# ASSESSMENT OF TOBACCO COMPANY EFFLUENT FOR RADIOACTIVITY AND OTHER PARAMETERS FOR GROUNDWATER AROUND THE COMPANY IN CHIKAJI, ZARIA, KADUNA, NIGERIA

**BY**

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**ZARIA, NIGERIA**

**APRIL, 2017**

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**A THESIS SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIES, AHMADU BELLO UNIVERSITY, ZARIA**
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**DEPARTMENT OF PHYSICS,**
**FACULTY OF PHYSICAL SCIENCE,**
**AHMADU BELLO UNIVERSITY,**
**ZARIA, NIGERIA**

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## DECLARATION

I declare that the work in this thesis entitled **"Assessment of Tobacco Effluent For Radioactivity and Other Parameters For Groundwater Around The Company in Chikaji, Zaria, Kaduna, Nigeria"** has been conducted by me in the Department of Physics under the supervision of Prof. D J Adeyemo and Dr.Y.I. Zakari. 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.

**Mikhail, OLAKUNLE**

M.Sc./SCI/26834/2012-2013 **Signature** **Date**

## CERTIFICATION

This thesis entitled: **"Assessment of Tobacco Effluent For Radioactivity and Other Parameters For Groundwater Around The Company in Chikaji, Zaria, Kaduna, Nigeria"** by Mikhail, OLAKUNLE (M.Sc./SCI/26834/2012-2013) meets the regulations governing the award of Masters Degree in Radiation Biophysics of Ahmadu Bello University, Zaria and is approved for its contribution to knowledge and literary presentation.

**Professor D.J. Adeyemo** _____

_____ Chairman, Supervisory Committee Signature _____
Date

**Dr. I.Y. Zakari** _____

_____ Member, Supervisory Committee Signature _____
Date

**Dr. I.Y. Zakari** _____

_____ Head of Department Signature _____
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**Professor S.Z. Abubakar** _____

_____ Dean, School of Postgraduate Studies Signature _____
Date

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## DEDICATION

This thesis is dedicated to Almighty God in whose mercy I completed this research work.

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**ABSTRACT**

Twenty (20) groundwater samples, four of which are control samples, comprising of ten (10) borehole and ten (10) locally hand-dug wells were drawn randomly around British America Tobacco Company, Zaria. Some physical parameters: temperature, pH, conductivity and total dissolved solids were measured usingthermometer, pH meter and conductivity meter. The samples were analysed for gross alpha and gross beta radiations using MPC-2000-DP (01872140) single channel analyser, a low background alpha and beta detector. The meantemperature, pH, conductivity and total dissolved solids in the water samples were found to be 27.8 °C, 5.1, 393µS/cm and 244.8 mg/l respectively.For practical screening purposes in the case of drinking water, the recommended guideline activity concentrations are 0.1 Bq/l for gross alpha and 1.0 Bq/l for gross beta activity (WHO, 1993; 2003). The gross alpha and beta

radioactivity concentrations in the samples showed that the alpha activity varied from (0.007 -- 0.133) Bq/l with a mean value of 0.046 Bq/l for borehole samples and (0.002 -- 0.285) Bq/l with a mean value of 0.056 Bq/l for well water samples. The beta activity varied from (0.113 -- 3.789) with a mean value of 1.627 Bq/l for borehole water samples and (0.001-3.810) with a mean value of 0.887 Bq/l for well water samples respectively. The mean for gross alpha activity and gross beta activity in the sample waters are 0.051±0.003 Bq/l and 1.251±0.091 Bq/l respectively.

# CHAPTER ONE

# INTRODUCTION

## 1.1 Background

Drinking water sourced from deep wells and boreholes are usually expected to have high concentration of radioactive nuclides. This is because they pass through fractures in bedrocks or within the soil which contains minerals deposits that might have radioactive constituents and thus leaking into the water ways. Radioactivity in drinking water is one of the major ways in which radionuclides from the environment gets into the human body, which might consequently lead to radiation-induced disorderness (USEPA, 2010). There is evidence from both human and animal studies that radiation exposure at low to moderate doses may increase the long term incidence of cancer and that the rate of genetic malformations may be increased by radiation over exposure (Otton, 1994). It is therefore important to determine the amount of radioactivity in drinking water for every area where people live in, so as to guard against its health hazards (WHO, 2006).

Groundwater could be contaminated by radioactive materials because terrestrial radioactivity increases with depth in the earth crust (WHO, 1998). These radioactive materials occur naturally and of most concern are the uranium and thorium series and the progenies (radon and thoron). They contribute to the radioactivity of the rain and groundwater which in turn affects drinking water. Due to these, drinking water from deep wells and boreholes are expected to contain high concentrations of radioactive elements. Radioactive materials could also be washed into wells, boreholes and even enter through burst pipes. Important radioactive elements in drinking water are tritium, potassium-40, radium and radon which are alpha or beta emitters (Surbeck, 1995). People who ingest polluted water can develop illness and with prolonged exposure to radioactive polluted water could cause cancers, toxicity of the kidneys or bear children with birth defects (WHO, 2006). Knowledge of the naturally occurring radionuclide

present in drinking water enables one to assess any possible radiological hazards to humans by the use of such water.

Manmade pollution of water is divided into two kinds: point source which is caused by discharge of pollutants from specific location for example discharge from factories sewage treatment plants and oil tankers into rivers, and non-point source which occurs from rainfall or melting of snow and the run-off washes away pollutants into lakes, rivers and coastal waters. Industrial waste is the most common source of water pollution in the present day (Ogedengbe and Akinbile, 2004) and it increases yearly due to the fact that industries are increasing because most countries are getting industrialized. Industries vary in size, nature of products, characteristics of waste discharged and the receiving environment. The major industrial categories in Nigeria are metals and mining, food, beverages and tobacco; breweries, distilleries, textile, leather products, wood processing and manufacture, furniture, pulp and paper industries and chemical and allied industries. Industrial effluents contain toxic and hazardous materials from the wastes that settle in river water as bottom sediments and constitute health hazards to the urban population that depend on the water as a source of supply for domestic uses (Akaniwor*et al*, 2007).

Groundwater quality is defined based on a set of health and safety regulations for domestic use. The World Health Organization (WHO) guidelines for drinking water suggest performing an indirect evaluation of committed dose by measuring gross alpha and beta radioactivity and checking compliance to derived limit; the proposed limits are 0.1Bq/l for gross alpha and 1.0Bq/l for gross beta radioactivity(WHO, 2003).

Ground water used for public domestic supply must adhere to a set of regulatory objectives for health and safety than ground water used strictly for irrigation needs. Groundwater contamination occurs when manmade products such as gasoline, oil, fertilizers, pesticides and

other chemicals get into groundwater and could cause it to be unsafe and unfit for human use. Septic systems, hazardous waste sites and landfills are major targets of pollution because rainfall and groundwater leach these highly contaminated substances into rivers, stream and waterways (surface water) which are inadvertently used by people in that area. (Asonye*et al*, 2007).

Contamination of drinking water supplies from industrial waste is as a result of various types of industrial processes and disposal practices. Industries that use large amounts of water for processing have the potential to pollute waterways through the discharge of their waste into streams and rivers, or by run-off and seepage of stored wastes into nearby water sources. Other disposal practices which cause water contamination include deep well injection and improper disposal of waste in surface impoundments. Industrial waste consists of both organic and inorganic substances. Organic wastes include pesticide residues, solvents and cleaning fluids, dissolved residue from fruits and vegetables, and lignin from pulp and paper. This impacts high organic pollutants on receiving waters consequently creating high competition for oxygen within the ecosystem. (Osibanjoand Adie, 2007).

## 1.2 Statement of Research Problem

In developed countries, radioactivity measurement and other parameters such as TDS, are always part of water quality assessment. Many countries are now adopting the guideline activities recommended by the World Health Organization (Avwiry and Agbalagba, 2007) of concentration for drinking water quality. Reports from most African countries and even from Europe reveal some aspects of uncontrolled garbage, roadsides littered with refuse, and streams blocked with junk, disposal sites constituting a health hazard to residential areas, and inappropriately disposed toxic wastes (Henry *et al.*, 2005; Tamiru, 2001). Reports have indicated that the manufacturing process produces liquid, solid and airborne wastes, some of

which are potential environmental hazards and may even pollute surface and groundwaters (Gunatilaka, 2006; Novonty and Zhao, 1999; USGS, 2005). In growing tobacco, several chemicals are applied and these may also pollute ground or river water through run off from the agricultural land (Drake, 1996; Anonymous, 2006). Studies in ground well water near tobacco fields at Gboko, Benue state have shown large amounts of pesticides, pesticide degradation products, and volatile organic compounds and dissolved organic carbon all of which apparently originated from the chemicals applied on the tobacco in the field (Johnson and Connel, 1997).

The tobacco manufacturing process produces liquid, solid, and airborne waste. Among those wastes, some materials, including nicotine, are designated by the EPA as Toxics Release Inventory (TRI) chemicals which are possible environmental health hazards. In the United States in 1992, the Toxics Release Inventory reported in the Statistical Record of the Environment that tobacco manufacturing generated more than 27 million kilograms of production-related chemical waste, of which 2.2 million kilograms were treated or released into the environment. Overall, the tobacco industry ranked 18th among all industries in total chemical waste production (Novotny and Zhao, 1999).

Increase in the radionuclide concentration levels has various health effects on the populace. These could be genetic or somatic; the genetic effects could be transferred to offspring while somatic effects could ultimately lead to death depending on the level of exposure. It is therefore imperative that basic study like this be carried out in order to investigate radioactivity levels in groundwater of the study area where Tobacco Company is located. This would ascertain whether the level of radioactivity in the groundwater system is elevated and or could pose any significant health hazard to the populace. The contribution of the tobacco wastewater to the groundwater quality of the borehole water and hand-dug well water in the study area, to the best of my knowledge, has not been documented. Such information would be important for the

authorities to reinforce the laws governing the indiscriminate disposal of wastes for environmental pollution.

### 1.3 Justification of the Research

The fertilizer, for example, phosphate fertilizers, favoured by the tobacco farmers to increase the size of the tobacco crops contains the naturally occurring radionuclide, radium. (USEPA, 2015). Radium radioactively decays to release radon, which rises from the soil around the plants. Radon rapidly decays into a series of solid, highly radioactive metals (radon decay products). These metals cling to dust particles which in turn are collected by the sticky tobacco leaves. The sticky compounds that seep from the trichomes is not water soluble, so the particles do not wash off in the rain. There they stay, through curing process, cutting, and manufacture into cigarettes (USEPA, 2015). The pollution caused by cigarettes does not stop in our bodies or the air; it affects our land and our water supply. Millions of cigarette butts are discarded onto the ground every day. Most of the garbage collected on a daily basis from sweeping streets is cigarette waste, and these are only the ones that are picked up in and not ones discarded down drains and sidewalk cracks. These end up in the rivers and lakes, causing fish and other animals to eat them by mistake, this could ultimately result to their death. The ones in the streets left unclean are left on the ground to decompose which may take an average of 25 years while all of the chemicals and additives leach into the ground, polluting the soil and underground water. (USEPA, 2015)

The tobacco leaves used in making cigarettes contain radioactive material; particularly lead-210 and polonium-210 which emit mostly alpha and gamma radiation. Polonium 210 emits highly localized alpha radiation which has been shown to cause cancer since the polonium 210 has a half-life of 21.5 years (Due to the presence of lead 210), it can put an ex-smoker at risk for years after he or she stops smoking (Brian, 2015).

Alpha and beta radiations are high Linear Energy Transfer (LET) radiations; hence they deposit energy at short distances and could cause serious biological effects to organs and tissues in the body. Beta particles are able to penetrate living matter to a certain extent and can change the structure of struck molecules. In most cases, such change can be considered to be damage, with results possibly as severe as cancer or death. If the struck molecule is DNA, it could lead to spontaneous mutation.

Therefore, there is need to determine the specific activities of the radionuclides present as well as concentration of alpha and beta radiations in water. The gross alpha and beta counting is the preliminary test, as stipulated in the World Health Organization guideline for water quality determination.

This survey is therefore important in the sense that it is concerned with the health of the populace in the sense that it will forestall probable radiological health effect due to the tobacco industry. It is equally economical because it will provide data necessary for complete purification of water in this area and if the water is safe some health problems will be eliminated and the government will save a lot of money for other developmental effects.

Since government always warn about the danger of tobacco to human health, other bodies wishing to carry out surveys of gross alpha and beta radiations and the other parameters in water in a broader scope around tobacco industries will use this work as a reference point for detailed survey. Also the data from this research will form the basis for the radionuclide specific test and other parameters where the tests are necessary; hence the research will contribute immensely to literature.

## 1.4 Aim and Objectives of the Study

### 1.4.1 Aim

The aim of this work is to assess the effect of tobacco company effluent for the radioactivity and other parameters for groundwater around the British American Tobacco Company located in Chikaji area of Zaria in Kaduna state.

### 1.4.2 Objectives

1. To determine the gross alpha and gross beta activity concentration levels in well and borehole

water samples around British American Tobacco Company, Chikaji in Zaria.

2. To establish the distribution pattern of radioactivity measured in the study area in order to identify and to compare the result with already established data.

3. To establish a base line data for the area of study.

## 1.5 Scope and Limitations

This work will cover measurement of gross alpha and beta activity and some parameters used for checking water quality in well and borehole waters from the study area. The extent of the work was limited to detectors and procedures available in the Centre for Energy Research and Training, Zaria. Other parameters such as TDS, temperature, conductivity and pH, which are used to check water quality, were carried out using portable calibrated mercury thermometer, conductivity meter and pH meter respectively.

# CHAPTER TWO

# LITERATURE REVIEW

## 2.1 Introduction

This chapter reviewed literature related to the study. The review specifically centers on issues as raised in chapter one:

## 2.2 Water Pollution

Polluted water or contaminated water is defined as any water whose quality has been significantly degraded (WHO, 1998). Water pollution like other environmental concerns has been the focus of widespread public interest for decades and this interest is increasing day-by-day (Abel, 1996). Water is polluted by the waste of civilization which enters water bodies through the discharge of water borne wastes. The same water could be used by the urban population for drinking and other domestic purposes (Welch, 1992). Other wastes like industrial wastes, pulping wastes, petroleum and refinery wastes, food processing wastes, mining wastes and agricultural wastes often contain some amount of pollutants as a result of the materials used in generating the wastes thereby adding to the level of water pollution if they enter the water bodies. Water can pick radioactivity materials as it flows through rocks soil or cracked cement surrounding a water source, there by contaminating the water sources (USEPA, 1996).

Groundwater could be contaminated by radioactive materials because terrestrial radioactivity increases with depth in the earth crust (WHO, 1998). These radioactive materials occur naturally and of most concern are the uranium and thorium series and the progenies (radon and thoron). They contribute to the radioactivity of the rain and groundwater which in turn affects drinking water. Due to these, drinking water from deep wells and boreholes are expected to

contain significant concentrations of radioactive elements. Radioactive materials could also be washed into wells, boreholes and even enter through burst pipes. Important radioactive elements in drinking water are tritium, potassium-40, radium and radon which are alpha or beta emitters (Surbeck, 1995). People who ingest polluted water can develop illness and with prolonged exposure to radioactive polluted water can cause cancers, toxicity of the kidneys or bear children with birth defects (WHO, 2006).

### 2.2.1 Industrial Effluent

Industrial effluent is a term used to describe liquid waste resulting from industrial activities. Effluents usually contain varying levels of organic and inorganic compounds, depending on their sources. The characteristics of industrial effluents vary widely across and within the same industry; the main determinants being the nature of raw materials used, physical and chemical processes employed, and various other factors(Wittman, 1983).. Most industries discharge their effluents into water bodies such as rivers, streams, lakes, etc(Wittman, 1983). The major concern about these effluents is that if discharged untreated, they may exhibit acute or chronic toxic effects on organisms in the receiving water bodies and result in ecological damage. One of the major visible indicators of water pollution is fish kill, which could mean a massive death of fish and other aquatic organisms in a water body (Wittman, 1983).

## 2.3 Groundwater

The quality of water available from underground aquifers may be superior in many respects to the quality of surface water. For instance, if a stream is located in a gravel stratum, a supply of suitable drinking water might be obtained by drilling or digging a well into the aquifer that recharges the river. Groundwater contains higher dissolved solids concentrations than surface waters of the same local environment. Majority of the minerals contribute to hardness (calcium and magnesium) and alkalinity (bicarbonate, carbonate, and hydroxide) due to increased concentration of carbon dioxide in the ground water (Ward and Robinson 1993).

Although, groundwater is less subject to contamination as compared to surface water, it is still contaminated by salt intrusion, domestic and industrial effluents, seepage of agricultural chemicals coupled with flooding by runoff water, all contribute to contamination (Kassas, 1978; Ajiwe, 1990). Groundwater can be extracted at any point in the geological formation but the depth and type of cover over the groundwater determine feasibility of constructing a well for water supply. Borehole is a well drilled into the sub-surface aquifer for the purpose of exploiting ground water (Powell, 1964). Aquifer is a porous and permeable rock hosting water or a water saturated geological unit or formation that may be exploited for water for economic use. It is solely drilled to provide water for drinking, domestic and industrial uses. (Leopold, 1977). Boreholes are situated in unconfined sedimentary basin that exceeds 2000m. Hand dug-wells are between 16-45m deep, there is seasonal fluctuation, the water column rises in rainy season but decreases or may dry up in dry season.

## 2.4 Radioactivity

Radioactivity is the term used to describe the disintegration of atoms. The atom can be characterized by the number of protons in its nucleus. Some natural elements are unstable therefore their nuclei disintegrate or decay, thus releasing energy in the form of radiation. This physical phenomenon is called radioactivity and the radioactive atoms are called radionuclides, or nuclides.

Unstable nuclei possess a high imbalance between protons and neutrons. Radioactive decay will occur through the disintegration of the unstable nucleus. The disintegration will result in the emission of several particles, photons, or a combination of both. The emission of these particles and photons from the unstable nucleus will be accompanied by a subsequent release of ionizing energy (Robertson *et al*, 1995). Radioactivity is therefore define as the spontaneous transformation of unstable nuclei that results in the formation of new elements with the emission of particles and radiations (Cember, 1996).

Not all radionuclides decay directly to the stable state. Some of these radionuclides will decay to another nuclide that is itself unstable, thus forming a chain of unstable nuclei. These types of chains are common in nature. The releases of ionizing energy from all subsequent radionuclides in the decay chain must be added to the energy release of the lead radionuclide to incorporate the continuous decay that occurs. The full characterization of the release of ionizing radiation from a radionuclide that leads a decay chain not only is cumulative over the existence of the parent radionuclide, but additive over the existences of each radionuclide in the decay chain as well. Each radioactive source decays at a fixed rate. Therefore, each radioactive source will exist for a fixed amount of time. A sample of radioactive material can be expressed as a source of particle emissions occurring at specific energies. These factors contribute to a cumulative release of ionizing energy over the fixed existence of the source material. The energies at which a source will disintegrate as well as the rate at which a source will disintegrate is specific to each radioisotope (Robertson *et al*, 1995).

### 2.4.1 Types of radiation

Radiation is an energy that comes from a source whereby unstable atoms become stable by emitting energy as radiation.The unstable nuclides can emit certain types of radiation known as alpha particles, beta particles, gamma rays (electromagnetic radiation) and neutrons (Esendu, 2012).

The term "radiation" is very broad, and includes such things as light and radio waves. In our context it refers to "ionizing" radiation, which means that because such radiation passes through matter, it can cause it to become electrically charged or ionized. In living tissues, the electrical ions produced by radiation can affect normal biological processes.

There are various types of radiation, each having different characteristics. The common ionizing radiations generally talked about and that can be associated with water with elevated radioactivity levels are:

**i. Alpha radiation:** This consists of heavy, positively charged particles emitted by heavy atoms of elements such as uranium and radium. Alpha radiation can be stopped completely by a sheet of paper or by the thin surface layer of our skin (epidermis). However, if alpha emitting materials are taken or ingested into the body by breathing, eating, or drinking, they can expose internal tissues directly and may, therefore, cause biological damage. (Institute for Water Quality Studies, 2002).

$$^{A}_{Z}X \rightarrow {}^{A-4}_{Z-2}Y + {}^{4}_{2}\alpha + energy \quad (2.1)$$

where X represents the chemical symbol of parent radionuclide and

Y, the chemical symbol of daughter radionuclide.

The rate of energy that is imparted to a body from a radioactive particle is defined by the linear energy transfer (LET). The quantity of LET radiation imparted to a medium will increase rapidly with the mass and the charge of the particle (Lamarsh, 1983). Therefore, alpha particle decay will impart the highest quantities of LET radiation. Particles that decay as high LET radiation have the potential to produce a greater biological effect in an absorbing medium.

**ii. Beta radiation:** This consists of electrons. They are more penetrating than alpha particles and can pass through up to around 1 centimeter of water. In general, a sheet of aluminum, a few millimeters thick, will stop beta radiation. (Institute for Water Quality Studies, 2002). Beta particles are electrons that have been ejected by the nucleus. Nuclei decay through beta particle emission through the emission of a negative beta particle (negatron) or a positive beta particle (positron). Regardless of the nature of the beta particle, sources that emit this form of decay encompass a wide range of energies. Unlike alpha particles, beta particles are found to be emitted with a continuous energy distribution ranging from zero to a theoretically expected

maximum energy. This theoretical value is based upon mass and energy considerations for each specific beta particle transition (Cember, 1989).

**a). Negative Beta ($\beta^-$) decay:** When there are an excess of neutrons compared to the stable isobar, an unstable atomic nucleus may undergo $\beta^-$ decay. There is a conversion of neutron within the parent nucleus to proton (p) with an emission of an electron and an anti-neutrino. Ignoring the other sub-nucleon particles, the transition that is occurring within the nucleus can be pictured as:

neutron→proton + negative electron + antineutrino.

In the process, one nucleon --the neutron--is converted to another --a proton.

The prototypical reaction is: (Knoll, 2000),

$$^{A}_{Z}X \rightarrow {}_{Z+1}^{A}Y + \beta^- + \bar{\nu} + \text{energy} \qquad (2.2)$$

**b). $\beta^+$ positive (Beta) decay:** The positive decay process is similar to that of beta negative decay; there is a conversion of one of protons in the nucleus to a neutron (n), a positron and neutrino during the positron emission. The transition that is occurring within the nucleus can be pictured as:

Proton → neutron + positive electron + neutrino.

The prototypical reaction is: (Knoll, 2000),

$$^{A}_{Z}X \rightarrow {}_{Z-1}^{A}Y + \beta^+ + \nu + \text{energy} \qquad (2.3)$$

**iii. Gamma rays:** This is electromagnetic radiation similar to X-rays, light, and radio waves. Gamma rays, depending on their energy, can pass right through the human body, but can be stopped by thick walls of concrete or lead. (Institute for Water Quality Studies, 2002).

**iv. Neutrons**: These are uncharged particles and do not produce ionization directly. But, their

interaction with the atoms of matter can give rise to alpha, beta, gamma, or X-rays that then produce ionization. (Institute for Water Quality Studies, 2002)

### 2.4.2 Interaction of Nuclear Radiation with Matter

Biological effects of radiation arise when ionizing radiation interacts with an organism/tissue and leaves some energy behind. The process by which electromagnetic photons are absorbed in matter depends on their energy and the atomic number of the absorbing material. Photons passing through matter transfer their energy through the following three main processes: photoelectric absorption, Compton scattering, and pair production (Figure 2.1).

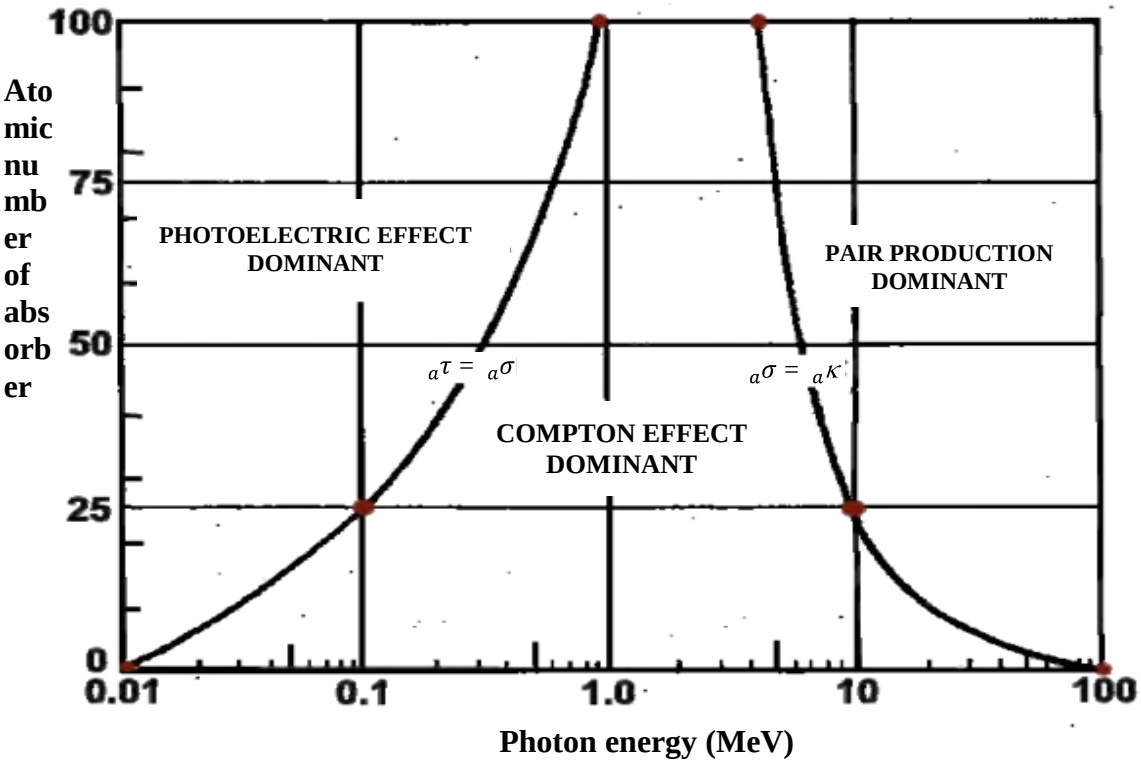


**Fig. 2.1 Dominant types of interactions as a function of the atomic number Z of the absorberand the energy of the photon radiation (Podgorsak, 2005).**

**2.4.2.1Photoelectric absorption:** In photoelectric absorption, the photon interacts with a bound inner shell electron in the atom of the absorbing medium and transfers its entire energy to the electron ejecting it from the occupied atomic shell. The incident photon disappears and the energy transferred is used to overcome the binding energy of the electron and the remainder appears as kinetic energy of the resulting photoelectron. Thus, the kinetic energy of the ejected photoelectron equals the energy of the incident photon minus the binding energy of the electron.

$$\text{Kinetic Energy}(\textbf{electr}\text{on}) = h\nu - E_b \qquad (2.4)$$

where

hν is the energy of incident photon, and $E_b$ is the binding energy of the electron.

The ejected photoelectron travels a certain distance within the absorber and loses its energy through secondary ionizations. In this way, the entire photon energy of the incident photon is deposited in the tissue irradiated. As a result, an atom that participated in photoelectric interaction is left ionized. The vacancy created due to ejection of the electron is instantly filled by an electron from an outer orbital of the same atom, emitting the balance of energy as a photon between the respective orbits with characteristic low energy. The photoelectric effect is the dominant energy transfer mechanism for X and $\gamma$ ray photons having energies below 50 keV in biological tissues, but it is much less important at higher energies. (An electron volt is a measure of energy which is the kinetic energy gained by an electron passing through a potential difference of one volt. 1 eV = 1.602 x $10^{-19}$Joules) (Podgorsak, 2005).

**2.4.2.2. Compton scattering:**The process of energy deposition called the Compton Effect occurs when the incident photon interacts with the outer orbital electron whose binding energy is very low compared with that of the incident photon. In this interaction, the incident photon transfers energy to an atomic electron causing its ejection from the atom. The photon is scattered with the remainder of the original energy in a different direction to that of the incident photon. Compton scatter thus causes ionization of the absorbing atom due to loss of an electron. The scattered electron (a secondary charged particle) travels some distance in matter and eventually loses energy by further ionization and excitation events to become part of the material. The probability of Compton scattering decreases with increasing photon energy. It is the principal absorption mechanism for X and γ rays in the intermediate energy range of 100 keV to 10 MeV. This range is in the therapeutic radiation range, and it also forms most of the γ radiation present in a nuclear explosion (Podgorsak, 2005).

**2.4.2.3. Pair production**When a photon of high energy ( >1.02 MeV) interacts with atoms of the medium, the incident photon can be spontaneously converted into the mass of an electron and positron pair by interaction of the Coulomb force in the vicinity of the nucleus. The oppositely charged particles are emitted in opposite directions to each other and cause damage as secondary charge particles. A positron is the anti-matter equivalent of an electron and it has the same mass as an electron, but it has a positive charge equal in strength to the negative charge of an electron. The energy of the interacting photon in excess of the equivalent rest mass of the two particles (1.02 MeV) appears as the kinetic energy of the pair and the recoil nucleus. The positron has a very short lifetime and, at the end of its range, it combines with a free electron. The entire mass of these two particles is then converted into two γ photons each of 0.51 MeV 17 energy emitted in opposite directions. The secondary electrons (or positrons) produced in any of these three processes frequently have enough energy to produce many further ionizations up to the end of their range(Podgorsak, 2005).

## 2.5 Measurement and Assessment of Radioactivity

Since the discovery of radioactivity by Becquerel, scientists have kept on studying and debating the work of radiation. Different terms of measurements are used depending on whether radiation is coming from a radioactive source; - the radiation dose absorbed by a person; the health risk or adverse health effects (e.g. biological effects) that a person could suffer when exposed to ionizing radiations. Activity concentration gamma dose rate, external hazard index (Hex), annual effective dose, radium equivalent activity are various approaches and terminology employed to discuss radiation measurement (Esendu, 2012)

The harmful effects of radionuclides do not come from their chemistry within tissue, but from the radiation associated with radioactive decay. Radiation of tissue increases the risk of cancer. However, the risk varies according to the type and energy of radiation, residence time in the selected tissue, and concentration of the radionuclide. Knowing these factors, the dose or

exposure to the radionuclide can be calculated. Dose is simply the product of the radionuclide intake and the appropriate dose conversion factor (DCF). Dose is reported in terms of Sieverts, which is equivalent to 1 Joule/Kg (Rahaman, 1998).

Substantial radiation doses from $^{210}$Po can be expected in many tissues of the body. In general, the spleen and kidney concentrate polonium more than other tissues except for temporary deposition in the lung after inhalation of an insoluble form. The lymph nodes and the liver are also affected. The alpha-emitters, $^{210}$Po and is highly concentrated on tobacco trichomes and insoluble particles in cigarette smoke. Levels of $^{210}$Po were measured in cigarette smoke by Radford and Hunt and in the bronchial epithelium of smokers and non-smokers by (Winters and Franza, 1982). In a person smoking 1.5 packs of cigarettes per day, the radiation dose to the bronchial epithelium in areas of bifurcation is 8000 mrem per year, the equivalent of the dose to the skin from 300 X-ray film of the chest per year (Winters and Franza, 1982). Intakes of radionuclides can occur via a number of routes such as inhalation and ingestion. The aim of dose assessment for internal exposures is to obtain from monitoring data estimates of committed effective doses or committed equivalent doses to individual organs or tissues. Monitoring data consist of measurement data on levels of radionuclides in the whole body or in organs and tissues, or on their rates of excretion or in their levels in the work environment that can be used as a basis for assessing theirintakes and for relevant dose calculations.

### 2.5.1 Absorbed Dose

The absorbed dose is defined as the quotient of dE divided by dm (Knoll, 2000),

$$D = \frac{dE}{dm} \tag{2.5}$$

wheredE is the mean energy imparted by ionizing radiation to the mass, dm, of the matter in volume element. It is a measure of energy deposition in any medium by all types of ionizing

radiation. Absorbed dose is expressed in a unit called the gray (G). A gray corresponds to one Joule per kilogram (J/kg). The gray is defined as the deposition of 1Joule in 1kg: $1G_y$= 1 J/kg

1 $G_y$= 1 Joule/kg

1 rad = 0.01sJ/kg

1 gray = 100 rad

### 2.5.2 Equivalent dose

From the biological point of view, it has been shown that equal amount of absorbed dose of different types of ionizing radiations do not have the same damage potentials. To put all type of ionizing radiations on an equal basis with regard to potential for causing harm, another quantity called dose equivalent is employed. Dose equivalent $H_{T,R}$is equal to the absorbed dose $D_{T,R}$ in an organ or tissue multiplied by the relevant radiation weighting factor, $W_{R.}$ The SI unit of equivalent dose is given as sievert (Sv) to distinguish it from absorbed dose. 1Sv = 1J/kg.

$$H_{T,R} = \Sigma W_{R.} D_{T,\,R} \qquad (2.6)$$

where

$H_T$ is the equivalent dose in J/kg or Sievert (Sv) or rem.

$D_{T,R}$is the average absorbed dose in the organ or tissue by the radiation type R

$W_{R.}$is the radiation weighting factor of the particular radiation R.

### 2.5.3 Effective Dose

Effective dose is used in radiation protection, to compare the stochastic risk of a non-uniform exposure to ionizing radiation, with the risks caused by a uniform exposure of the whole body. The stochastic risks are carcinogenesis and hereditary. It is not intended as a measure for acute or threshold effects of radiation exposure such radiation sickness or death. Effective dose equivalent is used to compare radiation doses on different body parts on an equivalent basis because radiation does not affect different parts in the same way. The effective dose (E) in Sievert (Sv) to an individual takes the radiation sensitivity of different tissue and organ into

account and it is found by calculating a weighted average of the equivalent dose (H) to different body tissues, with the weighting factors (W) designed to reflect the different radio sensitivities of the tissues: (Cember 1989)

$$E=\Sigma_i H_T W_T \qquad (2.7)$$

where

E is the effective dose to an individual, in Sievert (Sv)

$H_T$ is the equivalent to different body tissues, in $Jkg^{-1}$ or Sievert (Sv)

$W_T$. is the weighting factor.

### 2.5.4 Committed equivalent and effective dose.

When a radioactive compound enters the body, the activity will decrease with time, due both to physical decay and to biological clearance. The decrease varies from one radioactive compound to another. Accumulated dose over a certain period of time, usually 50 years, is called the committed equivalent dose $H_T(\tau)$ where $\tau$ is the integration time in years following the intake. If ($\tau$) is not specified, it is implied that the value is 50years for an adult and from intake to age 70years for children. The committed effective dose by extension is similarly defined and both refer to individual exposure (Alan and Samuel, 1986). To reflect the persistence of radionuclides in the body once ingested, the committed effective dose is a measure of the total effective dose received over a life time (50 – 70 years) following internal exposure. (WHO, 2003).

## 2.6 Chemical Effects of Radiation

Water is the most predominant molecule in living organisms (about 80 % of the mass of a living cell is water)(Podgorsak, 2005).. Therefore, a major proportion of radiation energy deposited will be absorbed in cellular water. A complex series of chemical changes occurs in water after 24 exposure to ionizing radiation. This process is called water radiolysis. The understanding of chemical changes in water is essential in studies of radiation effects on living cells. Interaction

of radiation with water causes ionization and excitation process producing short lived $H_2O^+$radical-cations, fast electrons, and electronically-excited water molecules ($H_2O^+$).$H_2O^+$ions and excited water molecules are unstable and decompose within $10^{-13}$s to form OH·and H· radicals

$$IR + H_2O \rightarrow H_2O^+ + e^-$$

$$H_2O + H_2O^+ \rightarrow H_3O^+ + OH^\bullet$$

$$IR + H_2O \rightarrow H_2O^* \rightarrow H_2O + \text{photon emitted}$$

$$H_2O^* \rightarrow OH^\bullet + H^\bullet$$

The hydroxyl radical has an unpaired electron and is a highly reactive oxidizing agent. It can diffuse a short distance and react with critical target molecules producing another radical. This can react with water forming an anion which rapidly dissociates to give a hydrogen atom (H·). The ejected secondary electrons may interact with a water molecule to form hydroxyl ions and a hydrogen atom (a hydrogen radical), or they may lose energy by a sequence of interactions with the medium until they attain thermal energies after about $10^{-11}$s. The thermalized electrons are then solvated by dielectric interactions with neighbouring water molecules to form $e^-_{aq}$i.e. $e^-_{aq}$is a free electron in a solvent cavity surrounded by a sheath of orientated water dipoles. It reacts with a proton to give a hydrogen atom (H·):

$$e^- + H_2O \rightarrow H_2O^- \rightarrow OH^- + H^\bullet$$

$$e_{aq} + H_+ \rightarrow H\bullet$$

$e_{aq}$is the strongest known reducing species at pH 7.0. In oxygenated solutions, $e_{-aq}$is converted to $O_{2-}$, which is a strong oxidizing agent and the precursor of hydrogen peroxide:

$e_{aq} + O_2 \rightarrow O_{2-}$

These primary water radicals ($e_{aq}$, OH, $H^{\bullet}$) have high reactivity towards molecules of cells, DNA, lipids and other subcellular constituents. In oxygenated solutions, hydrogen atoms can react with oxygen to give hydroperoxyl free radicals ($HO_2^{\bullet}$) (Podgorsak, 2005).

$$H^{\bullet} + O_2 \rightarrow HO_2^{\bullet}$$

The reaction of these radicals and their effects on the medium is through indirect action, which is more damaging to the medium than direct action. Thus the formation of chemical species by radiation results in chemical reactions of the species with the medium, which causes damages to biological organs (Alan and Samuel, 1992).

The relative yields of the water radiolysis products depend on the pH and LET of the radiation. The concentration of these radicals are expressed in terms of a G value which is defined as the number of radicals or molecules produced per 100 eV of energy absorbed in the medium. Typical G-values are $Ge^{-}_{aq}$= 2.6, $G_{OH^{\cdot}}$= 2.6, $G_{H^{\cdot}}$= 0.6(Podgorsak, 2005).

### 2.6.1 Other Water Quality Parameters and their Impacts on Water Uses

Physical parameters define those characteristics of water that respond to the sense of sight, touch, taste or smell (Cunningham, 2003). These are turbidity, temperature, dissolved and suspended solids .They have a marked effect upon the rate of re-aeration and therefore on the rate of self-purification of the ground water. Chemical characteristics are those that are to do with the chemical composition of water. Water is dipolar, creating a slightly positive end on the hydrogen end and slight negativity on the oxygen atom. This property makes water a very good universal solvent. Biological characteristics are those that have to do with presence of micro-organisms in water.

#### 2. 6.1.1 Physical Parameters

i. **pH:** pH, or the "potential of hydrogen", is a measure of the concentration of hydrogen ions in thewater. This measurement indicates the acidity or alkalinity of the water. On the pH scale of 0 --14, a reading of 7 is considered to be "neutral". Readings below 7 indicate

acidic conditions, while readings above 7 indicate that the water is alkaline, or basic. The more acidic the solution, the lower the pH, the more basic the higher the pH.

The scale is negatively logarithmic,

$pH = -\log[H+]$

where [H] = molar concentration of hydrogen ions, so that each whole number (reading downward) is ten times the preceding one (for example, pH 5 is 100 times as acidic as pH 7). The pH of natural waters can be made acidic or basic by human activities such as acid mine drainage and emissions from coal burning power plants and heavy automobile traffic. Naturally occurring fresh waters have a pH range between 6 and 8. The pH of the water is important because it affects the solubility and availability of nutrients, and how they can be utilized by aquatic organisms (Chapman, 1996).

ii. **Temperature:** Temperature is a measure of how cold or how hot the water is, expressed in degrees Celsius ($^{o}$C). Temperature is a critical water quality parameter, since it directly influences the amount of dissolved oxygen that is available to aquatic organisms. The amount of oxygen that will dissolve in water increases as temperature decreases. Water at 0 $^{o}$C will hold up to 14.6mg of oxygen per litre, while at 30$^{o}$C it will hold only up to 7.6 mg/L. Water temperature that exceeds 18 degrees Celsius (for Class A Waters) has a deleterious effect on several fish species in streams (Canter, 1985). For example, Salmons prefer waters of approximately 12 to 14 degrees Celsius. If the effluents from industrial cooling systems are discharged into a river, they may raise the temperatures of the river water.

iii. **Turbidity:** The American Public Health Association (APHA) defines turbidity as "the optical property of a water sample that causes light to be scattered and absorbed rather than transmitted in straight lines through the sample." In simple terms, turbidity answers the question, "How cloudy is the water?" Light's ability to pass through water depends on how

much suspended material is present. Any substance that makes water cloudy will cause turbidity. Turbidity may be caused when light is blocked by large amounts of silt, microorganisms, plant fibres, sawdust, wood ashes, chemicals and coal dust. The most frequent causes of turbidity in lakes and rivers are plankton and soil erosion from logging, mining, and dredging operations. The units of measure for turbidity are Nephelometric Turbidity Units or NTUs (Lutz, 2004).

iv. **Suspended Solids (SS):** Total Suspended Solids is the amount of material, by weight that is suspended (not dissolved) in a given volume of water and is expressed in mg/l. The solids mainly consist of living and dead phytoplankton and zooplankton, silt, human sewage, animal excrement, portions of decaying plants and animals and a vast range of industrial wastes (Cunningham, 2003). In 1980, a survey on the concentration of suspended solids in Lilongwe River, Malawi found out that suspended solids varied between 0.2 mg/l and 10 mg/l in the dry season and over 1,000 mg/l in flood flows (Dyson 1980). Large amounts of suspended matter may clog the gills of fish and shellfish and kill them directly. Suspended particles may provide a place for harmful microorganisms to lodge. Some suspended particles may provide a breeding ground for harmful bacteria (Chapman, 1996).

#### 2.6.1.2 Chemical Parameters

i. **Total Dissolved Solids (TDS):** Total dissolved solids (TDS) are a measure of the amount of particulate solids that are in solution. This is an indicator of non-point source pollution problems associated with various land use practices though point sources also contribute. The TDS measurement should be obtained with the conductivity meter and is expressed in mg/l (Chapman, 1996)).

ii. **Electrical Conductivity (EC):** Electrical Conductivity (EC) is the ability of the water to conduct an electrical current, and is an indirect measure of the ion concentration. The more ions present, the more the electricity that can be conducted by the water. EC is also an

indirect measure of Total Dissolved Solids.Electrical conductivity is directly proportional to Total Dissolved Solids. This measurement is done at 25 degrees Celsius and expressed in Micro Siemens per centimeter (μS/cm).

iii. **Dissolved Oxygen (DO):** Dissolved oxygen (DO) is the amount of oxygen dissolved in water and is measured in milligrams per litre (mg/l). This component in water is critical for the survival of aquatic life in streams, such as fish. Oxygen gets dissolved in water by diffusion from the surrounding air by aeration of water that has tumbled over falls and rapids, and as a waste product of photosynthesis. The ability of water to hold oxygen in solution is inversely proportional to its temperature. Thus, the cooler the water temperature, the more dissolved oxygen it can hold. When there is an overpopulation of aquatic life in the water, DO consumption may be high. Oxygen levels also can be reduced through over fertilization of water plants by run-off from farm fields containing phosphates and nitrates (the ingredients in fertilizers). Under these conditions, the numbers and size of water plants increase a great deal. Then, if the weather becomes cloudy for several days, respiring plants will use much of the available DO. When these plants die, they become food for bacteria, which in turn multiply and use large amounts of oxygen (Canter, 1985).

iv. **Biochemical Oxygen Demand ($BOD_5$):** Biological Oxygen Demand ($BOD_5$) is a measure of how much oxygen is used by microorganisms in aerobic oxidation, or breakdown of organic matter in the streams. The higher the amount of organic material found in the stream, the more the oxygen used for aerobic oxidation. This depletes the amount of dissolved oxygen available to other aquatic life. This measurement is obtained over a period of five days, and is expressed in mg/l. Unpolluted river waters are likely to have $BOD_5$ values of <3 mg/l and values above 5 mg/l indicate possible pollution (Harrison, 1992). The major point sources which may contribute high levels of BOD include wastewaters treatment facilities, meat and food processing plants. Good examples of non-point sources

are agricultural run-off, livestock wastes and urban wastes. In a survey conducted in Lilongwe River, the $BOD_5$ concentration varied between 0.5 mg/l and 8 mg/l. However, very high values of up to 20 mg/l were recorded downstream of the effluent discharge points (Dryton, 1980)

v. **Chemical Oxygen Demand (COD):** This parameter measures the amount of oxygen consumed for the breakdown of organic matter in a water body under the catalyst of a chemical oxidant. It also measures organic matter that does not decompose in 5 days but nonetheless eventually would decompose and affect water quality (Harrison, 1992).

vi. **Nitrate ($NO_3^-$):** Nitrate is a major ingredient of farm fertilizer and is necessary for crop production. When it rains, varying nitrate amounts are washed from farmland into nearby waterways. Nitrates also get into waterways from lawn fertilizer run-off, leaking septic tanks and cesspools, manure from farm livestock, animal wastes (including fish and birds), and discharges from car exhausts (Lutz, 2004). High levels of nitrate, along with phosphate, can over stimulate the growth of aquatic plants and algae, resulting in high dissolved oxygen consumption, causing death of fish and other aquatic organisms. This process is called eutrophication. Nitrates can be reduced to toxic nitrites in the human intestine to produce methemoglobin which causes blue baby disease in children.

vii. **Phosphates ($PO_4^{3-}$):** The element phosphorus is necessary for plant and animal growth. Phosphates enter waterways from human and animal wastes, phosphate-rich rocks, and wastes from laundries, cleaning and industrial processes, and farm fertilizers. Phosphates stimulate the growth of plankton and water plants that provide food for fish. This may increase the fish population and improve the waterway's quality of life. However if too much phosphate is present, algae and water weeds grow wildly, choke the waterway, and use up large amounts of oxygen. This is called eutrophication and may cause the death of fish and aquatic organisms. The aesthetic values of the river will dwindle; hence, the need to

control the amount of phosphates available to a water body. Generally to the humans or animals there are negligible direct effects from phosphates.

viii. **Hardness:** Hardness generally refers to the amount of calcium ions ($Ca^{+2}$) and magnesium ions ($Mg^{+2}$) in water. In household use, these cations (ions with a charge greater than +1) can prevent soap from sudsing and leave behind a white scum in bathtubs. In the aquatic environment, calcium and magnesium help keep fish from absorbing metals, such as lead, arsenic, and cadmium, into their bloodstream through their gills. Therefore, the harder the water, the less easy it is for toxic metals to absorb onto gills (Chapman 1996). Sources of calcium are soil leaching, sewage and some industrial wastes. Magnesium arises from weathering of rocks containing ferro-magnesium minerals.

ix. **Heavy Metals:** Heavy metals include metals like Lead, Cadmium, Mercury and others. Many of these metals undergo methylation, as a result of bioaccumulation where bacteria absorb these elements and convert them from a metallic state into a toxic organo-metallic state. By becoming incorporated with an organic component, these metals become readily available to the first trophic level of the food chain and eventually lead to biological magnification throughout the system.

Lead is a toxic heavy metal that has adverse effects on the human health. The common sources of lead are lead wastes, cell batteries; lead solders, lead gasoline and lead based paints. Excess exposure to lead can damage nervous systems and can also cause blood and brain disorders (Gurruswammy, 2000). In pregnant women lead can lead to miscarriages.

Cadmium is another toxic heavy metal. It can be released from car exhaust, metal processing industries, battery and paint manufacturing. Higher levels of cadmium may also be found in soils or water from industrial areas. Extreme high levels of cadmium cause lung damage and thereafter death.

#### 2.6.1.3 Biological Parameters

**i. Faecal Coliforms:** Faecal coliforms are microscopic organisms that live in the intestines of all warm blooded animals, and in animal wastes or faeces eliminated from the intestinal tract (Ritter et. al., 2002). Faecal coliforms may indicate the presence of disease carrying organisms which live in the same environment as the faecal coliform bacteria. The measurement is expressed as the number of organisms per 100 ml sample of water (N/100ml). (Dryton,1980) found out that faecal contamination in Lilongwe River was generally high with values in excess of 300 counts/100ml, in all streams that were sampled.

**ii. Quantity Parameters (Flow rate):** Flow rate is the volume of water moving past a point in a unit of time and is measured cumsecs (cubic metres per second ($m^3/s$)). Two things make up flow: the volume of water in the stream, and the velocity of the water moving past a given point. Flow affects the concentration of dissolved oxygen, natural substances, and pollutants in a water body.

### 2.7 Tobacco and Cigarette Industry

Tobacco and cigarette production industry is one of the most powerful industries in the world. The process used in this industry is confidential because of economical and rivalry reasons. The companies have to keep their product contents and their production technologies secret for several reasons. Today's tobacco products manufacturing is quite different from the ancient methods since it includes many chemical additions, to provide a better taste. Since every brand has its own secret flavour, it is almost impossible to know exact composition of these products. Non-tobacco smoking materials and denicotinization are other unknowns about tobacco manufacturing.

The tobacco manufacturing process produces liquid, solid, and airborne wastes. Liquid wastes include tobacco slurries, solvents, oils, and greases that originate from the manufacturing processes, building services, and facilities that may need special treatment or disposal. Solid

wastes include paper, wood, plastics, unusable tobacco, packaging materials and dirt that originate in the manufacturing process. These waste products are resold, recirculated, compacted, or put in landfills. Airborne wastes include non-toxic odours of manufacturing, in-plant dust, tobacco volatiles and particles, and other emissions. Abatement programmes for airborne wastes include use of filters, dust collectors and scrubbers, low-sulphur fuels, and other controls (Novotny & Zhao, 1999).

Tobacco industry wastewater contains some toxic contaminants which inhibit the microbial consortium in biological treatment plants. Sources of these toxic contaminants are nicotine, flavouring chemicals containing glycogen and alcohol, absorbable organic halogens (AOX), and pesticides from tobacco leaves ((Winters and Franza, 1982).

The tobacco manufacturing process produces liquid, solid, and airborne waste. Among the water produced in the manufacturing process are nicotine, designated by the EPA as Toxics Release Inventory (TRI) chemicals which are possible environmental health hazards. In the United States in 1992, the Toxics Release Inventory reported in the Statistical record of the environment that tobacco manufacturing generated more than 27 million kilograms of production-related chemical waste, of which 2.2 million kilograms were treated or released into the environment. Overall, the tobacco industry ranked 18th among all industries in total chemical waste production (Novotny and Zhao, 1999).

British-American Tobacco Company (BAT) located in Zaria in Kaduna state, Nigeria and other states of Nigeria is the only tobacco producing company in the country accounting for about nine different brands of cigarette tobacco smoked in the country. The tobacco leaves are produced from some farmlands located in Oke-Ogun (Ilua and Jobele areas) of Ibadan where special fertilizers are used for the growing of the tobacco leaves (Jibiri, 2011). These farms are major suppliers of tobacco leaves to British America Tobacco (BAT) Company, the major

tobacco company in Nigeria. The detrimental effects of tobacco have been considerably under estimated making it less likely that chemical carcinogens alone are responsible for the observed incidences of tobacco-related carcinoma. It is also known that tobacco companies use chemical phosphate fertilizers, year after year on the same soil (Winters and Franza, 1982).

It is therefore expected that the radioactivity level in tobacco would vary widely depending on where and how it is grown. The major source of the polonium is phosphate fertilizer which is used in .growing tobacco and the trichomes of the leaves concentrate the polonium which could persist even when tobacco leaves are dried and processed (Watson, 1983).

### 2.7.1 Wastewater Disposal Options

Wastewater disposal, refers to the management of contaminated water from industrial, commercial or domestic sewage activities.The wastewater (most of which is produced water) is deposited into deep geologic structures, many of which have trapped brine for millions of years. These structures are often a mile or more below underground drinking water sources, separated by billions of tons of impenetrable rock.

In wastewater disposal, treated wastewater is injected into the ground between layers of impermeable rocks to avoid polluting fresh water supplies or adversely affecting quality of receiving waters. Combined sewer, Evaporation pond, Groundwater recharge. Infiltration basin**,** Injection well, Irrigation, Marine dumping, Marine outfall, Sanitary sewer, Septic drain field, Sewerage, Stabilization pond, Storm drain, Surface runoff, Water reclamation are some of the known waste water disposal methods.

Injection wells are usually constructed of solid walled pipe to a deep elevation in order to prevent injectate from mixing with the surrounding environment.Injection wells are widely consideredto be the best method for disposal of treated waste water. Unlike outfalls or other direct disposal techniques, injection wells utilize the earth as a filter to further clean the treated

wastewater before it reaches the receiving water. This method of waste water disposal also serves to spread the injectate over a wide area, further decreasing environmental impacts.

The EPA has defined six classes of injection wells. Class I wells are used for the injection of municipal and industrial wastes beneath underground sources of drinking water. Class II wells are used for the injection of fluids associated with oil and gas production, including waste from hydraulic fracturing. Class III wells are used for the injection of fluids used in mineral solution mining beneath underground sources of drinking water. Class IV wells, like Class I wells, are used for the injection of hazardous wastes but inject waste into or above underground sources of drinking water instead of below. Class V wells are those used for all non-hazardous injections that are not covered by Classes I through IV. Examples of Class V wells include storm water drainage wells and septic system leach fields. Finally, Class VI wells are used for the injection of carbon dioxide for sequestration, or long term storage. Currently, there are no Class VI wells in operation, but 6 to 10 wells are expected to be in use by 2016. (EPA, 2012)

Wastewater must be managed under one of two federal laws – the Clean Water Act (CWA) or the Safe Drinking Water Act (SDWA). The CWA regulates wastewater that is discharged to surface waters. The SDWA regulates wastewater that is injected into disposal wells. This Q&A addresses wastewater managed under the SDWA. These "injection wells" are regulated under the SDWA's Underground Injection Control (UIC) program (IPAA, online source).

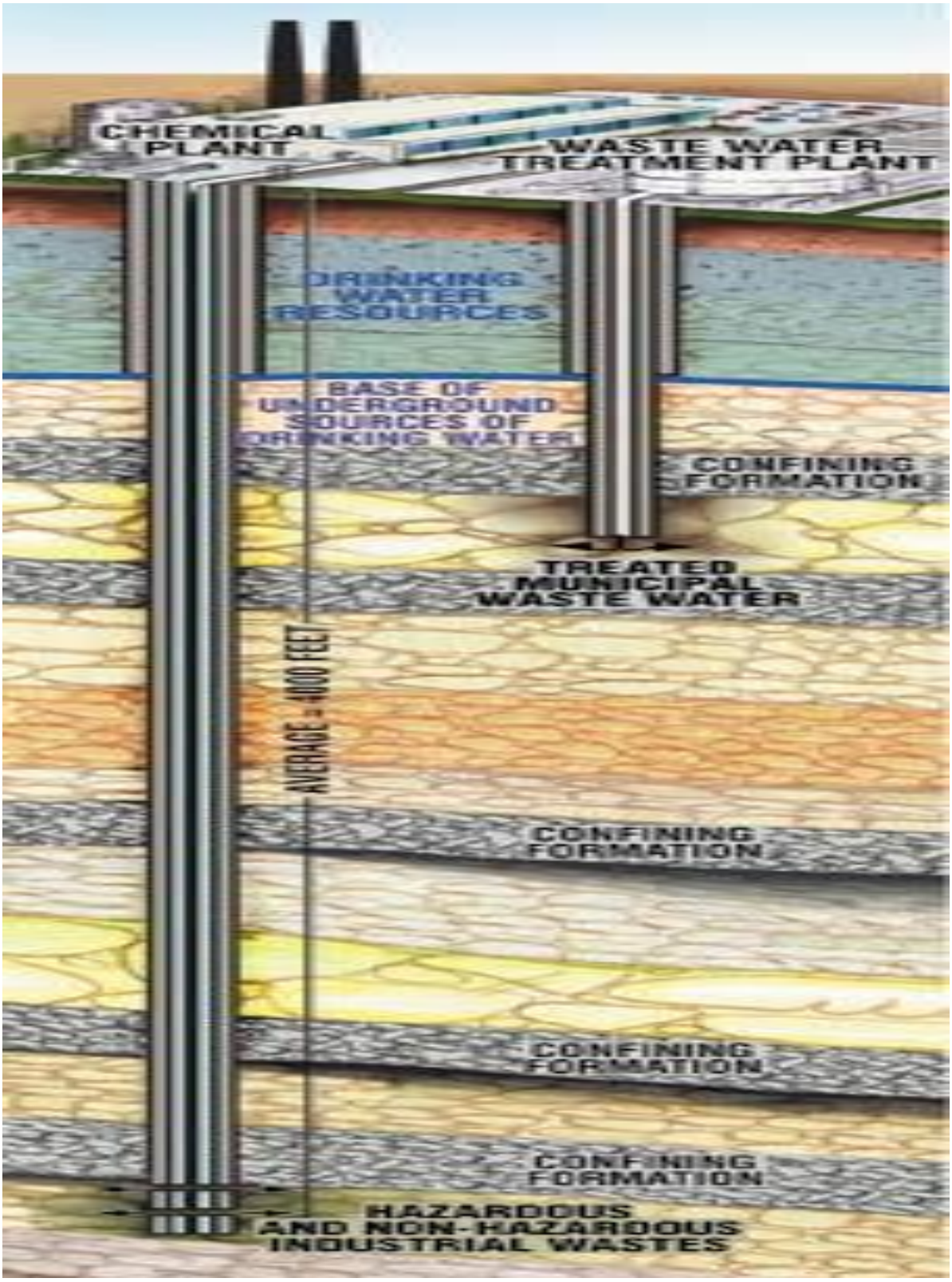


**Fig. 2.2: Deep injection well for disposal of hazardous, industrial and municipal wastewater, EPA Class I well**

## 2.8 Health Implications of Radioactivity in Water

When a radionuclide gets into the body through ingestion, inhalation or absorption through the skin, it continues to decay or disintegrate, emitting radiation such as alpha, beta or gamma radiation such that the organ or tissue is continuously irradiated. Consequently the tissue is damaged, the degree of which depends on the type of radiation. The damage is greatest with alpha, and least with gamma radiation. Some radionuclides are chemically similar to some minerals in the body and so when they are taken into the body, they mimic those minerals in the organs. For instance radium, strontium and barium are found to have chemical similarity with calcium in the bone. When these radionuclide gets into the body, they are deposited at the bone (bone seeking) causing damage to the bone cells through Osseo sarcoma (bone cancer) (Arno, 1988). This was the case of the radium dial painters in the early $20^{th}$ century, many of whom suffered degeneration of jawbones and died of anaemia following swallowing of minute amounts of radium each time a paint brush was pointed with their lips (Cember 1996). Uranium is known to have deleterious or chemo toxic effect to the kidney (Latouche, *et al.*, 1987).

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. It also suggests that the value could possibly be as high as 20 as had been shown by ICRP (Cothern, 1983). 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 radioactive radon, which has the 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 regions 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 of the mine shaft, thus leading to high concentration of radon and radon daughters in the air around the mine, of the order of $3.7 \times 10^5$ Bq/$m^3$ (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).

External contamination from low LET radiations such as X-rays and γ-rays is also detrimental to health. This is evidence from the incidence of skin cancer discovered among X-ray workers at the early discovery of medical use of X-ray. Over 100 cases of skin cancer associated with over exposure to radiations had been recorded (Cember, 1996).

### 2.8.1 Biological Effect of Radiation

Some substances formed from the chemical reactions of the radiation produced radicals, such as hydrogen peroxide, which are strongly toxic to biological cells and are stable within the cell. They may be removed by enzymes that are specifically to protect against these materials (BEIR, 1980). The cell damage may be in the form of:

i. Early death of the cell

ii. Prevention or delay of cell division

iii. A permanent modification (mutation) which is passed on to the daughter cells (Alan, 1986).

Biological effects of radiation can be acute or chronic. The acute radiation effect is a short term, deterministic effect in which high dose of radiation is received within a very short period. The individual or group must be exposed before acute effect can be got because there is a threshold amount of radiation dose (Alan, 1986). The acute radiation syndromes include vomiting,

diarrhoea, haemorrhage, gastrointestinal disorders, neuromuscular damage, shock and even death, depending on the dose of radiation (Mark and Barnett, 1976). Chronic or long-term radiation effects are those that manifest themselves long time after the original exposure. They result from low-level exposures over a very long time, or sparsely from previous acute dose effects. From the stand point of public health significance, the possibility of long term effects on the large number of people receiving low, chronic exposures is a cause for greater concern than the short-term radiation effects, which involves only a few individuals. Among the long-term effects of ionizing radiation thus far observed are cancer, cataracts, life span shortening, genetic mutation and embryological defects (BEIR, 1980). The long-term effect is stochastic, probabilistic and has no threshold and can result whether one is exposed to radiation field or not. Thus every increment of radiation dose, no matter how small, carries with it a corresponding increased probability of the long-term effects (Arno, 1988). Stochastic effects could be caused by radiation exposures through external contact with water, drinking of contaminated water, eating of contaminated food stuff, eating of meat or drinking of milk from contaminated animals.

### 2.8.2 Describing water quality in terms of its radioactivity content

The quality of water is described in terms of five water quality classes, each uniquely characterized by a colour. These water quality classes represent ranges of annual dose for daily use of a specific water source, associated health effects and typical exposure scenarios. Table 2.8.2 describes the different ranges of water quality.

**Table 2.1: Different ranges of water quality based on radioactivity**

| *Type* | *Dose range; mSv/a* | *Health Effects and Typical Exposure Scenarios* | *Intervention Decision Time Frames* |
|---|---|---|---|
| **Class 0 (Blue - Ideal water quality)** | 0.01 – 0.10 | There are no observable health effects.<br>This is the range of exposure from ideal quality water sources.<br>Most treated water falls in this water quality range.<br>Additional doses that result from human activities that fall within this range are difficult or impossible to determine and/or to distinguish from variations in background doses with sufficient confidence. | Intervention not applicable for this class of water. |
| **Class 1 (Green - Good water quality)** | 0.10 – 1 | There are no observable health effects.<br>It is the range of exposure from some natural and untreated water sources (e.g. ground water / wells) as well as water sources that could be influenced by mining and mineral processing activities.<br>A dose between 0.2 to 0.8 mSv/a is the typical worldwide range of ingestion radiation dose resulting from water as well as food.<br>A dose equal to 1 mSv/a corresponds to the regulatory public dose limit for human activities involving radioactive material. | No intervention is required although ALARA principles apply. |
| **Class 2 (Yellow-Marginal water quality)** | > 1 – 10 | A small increase in fatal cancer risk associated with this dose range.<br>Probably only a small number of natural water sources of this quality exist, resulting from exceptional geological conditions.<br>Abnormal operating conditions at some nuclear certified mineral and mining processes may result in a dose in this range when a person drinks the untreated water. Intervention will most likely be required to improve the quality of water that is released into the public domain.<br>The total natural background radiation from all exposure pathways, not only water, falls in this range. | Intervention considerations within 2 years. |
| **Class 3 (Red – Poor water quality)** | > 10 – 100 | Health effects are statistically detectable in very large population groups.<br>This range represents excessive exposure.<br>It is highly unlikely to find water of this poor quality in the natural environment. | Intervention is required in less than 1 year. |
| **Class 4 (Purple-Unacceptable water quality)** | 100 | Health effects may be clinically detectable and a significant increase in the fatal cancer risk (greater than one in a thousand).<br>A dose greater than 100 mSv can usually only occur during a major accident at a nuclear facility. These facilities have to demonstrate that such an accident cannot happen with a frequency of more than once in a million years. | Immediate intervention is required. |

Source: Department Of Water Affairs and Forestry, Institute of Water Quality 2002

This relation can only be established after many samples over a period of time. It was also shown that gross alpha activity concentrations could not be accurately correlated with dose. (Institute for Water Quality Studies, 2002)

## 2.9 Review of the Previous Works

Mahabir Nain et al, (2008) In their work, Alpha radioactivity in tobacco leaves: Effect of fertilizers, estimated the alpha radioactivity in tobacco leaves taken from tobacco plants grown using different types of chemical fertilizers like diammonium phosphate (DAP), zinc sulphate, potash, super phosphate, urea etc. in varying amounts before the plantation of the seedlings were made.

According to them, there are many reports on the presence of naturally occurring radionuclides viz., $^{210}$Pband $^{210}$Po in tobacco. Investigations on alpha-emitting radionuclides, especially on $^{210}$Po have gained significant importance as alpha interactions with chromosomes of cells may contribute to early arteriosclerosis developments in tobacco smokers. Due to relatively high activity concentration of $^{210}$Po and $^{210}$Pb that are found in tobacco and its product, cigarette can increase the internal intake of both the radionuclides and their concentrations in lung tissues. This causes an increase in the internal radiation dose which enhances the instances of lung cancer. Many workers have tried to explain the role of $^{210}$Po in tobacco in the epidemiological investigation of cancer and tumour formation. For these measurements α-sensitive LR-115 type II plastic track detectors were used. The results indicated an increase in alpha radioactivity with the use of some fertilizers.

Impact of brewery effluent on water quality in Majawe was investigated by Alao O. *et al*, 2010. Water quality assessment was carried out on samples collected at 4 different sampling points; effluent discharge point, 500 meters away and two other discharge points downstream. The physicochemical parameters studies shows that surface water and brewery effluent deviated from the WHO and FMENV standards but ground water sample was in line with the standards.

Taken together these findings show that there is contamination of surface water by brewery effluent, however groundwater was non-toxic and therefore safe for drinking purposes.

The impact of industrial effluent on water quality criteria of a river within Asa Dam industrial estate, Ilorin was investigated. Physicochemical and bacteriological properties of samples of the river were examined to determine the quality and extent of pollution. The effluents were found to cause gross pollution of the river. Total hardness ranged between 51 and 175.5 mg/l; while conductivity was between 65 and 318 μs. Calcium and Magnesium ions varied between 33.7 and 102.3 mg/l, and 3.5 and 57.1 mg/l respectively. E. coli was found in the samples and the coliforms counts were high. The major sources of pollution were identified to be the direct runoff from the industries and refuse dumps within the estate (Adekunle and Eniola, 2008).

The radionuclide concentration levels in surface soils in Ijero-Ekiti community (Ajayi*et al*., 1999) and in soil and water samples obtained around production facilities of cement companies in Ewekoro and Port Harcourt cities in Nigeria (Avwiri, 2005; Jubril*et al*., 1999) and in rocks found in Ekiti by Ajayi*et, al*., (1999) were measured. Results from these studies did not reveal any significant level of radionuclides in the environment.

Nwankwo (2008, 2010) determined the levels of radioactivity in groundwater within the University of Ilorin permanent site but no significant results were recorded. However, in a recent study of natural radioactivity of groundwater in Sango-Ilorin, the ingestion dose for some of the groundwater samples were above the new WHO recommended level of 0.1 mSv/yr for drinking water but falls within the tolerable level of 1 mSv/yr to the general public for prolonged exposure as recommended by ICRP (Nwankwo, 2012).

Jibiri (2011) in his study, soil samples from three farmlands in Ibadan used by British. American Tobacco for the production of the tobacco leaves were collected in order to determine the activity concentrations of $^{232}$Th, $^{226}$Ra and $^{40}$K in the farm soil, reported amidst his

conclusion that apparently, thespecialized fertilizer used in the tobacco leaf production may be responsible for the high values obtained in the study. He affirmed that through root uptake these radionuclides may accumulate on the tobacco plant in large quantities and will be a major source of internal alpha radiation dose burden to smokers especially from $^{210}Po$; as the trichomes of the tobacco leaves is known to concentrate polonium, which persists even when tobacco is dried and processed (Jibiri*et al;* 2011).

Mumbacarried out a study in a strip of a river and in a nearby well in the rainy and dry seasons to assess the impact of tobacco waste disposal on the roadsides. He reported significant seasonal variations in the concentration of nicotine being higher ($p<0.05$) in the dry season than in the wet season. Regardless of season however, nicotine was observed in highest amounts close to the dumpsite and none or just trace amounts were obtained upstream and in the well water. In the rainy season, the concentrations varied significantly ($p<0.05$) across the sample points, being highest at point close to the dumpsite followed by the value upstream and the least was obtained downstream (Mumba and Phiri, 2008).

Some work has been done on measurement of radioactivity in water in Nigeria. Onoja determined gross alpha and beta activity in well water from Zaria area. The result shows geometric mean value of 75.53 Bq/m3 (or 0.07553 Bq/l) for beta activity (Onoja, 2004). Tajudeen did similar work in Gwammaja area of Kano metropolitan city and the result shows a geometric mean value of 0.05 Bq/m3 for beta activity (Tajudeen, 2006). Habila worked on survey of gross beta radioactivity in wells and boreholes from Jos city .The result shows ranges of beta activity from 0.25 to 9.64 Bq/l, with a Geometric mean of 1.56 Bq/l (Habila, 2008). Avwiri and Agbalagba surveyed gross beta radionulide activity in Okpare-Creek Delta State and reported that mean beta activity was 0.481 Bq/l (Avwiry and Agbalagba, 2007).

Saidu (2010) worked on gross beta radioactivity in wells and boreholes water in Sokoto city. The result obtained from proportional counter shows that the beta activity for: wells ranges from 0.35 to 49.85 Bq/l with geometric mean of 4.86 Bq/l; and that of boreholes ranges from 0.71 to 32.69 Bq/l with geometric mean of 3.38 Bq/l. These results also show activities above practical screening level. Although Saidu carried out his work within Sokoto city but the water samples from UsmanuDanfodiyo University permanent site was not included. This is the reason why it deem necessary to carry out this research for the fact that the major source of drinking water on the campus is underground water.

Baba-kutigi, *et al*, (2012) in his work 'Analysis of Gross Alpha and Gross Beta Radioactivity in Sachet Water Hawked in BirninKebbi, Kebbi State' reported that 85.71 % of the alpha activity and 7.1 % of the beta activity were below the contaminant limit of 0.5 and 1.0 Bq/l respectively, as set out by WHO (2006), while 14.29 % of the alpha activity and 92.9 % of the beta activity were above the contaminant limit.

An assessment of levels of natural radioactivity in groundwater of parts of Sheet 102, Zaria was carried out by Garba*et al., (*2013). A total of 20 groundwater samples were collected and analyzed for gross alpha and gross beta radioactivity, using a liquid scintillation counter. Results obtained showed that the gross alpha radioactivity of the groundwater ranged from <0.01 Bq/l to 0.035 Bq/l, with a mean of 0.0149 Bq/l. Gross beta radioactivity ranged from 0.06 Bq/l to 0.91Bq/l with a mean of 0.3295 Bq/l. Results obtained for both the gross alpha and beta for all samples studied fall within the World Health Organization (WHO) 1999 Drinking water standards of 0.1Bq/l for alpha and 1.0 Bq/l for gross beta.

Importance of water quality assessment and monitoring in the context of radioactivity cannot be overemphasized. Akinloye (1998) studied the radioactivity in a number of media, which include meat, fish, soil and water, as part of a pre-operational study of the nuclear facilities located in

the Obafemi Awolowo University, Ile-Ife campus, Nigeria. The results of the studies showed that no man-made radionuclides were measured.

Vengosh*et al.* (2009) reported that high levels of naturally occurring and carcinogenic radium isotopes have been measured in low saline and toxic groundwater from the Rum Group of the Disk sandstone aquifer in Jordan. They revealed that the combined $^{228}$Ra and $^{226}$Ra activities in their study area are up to 2000 % higher than international drinking water standards.

# CHAPTER THREE

# MATERIALS AND METHODS

## 3.1 Materials

The following are the list of materials used in this study

**Equipment**

i. Single channel, gas free portable MPC 2000 gross Alpha/Beta counter
ii. Hot plate
iii. 100 ml - 1500 ml Beakers (Pyrex)
iv. 2 L plastic containers
v. Graduated measuring cylinder (100 $cm^3$)
vi. Porcelain Dish (50ml)
vii. Sterilized spatula
viii. Placket (3 cm stainless steel)
ix. Weighing balance
x. Gloves
xi. Needle and Syringe
xii. Masking tape
xiii. Thermometer

**Chemicals**

i. Concentrated Nitric acid of concentration 1.5 g/ml
ii. Freshly distilled water,
iii. Vinyl acetate and Acetone,

## 3.2 Methodology

### 3.2.1 The Study Area

The study area lies within latitudes $11^0$5’30"N and $11^0$ 7 50"N and longitudes $7^0$ 42' 25"E to $7^0$ 44' 45"E and is shown in Fig.3.1. The study area is within the Guinea Savanna belt (Sheet 21, Zaria) and Zaria is located on a plateau at a height of about 670 m above sea level and more than 640 km away from the sea (Hore, 1970). It is accessible by road within Zaria metropolis. It has a typical savannah climate of distinct wet and dry seasons, with a moderate rainfall of about 1047 mm/a (Garba and Schoeneich, 2003). The rainy season usually starts in May and ends in October and the dry season starts from late October to April.

#### 3.2.1.1 Experimental Design

The field data collection was carried out in the month of March and it lasted for about one week. The period was chosen because it represents the peak of the dry season in the study area. This is also the time when water quality determination is critical; no flow of one source into another and good accessibility is enhanced. Groundwater (Borehole and well) samples from tobacco company areas in Zaria covering Guinea Savanna belt (Sheet 21, Zaria) were collected.

#### 3.2.1.2 Sample population

The sample population is regarded as target population. In this work the target population is the drinking (potable) water collected from boreholes and hand-dug wells in the study area around the Tobacco Company in Zaria.Samples were collected at random and based on availability of hand-dug wells and boreholes. A Geographical Position System (GPS Meter) was used to obtained co-ordinates and elevations of the sampling points, as presented in Table 4.1.

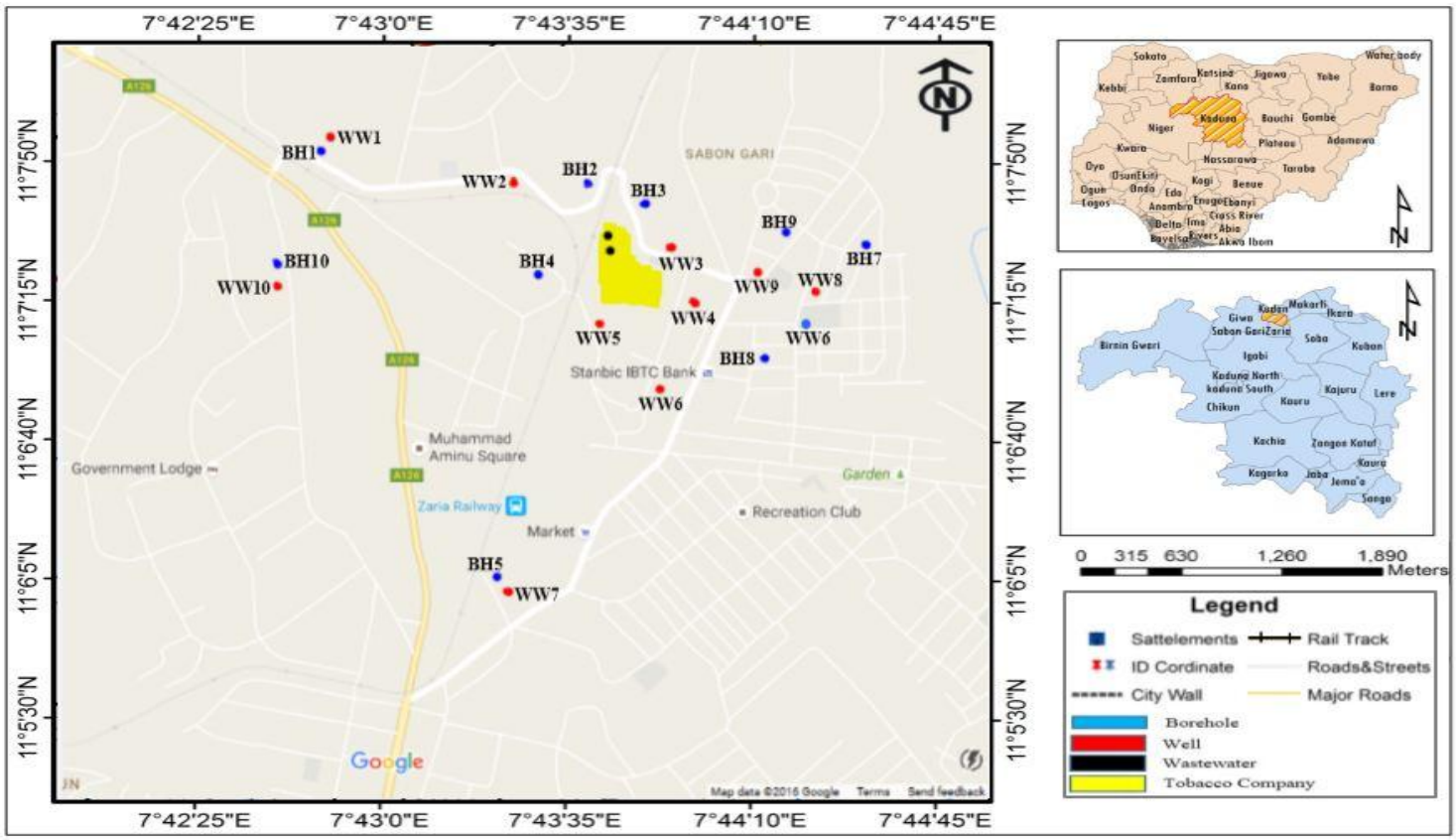


Fig. 3.1 Digitalized satellite image of the study area
Source: Satellite image of Zaria,

### 3.2.2 Sample Collection

Twenty-two (22) water samples consisting of ten (10) borehole samples, two (2) tobacco wastewater samples from the discharge point of the company and ten (10) well water samples were collected from the study area.

Four (4) of the sampled water, control samples, each from borehole and well water, were taken from two different locations far off the tobacco plant. Two litres of the water samples were drawn from each borehole and well source in a plastic container which was rinsed twice with the water sample to avoid cross contamination. Immediately after collection, the sample was acidified with nitric acid to reduce the pH to less than 2 in order to retain the radioactivity content in the samples, minimized precipitation and adsorption by the walls of the container as well as to prevent the growth of micro-organisms. The amount of water collected was such that an air space of 1% of the container capacity was left for thermal expansion. The samples were air tight.

### 3.2.3 Sample Preparation

Each of the water sample was evaporated in an open 600ml beaker using electric hot plates, this was done at moderate heat temperature without stirringto avoid thermal agitation that could lead to the evaporation of required residue.It took an average of about 16 hours to complete the evaporation of one litre of each sample.In the process of evaporation, when the level of sample in the beaker was about 50 ml, it was then transferred into a petri-dish and placed under infrared light source to completely dry the residue. After evaporation, residues were kept in the desiccators until they were ready for counting. It was then allowed to cool before weighing was done. The weight of the residue was obtained by subtracting the weight of the empty petri-dish from the weight of petri-dish plus sample residue. An empty planchette was weighed after whichabout 0.077 g of the residue was transferred to the planchette (ISO-STANDARD). The planchette plus residue was then weighted. A few drops of Vinyl acetate were put on the sample

to make them stick to the planchette to prevent scattering of the residue during counting. Few drops of Acetone were used to sterilizethe planchets in order to prevent cross contamination.

### 3.2.4 Analysis

Volume, *V*, of sample that will produce 0.077 g was calculated using the relationship in equation (3.1): (Mangset*et al*, 2014).

$$0.077\ \text{g} \times V_T = T_R \text{V} \qquad (3.1)$$

where

$V_T$ = Volume that produce the total residue

$T_R$ = Weight of the total residue
$V$ = Volume that will give 0.077 g

**Sample preparation efficiency**

For samples with residues less than 0.077g, sample preparation efficiency could be obtained from

the relation in equation (3.2): (Mangset*et al* 2014)

$$\text{Sample preparation efficiency} = \frac{weight_{of residue}}{0.077g} \times 100\% \qquad (3.2)$$

**Sample efficiency**

Sample efficiency could be calculated from the relationship in equation (3.3) (Onoja*et al*,2013)

$$\text{Sample efficiency} = \frac{R_P}{T_R} \times 100\% \qquad (3.3)$$

where:

$R_P$ = Sample weight on the planchette in (mg)

$T_R$ = The total sample weight from evaporating 1000 ml of water sample weigh in (mg)

**Statistical Analysis:**The statistical analyses used for the analysis of gross alpha and beta activity concentration include estimation of the central tendencies, standard deviations and histogram distributions.

**Statistical Precision:** This was calculated for each channel on each measurement and it depends only on the preset count whose value is declared indirectly. Assuming N measurements are made during a time T so that $x_i$ values are obtained (from N measurements), according to a normal distribution law of averages, the average (mean) value $\bar{X}$ is given by expression (Nwoke, 2006):

$$\bar{X} = \sum \frac{x_i}{N} \quad (3.4)$$

**Standard Deviation:** The standard deviation, $\delta$, associated with the activity of thesample corrected for background is calculated (ISO 9697: 1992 (E) ) as

$$\delta = \sqrt{\frac{R_b}{t_o}} + \frac{R_a}{t_o} \times \frac{14.4 \times m \times 1.02}{(R_b - R_{o)} \times 1000 \times V} \quad (3.5)$$

$R_b$ is observed sample count rate ($S^{-1}$), $R_o$ is background count rate ($S^{-1}$), Vis volume of sample in litres, m is mass in milligrams of ignited residue from volume V**;** the factor 1.020 was included in the final equation to correct for the 20 ml of the Nitric acid added to the sample as a stabilizer.

### 3.3 Instrumentation

Single channel, gas free portable MPC 2000 gross Alpha/Beta counter was used in analyzing the preserved sample.

#### 3.3.1 Gross Alpha and Beta Counter (MPC-2000-DP*)*

The gross alpha and beta counting equipment used for this research is Desktop lightweight gross alpha/beta counter, MPC 2000 model. The machine has alpha plus beta, alpha only and beta only modes respectively. It uses critical portions of PIC's electronic and mechanical designs that have been successful in other systems. It has modern control and interface options, a significantly reduced footprint, and a non-gas flow detector option. The MPC-2000 has two

detector options available. A 2" active area, gas flow proportional detector is standard. This detector can be used with or without a user changeable ultra-thin entrance window. An optional non-gas flow detector is also available. The MPC-2000-DP version (with non-gas flow detector) used in this study completely eliminates the need for tanks of compressed counting gas. The sample drawer has been carefully designed to require the least effort and range of motion from users. The design greatly reduces the chance of repetitive motion injury. The sample drawer design also gives clear, unambiguous feedback to show that it is open or closed.

#### 3.3.1.1 EfficiencyCalibration

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

**Equipment Standard**

The alpha standard used for this project work is plutonium-239 sources. It is a sealed calibration source used to determine efficiency in the proportional counter. While the beta standard is strontium-90.The alpha and beta standards were used to calibrate the proportional counter.

**Background Measurement:**This measurement is aimed at getting the channel efficiency. It was carried out with empty counting planchette, washed with deionized water and dried. The operational high voltages, 1650 V was set for alpha and 1650 V for beta. The background radioactivity of the detector was determined with measurement for length of time that routine sample were counted and were measured using a clean, empty planchette in the detector. The repetitive determination of background served as a check on the operation of the system, with average values of 0.0015 and 0.02 cpm background counting rate for alpha and beta respectively. The background count rates were recorded in counts per minute in alpha only and beta only modes.

**Plateau Test:** This test was used to verify the suitable optimal and operational voltages for the different counting modes. The modes employed are alpha($\boldsymbol{\alpha}$) only and beta ($\boldsymbol{\beta}$) only mode using $^{239}$Pu and $^{90}$Sr standards respectively. For each of the mode, the voltage is varied from the

minimum to a maximum specified voltage at intervals of 50V until a 'plateau' line parallel to the time axis is obtained depicting the operational voltage of 1650V at which the detector was efficient for the required purpose.

#### 3.3.1.2 Counting

For the gross alpha and beta counting, the sample was placed in a 5 cm diameter stainless steel planchette and the planchette was placed in a sample carrier. The carrier was then placed on the sample drawer and closed. The procedure involves entering the present time, number of cycles and the operational voltage. Counting was done automatically according to the selected count mode when the appropriate sample information (detector efficiency and background count rate, volume of sample used and sample efficiency) was entered. The operating voltage obtained from the plateau test was on the detector was selected to be 1650 V. The system was calibrated for alpha and beta energies by preparing standard samples which contains equal concentrations of $^{239}$Pu (931 Bq) and $^{90}$Sr (931 Bq). The counting efficiencies, being the calibration factor, for the system are 87.95 % for alpha and 42.06 % for beta.The count characteristics (channel efficiency and background count rate) data for the detector were collected, stored and used for corrections. The background of the detector was determined with measurement for length of time that routine sample were counted and were measured using a clean, empty planchette in the detector. The repetitive determination of background served as a check on the operation of the system, with average values of 0.0015 and 0.02 cpm background counting rate for alpha and beta respectively. The minimum Detectable Activity MDA is expressed (Curie, 1968).

$$\text{MDA (Bq/l)} = \frac{L_d}{VT\varepsilon\ 60} \tag{3.6}$$

$$\text{with} L_d = 2.71 + 4.65\sqrt{C_B T}$$

where$V$ is the volume of sample (l)

$T$ in (min) is the sample measuring time (which is the same as for the background)

$\varepsilon$ is the efficiency and $C_B$ is the background count rate (count per minute)

### 3.3.1.3 Alpha/ Beta - Activity presentation

The activity concentration (C) in Becquerel per litre for gross alpha/ beta was calculated using the expression in equation (3.7) (Baba-Kutigi*et al,* 2012)

$$C\ (Bq/l) = \frac{\text{Net count}}{CE \times SE \times SV} \times 0.0167 \qquad (3.7)$$

0.0167 is a conversion factor from count per minute (cpm) to count per second (cps)

Net count = Sample count rate – Background count rate

$$\text{The sample count rate} = \frac{Raw\ sample\ count}{Count\ time} \qquad (3.8)$$

where

C = activity in Becquerel per Litre,
SE = The sample efficiency
CE = The channel efficiency
SV = Volume of water (1)

### 3.3.1.4 Contour Distribution

The gross alpha and gross beta activity concentrations were shown in contour distributions. This is aimed at finding out the geographical areas of high distribution.

### 3.3.2Measurement of Electrical Conductivity (EC)

The conductivity of water is a measure of the ability of water to carry an electric current. The conductivity of water is directly linked to the concentration of the ions and their mobility. The ions in water acts as electrolytes and conducts the electricity. The Conductivity depends on the value of the pH, on the temperature of measurement and on the amount of $CO_2$ which has been dissolve in water in forms of ions. In fact chemical composition of water determines its conductivity.

Conductivity is measured with probe and a meter. A voltage is applied between the two electrodes in the probe immersed in the sample water. The meter converts the probe measurement to micro mhos per centimetre and displayed the result.

Materials used for the experiment are:

1. A clean, properly sterilized beaker (250mL), measuring jar, and funnel that was free of dust or other particles, magnetic stirrer.
2. A sample of the water to be analysed, collected into the sterilized beaker. Ideally, the sample should be at 25° C (or 77° F) at the time of analysis.
3. An electrical conductivity meter HD2306 with electrodes — a device used to measure a solution's ability to conduct electricity. It works by releasing a current into a liquid, then measuring the resistance.

Chemicals used for the experiment are:

1. Potassium Chloride
2. Distilled water

**Calibration of Conductivity Meter:** A beakercontaining 0.1 N of Potassium Chloride (0.7456 g of Potassium Chloride mixed with distilled water) was placed on a magnetic stirrer and the magnetic stirrer was switched on. The electrode was placed inside the solution. The calibration button was enabled and the conductivity of the 0.1 N of potassium chloride solution was adjusted to 14.12 microsiemens / cm at 30 $^{0}$C. The conductivity meter was ready for the measurement of samples.

**Measurement:** The beaker with the water sample in it was placed on a flat, stable surface. The measuring lead of the electrical conductivity meter was inserted into the sample. The conductivity meter was turned on thus releasing a current into the liquid thus measuring the resistance of the sample.

- The reading on the conductivity meter is allowed to stabilize (wait a few seconds until the number on the display stops changing) before taking the readings.
- The measurement displayed on the electrical conductivity meter is the purity of the water, measured in µS (micro-Siemens). The lower the µS value, the purer the water, with 0 µS being pure, unpolluted water.

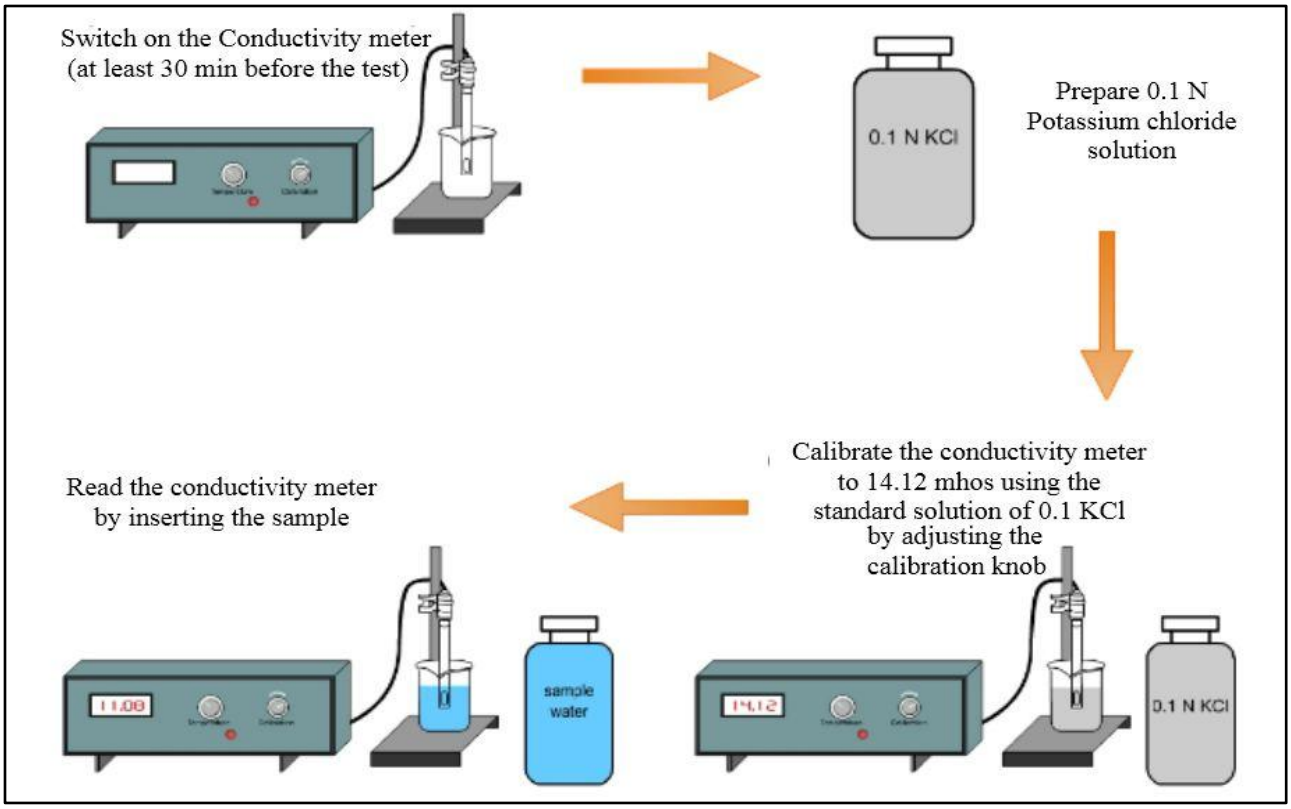


**Fig. 3.2: Measurement of electrical conductivity**

### 3.3.3 Determination of Total Dissolved Solids (TDS).

Data recorded will be plugged into the basic formula for calculating total dissolved solids using the modified relation in equation (3.9)(Onoja,*et al* 2013).

$$TDS\ (mg/l) = EC \times CF \qquad (3,9)$$

Where, EC is conductivity of each sample (the reading from electrical conductivity meter), and CF is the correlation factor.

The correlation factor depends on the liquid being used as the sample, and it may also vary according to atmospheric conditions. It varies between 0.55 and 0.96. The correlation factor at the current temperature and in the current pressure conditions is 0.67.

### 3.3.4 Determination of Effective dose

The annual alpha and beta effective dose due to intake of water was determined by averaging the individual annual committed effective doses contributed by the major alpha and beta emitters in the U-238 and Th-232 series of the naturally occurring radionuclides using the relation (UNSCEAR, 2000):

$$E_{avg}(\alpha/\beta) = \sum_{i}^{R(\alpha/\beta)} A_{i(\alpha/\beta)}) \times DCF_{i(\alpha/\beta)} \times 730$$

Assume a daily water intake of 2 L/day is assumed (EPA, 2000–05) thus resulting in annual consumption rate of 730 L/year.

where $E_{avg}(\alpha/\beta)$ is the average gross annual alpha or beta committed effective dose in the drinkable water, $A_{i(\alpha/\beta)}$ is the gross alpha or beta activity concentration of individual radionuclides present in the water sample and $DCF_{i(\alpha/\beta)}$ is the dose conversion factor ($3.58 \times 10^{-7}$Sv/yr) for ingestion of the individual natural radionuclides for an adult (UNSCEAR 2000).

# CHAPTER FOUR

# RESULTS AND DISCUSSION

## 4.1 Introduction

The purpose of this study was to assess the effect of tobacco effluent on radioactivity and other parameters of groundwater around the company in Chikaji, Zaria, Kaduna, Nigeria. The statistical analyses used for the analysis of gross alpha and beta activity concentration include estimation of the central tendencies, deviations and histogram distributions. Contour distributions aimed at finding out the geographical areas of high distribution of radioactivity was employed using Surfer 12.0 Golden computer software.

Therefore, in this chapter analytical summary of results of this research were presented, discussion on the results were also made and presented. Here, the core concern of the entire work is presented with the purpose of providing basis for conclusion and highlighting the study's contribution to knowledge. Therefore, descriptive and inferential analysis are presented in such a way that the aim and objectives of the study are addressed thereby paving way for recommendations hence decision making using findings from the literature review.

## 4.2 Results

Table 4.1presents the physical parameters such as pH, Temperature, Conductivity, and Total Dissolve Solids while table 4.2 presents the measured gross alpha and gross beta radioactivity in water samples from the study area.

**Table 4.1 Physical parameters measured in the samples.**

| Sample ID | Geographical coordinate | | pH | Temperature ($^0$C) | Conductivity (μS/cm) | TDS (mg/l) |
|---|---|---|---|---|---|---|
| | Longitude | Latitude | | | | |
| **WW1** | **11.122 $^0$** | **7.718 $^0$** | **5.0** | **29.6** | **512** | **343.07** |
| **WW2** | **11.122 $^0$** | **7.718 $^0$** | **5.0** | **29.2** | **405** | **271.35** |
| **WW3** | **11.119 $^0$** | **7.730 $^0$** | **5.0** | **28.9** | **350** | **234.50** |
| **WW4** | **11.119 $^0$** | **7.730 $^0$** | **5.5** | **29,0** | **255** | **170.85** |
| **WW5** | **11.107 $^0$** | **7.723 $^0$** | **5.0** | **30.4** | **513** | **343.71** |
| **WW6** | **11.118 $^0$** | **7.730 $^0$** | **5.0** | **27.6** | **348** | **233.16** |
| **WW7*** | **11.119 $^0$** | **7.735 $^0$** | **5.0** | **24.8** | **196** | **131.32** |
| **WW8** | **11.119 $^0$** | **7.732 $^0$** | **5.0** | **25.6** | **240** | **160.80** |
| **WW9** | **11.124 $^0$** | **7.723 $^0$** | **5.0** | **29.5** | **330** | **221.10** |
| **WW10*** | **11.117 $^0$** | **7.717 $^0$** | **4.5** | **28.0** | **260** | **174.20** |
| **BHW1** | **11.122 $^0$** | **7.718 $^0$** | **6.0** | **27.5** | **500** | **335.00** |
| **BHW2** | **11.122 $^0$** | **7.718 $^0$** | **5.0** | **25.2** | **415** | **278.05** |
| **BHW3** | **11.123 $^0$** | **7.725 $^0$** | **5.0** | **28.5** | **450** | **301.50** |
| **BHW4** | **11.117 $^0$** | **7.725 $^0$** | **5.5** | **26.4** | **355** | **237.85** |
| **BHW5*** | **11.107 $^0$** | **7.723 $^0$** | **5.0** | **28.5** | **510** | **341.70** |
| **BHW6** | **11.118 $^0$** | **7.730 $^0$** | **6.5** | **29.7** | **460** | **308.20** |
| **BHW7** | **11.119 $^0$** | **7.735 $^0$** | **5.0** | **28.4** | **396** | **265.32** |
| **BHW8** | **11.119 $^0$** | **7.732 $^0$** | **4.5** | **27.7** | **440** | **294.80** |
| **BHW9** | **11.107 $^0$** | **7.723 $^0$** | **5.0** | **25.5** | **445** | **298.15** |
| **BHW10*** | **11.117 $^0$** | **7.717 $^0$** | **5.0** | **25.6** | **480** | **321.60** |
| **TWW1** | **11.119 $^0$** | **7.718 $^0$** | **7.0** | **38.5** | **570** | **381.90** |
| **TWW2** | **11.123 $^0$** | **7.718 $^0$** | **6.0** | **40.2** | **650** | **435.50** |

WW: Well Water, BHW: Borehole Water; TWW: Tobacco WasteWater* Control sample

**Table 4.2: Gross alpha and beta activity in the studied samples:**

| Sample ID | Geographical coordinate | | Elevation (m) | Gross Alpha Activity [Bq/l] | Gross Beta Activity [Bq/l] |
|---|---|---|---|---|---|
| | Longitude | Latitude | | | |
| **WW1** | **11.122 $^0$** | **7.718 $^0$** | **640.0** | **0.010 ± 0.001** | **0.530± 0.022** |
| **WW2** | **11.122 $^0$** | **7.718 $^0$** | **653.4** | **0.011 ± 0.001** | **0.009 ± 0.042** |
| **WW3** | **11.119 $^0$** | **7.730 $^0$** | **629.0** | **0.285 ± 0.016** | **0.001± 0.207** |
| **WW4** | **11.119 $^0$** | **7.730 $^0$** | **598.8** | **0.144 ± 0.002** | **0.960 ± 0.104** |
| **WW5** | **11.107 $^0$** | **7.723 $^0$** | **631.0** | **0.023 ± 0.001** | **0.265 ± 0.042** |
| **WW6** | **11.118 $^0$** | **7.730 $^0$** | **629.0** | **0.020 ± 0.002** | **1.150 ± 0.090** |
| **WW7*** | **11.119 $^0$** | **7.735 $^0$** | **631.0** | **0.031 ± 0.007** | **3.810 ± 0.377** |
| **WW8** | **11.119 $^0$** | **7.732 $^0$** | **632.9** | **0.002 ± 0.002** | **0.220 ± 0.093** |
| **WW9** | **11.124 $^0$** | **7.723 $^0$** | **602.6** | **0.009 ± 0.004** | **0.382 ± 0.020** |
| **WW10*** | **11.117 $^0$** | **7.717 $^0$** | **495.0** | **0.021 ±0.001** | **1.544 ± 0.063** |
| **BHW1** | **11.122 $^0$** | **7.718 $^0$** | **640.0** | **0.051± 0.003** | **1.547 ± 0.070** |
| **BHW2** | **11.122 $^0$** | **7.718 $^0$** | **653.4** | **0.060 ± 0.001** | **1.532 ±0.097** |
| **BHW3** | **11.123 $^0$** | **7.725 $^0$** | **538.4** | **0.025 ±0.000** | **2.199 ± 0.015** |
| **BHW4** | **11.117 $^0$** | **7.725 $^0$** | **629.0** | **0.017 ± 0.001** | **0.861 ± 0.054** |
| **BHW5*** | **11.107 $^0$** | **7.723 $^0$** | **631.0** | **0.133 ± 0.004** | **2.190 ± 0.160** |
| **BHW6** | **11.118 $^0$** | **7.730 $^0$** | **629.0** | **0.037 ±0.001** | **0.591± 0.068** |
| **BHW7** | **11.119 $^0$** | **7.735 $^0$** | **621.0** | **0.007 ± 0.003** | **0.113 ±0.011** |
| **BHW8** | **11.119 $^0$** | **7.732 $^0$** | **632.9** | **0.030 ± 0.002** | **2.199± 0.015** |
| **BHW9** | **11.107 $^0$** | **7.723 $^0$** | **602.6** | **0.055 ± 0.003** | **3.789 ± 0.170** |
| **BHW10*** | **11.117 $^0$** | **7.717 $^0$** | **495.0** | **0.046 ± 0.002** | **1.250 ± 0.105** |
| **TWW1** | **11.119 $^0$** | **7.718 $^0$** | **626.0** | **0.023 ± 0.002** | **3.105 ± 0.064** |
| **TWW2** | **11.123 $^0$** | **7.718 $^0$** | **538.4** | **0.034 ± 0.003** | **6.911 ± 0.131** |

WW: Well Water, BHW: Borehole Water; TWW: Tobacco WasteWater * Control sample

The measured physical parameter ranges were 4.5-6.5 for pH, 24.8 – 29.6 °C for temperature, 196 – 513 µS/cm for conductivity and 131.32 -343.71mg/l for total dissolved solid. The minimum and maximum elevation values discovered were 495 and 653.4 m respectively and mean elevation value of 610.1 m above sea level. The mean value for pH, temperature, conductivity and total dissolved solid in the samples collected were 5.1, 27.8 °C, 393.0 µS/cm and 263.312mg/lrespectively. The results in table 4.2 are presented in the figure 4.1 for gross alpha activity using the estimation of the central tendencies, deviations and histogram distributions.

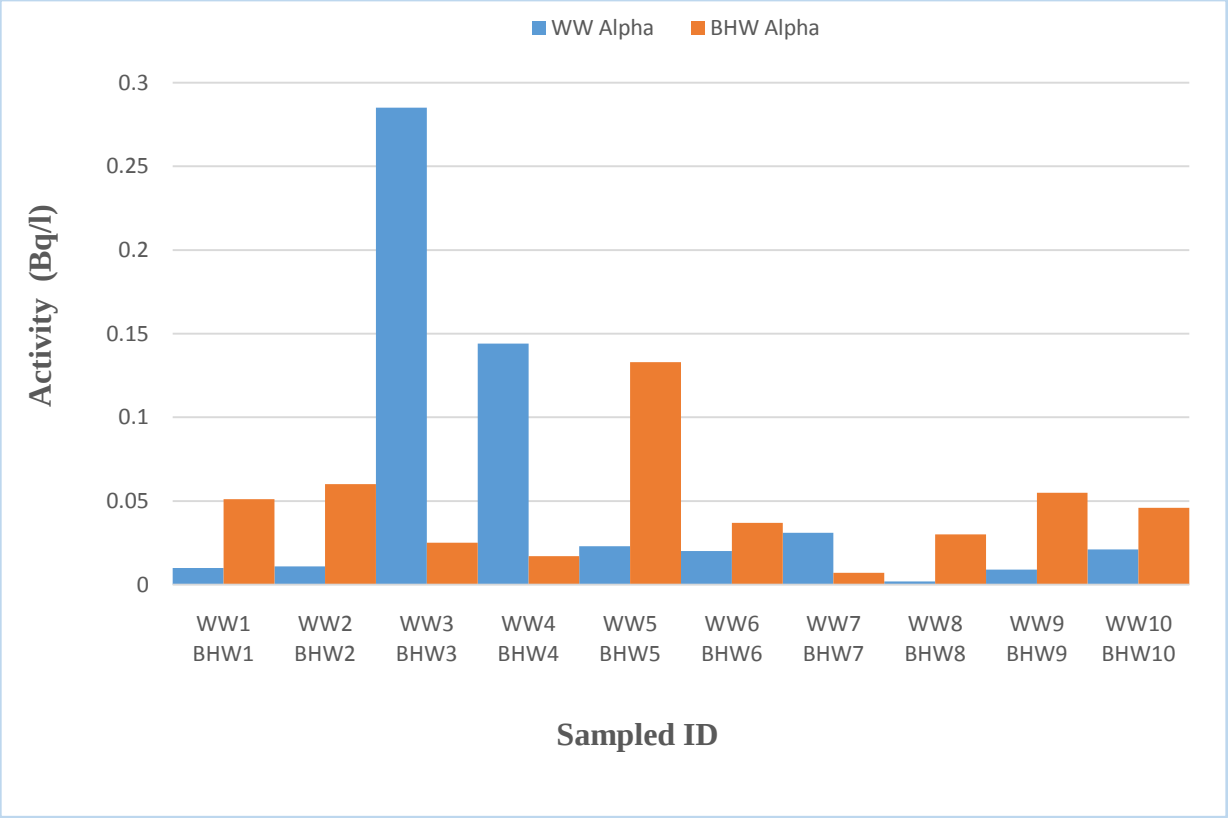


**Fig. 4.1: Distribution of Alpha Activity in Wells and Boreholes Waters.**

It can be seen from the Table 4.2 that 90 % of the samples from bore holes and 80 % from the wells are within the recommended value of < 0.1 Bq/l for alpha activity; and 10 % from the bore holes and 20 % from wells did not meet specification (0.1 Bq/l for alpha activity) as

recommendations by WHO. The gross alpha activity is generally lower than the corresponding gross beta activity presented in Figure 4.3.

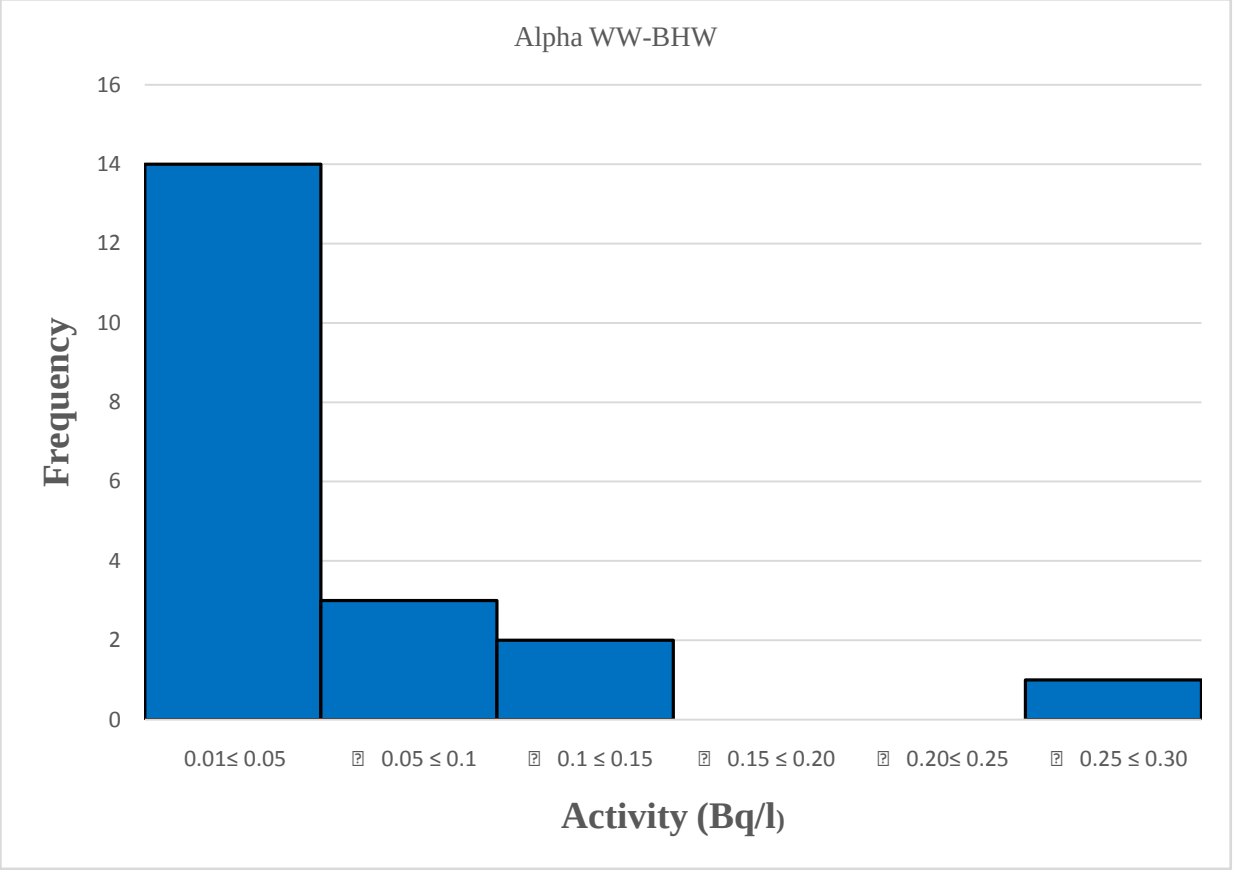


**Fig. 4.2: Distribution of Alpha Activity in the Sampled Water**

From Fig. 4.2 the result shows the highest frequency distribution of 14 between 0.01 Bq/l to <0.05 Bq/l and a closely followed frequency distribution of 3 between 0.05 Bq/l to <0.1 Bq/l. The lowest frequency distribution of 1 is between 0.25 Bq/l and 0.28 Bq/l. The distribution skewed towards the left. This shows a generally low alpha activity in the water samples. The mean of the distribution is 0.056 Bq/land 0.046 Bq/l for well and borehole water respectively. The standard deviation of the alpha activity in the groundwater is 0.045. The frequency distribution of 2 between 0.023 Bq/l and 0.034 Bq/l shows alpha activity from the tobacco waste water sample.

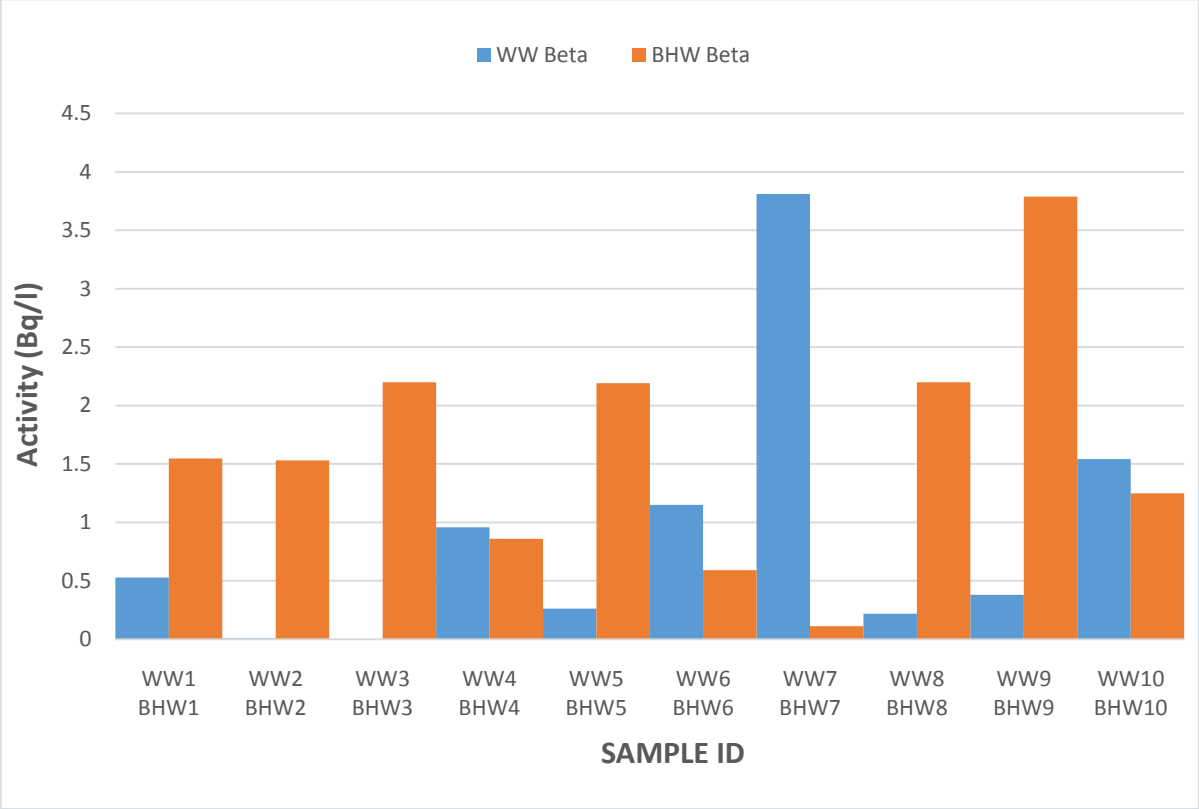


**Fig. 4.3: Distribution of Beta Activity in Sampled Wells and Boreholes Waters.**

It can be seen from Fig. 4.3 above that 30 % of the samples from the bore holes and 70 % from well water met the recommended value of 1 Bq/l for beta activity, and 70 % from the bore holes and 30 % from wells did not meet specification (1 Bq/l for beta activity) as recommendations by WHO and ISO, The gross beta activity is generally higher than the corresponding gross alpha activity presented in Figure 4.1. The mean of the distribution is 0.089 Bq/l and 1.627 Bq/l for well and borehole waters respectively. The standard deviation for total beta activity is 0.552.

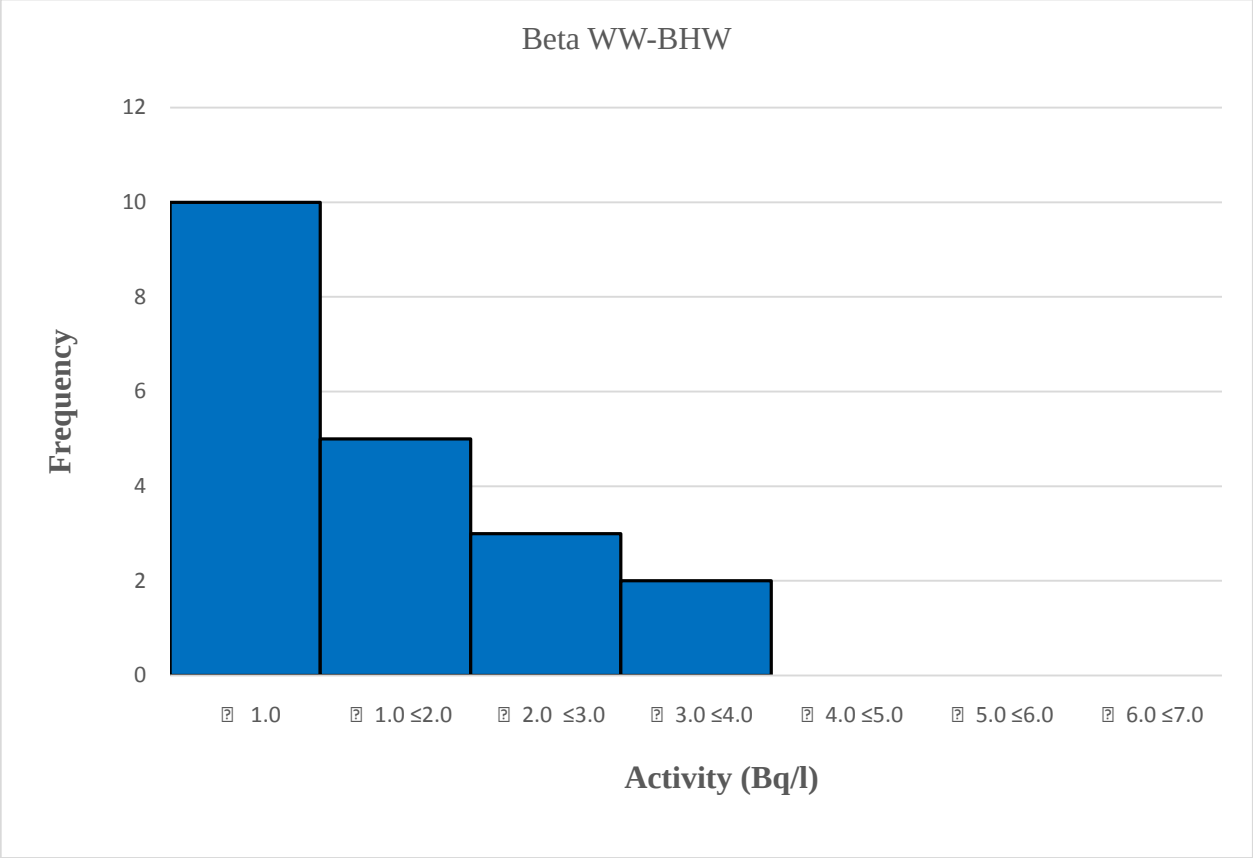


**Fig. 4.4: Distribution of Beta Activity in Well and Borehole water samples.**

Fig. 4.4 shows that the highest frequency distribution of the beta activity is 10 which is between 0.00Bq/l and 0.960 Bq/l while the lowest frequency distribution of 2 is between 3.00 Bq/l and 4.00 Bq/l. The distribution skewed towards the left, showing low distribution, with a mean of 1.167 and standard deviation of 0. 552.

Fig. 4.5 showed that the alpha activity in the sampled tobacco wastewater is lower than the corresponding gross beta activity presented in fig. 4.6where**a**frequency distribution of 1 between 3.105 Bq/l and 6.911 Bq/l shows high beta activity obtain **f**rom tobacco waste water samples.

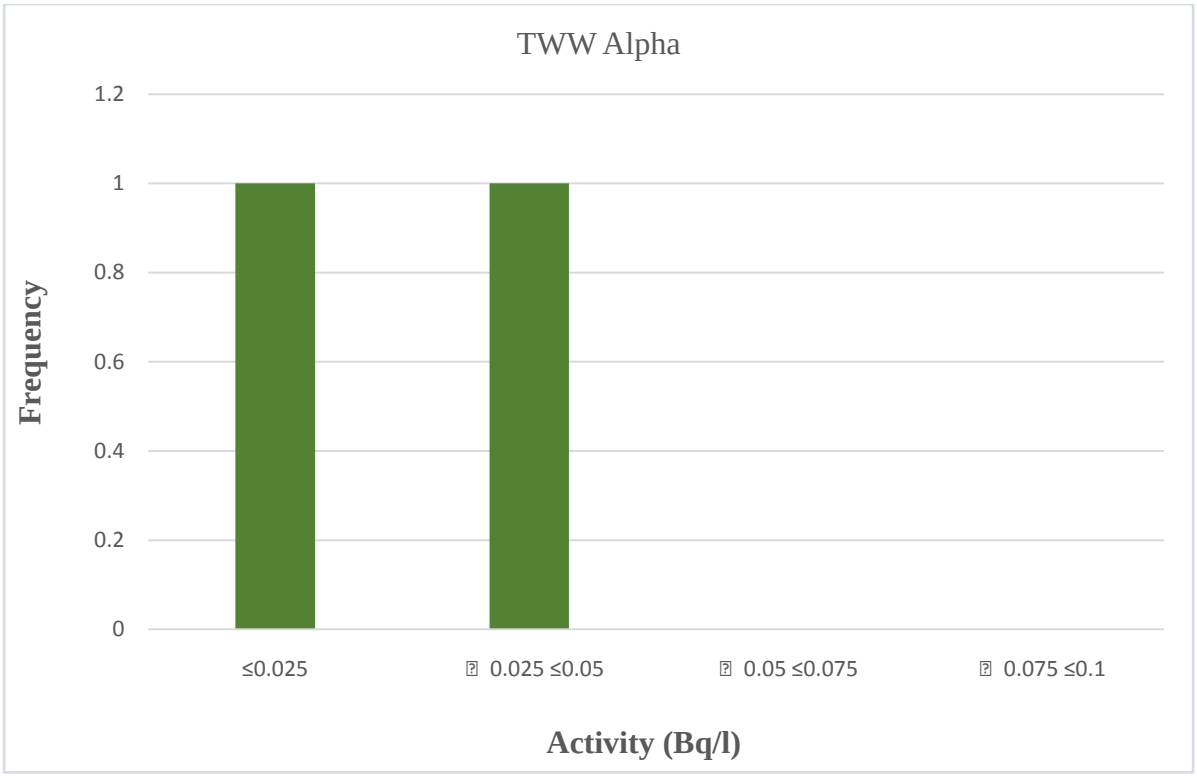


**Fig. 4.5: Distribution of Alpha Activity in the Sampled Tobacco wastewater.**

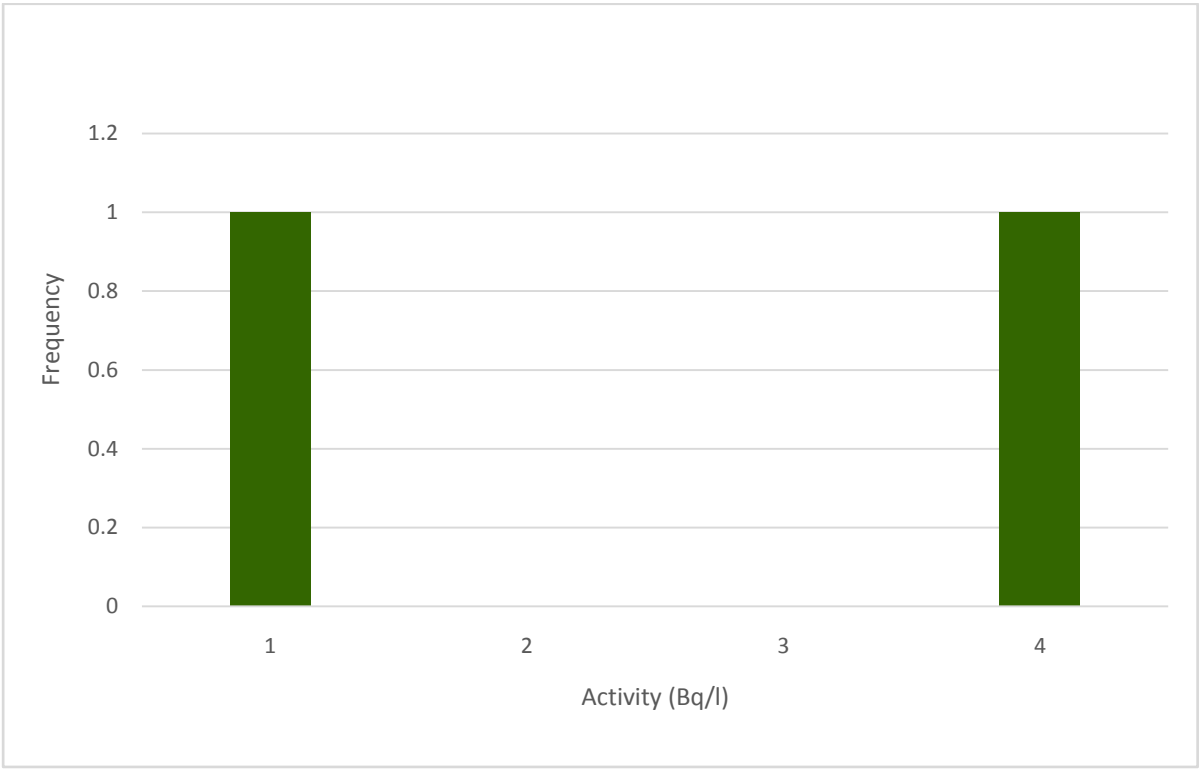


**Fig.4.6: Distribution of Beta Activity in Sampled Tobacco wastewater.**

The results from figure 4.5 and 4.6 when compared with the control samples in table 4.2 showed that the alpha activity in the tobacco wastewater is very low compared to the

corresponding beta activity which is high. This pointed out that the control samples which also exhibited high beta activity may not be as a result of elevated beta activity from the tobacco wastewater but may be due to geological formation of the area.

### 4.3 Contour Mapping

Contour plots were also used for the analysis of the results of alpha and beta activity concentration in the water samples from the study area. Figures 4.7 to 4.12 show the contours graphs ofthe gross alpha and gross beta activity concentrations. This is aimed at finding out the geographical areas of high distribution.

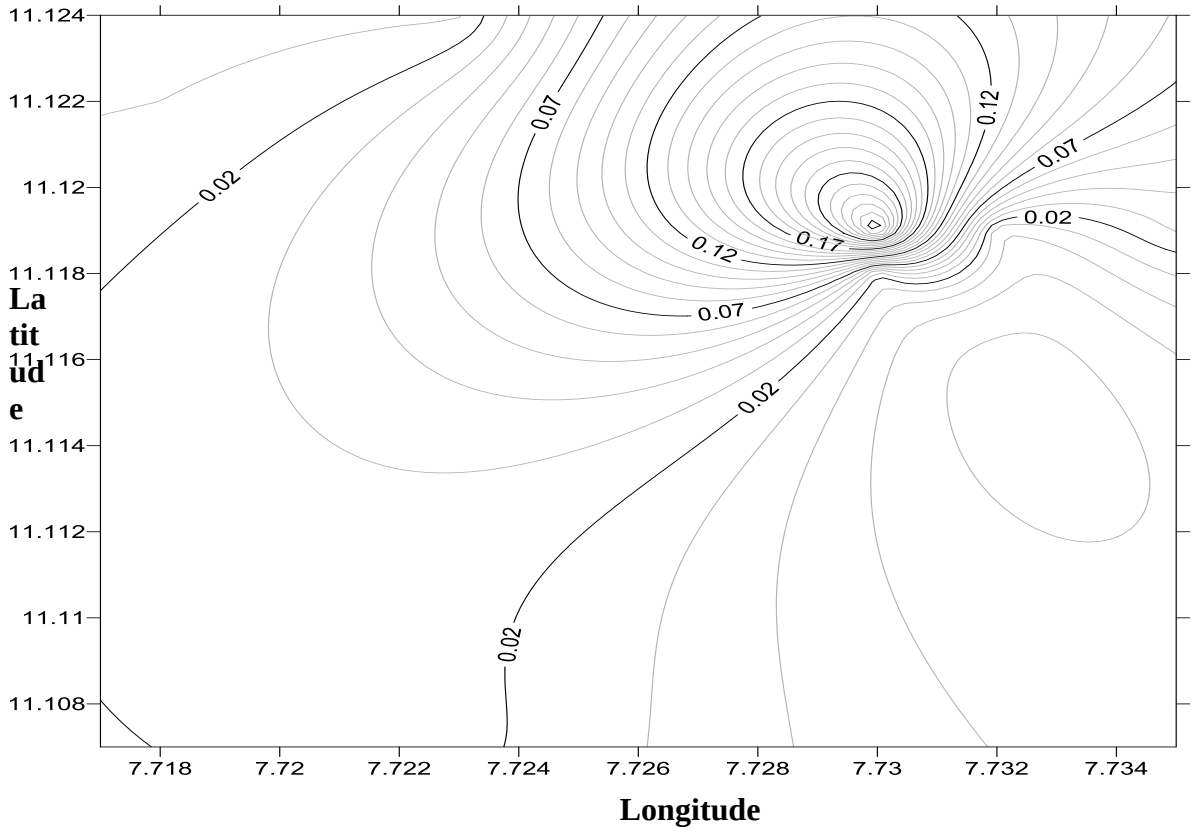


**Fig. 4.7: Contour Plot of alpha activity distribution in the well water**

From Fig. 4.7, there is high alpha distribution greater than 0.1 Bq/l within the narrow region bounded by latitude 11.118$^0$N - 11.121 $^0$N, and longitude 7.725 $^0$E - 7.732 $^0$E. 80 % of the sampled hand-dug well water depicted low range of alpha distribution less than 0.1Bq/l in the

region bounded by latitude 11.108 $^0$N - 11.121 $^0$N, longitude 7.718 $^0$E - 7.725 $^0$E and latitude 11.108 $^0$N - 11.121 $^0$N, longitude 7.732 $^0$E –7.734 $^0$E.

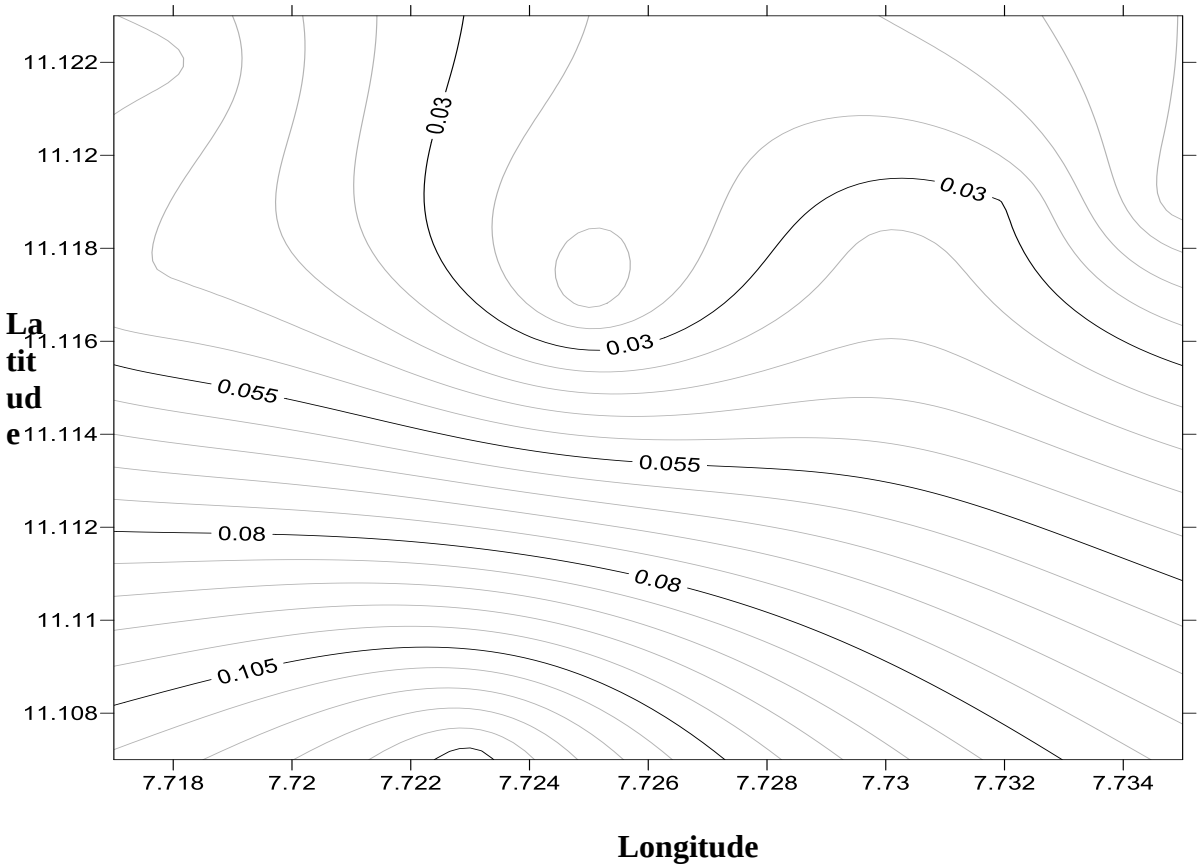


**Fig. 4.8: Contour Plot of Alpha Activity Distribution in the Sampled Borehole water**

From Fig 4.8, there is high alpha distribution greater than 0.1 Bq/l within the narrow region bounded by latitude 11.107 $^0$N - 11.108 $^0$N, and longitude 7.717 $^0$E - 7.728 $^0$E. 90 % of the sampled borehole water depicted low range of alpha distribution less than 0.1Bq/l in the region bounded by latitude 11.109 $^0$N - 11.124 $^0$N, longitude 7.717 $^0$E - 7.734 $^0$E.

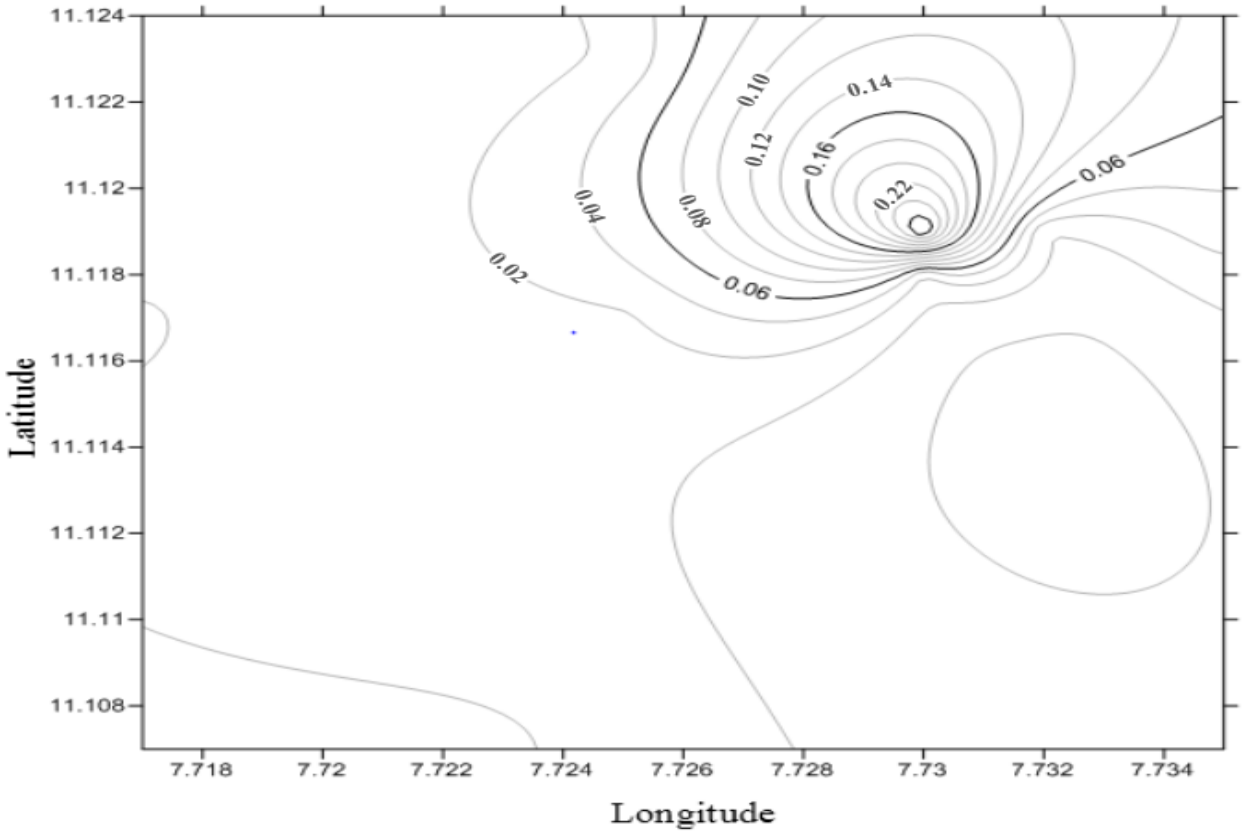


**Fig. 4.9: Contour Plot of Total Alpha Activity in the sampled water**

Fig. 4.9 shows high alpha activity distribution of 0.285 Bq/l and above at a narrow area bounded by latitude $11.119^0$ - $11.12^0$ and longitude $7.73^0$ - $7.731^0$. The areas include the sample point WW3. There is also a high alpha activity distribution of 0.144 Bq/l and above around the sampling point WW4 in between the area bounded by the latitude $11.118^0$ - $11.123^0$ and longitude $7.725^0$ - $7.732^0$ and finally there is high distribution of 0.133 Bq/l at area bounded by latitude $11.118^0$ - $11.124^0$ and longitude $7.727^0$ - $7.732^0$ around sampling point BHW5. The areas bounded by latitude $11.108^0$ – $11.118^0$ and longitude $7.718^0$ - $7.729^0$ and the areas bounded by latitude $11.108^0$ – $11.118^0$ longitude $7.732^0$ - $7.736^0$ have low distribution of 0.002Bq/l – 0.01 Bq/l. thereby leaving a narrow margin of latitude $11.118^0$ - $11.124^0$ and longitude $7.727^0$ - $7.732^0$ where relatively high distribution of alpha activity is noted.

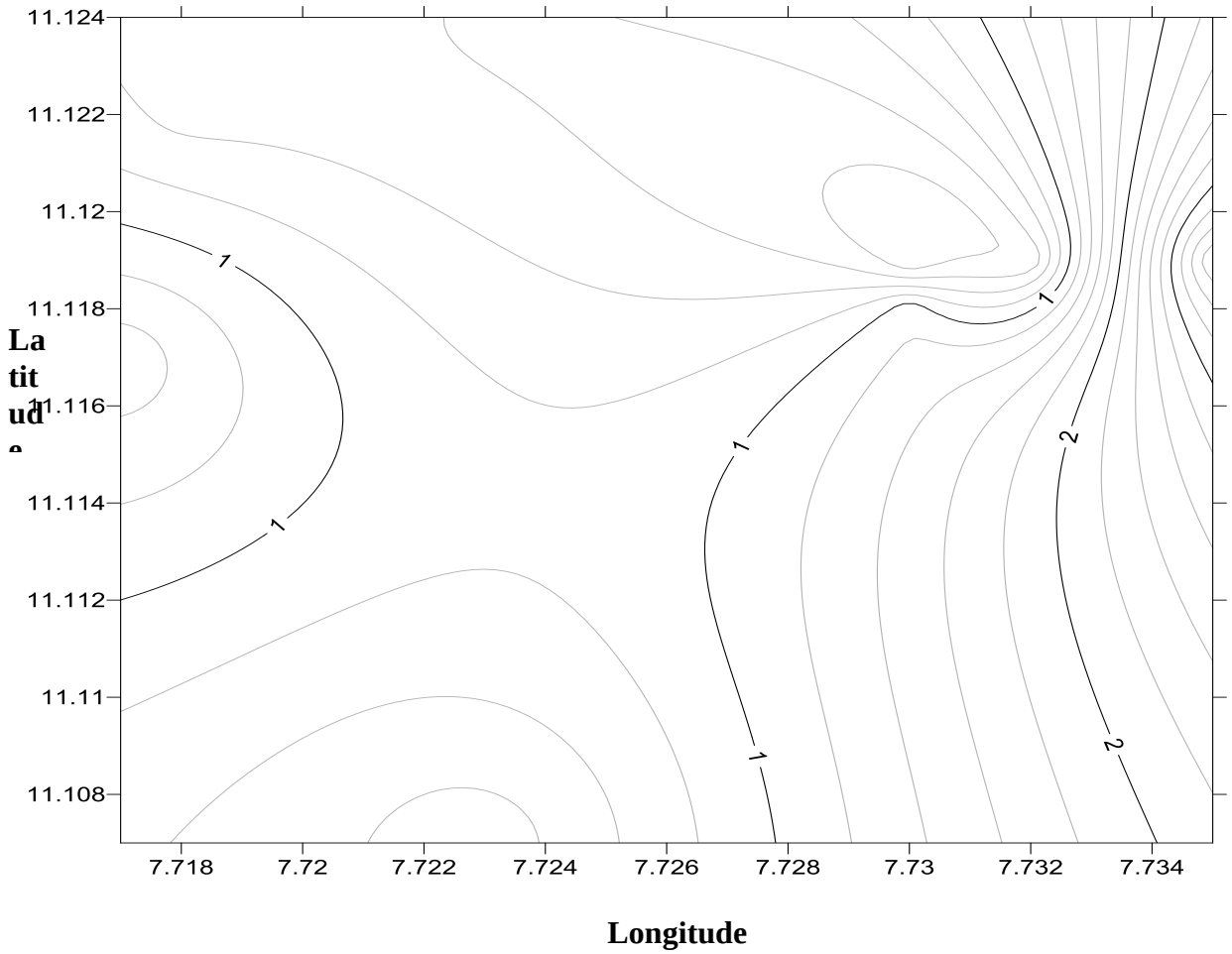


**Fig. 4.10: Contour Plot of Beta Activity Distribution in the sampled well water**

Fig 4.10 showed high beta activity  1.0 Bq/l in sampled well water within the region bounded by latitude 11.107 $^0$N– 11.124 $^0$N and longitude 7.727 $^0$E - 7.734 $^0$E. 70 % of the sampled well water exhibited low beta activity 1.0Bq/l in the region bounded by latitude 11.107 $^0$N – 11.124 $^0$N and longitude 7.717 $^0$E - 7.727 $^0$E.

Fig 4.11below, showed that 70 % of the sampled borehole water exhibited high beta activity distribution  1.0 Bq/l within the region bounded by latitude 11.107 $^0$N– 11.124 $^0$N and longitude 7.717 $^0$E - 7.723 $^0$E. 30% of the sampled borehole water exhibited low beta activity distribution less than 1.0Bq/l in the region bounded by latitude 11.107 $^0$N – 11.124 $^0$N and longitude 7.724 $^0$E -7.734 $^0$E.

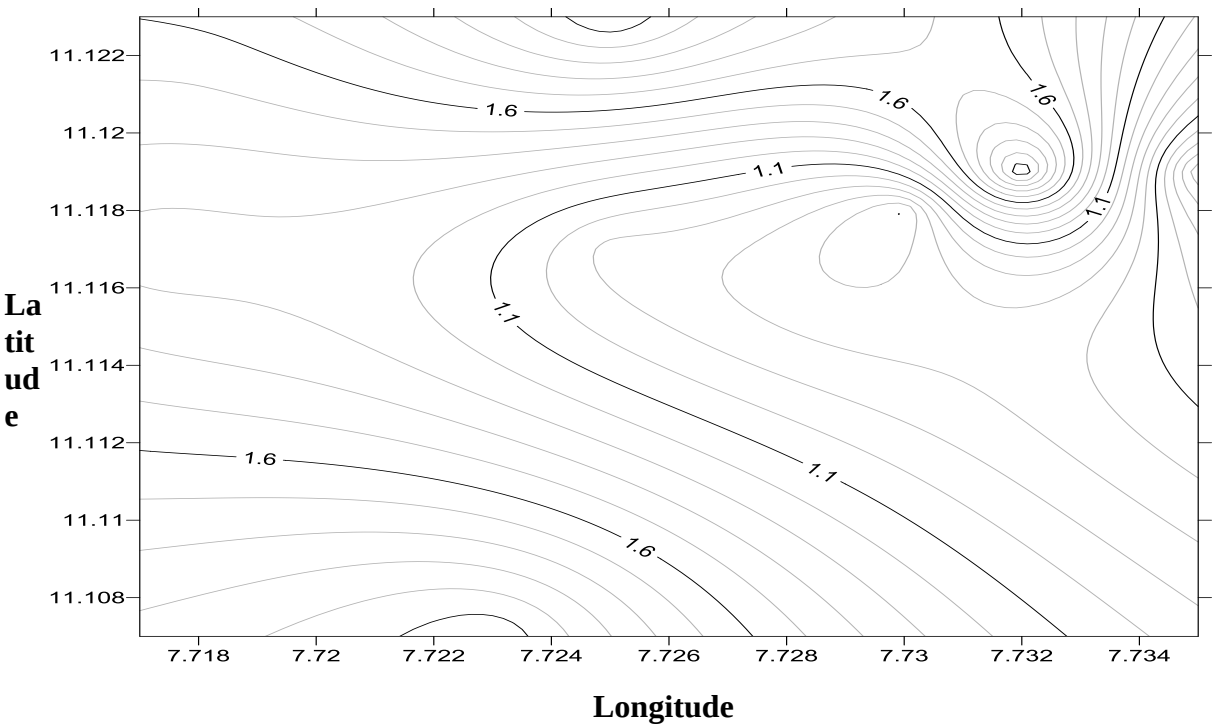


**Fig. 4.11: Contour Plot of Beta Activity Distribution in the sampled borehole water.**

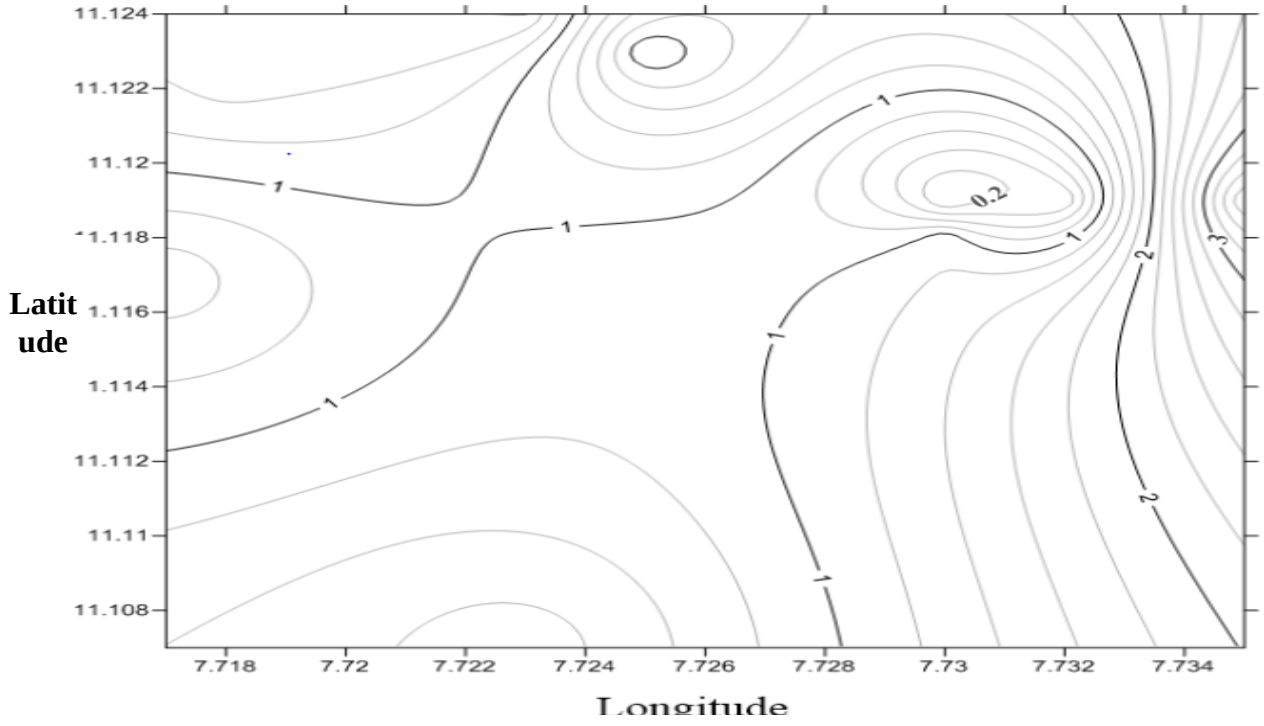


**Fig. 4.12: Contour Plot of total Beta Act** **Longitude** **water**

Figure 4.12 shows a high distribution of beta activity of 2.0 Bq/l and above in the areas bounded by latitude $11.108^0$ – $11.224^0$ and longitude $7.733^0$ – $7.736^0$ around the sampling point WW7, BHW3, BHW5, BHW8 and BHW9. There is also a high distribution above 1.0 Bq/l at the areas bounded by latitude $11.108^0$ - $11.224^0$ and longitude $7.728^0$ – $7.733^{0.}$ There is extremely low distribution of 0.001Bq/l – 0.960 Bq/l in the areas bounded by latitude $11.108^0$ - $11.12^0$ and longitude $7.718^0$ - $7.728^0$.

### 4.4 Determination of Annual Committed Effective Dose

The average annual committed effective dose for gross alpha due to intake of water from hand-dug well and borehole were found to be 0.15 mSv/yrand 0.12mSv/yr respectively which is lower than the recommended world permissible reference level of 0.3 mSv/yr. for ingested dose from drinkable water.

The mean annual effective dose for gross beta due to intake of water from hand-dug well and borehole were found to be 2.30 mSv/yr and 4.25 mSv/yr respectively which is higher than the recommended world permissible reference level of 0.8 mSv/yr. for drinking water. (UNSCEAR, 2000).

# CHAPTER FIVE

# SUMMARY, CONCLUSION AND RECOMMENDATION

## 5.1 Introduction

The chapter summarizes the whole study under the following headings: Summary, Conclusion and Recommendations.

### 5.1.2 Summary

The low level gross alpha and gross beta results might be indicative of low level concentration of the parent radionuclides in the aquifer material, since for an elevated gross alpha radiation to occur, the parent radionuclide uranium and radium must occur in elevated concentration in the parent rock that constitute the aquifer. Alternatively, the low activity might be due to the adsorption of $^{226}Ra$ by Fe oxide surface or its precipitation, as reported by Wanty and Nordstrom (1993). In general, anomalous radionuclide concentrations are related to rock composition, mineralogy, geologic structures and groundwater chemistry (Asikainen and Kahlos, 1989;Wanty and Nordstrom, 1993).

Gross alpha and beta activities in water from the borehole and well water around Tobacco Company environ were measured. The range of alpha activity was found to be from (0.001 to 0.283) Bq/l, with a mean of $0.051 \pm 0.003$ Bq/l and the range of beta activity was from (0.001 to 3.81) Bq/l with a mean of $1.2571 \pm 0.091$ Bq/l.

Figure 4.1 - 4.6 showing the distribution pattern of alpha and beta activity shows almost no elevated alpha activities and few elevated beta activities. It can be seen in figure 4.2, that the distribution of alpha activity is skewed towards the left. This indicates that most of the sampled water has low alpha activity. Similarly, figure 4.4 shows similar pattern for the distribution of beta activities which is almost skewed to the left; indicating that most of the sampled water has low beta activity. However the highest pocket of beta activity from the histogram is that of 1-3

level of activity, and this shows that some of the areas have beta activity above the level set by USEPA and WHO.

### 5.1.3 Comparison of Results

**Table 5.1: Comparison of Gross Activity levels between Wells, Borehole waters and Tobacco wastewater around Tobacco Company**

| Sample Description | Alpha (Bq/l) | | Mean of Alpha (Bq/l) | Beta (Bq/l) | | Mean of Beta (Bq/l) |
|---|---|---|---|---|---|---|
| | MIN | MAX | | MIN | MAX | |
| Borehole | 0.007 | 0.133 | 0.046 | 0.113 | 3.789 | 1.627 |
| Well water | 0.002 | 0.285 | 0.056 | 0.001 | 3.81 | 0.887 |
| Tobacco Wastewater | 0.023 | 0.034 | 0.029 | 3.105 | 6.911 | 5.008 |
| Control samples Well Water | 0.021 | 0.031 | 0.026 | 1.544 | 3. 810 | 2.677 |
| Control samples Borehole Water | 0.046 | 0.133 | 0.090 | 1.250 | 2.190 | 1.720 |

The results presented in table 5.1 showed that the alpha activity in the tobacco wastewater is very low compared to the corresponding beta activity which is high. It equally pointed out that the control samples also exhibited high beta activity.

Comparison of the alpha activity in the groundwater samples and tobacco wastewater with the recommended value set by WHO for alpha activity showed that the groundwater in the study area satisfied the recommended safety standard set by WHO for alpha activity concentration in potable water. Comparison of the beta activity in the groundwater samples and tobacco wastewater with the recommended value set by WHO for beta activity showed an elevated beta activity in the groundwater of study area.

**Table 5.2: Comparison of Measured Gross Activities in the study area with WHO and USEPA Standards and with Results Obtained from Other Places**

| Location | Range of Alpha (Bq/l) | Range of Beta (Bq/l) | Source of data |
|---|---|---|---|
| Belgium | 0.006 - 0.028 | 0.056 - 0.722 | CEC, 1982 |
| Netherlands | 0.028 - 0.064 | 0.035 - 0.139 | CEC, 1982 |
| UK | 0.030 - 0.150 | 0.030 - 0.330 | CEC, 1982 |
| Zaria | 0.0023 - 5.790 | 0.037 - 5.280 | Onoja R.A. 2004 |
| Zaria (BAT Environ) BHW | 0.007- 0.133 | 0.113 - 3.789 | This work 2016 |
| " WW | 0.002- 0.285 | 0.001 - 3.81 | This work 2016 |
| | $\leq 0.55$ | $\leq 1.85$ | USEPA |
| | $\leq 0.1$ | $\leq 1.0$ | WHO |

Comparing the average mean value of 0.556 Bq/l for gross alpha activity in the hand dug well water and 0.0461 Bq/l in the borehole water with the recommended safety values of 0.55 Bq/l for Gross Alpha by USEPA, and 0.1 Bq/l by WHO, it was noted that most of the activities are within these safe limits. Comparison of Beta activity of 0.887 Bq/l for hand dug well water and 1.627 Bq/l in borehole water samples with the standard safe limits of 1.0 Bq/l and 1.85 Bq/l for beta activity by WHO and USEPA respectively, showed that activities are higher than that of similar sources in other countries i.e. Belgium, Netherlands, and UK. These water bodies, especially borehole water samples, therefore pose the risk of exposing the human beings within the area to serious health hazards.

Generally, results obtained depicted a low radiation level of $0.051 \pm 0.003$ Bq/l for gross alpha which invariably satisfied the recommended standard value of $\leq 0.1$ and $\leq 0.55$ Bq/l set by WHO and USEPA respectively.

Based on USEPA standard, the values of 1.2571±0.091Bq/l obtained in this study falls below USEPA recommended value of 1.85Bq/l for gross beta activity for good quality drinking water, hence certifying the portability of the water used by inhabitants of the area for their domestic activities.

Based on WHO standard, the water in the affected locations is not safe. The values of 1.2571±0.091Bq/l is slightly above WHO recommended value of 1.0Bq/l for gross beta

The mean annual Effective Dose for gross alpha in the sampled water is 0.265 mSv/yrThis value is lower than world permissible values of 0.3 mSv/yr for Alpha. The mean annual Effective Dose for gross beta in the sampled water is 6.539 mSv/yr which is greater than world permissible values of 0.8 mSv/yr for Beta (UNSCEAR, 2000).

## 5.2 Conclusion

From the results obtained, seventeen (17) samples out of the twenty (20) representing 85 % for total alpha activity satisfied the recommended contaminant limit and other remaining samples fall out of range recommended by International Standard Organization (ISO) recommended acceptable value. Also 10 samples out of the twenty (20) representing 50 % for total beta activity satisfy the recommended contaminant limit and other remaining samples fell out of range recommended by International Standard Organization (ISO).

Results showed that it would be dangerous to consume well water from the sampling point, WW3 in a narrow area bounded by latitude $11.119^0$ - $11.12^0$ and longitude $7.73^0$ - $7.731^0$; and from the sampling point, BHW5 bounded by latitude $11.118^0$ - $11.124^0$ and longitude $7.727^0$ - $7.732^0$ due to the high level of the alpha and beta radioactivity concentration when compared to the WHO recommended safety value of 0.1 Bq/l and 1.0 Bq/l respectively at this period of the year.

The EPA has defined six classes of injection wells. Class I wells are used for the injection of municipal and industrial wastes beneath underground sources of drinking water. It can be concluded, from this work, that the British American Tobacco Company, Zaria does not pose a radiological threat to the potable groundwater in the part of the study area however, it could be, in case there is leakage in the course of wastewater discharge, one of the possible sources of pollution affecting the area with elevated beta activity especially water samples BHW1, BHW2, BHW3, BHW5, BHW8, BHW9, BHW10 and WW6, WW7, WW10, considering the statistical representation of tobacco wastewater in Fig 4.6 where high beta activity was presented.

The results from Figure 4.5 and 4.6 when compared with the control samples and other samples in Table 4.2 showed that the alpha activity in the tobacco wastewater is very low compared to the corresponding beta activity which is high. This pointed out that the Tobacco Company could not be responsible for the elevated alpha activity recorded insome part of the study area. It could be inferred that the injectate from the company may not be a factor responsible for the elevated beta activity in the study area, especially in some of the borehole samples.

Considering the control samples, within latitude $11^0$ 6' 26.7"N, longitude $7^0$ 43' 24.1" E and latitude $11^0$ 7' 2.9" N, longitude $7^0$ 42' 59.4" E, where significant beta activity is recorded, the elevated beta activity in the study area may not be as a result of the effluent from the company but may be due to geological formation of the area.

These results as contoured further showed that the gross alpha activity and gross beta activity for alpha and beta radiations tend to concentrate towards the Eastern part of the study area (Fig.4.7 – 4.12), which is a pegmatite rich area (MC curry 1973, Garba 2008).

Physical parameters, TDS varies directly as Electrical Conductivity. From Table 4.1, all the values obtained for TDS were within the acceptable limits of WHO and the Environmental Protection Agency's standards of 500 mg/l for drinking water. A high TDS does not necessarily

mean that water is unsafe for consumption; it may just suggest that the water will have unpleasant aesthetic qualities in terms of colour, taste, smell, etc.

## 5.3 Recommendations

Since many samples: (30 %) from the bore holes and 70 % from well water meet the recommended value of 1 Bq/l for beta activity, and (70 %) from the bore holes and 30 % from wells do not meet specification as recommendations by WHO and ISO, in similar vein since (90 %) from the bore holes and 80 % from wells meet the recommended value of < 0.1 Bq/l for alpha activity, and (10 %) from the bore holes and 20 % from wells do not meet specification as recommendations by WHO and ISO there is therefore need for:

i. Further screening on beta activity in high concentration from boreholes that are used within the area for drinking is recommended because continue usage may pose serious health side effects like cancer, skin diseases etc. to the public users.
ii. Further screening on beta activity in high concentration from wells that are used within the area for drinking is also recommended.
iii. Screening for confirmation of acceptable low activities concentration from wells and boreholes that are used within the area for drinking is recommended.

## 5.4 Contribution to knowledge

This research work showed that the mean for gross alpha activity and gross beta activity in the sample waters are 0.051±0.003 Bq/l and 1.251±0.091 Bq/l respectively compared to the WHO recommended safe limit of 0.1 Bq/l and 1.0 Bq/l for gross alpha and gross beta activity respectively.

1. High concentration of beta activity is observed in most of the borehole water samples in the section of the area investigated.
2. The Tobacco Company effluent poses no radiological threat to the potable groundwater being used by the inhabitants.

## REFERENCES


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