Naturally occurring radionuclides are created in the upper atmosphere and are found in the Earth's crust. They are

found in certain types of rocks and soils that contain trace amounts of the radioactive isotopes (forms) of uranium, thorium and/or actinium.

As these rocks weather, the resulting clays and other materials may transmit radionuclides into drinking water. Higher levels of radionuclides tend to be found more often in groundwater, such as from wells, than in surface water, such as lakes and streams (Bruse, *et al.,* 2008).

Geological formation of an area determines, to some extent the radionuclide in water. Application of phosphates fertilizers in the soil, and industrial wastes disposal also introduce radioactivity in water.

Some physical and chemical parameters such as volume, depth, chemical composition, and its state (flowing or stagnant) of the water influence the radionuclide of the surface water. In the case of stagnant water like lakes the depth is very important. Radioactivity concentration in the lakes is usually higher than the activity in the flowing rivers or seas, because a significant quantity of the radioactive substance brought by the rivers into the lakes accumulates there (Sajo-Bohus, *et al*., 1997).

Over time, radionuclides decay. As they decay, they produce daughter products that are shorter lived, and "more radioactive." Of particular concern are naturally occurring uranium and radium, which can accumulate to harmful levels in drinking water.

As radionuclides decay, they emit radioactive particle such as alpha particles, beta particles and gamma rays (Bruse, *et al.,* 2008).This energy is transmitted through space or another medium in waves or particles and is capable of either directly or indirectly removing electrons from atoms, thereby creating ions, which are electrically, charged atoms. Each type of particle produces different effects on humans.

2.5 Health Effects from Radiation Exposure

Radioactivity refers to the particles that are emitted from nuclei as a result of nuclear instability. The most common types of radiation are alpha, beta, and gamma radiation. Alpha particles consist of two protons and two neutrons bound together into a particle identical to a helium nucleus; these particles are emitted by radioactive nuclei such as uranium or radium by a process known as alpha decay. Beta particles are high-energy, high-speed electrons or positrons emitted by certain types of radioactive nuclei, such as ^{40}K; the production of beta particles is called beta decay. Alpha emitters and beta emitters differ in the magnitude of their biological effects (Baweja, *et al.,* 1987). Alpha particles interact very strongly with human tissues through a transfer of energy. Beta particles interact less strongly than alpha particles, which allow them to travel farther through tissue before their energy is transferred. The difference between alpha and beta particle effects is the concentration of tissue damage. Alpha particles may damage many molecules over a short distance, whereas beta particles may damage molecules spread out over a greater distance. The extent of damage depends upon the energy emitted by individual alpha or beta particle species (Baweja, *et al.,* 1987). Gamma radiation is a form of electromagnetic radiation or light emissions at a specific frequency resulting from subatomic particle interactions such as radioactive decay. Gamma radiation is generally considered as light having the highest frequency and energy as well as the shortest wavelength within the light spectrum. As a result of its high energy content, gamma radiation is able to cause serious damage when absorbed by living cells (Health Canada, 2004).

When ionizing radiation passes through matter, neutral atoms and molecules acquire an electric charge as a result of interactions in which small amounts of energy are transferred to the atoms

of the material. If the material is body tissue, this can result in alterations of sensitive biological structures (Lubin, 1994).

Radiation causes damage to human tissue or any other material through the ionization of atoms. Ionizing radiation absorbed by human tissue has enough energy to remove electrons from the atoms that make up molecules of the tissue. In very simple terms, when an electron shared by atoms forming a molecular bond is dislodged, the bond is broken, and the molecule falls apart. This process may occur by a direct "hit" to these atoms, or it may result indirectly by free radical formation due to irradiation of adjacent molecules. The most sensitive structure in the cell is the DNA molecule, which carries the genetic blueprint for the cell and, indeed, for the whole organism. If radiation damage to the DNA is not repaired, the cells may fail to survive or reproduce. If insufficient cells survive, then loss of tissue or organ function may occur. Alternatively, the damage may be incompletely or improperly repaired so that the cells continue to divide, but become transformed or cancerous (UNCEAR, 2000).

There are basically two broad classes of radiation effects on the human body. The first class involves *deterministic* effects, which do not occur until the dose reaches a certain threshold level. Above this level, the effect will definitely occur, and the severity of harm will increase with dose. *Deterministic* effects include nausea, vomiting, diarrhea, hair loss, haemorrhage, immune function loss, nervous system damage, and death. The threshold for these effects in humans is about 500mSv delivered over a short period of time (hours to days). Fortunately, such doses are extremely rare and do not arise from environmental exposures, such as ingestion of radionuclides in drinking water (US EPA, 1999). The second class of effects is termed *stochastic* effects, which means that the likelihood of occurrence increases with the amount of radiation received. These effects may occur at doses well below the threshold for *deterministic* effects. The main

stochastic effects in humans are cancer in the exposed individual and possible genetic effects in the offspring. The types of cancer most frequently associated with radiation exposure are leukaemia and solid tumours of the lung, breast, thyroid, bone, digestive organs, and skin. The latency period between exposure and recognition of a cancer can range from 5 years to several decades (ICRP, 1991). No conclusive evidence exists for hereditary radiation effects in humans, although experimental studies on plants and animals suggest that such effects occur.

Radiation-induced cancers are indistinguishable from those that occur from other causes. The correlation between radiation and cancer induction can be shown only in large populations of irradiated individuals as an increase of cancers over the background incidence (NICRP, 1987). The main sources of epidemiological information on radiation risks and effects have come from studies of individuals or groups who have had relatively high exposures, such as:

- atomic bomb survivors at Hiroshima and Nagasaki;
- patients who received high radiation doses for diagnostic or therapeutic purposes; and
- Occupationally exposed workers, including uranium miners and radium dial painters.

Since it is impossible to establish with any certainty the shape of the dose-response relationship for *stochastic* effects, particularly at low doses and low dose rates, it is usually assumed that the frequency of their occurrence is linear with dose and without threshold (linear no-threshold hypothesis). The absence of a threshold implies that there is no dose, however small, that may be considered absolutely safe (WHO, 2008). This assumption is simple, and there is considerable evidence that it is conservative (i.e., it is more likely to overestimate than to underestimate the risk). In 1996, ICRP published a revised set of dose coefficients for individuals. This revision is based on more recent measurements and more accurate metabolic models for the uptake and

retention of radionuclides by the various organs of the body. The revised dose coefficients used to derive the MACs in this technical document assume the linear no-threshold hypothesis.

The ICRP (1991) has determined the lifetime probability of fatal cancer induction following a single low-dose, low dose rate exposure to be 5% per sievert. If allowance is made for hereditary risks and for non-fatal cancers weighted for severity, then the lifetime risk rises to 7.3% per sievert. The CNSC has set a dose limit of 1mSv/year for members of the public (for artificial sources excluding natural background radiation and medical treatments). The linear no-threshold hypothesis implies that exposure to 1mSv/year of radiation would give a lifetime excess cancer risk of 7.3×10^{-5} per year of exposure. Radionuclides in drinking water are assessed based on a reference dose level that is one-tenth of this dose limit. Even if the linear no-threshold hypothesis is valid, any health effects produced at this low level of exposure would be lost in the statistical background of spontaneous occurrences.

2.6 Health Effects from Natural Radionuclide in Drinking water

Radiation protection is based on the assumption that any exposure to radiation involves some level of risk. For prolonged exposures, as is the case for ingestion of drinking water containing radionuclides over extended periods of time, evidence of an increased cancer risk in humans is available at doses above 100mSv (Brenner, *et al*., 2003). Below this dose, an increased risk has not been identified through epidemiological studies.

The international commission on radiological protection (ICRP) estimates that the blood stream from gastrointestinal tract absorbs an average of 5 per unit of ingested uranium. Radioactivity in drinking water was estimated for gastrointestinal absorption to be 1.4% (wrem, *et al*., 1985). In

preliminary results from experiments that used fasting human subjects a value of between 0.5% to 1% was suggested (Crawford-Brown, 1990). In view of these results both 1.4% and 5% estimates are reasonable average level to use in risk calculations (Milla, 1990).

The national Academy of sciences (NAS, 2000) has concluded that a long-term exposure to elevated levels of radium in drinking water does indeed pose a "higher risk of bone cancer for the people exposed". EPA, (2000) estimates that long-term consumption of water containing 5pCi/l radium will cause 44 added cancer deaths for every million people exposed. The risk doubles to 88 per million at 10pCi/l, triples to 132 at 15pCi/l, etc.

The radioactive radon, which has largest single contribution to background radioactivity, has been attributed to the incidence of lung cancer. This was thought so at about 1924, following the increased incidence of lung cancer death among the miners in Schoenberg and Joachimsthal region in the Carpathian Mountains as at the sixteenth century (Cember, 1996). It was discovered that the mine, though worked for mainly cobalt, was very rich in uranium and radium. As a consequence of high radium content of the soil, radon gas the radioactive daughter of radium, is produced and diffuses out of the ground into the air around the mine, of the order of 3.7 x 105Bq/m^3 (Cember,1996). This concentration is high if compared to 1000Bq/m^3 recommended by WHO. Stomach cancer is also attributed to ingestion of radon daughters (Crawford-Brown, 1990).

Adverse health effects due to potassium consumption from drinking-water are unlikely to occur in healthy individuals. Potassium intoxication by ingestion is rare, because potassium is rapidly excreted in the absence of pre-existing kidney damage and because large single doses usually induce vomiting (WHO, 2009).

2.7 Maximum Acceptable Values (MAV) of Radioactivity in Water

The risk associated with the presence of radionuclides in water is an increase in cancer rate. This prompt for the need to set limit for radiological determinants, so that, the exposure resulting from the presence of radionuclides in water represents only a small part of radiation exposure from natural sources. The maximum permissible contaminant level of radioactivity in water as set by the National Interim regulation of the USEPA, (Milvy and Cothern, 1990) is as follows

Gross alpha	550Bq/m^3
Radium-226 and Radium-228	185Bq/m^3
Gross Beta	1850Bq/m^3

From the above limit an activity concentration that exceeds gross alpha and beta maximum need to be further investigated to establish the overburden on the environment.

The maximum regulatory equivalent dose from man-made radionuclides was set at 0.04mSv. It is believed that no interim maximum contamination level standard for uranium in drinking water exists (Milvy and Cothern, 1990). Many experts have suggested that maximum contamination level be set in the range of 0.74 x 10^{-3}Bq/m^3 to 3.7 x 10^{-3}Bq/m^3, based on the chemotoxic and radiological risk of uranium.

2.8 Detection of Radioactivity in Samples

2.8.1 Gamma Spectrometric Measurement

Gamma rays are high energy electromagnetic radiations emitted in the process of de-excitation of the atomic nucleus. Gamma rays from spontaneous nucleus decay are emitted with a rate and energy (colour) spectrum that is unique to the nuclear species that is decaying. The uniqueness provides the basis for most gamma ray assay techniques; by counting the number of gamma rays emitted with a specific energy it is possible to determine the types and number of the nuclei that emitted that radiation.

It was discovered early in the history of radiation measurements that certain materials would give off a flash of light when exposed to radiation. It was also recognized early on that some materials were more sensitive to different forms of radiation. As technology improved these scintillation materials were coupled to photomultiplier tubes to measure the flashes of light (Ehmann, 1991). Inorganic scintillation detectors based on alkali halides were used in most of the early gamma spectrometry systems. The most common scintillation crystals used in these systems were sodium iodide doped with thallium and were referred to as NaI(Tl) detectors (Tsoulfanidis, 1983).

When crystal scintillators used as a gamma ray detector, the scintillator does not directly detect the gamma rays. Instead the gamma rays produce charged particles in the scintillator crystals that interact with the crystal and emit photons. These photons (of lower energy) are subsequently collected by the photomultiplier tubes (PMTs).

In gamma spectrometry, the characteristic photon energy is measured and used to quantify the different radionuclides in the sample. The count rate in distinct energy windows (3 or 4 windows) for the gamma of a particular radionuclide is recorded (Habu, 2013).

2.8.2 Characteristics of a Gamma Spectrum

There are three ways a gamma photon can interact with matter and each type of interaction must be understood to properly interpret gamma spectral data with either a NaI(Tl) or HPGe detector. The three modes of interaction are photoelectric absorption, Compton scattering, and pair production. The probability or cross-section for each of these interactions is a function of the energy for the incident gamma photon (Knoll, 1989). For gamma spectrometry the photoelectric absorption is the preferred mode of interaction since it results in a full-energy photo peak in the spectrum that is used to quantify and identify the radionuclide. If the photon interacts with the detector material by Compton scattering there is a loss of energy by the incident photon that is transferred to a recoil electron. Since this energy loss is a function of the scatter angle, and all angles are possible, this scattering interaction results in the Compton continuum that is observed in the gamma spectrum as an increase in the spectral background (Evans, 1958). The third mode of interaction is pair production which can only occur with incident gamma photons that have energy greater than 1022keV. The process of pair production absorbs all the incident gamma photon energy and results in the creation of an electron-positron pair within the active volume of the detector. Then as the positron loses energy it will combine with an electron which results in the annihilation of the charged particles and the release of two annihilation photons that have an energy of 511keV each. Depending upon the detector size it is possible for either one or both of the 511keV annihilation photons to escape from the active volume of the detector. If both of the

annihilation photons escape the active detector volume a "double escape peak" would be observed in the gamma spectrum that would be located 1022keV below the full-energy peak. It is also possible to have a "single escape peak" located 511keV below the full energy peak if only one of the annihilation photons escape the detector volume (Knoll, 1989).

To ensure a low background detectors used for gamma spectrometry are typically surrounded with at least lead shielding. Also, the crystals used in both NaI(Tl) and HPGe detectors are encased in an aluminum shell. These various materials around the detector can interact with the radiation from a sample source and cause additional background structure in the gamma spectrum. The same interactions that occur within the detector are also experienced with these materials surrounding the detector; however, these interactions external to the detector have a different impact on the spectral background. For example, Compton scattering within the lead shielding will result in a broad backscatter peak that is located in the lower energy region (< ~250keV) of the spectrum. The location of the peak maximum (E_{BS}) for this backscatter peak, which is observed at a backscatter angle of π, can be estimated from the following equation:

$$E_{BS} = \frac{E_{\gamma}}{1+(2E_{\gamma}/511KeV)}$$

where, E_{γ} is the energy in keV for the incident gamma photon (Friedlander *et al.*, 1981).

For gamma photons with energy greater than 1022keV, the photon interaction with the lead

shielding can result in pair production. The annihilation of the positron produced during this pair production process can result in a 511keV gamma that escapes from the lead shielding and ends up being superimposed on the gamma spectrum (Horrocks, 1974). Another source of pair production within the lead shielding is cosmic radiation. The sample source counted for the

gamma spectrum can also contribute to the 511keV gamma peak if there are any positron emitters present in the sample. This source of 511keV gamma-rays results for the absorption of the positron, and subsequent annihilation, by the aluminum casing surrounding the detector crystal (Tsoulfanidis, 1983).

The photoelectric absorption of radiation by the lead shielding and other material surrounding the detector can result in characteristic x-rays in the lower energy region of the gamma spectrum. For example, the lead Kα and Kβ x-rays are almost always present as part of the background in a gamma spectrum. There are commercially available gamma detector shields that are lined with cadmium and copper to reduce the level of lead x-rays in the background. In addition to the lead x-rays, characteristic x-ray from any material located near the source and detector can end up in the background spectrum (Evans, 1958).

Environmental and other low level samples may require very long counting times to satisfy the low detection limits needed for regulatory applications and other special projects. The background spectra associated with these long counting periods will show additional structure from the natural background radiation surrounding the gamma spectrometer system (Ehmann, 1991). Naturally radioactive trace elements present as impurities (i.e., uranium decay daughters, ^{40}K, etc.) in the shielding material may contribute to the background and can become significant with long counting periods. One final source of background radiation that must be considered with long counting periods are prompt γ-rays from the thermal neutron capture of cosmic ray neutrons within the detector and shielding materials. An excellent indicator for this type of background problem is cadmium which is frequently present in graded shields (Cd-Cu lined lead) for gamma spectrometry systems. One of the naturally occurring isotopes of cadmium (^{113}Cd) has an extremely high cross section (~20,000 barns) for thermal neutron capture and will

yield a 558keV prompt γ-ray. There can also be prompt γ-rays from the lead and even the germanium crystal, but well below the level experienced with cadmium. In general, any background structure due to prompt γ-rays should be significantly lower than the 511keV annihilation peak and the 1460keV from ^{40}K (Horrocks, 1974).

2.8.3 Gross Alpha and Beta Measurement

The growing need to quantitate alpha emitting radionuclides in the environment and in nuclear fuel processing and disposal has resulted in dramatic increases in gross alpha/gross beta measurements. In fact, gross alpha/gross beta counting has become the most widely used method of monitoring for the presence of radioactivity. Much of the interest is due to the need to address safety, regulatory compliance, and disposal issues for both alpha and beta radionuclides. The potential for litigation has also heightened interest in screening samples for gross alpha/gross beta activities (Jim Floeckher, 2008).

Traditionally, gas flow proportional counting has been used for making gross alpha/gross beta measurements. In these devices, a sample is inserted into the chamber of a proportional counter. Any emitted radiation causes ionization of the gas in the counter that is electronically amplified and counted.

a) Thin-windows Proportional counter

This counter can detect alpha and low energy beta radioactivity. The counter is of very thin shielding, of plastic film less than 250mgcm$^{-2,}$ and tube of about 5cm in diameter, and/or anti coincidence guard circuitry. It is about one-half as sensitive as internal proportional counter due to poor geometry; and absorbing losses (Jarettee, 1946). The counter is less affected by

contamination from loose residues, and poor electrical conductance, because the sample is outside (Jarette, 1946), unlike the internal proportional counter.

b) Internal proportional Counter

Internal proportional counters are suitable for determining alpha activity, at the alpha operating plateau and alpha plus beta activity at the beta-operating plateau. The alpha or beta activity, or both, can emanate from a single or several radionuclides. The internal proportional counter accepts counting pans within the counting chambers and at the beta operating voltage records all alpha, all beta and some gamma radiations emitted into the gas (Arnold, *et al.*, 1992). Theoretically half of the radiation is emitted in the direction of the counting pan. Some of the beta radiation, but only 1% to 2% of the alpha radiation, is backscattered into the counting gas by sample solids, the counting pans or walls of the counting chamber. The percentage of beta radiation detected may be around 60% while that of the alpha is 50% for substantially weightless sample (Arnold, *et al.*, 1992).

2.8.4 Problems with Counting Instruments

The different counting instruments have different modes of operation and each has problems associated with it. A typical problem of most counters is the background or instrument counting rate, usually due to cosmic radiation contaminations in instrument parts and the counting room construction materials, and due to nearness of radioactivity source (Onoja, 2004).

2.9 Review of Previous Work

Some works had been done in the field of radioactivity in water in different parts of the world including Nigeria in the past. Nwankwo, *et al.*, (2005), studied external background ionizing

radiation in the Asa Dam Industrial Layout of Ilorin in Kwara State. The study has revealed that the external background ionizing radiation is averagely 0.0134mR/hr with a deviation of about 22% which is relatively higher than the standard background radiation of 0.011mR/hr. This result suggests the possibility of the presence of radionuclide sources in the environment.

Agalga, *et al.,* (2013), measure the concentrations of natural radionuclide ^{238}U, ^{232}Th and ^{40}K in the sediments of the Tono irrigation dam, Navrongo, Ghana, using gamma spectrometry. From the study, the concentrations of natural radionuclides ^{238}U, ^{232}Th and ^{40}K ranged from 5.19Bq/kg to 8.66 Bq/kg with an average of 7.31Bq/L for ^{238}U, 5.83Bq/kg to 8.16Bq/kg with an average of 6.91Bq/kg for ^{232}Th. and 218.73Bq/kg to 453.25Bq/kg with an average of 379.94Bq/kg for ^{40}K.

Ozturk, *et al.,* (2009), determined the **heavy metals in fish, water and sediments of Asar Dam Lake in Turkey.** The obtained results showed that the average values of Fe in water samples were higher than the respective reference values for fresh water. The analysis of heavy metals in sediments indicated that among the six heavy metals tested; Fe was maximally accumulated, followed by Ni, Cu, Cr, Pb and Cd. In the fish samples, cadmium, chromium, nickel and lead concentrations exceeded the tolerable values provided by international institutions.

Khatun, *et al.,* (2013), Studied the assessment of natural radioactivity and radiation hazard in soil samples of rajbari district of bangladesh**,** the experiment has been done by using gamma ray spectrometry system consisting of a HPGe detector coupled with MCA and associate electronics. The results are also compared with the literature values reported for other regions of the world and found that the soil of the study area are not hazards by the radiation and does not pose any harmful effect to the environment. Radioactivity measurements in river sediments and Aquatic organisms of Kanyakumari District were carried out by Eugin, *et.al.* (2012), using alpha scintillation counter and low beta counter. The results obtained revealed no significant radiological threat to the environment.

Mohsen, *et al.,* (2008) carried out the assessment of natural radioactivity in water and sediments from Amang (Tin Tailing) processing ponds using Gamma Spectroscopy to determine the concentrations of Uranium- 238 and thorium- 232 concentrations in the environment of Amang processing. The results showed that the concentration of these radionuclides were higher than the background indicating that Amang processing activity has enhanced the natural radionuclides contents in water and sediments.

Nwogu (2001) determined the concentration of trace elements in commercial water supplies. Analysis of fadama water, soil and vegetation for heavy metals was carried out by Odogu (2001). All these studies did not give the actual concentration of alpha and beta radiations in water. Onoja (2004) determined the gross alpha and gross beta radioactivity in well water in Zaria. This work though gave the concentrations of alpha and beta radiations in the sampled water but was limited to well water.

Kucukomeroglu, *et al.,* (2010) determined the natural gross alpha and gross beta activities in Firtina river in eastern black sea region of Turkey. The result obtained showed that natural gross alpha and gross beta activity concentrations in water samples ranged from 12.43.4mBq/l to 66.29.2mBq/l and from 27.9mBq/l to 133.34.1mBq/l, respectively. The mean activity concentrations were 32.63.8mBq/l for gross alpha and 69.94.4mBq/l for gross beta for which the activity concentration did not exceed the recommended levels by WHO and ITS. Cothern and Lappenbush (1990) measured uranium in ground and surface water in the USA and reported that many of the community drinking water supplies exceeded a uranium concentration of 370 and 185Bq L^{-1} limits by USAEPA and WHO respectively

Avwiri, *et al*. (2007) surveyed the radionuclide concentration of soil, sediments and water in Aba River, Nigeria and reported that the results obtained for the observed radionuclide isotopes were

below international standard and concluded that the river has no radiological burden on the populace.

Juliet (2006) also measured the gross alpha and beta radioactivity in River Kaduna and reported a mean value of 0.117±0.002 and 0.439±0.006BqL^{-1} for alpha and beta activity, respectively. The overall results in the two separate research work show that both alpha and beta activities are below the WHO practical screening level of radioactivity in drinking water.

Arkian, *et al.,* (2006) measured the gross alpha and beta radioactivity in the surface air of Tehran Nuclear Research Centre in Iran. The gross alpha and beta activity concentration was found to range from 71.04-121.20 and 174.91-305.46 respectively.

Dogru, *et al.,* (2008) measured the gross alpha and beta radioactivity in the ground water of Van in Turkey. The gross alpha and beta activity concentration was found to range from 630-782 and 21-816Bqm^{-3} respectively.

Tajudeen (2006) measured the gross alpha and beta activity concentration in well water from Gwammaja in Kano State of Nigeria. The results indicated very low and beta activity concentrations with a range of 2.06-11.48Bqm^{-3} for alpha and 2.00-17.75 for beta.

Avwiri and Agbalagba (2007) carried out survey of gross alpha and beta activity in Okpare-Creek Delta state Nigeria. The results show that the average alpha activities in the farming, residential/commercial and industrial zones are 1.0030.097, 4.2610.109 and 10.2960.489Bq/L respectively. The average beta activities in the three zones are 0.1290.100, 0.5230.003 and 0.7930.0110Bq/L, respectively. The overall result showed that the alpha and beta activities in the three zones are far below the practical screening level for both alpha and beta.

Natural radionuclides level have also studied in surface soils in Ijen-Ekiti (Ajayi, *et al.,* 1995), in soil and water around cement company in Ewekoro by Jibiri, et al., (1991) and in rocks in Ekiti by Ajayi, *et al.,* (1991) in all these studies a non- significant level of radioactivity was observed.

El-Daly and Hussaini (2008), studied the concentration of naturally occurring radionuclides ^{238}U, ^{232}Th and ^{40}K in soil and sediment samples from North Western desert of Egypt using gamma spectroscopy. The measurement results indicate that the region has background radioactivity levels within natural limits.

A Research was carried out by Ramasamy, *et al.,* (2009) to determine the distribution of radionuclides ^{238}U, ^{232}Th and ^{40}K in beach sediment samples along north east coast of Tamilnadu, India using a NaI(TI) gamma ray spectrometric technique. The mean activity concentrations of measured radionuclides were compared with other literature values.

CHAPTER THREE

MATERIALS AND METHOD

3.1 Materials

a) **Sampling materials:** 15 plastic container (2 litre) each, Disposable hypodermic syringe (20ml), dilute nitric acid, hand held GPS, Thermometer, indelible pen, masking tape, and Polyethylene bags for sediment samples.

b) **TDS experiment materials:** cellulose membrane filtration (0.4μm pore size), Filtration apparatus, Mechanical suction pump, Analytical balance (0.1mg), Measuring cylinder, beakers and evaporating dish.

c) **Sample preparation materials:** Hot plate for evaporation, vinyl Acetate, ethanol for even spread of the sample in the planchet, sources for alpha and beta standards, deionized water, planchet, candle wax, Vaseline, pulverizer, mortar and pestle.

d) **Analytical Techniques**

Gamma ray spectrometry system

Alpha/beta detecting system

3.2 Sampling sites

Samples of water and sediment were collected from Zobe Dam, Dutsinma Local Government Area, Katsina State, Nigeria. The sample locations areas are shown in Figure 1.

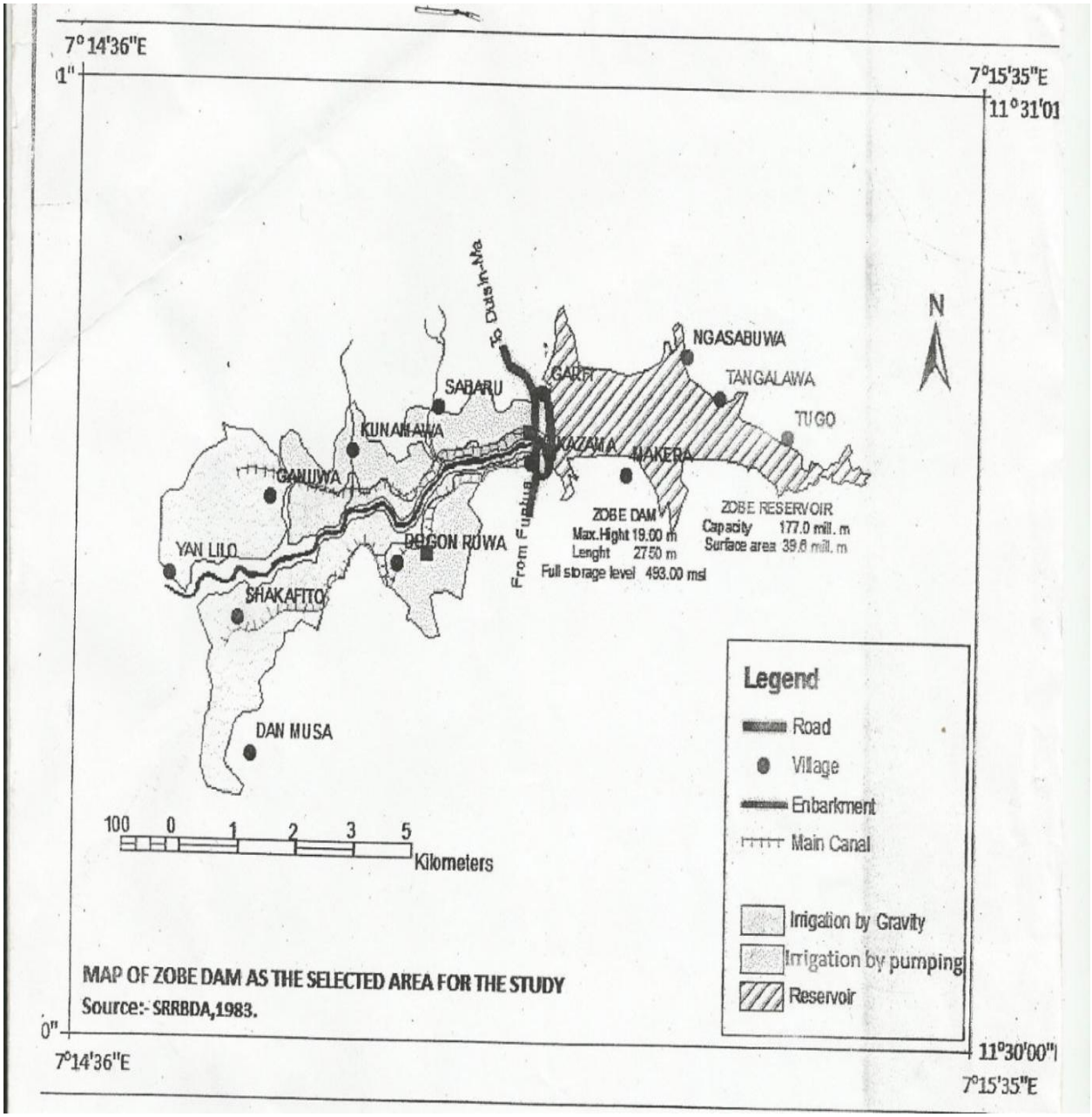

Figure 3.1: map of Zobe Dam (ksstgov., 2001)

3.3 Sample Collection Procedures

Water and sediments were collected from Garhi A, Garhi B, Makera and Tabobi. These are the areas where farming, domestic/live stocks activities and fishing are very high. In the control area the activities mentioned are very less. The sample collection method was achieved as described below.

3.3.1 Water Sample Collection

Fifteen (15) water samples were collected. Four (4) samples each were collected in an area where farming, domestic/livestock activities and fishing is very high and three (3) from the control area where farming, domestic/livestock activities and fishing is very less. The stratified random sampling (Willians, 1977) was used in each of the four region. The point of collection of each sample were given a unique code and noted with its GPS coordinate taken with a handheld GPS device. Samples were collected in 2 liter plastic bottles with tight covers. The sampling bottles were carefully washed in the laboratory and rinsed three times with the sample water to be sure that sample collected are representative of the bulk. The water was collected near the bank of the Dam where there is less dilution of the washout from the surrounding environment. The samples at the time of collection were acidified with about 20ml of nitric acid per litre to reduce the pH to 2. This is to minimize precipitation of the radionuclide present in the sample water and also to prevent the absorption of radioactivity by the walls of the sample container. The sample container was tightly covered with a space of about 1% of the volume left for expansion of water and date. The samples were kept in the Laboratory until they were analyzed.

3.3.2 Sediment Samples Collection

Bottom sediments were collected from the 15 different locations from the areas mentioned above in period of low water levels during the dry season so that undisturbed sediments could be taken (Kabir, *et al.*, 2008). The sediment were put into different polyethylene bags and labeled transported to the laboratory. The point of collection of each sample were given a unique code and noted with its GPS coordinate taken with a handheld GPS device.

3.4 Sample preparation

3.4.1 Determination of Total Dissolved Solids (TDS) for Water Sample.

In the Laboratory certain volume (100ml) V_A of each of the samples was filtered in the filtration unit with suction pump using cellulose membrane filter of 47mm in diameter with effective pore size of 0.45µm. The filtrate was transferred to porcelain evaporating dish of mass M_B in grams and evaporated to dryness in a hot plate. The mass of the evaporating dish and dried residue M_C was obtained. The difference between the former and later weighing gave the mass of the residue M_C - M_B (g). The total dissolved solid (TDS) for each of the samples was calculated in mg/l using the formula (ISO 9697 1992)

$$\text{TDS} = \frac{M_C - M_B}{V_A} \text{ x } 10^6 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3.1)$$

The value of the TDS for each sample was used to calculate the volume of sample V_P which when evaporated will give a mass of residue corresponding to 0.1A mg where A is the area of planchet, which from equation 3.1 we have

$$V_P = \frac{0.1A}{TDS} \text{ x } 10^6 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3.2)$$

3.4.1.1 Water Sample Preparation for Gross Alpha and Beta

The preparation of the samples for the gross alpha and beta counting was done in the following way: the calculated volume V_P of each of the samples was measured into a beaker about 50ml volumes and evaporated on a hot plate at a temperature of about 50.0^0C to 60.0^0C, down to 20ml the volume were transferred to a clean dry evaporating dish for continues evaporation till required residues were obtained. Few drops of vinyl Acetate were added to the sample during evaporation to act as a binder to prevent the precipitation of the source of the radionuclides in the sample. The residue was transferred onto a clean, dry and previously weighed planchet. The planchet and residue was weighed and the difference between the mass of empty planchet and that of planchet and residue gives the mass of the residue M_T. The residue was uniformly spread on the planchet by dropping a few drops of ethanol. The residue was allowed to dry and then covered with mylar film ready for gross counting.

3.4.2 Sediment Samples Preparation for a Gamma Ray Spectroscopy

The collected samples were kept opened to dry at an ambient temperature in the laboratory in a clean environment in order to avoid contaminations. The dried samples were grounded into a fine powder with the use of a table ceramic mortar and pestle 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 (Ibeanu, 1999) 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 Ra-222 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-seal lid container with

a masking adhesive tape. The prepared samples were then stored for period of 30 days to allow radon and its short-lived progenies to reach secular radioactive equilibrium prior to gamma spectroscopy measurements.

3.5 Analytical Techniques

3.5.1 Gross Alpha and Beta

3.5.1.1 Detector Characterization

For the detector to be put into use certain measurement were made. These include the background measurement and plateau test.

3.5.1.2 Background Counting

In compliance with the ISO 9696 standard, clean empty planchet were counted to determine the background radioactivity of the environment. The operational high voltages 1600V for alpha and 1700V for beta and 1750V alpha and beta simultaneous was set and the detector was allowed to run for 900s per cycle for alpha background and twenty-five cycles of 1800s per cycle for beta.

The background count rates were determined in counts per minute.

3.5.1.3 Plateau test

This test is design to verify the suitable voltages to be used for the different counting modes and also to determine the efficiencies and detection limits of the detector channel. The test was performed with manufacturers' standard sources using 239Pu and 90Sr standards respectively for alpha and beta modes. For each mode, the voltage varied from the minimum to a maximum specified voltage at intervals of 50V. The channel efficiencies were obtained for the three modes of counting thus, the alpha only (1,100V), beta only (1,550V) and alpha and beta simultaneous (1,650V) mode.

3.5.1.4 Counting

The counting equipment is automated. The procedure involves entering the present time, number of cycles and the counting (operational) voltage. Also the counter characteristics (channel efficiency and background count rate), volume of the sample used and sample efficiency were entered. The sample efficiency was calculated as:

$$Sample\ efficiency = \frac{M_T}{0.1A} \text{ x } 100\% \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3.3)$$

where M_T is the mass of the residue in the planchet got from sample preparation and 0.1A (mg) is the expected mass of the residue in the planchet.

3.5.1.5 Gross Alpha Counting

In the gross alpha counting, the operational high voltage was set at 1600V and the samples were counted for 3 cycles of 3600s per cycle. The displayed results were presented as raw count: count rate (count/min.), activity and standard deviation. The data were acquired for alpha mode only and the alpha count rate as well as the alpha activity was calculated using the formula; (ISO 9696: 1991).

$$Rate\ \alpha\ (count/sec.) = \frac{Raw\ \alpha\ count \text{ x } 60}{Count\ time\ (sec)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3.4)$$

$$Activity\ \alpha = \frac{Raw\ \alpha \text{ x } Bgd\ \alpha \text{ x } \alpha\ unit\ coefficient}{Channel\ \alpha\ efficiency \text{ x } Sampl\ efficiency \text{ x } Sample\ vol.} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3.5)$$

where unit coefficient is the multiplication coefficient making it possible to obtain the result expressed in units used for the operation (Pci/l, efficiency in %).

3.5.1.6 Gross Beta Counting

The operational high voltage for gross beta counting was set at 1700V and samples were also counted for 3 cycles of 3600s in beta mode only. The count rate and activity were calculated using the formula; (ISO 9696: 1991),

$$Rate\ \beta\ (count/sec) = \frac{Raw\ \beta\ count \times 60}{Count\ time\ (sec)} \quad \ldots\ldots\ldots\

In this particular work, differential spectrometry is employed in three channels and this was achieved by using a computer based Multichannel Analyser (MCA) MAESTRO Programme from ORTEC for data acquisition and analysis of gamma spectra. The 1764 keV Gamma-line of ^{214}Bi for ^{238}U was used in the assessment of the activity concentration of ^{226}Ra, while 2614.5 keV Gamma-line of ^{208}Tl was used for ^{232}Th. The single 1460 keV Gamma-line of ^{40}K was used in its content evaluation.

All the obtained raw data were converted to conventional units using calibration factors to determine the activity concentrations of ^{40}K, ^{226}Ra and ^{232}Th respectively. In order to determine the specific activity concentrations in the samples, the IAEA mixed standard consisting of ^{40}K, ^{226}Ra and ^{232}Th of the same dimension as the samples were subjected to the same experimental procedures. After the subtraction of background counts, conversion of the count per second to activity concentration in Bq/kg was performed using the conversion factors which are different for each nuclide such that for ^{40}K, ^{226}Ra and ^{232}Th as 6.431, 8.632 and 8.768, respectively.

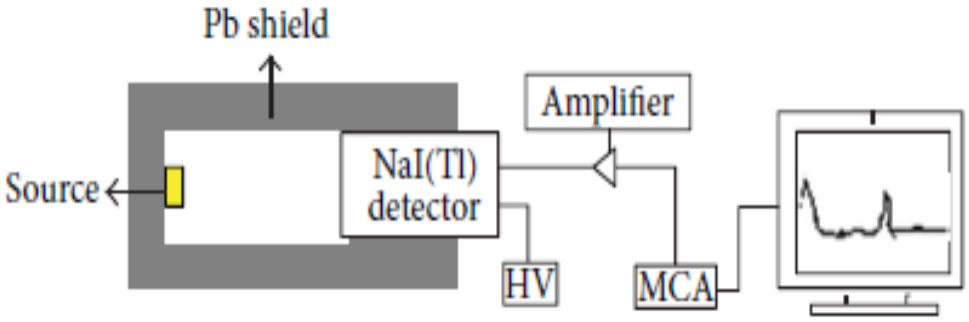

Figure 3.2; Experimental setup of NaI Detector

3.5.2.1 Sample Activity Acquisition and Analysis in Gamma Spectrometry

Gamma spectrometry is a widely used analytical method that depends on one physical property of most radionuclides, namely the emission of gamma rays, when the radionuclides decay.

The radioactive chain of uranium and thorium includes daughter isotopes that emit gamma rays of characteristic energy level. In gamma spectrometry, the spectra from natural (un-irradiated) samples are measured to determine the bulk uranium, thorium and potassium content of the samples.

Gamma ray spectrometry technique was employed in the spectral collection of the prepared samples using the higher energy region of the γ-lines as indicated in table 3.1 below:

Table 3.1: Spectral Energy windows used in analysis using NaI(Tl) gamma spectroscopy system

Element Analyzed	Isotope used	Gamma Energy(keV)	Energy windows (keV)
^{238}Th	^{208}Tl	2614.5	2590-2710
^{238}U(^{226}Ra)	^{214}Bi	1764.0	1690-1820
^{40}K	^{40}K	1460.0	1380-1510

3.6 Activity Concentration of the Sediments

The activity concentrations in the sediment samples were obtained using the equation 3.8 (Obed *et al.*, 2005; Jibiri, *et al.*, 2007).

$$C(Bqkg^{-1}) = kC_n \quad \ldots\ldots\ldots\

limits to be 310.99Bqkg^{-1} for ^{40}K, 16.21Bqkg^{-1} for ^{226}Ra and 123.16Bqkg^{-1} for ^{238}Th respectively. This was subtracted from the measured γ-ray spectrum of each sample.

3.6.1 Calculation of absorbed dose rate from measured activity concentration for sediments

Radiation emitted by a radioactive substance is absorbed by any material it encounters. (UNSCEAR, 2000) has given the dose conversion factors for converting the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K into dose (nGyh^{-1} per Bqkg^{-1}) as 0.427, 0.662 and 0.043, respectively. Using these factors, the total absorbed dose rate in air is calculated as given in the Equation (3.10) (UNSCEAR, 2000).

$$D = (0.427C_{Ra} + 0.662C_{Th} + 0.043C_K)\ nGyh^{-1} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3.10)$$

where C_{Ra}, C_{Th} and C_K are the activity concentrations (Bqkg^{-1}) of radium, thorium and potassium, respectively in the samples.

3.6.2 Calculation of annual effective dose from sediment

The estimation of the annual effective dose rates, depended on conversion coefficient from absorbed dose to effective dose as 0.7SvGy^{-1} and outdoor occupancy factor of 0.2 as proposed by (UNSCEAR, 2000). The effective dose rate in units of mSvGy^{-1} was calculated by the following formula in equation (3.11)

$$\text{Effective dose rate } (mSvGy^{-1}) = D\ (nGyh^{-1}) \times 870h \times 0.2 \times 0.7SvGy^{-1} \times 10^{-6} \quad \ldots\ldots \quad (3.11)$$

3.6.3 External hazard index (H_{ex})

Radiation exposure due to ^{226}Ra, ^{232}Th and ^{40}K may be external. This hazard, defined in terms of external hazard index or indoor radiation hazard index and denoted by H_{ex}, can be calculated using the equation (3.12) (Beretka, *et al.*, 1995):

$$H_{ex} = \frac{C_{Ra}}{370} + \frac{C_{Th}}{259} + \frac{C_K}{4810} \quad \ldots\ldots\ldots\

$$C = \frac{(R_b - R_0)\ \text{x}\ \ a_s\ \text{x m x 1.02}}{(R_S - R_0)\ \text{x 1000}\ V} \quad \ldots\ldots\ldots\

CHAPTER FOUR

RESULT AND DISCUSION

4.1 INTRODUCTION

The spectra that were generated from samples during spectrometric analysis were used in identification of the radionuclides in the samples. This has made possible to have a comprehensive activity concentration ($Bqkg^{-1}$) of ^{232}Th, ^{226}Ra and ^{40}K for the sediment collected at various locations.

4.2 Activity Concentration in Sediments

The activity concentrations of the three primordial radionuclides ^{226}Ra, ^{232}Th and ^{40}K were measured and an average of 49.67±3.07 $Bqkg^{-1}$, 127.29±4.42 $Bqkg^{-1}$ and 443.43±9.51 $Bqkg^{-1}$ respectively were obtained. The minimum activities for ^{226}Ra, ^{232}Th and ^{40}K were found to be 41.51 $Bqkg^{-1}$, 62.49 $Bqkg^{-1}$ and 316.18 $Bqkg^{-1}$ while the maximum values were 57.91 $Bqkg^{-1}$, 291.9 $Bqkg^{-1}$ and 516.29 $Bqkg^{-1}$ respectively. Table 4.1 shows the activity concentrations of the natural radionuclides ^{226}Ra, ^{232}Th and ^{40}K and their coordinates in all the sampling sites and Table 4.2 shows the mean activity concentrations and the range for the three natural radionuclides ^{226}Ra, ^{232}Th and ^{40}K in all the sampling sites.

Table 4.1 Activity Concentration of the natural radionuclides ^{226}Ra,^{232}Th and ^{40}K and their coordinates measured in this work.

Sample Location	Sample code	^{226}Ra (Bq/kg)	^{232}Th (Bq/kg)	^{40}K (Bq/kg)	Coordinates
GARHI A	SA_1	44.84±2.20	42.07±0.57	272.78±11.04	N12^0 22.784
					E007^0 27.987
	SA_2	57.70±3.82	96.00±2.85	800.77±12.59	N12^0 22.787
					E007^0 27.905
	SA_3	39.62±4.51	163.28±3.30	704.66±14.61	N12^0 22.642
					E007^0 27.926
	SA_4	23.87±1.04	41.73±2.16	286.93±	N12^0 22.613
					E007^0 27.925
	MEAN	41.51±2.89	85.77±2.22	516.29±12.48	
GARHI B	SB_1	52.95±6.95	51.31±6.61	458.79±3.11	N12^0 21.173
					E007^0 30.250
	SB_2	84.59±5.33	68.87±1.82	496.27±12.59	N12^0 21.210
					E007^0 30.256
	SB_3	32.91±2.20	99.20±2.74	562.90±12.47	N12^0 21.216
					E007^0 30.289
	SB_4	51.56±3.13	72.52±2.96	320.22±7.6	N12^0 21.261
					E007^0 30.139
	MEAN	55.50±4.40	291.9±3.53	459.56±8.5	
MAKERA	SC_1	52.26±2.89	105.93±3.53	556.45±11.66	N12^0 22.480
					E007^0 27.885
	SC_2	55.85±1.74	66.48±1.37	487.09±8.86	N12^0 22.496
					E007^0 22.896
	SC_3	65.01±4.06	57.81±2.28	436.08±9.07	N12^0 22.517
					E007^0 27.904
	SC_4	58.52±3.24	45.84±1.03	447.12±9.95	N12^0 22.433
					E007^0 27.873

	MEAN	57.91±2.98	69.02±2.05	481.69±10.07	
TABOBI	SD_1	95.71±1.29	54.28±8.44	483.20±3.11	$N12^0$ 23.121 □
					$E007^0$ 30.715 □
	SD_2	44.73±1.74	83.24±1.59	223.34±5.13	$N12^0$ 23.51 □
					$E007^0$ 30.737 □
	SD_3	34.53±3.01	49.94±4.56	241.99±11.35	$N12^0$ 23.299 □
					$E007^0$ 30.656 □
	MEAN	43.74±2.01	62.49±4.86	316.18±6.53	

Table 4.2 Mean Activity Concentrations for the three natural radionuclides ^{226}Ra, ^{232}Th and ^{40}K measured in this work

Activity Concentrations (Bq/kg)						
	^{226}Ra		^{232}Th		^{40}K	
SITE	MEAN	RANGE	MEAN	RANGE	MEAN	RANGE
SA	41.51±2.89	23.87-57.70	85.77±2.22	41.73-163.28	516.29±12.48	272.78-800.77
SB	55.50±4.40	32.91-84.59	291.9±3.53	51.31-99.20	459.56±8.95	320.22-562.99
SC	57.91±2.98	52.26-65.01	69.02±2.05	45.84-105.93	481.69±10.07	436.08-556.45
SD	43.74±2.01	34.53-95.71	62.49±9.86	49.94-83.24	316.18±6.53	326.46-633.19
AVERAGE	49.67±3.07	35.89-75.75	127.29±4.42	47.21-112.91	443.43±9.51	338.88-638.40

Activity concentrations for ^{40}K are generally high than those of ^{226}Ra and ^{232}Th in all the sampling sites. The highest values of ^{226}Ra were found at site SC, It could be due to the presence of the loamy sediments (El-Gamal, Nasr, & El-Taher, 2007). While the highest value of ^{232}Th is found at site SB, this may be due to the high content of monazite (Orgun *et al.*, 2007).

There is generally higher activity concentration of ^{40}K at SA. These can be attributed to Dam from the intensive use of agrochemical such as NPK fertilizer for agricultural practice.

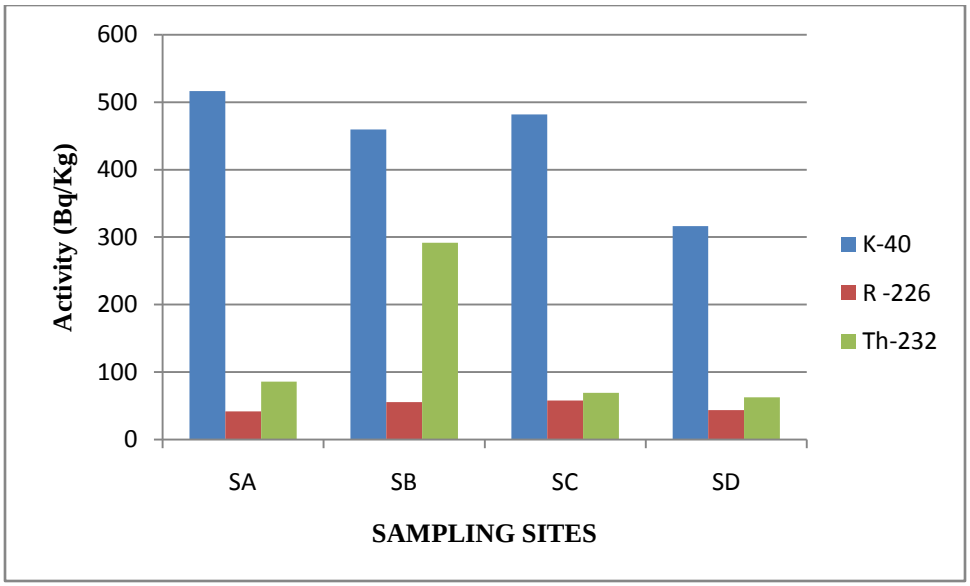

Figure 4.1: Activity concentrations of the natural radionuclides ^{226}Ra, ^{232}Th and ^{40}K in sediments samples measured in this work.

Average activity concentration for ^{226}Ra, ^{232}Th and ^{40}K are higher than world average value of (UNSCEAR, 2000). This is shown in table 4.3.

Table 4.3: Activity concentration of natural radionuclides in the sediments measured in this work compared to world average.

Radionuclides	This study (Average) (Bq/Kg)	World (Average) (Bq/Kg)
^{40}K	443.43±9.1	420
^{226}Ra	49.67±3.07	32
^{232}Th	127.29±4.42	45

4.3 Dose rate

The total dose rates from the sediments of Zobe Dam were calculated for all the sampling sites. The total dose rate was found to be 124.52±4.62 $nGyh^{-1}$ with the minimum value being 73.62 $nGyh^{-1}$ and the maximum 236.68 $nGyh^{-1}$. Table 4.4 shows the average dose rates of the natural radionuclides in all the sampling sites and the total dose in Zobe Dam. The total dose rates were estimated using equation (3.10).

Table 4.4: Average dose rates of the natural radionuclides and the total dose rates measured in this work for all sampling sites.

	Dose Rates (nG/h)			
SITES	^{226}Ra	^{232}Th	^{40}K	TOTAL
SA	17.72±1.23	56.77±1.46	22.20±0.53	96.69
SB	23.69±1.87	193.23±2.33	19.76±0.36	236.68
SC	24.72±1.27	45.69±1.35	20.71±0.43	91.12
SD	18.67±0.85	41.36±6.52	13.59±0.28	73.62
AVERAGE	21.20±1.30	84.26±2.91	19.06±0.40	124.52

Contribution of each radionuclide to the gamma dose rate varied with the sampling sites. Figure 4.2 shows dose rates in which the sampling site SB has the value above the average for the whole Dam. The sampling site is on the southern region of Dam (Figure 3.1). The sampling sites SD and SC are within the worldwide value range which is from 18 $nGyh^{-1}$ to 93 nGyh-^{1}. While the sampling sites SA and SB are higher than the worldwide value.

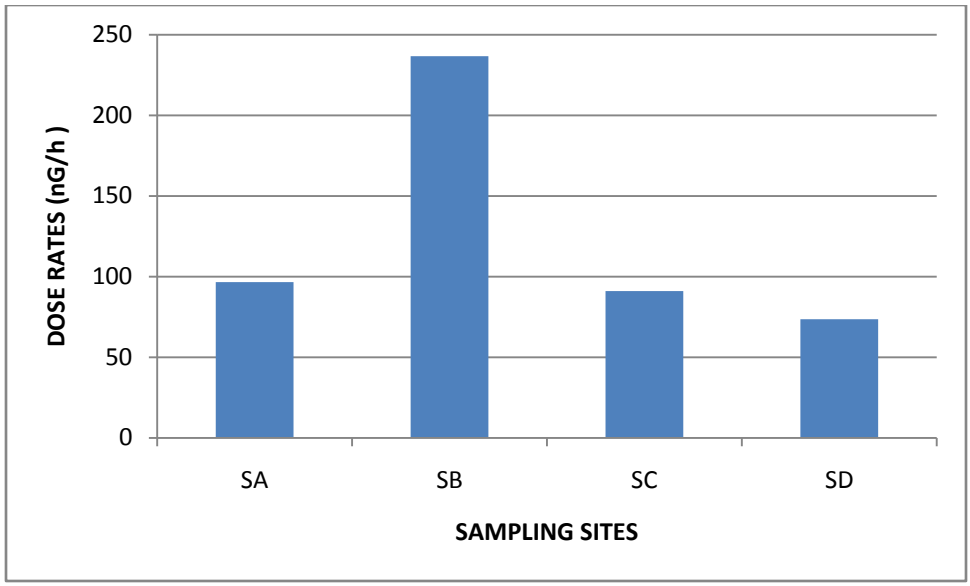

Figure 4.2: Dose rates for sediment samples measured in this work.

There is greater contribution of dose rates by ^{232}Th and ^{226}Ra than ^{40}K as illustrated on figure 4.3.

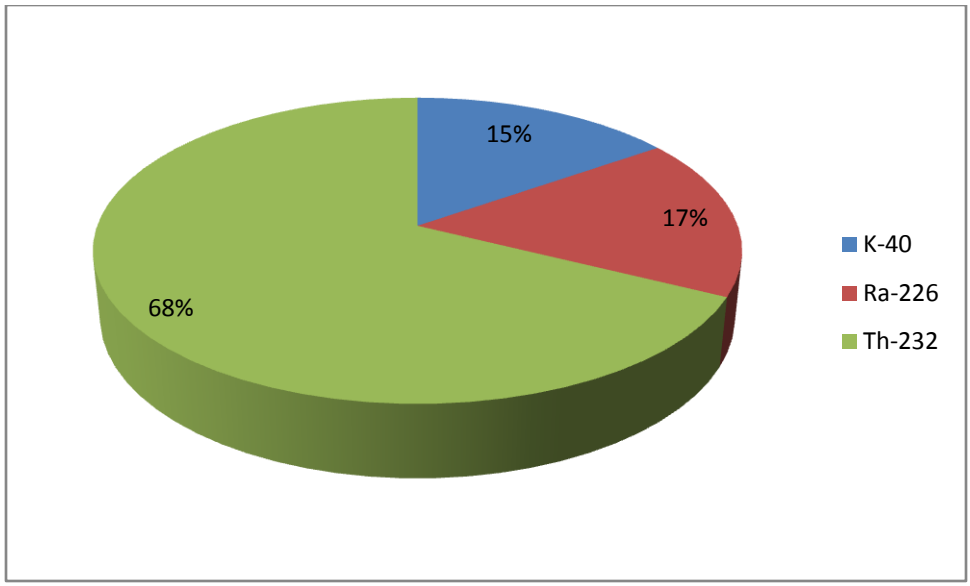

Figure 4.3: Estimate of the average dose rates contribution by the three radionuclides in sediment samples measured in this work.

4.4 Annual Effective Dose Rate (AEDR), External Hazard and Internal Hazard index.

The annual effective dose rates (AEDR), external hazard index (H_{ex}) and internal hazard index (Hi_n) were calculated for the sediments of Zobe Dam. The mean annual effective dose rate was found to be 0.152±0.014 $mSvy^{-1}$ with a minimum value of 0.090±0.009 $mSvy^{-1}$ at the sampling site SD at the northern side of the Dam and maximum value of 0.2901±0.0056 $mSvy^{-1}$ at the sampling site SB on the western side of the Dam. Table 4.5 shows the values of AEDR, H_{ex} and H_{in} values for all the sampling sites. The AEDR is below the maximum allowed limit of 1 $mSvy^{-1}$ of radiation exposure to the public (ICRP, 1991).

The external (H_{ex}) and internal (Hi_n) hazard indices represent the risk associated from exposure of the radionuclides in the sediment samples. The external hazard index was found to be 0.717±0.126 with a minimum value of 0.425±0.445 at sampling site SD and maximum value of 1.372±0.027 at sampling site SB while the internal hazard index was found to be 0.851±0.035 with a minimum value of 0.543±0.050 at sampling site SD and maximum value of 1.522±0.039 at sampling site SB. This indicated that the risk associated with sediments sample is quite below the limit set by (ICRP, 2000) for radiological exposure protection to the public which is unity. Since the value of the external hazard index is less than unity we can therefore say that the radiation hazard due the sediments of the Dam is low. However at the sampling site SB there are elevated values of external and internal hazard index which are above the unity and this indicate that the sediments sample at the site can pose a health risk to the public when use as building material. Figures 4.4, 4.5 and 4.6 shows the AEDR, external hazard and the internal hazard index for all the sampling sites.

Table 4.5: The annual effective dose rate (AEDR), external hazard index (H_{ex}) and internal hazard index (H_{in}) for sediment samples measured in this work.

SITE	AEDR ($mSvy^{-1}$)	H_{ex}	H_{in}
SA	0.119±0.039	0.550±0.018	0.662±0.026
SB	0.290±0.005	1.372±0.027	1.522±0..039
SC	0.112±0.003	0.523±0.017	0.679±0.026
SD	0.090±0.009	0.425±0.0445	0.543±0.050
AVERAGE	0.152±0.14	0.717±0.126	0.851±0.035

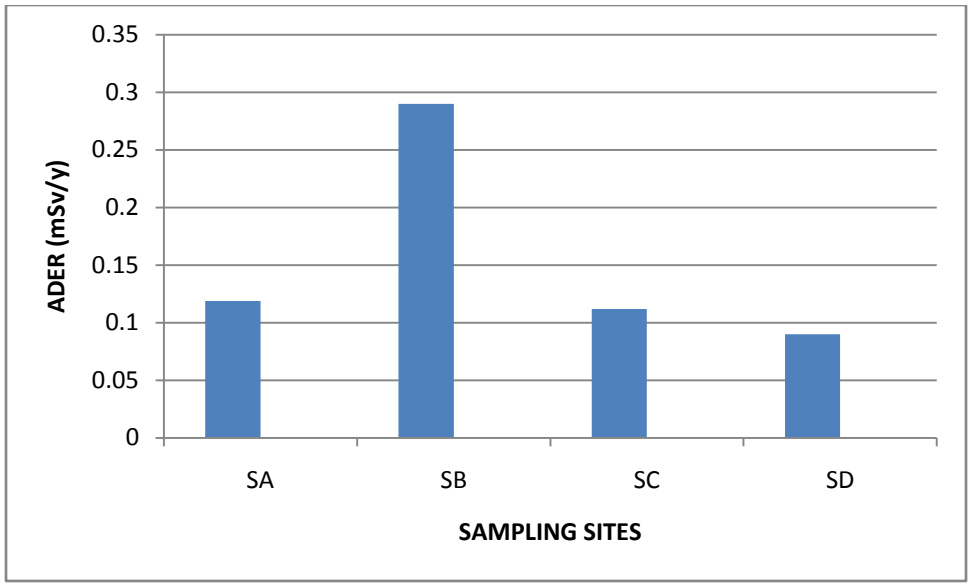

Figure 4.4: Annual Effective Dose Rate (AEDR) for sediment samples analysed in this work.

Figure 4.5: Estimate of the external hazard index for the sediment samples analysed in this work.

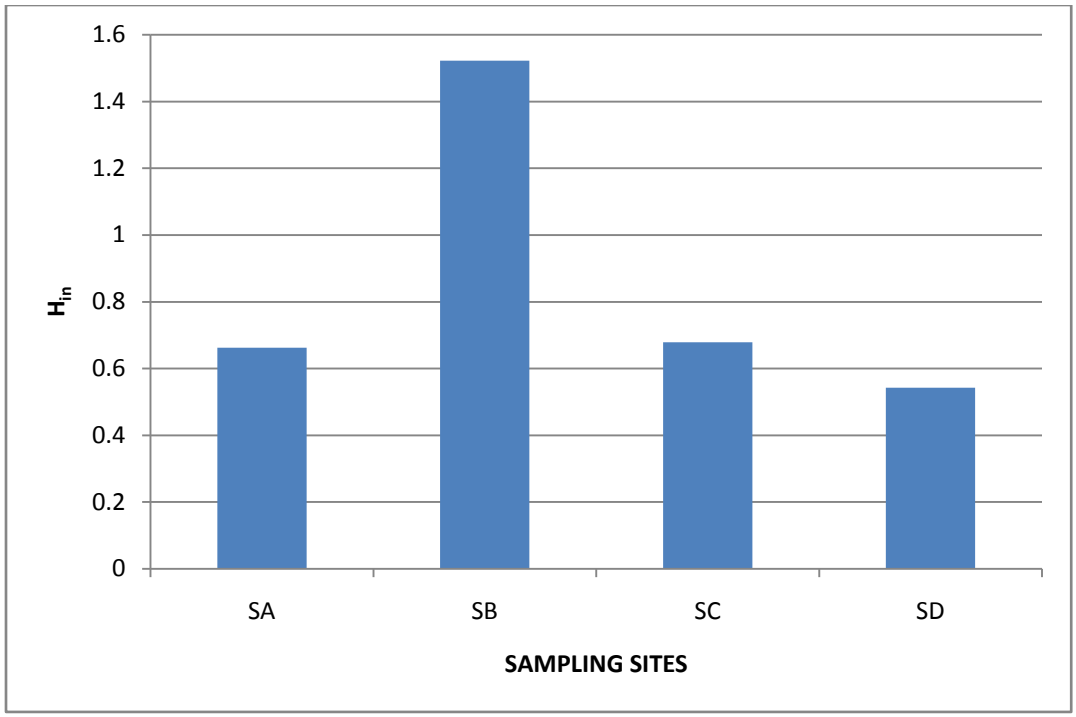

Figure 4.6: Estimate of the internal hazard index for the sediment samples analysed in this work.

4.5 Alpha and Beta Activity Concentration in Water Samples

The gross alpha and beta activity concentration analysis for the collected water samples is presented in table 4.6. The alpha activity concentrations have an average value of 6.831±0.312 Bq/L in zone A, in zone B the activity concentrations have an average value of 4.310±0.32 Bq/L, the average activity concentration value in zone C is 6.437±0.31 Bq/L. In the control zone i.e zone D, the average activity concentration of 7.171±0.27 Bq/L was obtained. The beta activity concentrations have an average value of 8.286±0.4 Bq/L in zone A, the activity concentrations have an average value of 6.354±0.59 Bq/L in zone B, the average concentration value in zone C is 9.315±0.44, while in zone D the average concentration value of 9.373±0.36 was obtained.

Table 4.6: Alpha and Beta Activity Concentration for Water Samples measured in this work.

Alpha and Beta Activity Concentrations in Bq/L			
Sample Locations	**Sample ID**	**Alpha Activity**	**Beta Activity**
Zone A	WA1	11.397±0.38	10.997±.048
	WA2	7.618±0.28	6.966±0.36
	WA3	1.087±0.31	BDL
	WA4	7.223±0.28	6.896±0.36
Zone B	WB1	7.458±0.32	BDL
	WB2	7.475±0.33	9.872±0.41
	WB3	0.595±0.26	BDL
	WB4	1.713±0.62	2.837±0.77
Zone C	WC1	0.826±0.23	BDL
	WC2	9.547±0.37	12.119±0.46
	WC3	BDL	BDL
	WC4	8.940±0.33	6.511±0.43
Zone D	WD1	BDL	BDL
	WD2	9.067±0.33	11.721±0.45
	WD3	5.276±0.22	7.025±0.27
	MEAN	6.187±0.37	8.332±0.44
	MAX	9.547±0.37	12.119±0.46
	MIN	BDL	BDL

From the table 4.6 above, the results obtained for gross alpha activity concentration from the water sample ranges from BDL to 9.547±0.37 Bq/L with average value of 6.187±0.37 Bq/L, while the beta activity ranges from BDL to 12.119±0.46 Bq/L with average 8.332±0.44 Bq/L.

The average value 6.187±0.37 Bq/L of alpha activity obtained from this work exceeds the Australia Causeway River water alpha activity by 6.02 Bq/L (Onoja, 2004), the average alpha activity also exceed the average alpha activity of river Kaduna (0.1173 Bq/L) by 6.0697 Bq/L (Juliet, 2006). However, the value is lower than the mean alpha activity value reported earlier for Okpare Creek (Avwiri and Agbalagba, 2007) and is also lower than the alpha activity value of 6.7±0.074 Bq/L reported for Opa River irrigation farmland (Fassasi, *et al.,* 1999). The average gross alpha activity measured in this work is higher than 0.1 Bq/L recommended for drinking water by WHO (2003).

The average beta activity obtained from this work is 8.332±0.44 higher than the maximum screening level of 1.0Bq/L recommended for drinking water by (WHO, 2003).

Comparing the average value 8.332 Bq/L of beta activity obtained in this work with: 0.07553Bq/L obtained in Zaria by Onoja (2004); 0.00005Bq/L in Kano by Tajudeen (2006); and 1.56Bq/L in Jos by Habila (2008); this shows that Gross beta activity measured in all the sampling sites in Zobe Dam are relatively high.

It also shows from the table that the gross beta activity is generally higher than the corresponding gross alpha activity in all zones. The higher value of Gross beta activity could be as a result of the geological formation of the area whose land is highly invaded with phosphorus, a by-product of phosphate that has potassium-40 which is a beta and gamma emitter whose source is fertilizer used by farmers. Figure 4.6 shows the activity concentration of alpha and beta in all zones.

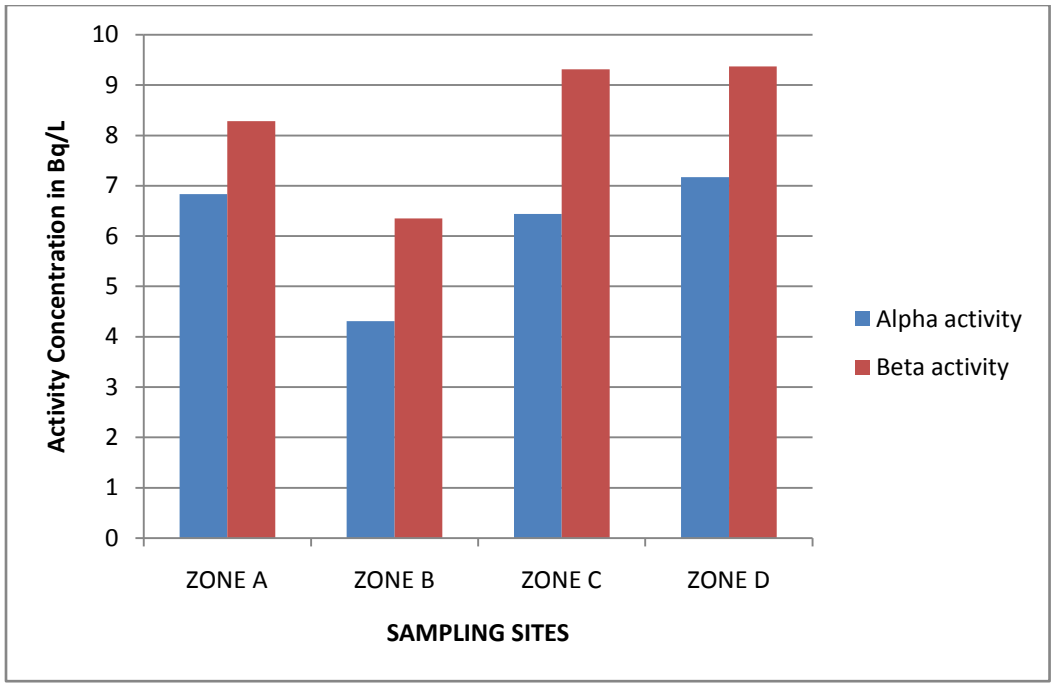

Figure 4.7: Alpha and Beta activity concentration in all zones.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The study showed that the radioactivity levels of ^{226}Ra, ^{232}Th and ^{40}K were 49.67±3.07 Bq/kg,127.29±4.42 Bq/kg and 434.43±9.51 Bq/kg respectively and were comparable with the world average values. However, slight variation in the radioactivity content in soil observed with different locations worldwide mainly due to soil type, formation and transport process involved. This may be the reason for the variation. The mean absorbed dose rate obtained in the present study (124.52±4.61 nGy/ h) is comparable to the world average (55 nGy/h). The measured average annual effective dose rate in this study is 0.152 mSv/y, and is lower than the world average value 1 mSv/y (UNSCEAR, 2000). The measured average values of external and internal hazard index found in this study are 0.717 and 0.851 (all are lower than unity), which indicate that the sediments in all the sampling sites can be used for safety construction of buildings. This information is important for the local people to utilize the Zobe Dam sediments.

The average results obtained for gross alpha and beta activity from the water samples of Zobe Dam are 6.187±0.37 and 8.332±0.44 Bq/L, and are higher than the limit set by WHO by 6.087 Bq/L for gross alpha and 7.332 Bq/L for gross beta and this indicate that the water in all the sampling sites is not safe for livestock and domestic consumption. The obtained data in this study serve as base–line data used to evaluate the possible health impact of the water and sediments. This work could help to create a public awareness about the total or gross alpha and beta activities in drinking water and the radiological impact on the dweller's health.

5.2 Recommendations

1. There is need to extend this study to cover the entire Dam's sediment and water in order to have a comprehensive radiological assessment of the Dam.
2. There is also need to have radiological assessment of all the fish within the Dam.
3. There is also need for further screening for Radioactivity level measured in all the sampling sites of Zobe Dam in order to safeguard the life of the settlers that are using the water for their daily activities.
4. The regular program of environmental audit and monitoring is also recommended.

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