RADIOACTIVITY MEASUREMENT AND HEAVY METAL ASSESSMENT OF SOIL AND WATER FROM SUGARCANE FARM IN JIBIA, KATSINA STATE, NIGERIA

BY

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RADIOACTIVITY MEASUREMENT AND HEAVY METAL ASSESSMENT OF SOIL AND WATER FROM SUGARCANE FARM IN JIBIA

BY

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DECLARATION

I, Mustapha NDAWASHI (M.Sc./SCI/42594/2012-2013) declare that the work in this thesis entitled "**Radioactivity measurement and heavy metal assessment of soil and water from a sugarcane farm in jibia, Katsina State, Nigeria**" has been carried out by me in the Department of Physics under the supervision of Dr.Y.I. Zakari and Prof. D.J. Adeyemo. 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.

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(Name of Student)	Signature	Date

CERTIFICATION

This thesis entitled "**Radioactivity measurement and heavy metal assessment of soil and water from a sugarcane farm in Jibia, Katsina State, Nigeria**" written by Mustapha NDAWASHI (M.Sc./SCI/42594/2012-2013) meets the regulations governing the award of Master's Degree in Radiation Biophysics of Ahmadu Bello University, Zaria and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

To the effort and prayers of my dare parents; love and support of my lovely Wife and Son.

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ABSRACT

This study was conducted to investigate the concentration of heavy metals as well as measurement of radioactivity in both soil and water from the effluent of Jibia water treatment plant that was used for irrigating a sugarcane farm land. Water and soil samples were collected at different grid points, and analyzed for copper (Cu), Zinc (Zn), Iron (Fe), cadmium (Cd), and Arsenic (As) concentration using Atomic Absorption Spectrometry (AAS); And for gross alpha/beta activity measurements using a gas filled proportional counter. Preliminary results show the mean values obtained for AAS analysis of the soil to be (0.327±0.022 mg/kg)Zn, (0.812±0.082 mg/kg)Cu, (0.327±0.015 mg/kg)Cd, (0.563±0.0217 mg/kg)As and (279.675±9.555 mg/kg)Fe; And for water, the mean values obtained are (0.033±0.007mg/L)Zn, (0.149±0.03 mg/L)Cu, (0.134±0.008mg/L)Cd, (0.015±0.004mg/L)As, and (1.272±0.032 mg/L)Fe respectively and all fall within WHO maximum allowable concentration (MAC) recommended for irrigation purpose, except for cadmium (Cd) and Arsenic (As) that are above the recommended safe limits of heavy metals by WHO, FAO, EU Standards for agricultural reuse. Gross alpha and beta mean activity concentrations in the soil are (63.018±12.811)Bq/g and (1778±768.131)Bq/g respectively; And (0.0315±0.0036)Bq/dm^3 and (0.216±0.019)Bq/dm^3 for water respectively. The study revealed that radioactivity measurements in water and soil samples are above reported values in similar environment but fall within the permissible limits set by WHO and the area can be considered safe for irrigation farming of sugarcane, tomato, cabbage, spinach, lettuce and other selected wild plants; since vegetable plants generally require these elements in appreciable quantities.

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CHAPTER ONE

INTRODUCTION

1.1 Background of the study

Wastewater treatment is employed as an action to protect the quality of limited freshwater resources and therefore makes it more acceptable for beneficial reuse. However, achieving this objective remains elusive as the total discharge of biologically treated sewage effluent (BTSE) is continually on the rise due to increasing population and urbanization. Wastewater reclamation is recognized as one of the most effective ways of increasing the availability of limited freshwater and at the same time, the use of reclaimed water can reduce the demand for freshwater (Shon *et al.,* 2010).

With increasing global population, the gap between the supply and demand for fresh water is widening and is reaching such alarming levels that in some parts of the world it is posing a threat to human existence. This gave scientists around the globe an opportunity of conserving water by recycling it through the reuse of urban wastewater, for irrigation and other ecosystem services (Hussain *et al.*, 2002). Wastewater reuse, reclamation and recycling are essential in coming years for the development of sound water and environment management policies. In arid and semi arid regions marginal water utilization is a vital component of their water resources development ensuring alternative water resources, sustainability, reduction of environmental pollution and health protection. Wastewater from different industries, which falls under marginal water quality, can be utilized beneficially for irrigation if proper treatment, monitoring and management measures were taken. The challenges and the benefits of marginal water quality utilization has to

be ascertained and appropriate package of practices which are location specific needs to be followed for the real success and long term sustainability(Rekha and Ambujam, 2013).

Generally, liquid waste or effluent comes from domestic wastewater, industrial wastewater, storm water, and groundwater seepage entering the municipal sewage network. Domestic wastewater for example, consists of effluent discharges from households, institutions, and commercial buildings; and they are made up largely of organic carbon, either in solution or as particulate matter. Industrial wastewater is the effluent discharged by manufacturing units and food processing plants (Davies, 2005 and Hussain *et al.*, 2002).

Regardless of its source, its impact to human health and to environment can be considered as both a resource and a problem. Wastewater and its nutrient content can be used extensively for irrigation and other ecosystem activities since its reuse can deliver positive benefits to the farming community, society, and municipalities. However, wastewater reuse also exacts negative externality effects on humans and ecological systems, which need to be identified and assessed (Hussain *et al.*, 2002).

Increased demand for food and the need to sustain the ever increasing country population have led to massive increase in both agricultural and industrial activities. Although Nigeria is well known for its petroleum, agriculture which contributes over 28 percent to the country's gross domestic product (GDP) has provided employment for over 41 percent of the total population and over 90 percent of the rural population (NBS, 2014; Mobuogwu, 2013).

There are number of crops grown by farmers that include different food crops, commercial crops, oil seeds etc. Sugarcane is one of the important commercial crops grown in Nigeria and quiet a reasonable portion of rural labourers in the country largely rely upon this industry. Sugar Industry is one of the agricultural based industries and like any other industries is faced with problems arising from the negative impact of economic development due to water or industrial pollution (Rais and Sheoran, 2015).

Rapid progress made in industrialization without adequate environmental safety measures have lead to pollution of water, which in turn, results in lack of good quality water both for irrigation and drinking purposes. Every human society, whether urban, industrial and most technologically advanced, disposes off certain kinds of by-products and waste products into the biosphere in large quantities, ultimately affecting the normal functioning of the ecosystem and has adverse effect on plants, animals and human. Awareness of environmental problems and the potential hazards caused by industrial wastewater has promoted many countries to limit the discharge of polluting effluents (Rais and Sheoran, 2015).

However, depending upon its sources and treatments, industrial wastewater may contain high concentration of nutrients and toxic heavy metals and it application may create

undesirable effects in soils, which may lead to bio-accumulation in plants and pose a health risk for human beings. Also, the rising trends of using the wastewater (industrial effluents) for irrigation has the advantage of polluting the soil and environment as the pollutants are partly taken up by the plants and partly transformed in the soil thereby causing damage to the crops (Damodharan and Reddy, 2012).

Sugarcane is usually grown in high rainfall or well-irrigated areas and is one of the world's best established industrial crops that is efficiently grown and harvested to produce both food and bioenergetics. It is mainly grown in Nigeria, in the alluvial valley soils of Kaduna and Kano States. The major sugar plantation estates in Nigeria are located at Numan in Adarnawa State, Sunti and Mokwa in Niger State, Lafiagi and bacita in Kwara State. Sugarcane is a crop that makes a high demand on essential plant nutrients. Sugarcane production practices throughout the world vary depending on soil types, climatic factors and custom (Thai, 2013; Adekola and Akinpelu, 2002).

As a result of high demand of sugarcane on essential nutrients, it is possible that trace elements (cadmium, copper, lead, zinc, manganese, arsenic and iron) if present in the irrigation water or soil could eventually be absorbed thereby resulting in important concentrations of these elements in the cane juice; hence the need to understand the possible effect or influence of the physicochemical quality of the irrigation water and also of the soil on the quality of cane juice produced in these farmlands (Adekola and Akinpelu, 2002). Monitoring of the level of these trace elements, and especially the most toxic ones such as cadmium (Cd), Arsenic (As) and lead (Pb), in both water and soil becomes very necessary since they are included in the list of metals

considered important by the global environment monitoring system (GEMS) by the United Nations Environmental Programme (UNESCO/WHO/UNEP, 1992).

1.2 Statement of research problem

Sugarcane (*Saccharum officinarum*) has been described as the most' efficient of all storers of the sun's energy and if the maximum potential of this plant is to be approached, the soil-plant relationship must be at an optimum. Sugarcane production is an integration of various factors such as weather, water, biotic, soil and economic factors. All factors apart from weather are within man's control (Abayomi, 1987).

The need for proper use of freshwater to drain sugarcane farmlands has been observed to be an important factor in agronomic practice which concerns not only their quality, but also their quantity, as too little of the freshwater does not yield the most economic return, while too much of wastewater will adversely affect the crop (Rais and Sheoran, 2015).

Similarly, elements required in low quantity by living beings have been identified in literatures as microelements, trace elements, or micronutrients. These elements are necessary for living beings to continue life, but only in minor amount (e.g., vitamins and minerals) and plays an important

role in chemical, biological, biochemical, metabolic, catabolic, as well as enzymatic reactions in the living cells of plants, animals, and human beings (Waseem *et al*., 2014). These elements appear in man, in food and in various environmental compartments in a broad concentration range from natural ultra trace levels at the ppt level and sometimes even below to the often increased due to anthropogenic pollution ppm level. Some of the heavy metals are considered to be xenobiotic because these have no beneficial role in body functioning and are even very harmful in minor concentrations.

Cadmium, Beryllium, Aluminium, Uranium, Mercury, Lead, Bismuth, Barium, Antimony, Arsenic, and so forth are included in toxic metals. Higher levels of these metals are highly toxic to animals including humans and plants, and their solubility in water is considered to be one of the major environmental issues (Waseem *et al*., 2014).

There is need to investigate the effect of toxic trace elements (Cu, Pb, Cd, Zn, Fe, As and Mn) on growth and quality of sugarcane in Jibia. It is therefore the objective of these studies to evaluate the effects of different rates of effluents on growth, yield and quality of sugarcane cultivar Co 957, which is an important commercial cultivar in sugar estates in Nigeria (Rais and Sheoran, 2015).

1.3 Justification

Studies have identified benefits, risks, drivers and characteristics of wastewater use for irrigation farming in developing countries inadequately tackled the issues pertaining to heavy metal contamination in wastewater irrigation farming as some of crop cultivators use wastewater from domestic sewage and industrial effluents to irrigate crops in their gardens. Although wastewater might have potential value to agriculture through the provision of water and nutrients to crops, there are however potential risks associated with consumption of heavy metal contaminated food crops which have implications on the livelihoods of people. The sources of heavy metals in wastewater include mining, smelting and industrial activities in towns and villages (Kapungwe, 2013).

Relevant authorities such as the National Environmental Standards and Regulatory Enforcement Authority (NESREA) need to develop and enforce appropriate measures for monitoring and control of heavy metal contamination in wastewater irrigation farming systems in order to ensure compliance with the Clean Water and food safety Act (1977). The legislation should be concerned with the prevention of water pollution, and therefore sets concentration limits on dissolved organic carbon (as BOD or COD), nitrogen and phosphates which cause eutrophication in receiving waters. This will also attempts to limit the discharge of known toxic chemicals by setting allowable concentration limits in the effluents (Davies, 2005).

On like other food crops that may undergo further purification before consumption, sugarcane is consumed directly as such the toxic chemicals carried into the soil and crop by wastewater irrigation farming can inhibit either the catabolic pathways of respiration or the anabolic pathways of synthesis and growth. Irrespective of which pathway is actually inhibited, all three processes of Ingestion, Growth and Respiration will be similarly inhibited. It is for this reason that toxicity tests be conventionally carried out to ascertain and measure the gross alpha and gross beta activity in the samples (Anon, 2008 and Davies, 2005).

1.4 Aim and Objectives

The aim of this research is to provide adequate information on the elemental compositions and to determine the gross alpha and beta activity within the samples, and thus determine if further, more detailed analyses are required for the samples.

The specific objectives are therefore to:

- Determine the concentration of the elemental composition and other colloidal particles present in both soil and water samples.
- Investigate the level of toxicity effects derived from effluents of Jibia water treatment plant on both the soil and sugarcane produce.
- Identify weather there are environmental pollution associated with effluent from the water treatment plant directly on the soil.

1.5 Scope of the study

The scope of the study covers Jibia water treatment plant in Jibia Local Government Area of Katsina state. This is due to the location of Jibia Dam which drain the water treatment plant that supply water for drinking and for irrigation of sugarcane farm lands.

CHAPTER TWO

LITERATURE REVIEW

2.1 Sources, Characteristics and Composition of Wastewater

Generally, municipal wastewater is made up of domestic wastewater, industrial wastewater, storm water, and also groundwater seepage entering the municipal sewage network. Domestic wastewater consists of effluent discharges from households, institutions, and commercial buildings. Industrial wastewater is the effluent discharged by manufacturing units and food processing plants (Hussain *et al*., 2001).

The actual composition of wastewater may differ from community to community depending on the source and the activities taking place at the source, all municipal wastewater contains the following broad groupings of constituents:-

- ✓ Organic matter
- ✓ Nutrients (Nitrogen, Phosphorus, Potassium)
- ✓ Inorganic matter (dissolved minerals)
- ✓ Toxic chemicals
- ✓ Pathogens

The final composition of raw wastewater depends on the source and its characteristics. In the case of mixed municipal wastewater this depends on the types and numbers of industrial units and the characteristics of the residential communities. A brief overview of the wastewater constituents, parameters, and possible impacts are given in table 1 (Hussain *et al*., 2001).

Table 1. Pollutants and contaminants in wastewater and their potential impacts through agricultural use.

Pollutant/ Constituent	Parameter	Impacts
Plant food nutrients	N, P, K, etc.	- Excess N: potential to cause nitrogen injury, excessive vegetative growth, delayed growing season and maturity, and potential to cause economic loss to farmer - excessive amounts of N, and P can cause excessive growth of undesirable aquatic species. (eutrophication) - nitrogen leaching causes groundwater pollution with adverse health and environmental impacts
Suspended solids	Volatile compounds, settleable, suspended and colloidal impurities	- development of sludge deposits causing anaerobic conditions - plugging of irrigation equipment and systems such as sprinklers
Pathogens	Viruses, bacteria, helminth eggs, fecal coliforms etc.	- can cause communicable diseases (discussed in detail later)
Biodegradable organics	BOD, COD	- depletion of dissolved oxygen in surface water - development of septic conditions - unsuitable habitat and environment - can inhibit pond-breeding amphibians - fish mortality - humus build-up
Stable organics	Phenols, pesticides, chlorinated hydrocarbons	- persist in the environment for long periods - toxic to environment - may make wastewater unsuitable for irrigation
Dissolved inorganic substances	TDS, EC, Na, Ca, Mg, Cl, and B	- cause salinity and associated adverse impacts - phytotoxicity - affect permeability and soil structure

Heavy metals	Cd, Pb, Ni, Zn, As, Hg, etc.	- bio accumulate in aquatic organisms (fish and planktons) - accumulate in irrigated soils and the environment - toxic to plants and animals - systemic uptake by plants - subsequent ingestion by humans or animals - possible health impacts - may make wastewater unsuitable for irrigation
Hydrogen ion concentrations	pH	- especially of concern in industrial wastewater - possible adverse impact on plant growth due to acidity or alkalinity - impact sometimes beneficial on soil flora and fauna
Residual chlorine in tertiary treated wastewater	Both free and combined chlorine	- leaf-tip burn - groundwater, surface water contamination (carcinogenic effects from organochlorides formed when chlorine combines with residual organic compounds) - greenhouse effect

Source: Hussain *et al.*, 2002

Wastewater from different industries, which falls under marginal water quality, can be utilized beneficially for irrigation if proper treatment, monitoring and management measures were taken. The challenges and the benefits of marginal water quality utilization

has to be ascertained and appropriate package of practices which are location specific needs to be followed for the real success and long term sustainability.

2.1.1 Wastewater irrigation - Domestic

Wastewater reuse and reclamation may produce reliable source of water even in drought years. It provides a unique and viable opportunity to augment traditional water supplies (Asano, 2002). It can help to close the loop between water supply and wastewater disposal. Moreover, nutrients beneficial to plant growth are available in the domestic waste. Irrigation water and plant nutrients being limiting factors for agricultural production in the country, exploitation of nutritional/manorial and irrigational sources from wastewater is an appropriate strategy. Many farmers use treated or untreated wastewater for irrigation activities. Thus the necessity of wastewater irrigation has been realized and recognized worldwide resulting in increased expansion of wastewater irrigation programmes throughout the world (Rekha and Ambujam, 2013).

2.1.2 Wastewater irrigation - Industrial

Though the concept of reusing and recycling wastewater for irrigation was an age-old practice, the industrial effluent irrigation is only of recent. It has been adopted with great vigour by most industries because the effluent standards to be met for disposal are higher when compared to land application and the pollution control measures are implemented by effective legislation and by the State Pollution Control Board. Wastewater from different industries, which falls under marginal water quality, can be utilized beneficially for irrigation with proper management. The effluents from agro based industries, which use agriculture products as the raw material, and industries, which involved in processing of agricultural products are not detrimental to the environment since the wastes are organic in nature and biodegradable (Raman *et al.,* 1996 and Ramaswamy 1999).

Researchers have grouped industrial effluent according to the possibility of irrigation reuse of their wastewater as shown in Table 2.

Table 2: Industrial Effluent for Irrigation

Industry Group	Possibility of irrigational reuse	Some selected examples
I	Irrigational reuse of effluent is permitted	Beer, Vine, Yeast, Starch, Micro food Canning
II	May be permitted on certain conditions	Sugar, Slaughter house, Meat processing, Tanning, Pulp and paper, Textile
III	Not suitable as irrigation water	Paint, Polish, Soap, Pharmaceutical, Metal sulphide, cellulose.

Source: Sarikaya and Eroglu (1993)

2.2 Potential Impacts of Wastewater Use in Agriculture

Wastewater when use for agricultural purposes is characterised with the following potential impacts to both the soil and the human health. Thses include:-

- Public health
- Crops
- Soil resources
- Groundwater resources

- Property values
- Ecological impacts
- Social impacts

2.2.1 Public heath

The use of untreated wastewater for irrigation, no doubt, pose a high risk to human health in all age groups because of the heavy metals ingested in sufficient concentration. Although the degree of risk may vary among the various age groups, untreated wastewater irrigation leads to relatively higher prevalence of hookworm (Hussain *et al*., 2001; Feenstra *et al*., 2000), and Ascariasis infections among children (Cifuentes *et al*., 2000; and Habbari *et al*., 2000).

2.2.2 Crops

Generally speaking, wastewater is extensively used in agriculture because it is a rich source of nutrients and provides all the moisture necessary for crop growth. Most crops give higher than potential yields with wastewater irrigation; reduce the need for chemical fertilizers, resulting in net cost savings to farmers. If the total nitrogen delivered to the crop via wastewater irrigation exceeds the recommended nitrogen dose for optimal yields, it may stimulate vegetative growth, but delay ripening and maturity, and in extreme circumstances, cause yield losses (Hussain *et al*., 2001; Feenstra *et al*., 2000).

2.2.3 Soil Resources

Impact from wastewater on agricultural soil, is mainly due to the presence of high nutrient contents (Nitrogen and Phosphorus), high total dissolved solids and other constituents such as heavy metals, which are added to the soil over time. Wastewater can also contain salts that may accumulate in the root zone with possible harmful impacts on soil health and crop yields. The leaching of these salts below the root zone may cause soil and groundwater pollution (Hussain *et al*., 2001; Bond, 1999).

2.2.4 Groundwater Resources

Wastewater application has the potential to affect the quality of groundwater resources in the long run through excess nutrients and salts found in wastewater leaching below the plant root zone. However, the actual impact depends on a host of factors including depth of water table, quality of groundwater, soil drainage, and scale of wastewater irrigation. For instance the quality of groundwater would determine the magnitude of the impact from leaching of nitrates. If the groundwater is brackish, the leaching of nitrates would be of little concern as the water has no valuable use attached to it. The proximity of wastewater irrigation to sources of potable water supplies such as wells or pump wells will influence how we evaluate the severity of groundwater pollution effects (Hussain *et al*., 2001; Downs *et al*., 1999; Gallegos *et al*., 1999).

2.2.5 Property Values

In discussing the effects of environmental pollution on property values, we must distinguish between two types. The first is the discomfort from a pollution source associated with, nuisance, noise, odor, hazards, and unsightliness, have been studied extensively. The costs may include health, clean up costs and legal liability. Properties located along a polluted stream had significantly lower market prices than properties located along clean streams (Hussain *et al*., 2001; Page and Rabinowitz, 1993).

The second type is the eventual use one might make of a polluted resource associated with

property. Residential, commercial or industrial areas that use groundwater as a source of water may reduce in property value as opposed to areas with clean ground-water because the resource cannot be used for the designated purpose. If on the other hand, other sources of water exist, then the only effect on property value that should be accounted for is the first type. Wastewater induced salinity and so dicity may also have negative effects on soil productivity, which in turn may affect land prices and lease revenues (Hussain *et al*., 2001; Page and Rabinowitz, 1993)

2.2.6 Ecological Impacts

When drainage water from wastewater irrigation schemes drains particularly into small confined lakes and water bodies and surface water, and if phosphates in the orthophosphate form are present, the remains of nutrients may cause eutrophication. This causes imbalances in plant microbiological communities of water bodies which may in turn affect other higher forms of aquatic life and influence the presence of water birds and reduce biodiversity (Smith *et al.,* 1999).

2.2.7 Social Impacts

In the context of this analysis, social impacts are the concerns/doubts expressed by the public about wastewater irrigation. These concerns can be classified as follows:

- ***General concern**s* such as nuisance, poor environmental quality, poor hygiene, odor, noise, higher probability of accidents, etc.
- ***Social concerns*** such as food safety, health and welfare, impaired quality of life, loss of property values, and sustainability of land use.
- ***Natural resource concerns*** such as pollution of vital water resources, loss of fish, wildlife, exotics species, etc (Hussain *et al*., 2001).

Table 3: Recommended standards of heavy metal concentration for agriculture reuse

Element	KSA Guideline(mg/L)	USEPA(mg/L)
Fe	5.6	5.0
Cd	0.02	0.01
As	0.01	0.1

Cu	0.2	0.2
Pb	2.0	2.5
Zn	1.0	2.0
Co	0.08	0.05
Mn	-	0.2
Cr	-	0.1
Ni	-	1.2

Source: FAO/WHO, 2007; USEPA and ANEFA, 1991.

2.3 Component of wastewater

2.3.1 Organisms

Many different types of organisms live in wastewater and some are essential contributors to the treatment. A variety of bacteria, protozoa, and worms work to breakdown certain carbon-based (organic) pollutants in wastewater by consuming them. Through this process, organisms turn wastes into carbon dioxide, water, or new cell growth. Bacteria and other microorganisms are particularly plentiful in wastewater and accomplish most of the treatment (Catherine *et al.* 1997).

2.3.2 Organic matter

Organic materials are found everywhere in the environment. They are composed of the carbon-based chemicals that are the building blocks of most living things. Organic materials in wastewater originate from plants, animals, or synthetic organic compounds, and enter wastewater in human wastes, paper products, detergents, cosmetics, foods, and from agricultural, commercial, and industrial sources. Organic compounds normally are some combination of carbon, hydrogen, oxygen, nitrogen, and other elements. Many organics are proteins, carbohydrates, or fats and are biodegradable, which means they can be consumed and broken down by organisms.

2.3.3 Oil and grease

Fatty organic materials from animals, vegetables, and petroleum also are not quickly broken down by bacteria and can cause pollution in receiving environments. When large amounts of oils and greases are discharged to receiving waters from community systems, they increase Biological Oxygen Demand (BOD) and they may float to the surface and harden, causing aesthetically unpleasing conditions.

They also can trap trash, plants, and other materials, causing foul odors, attracting flies and mosquitoes and other disease vectors. In some cases, too much oil and grease causes septic

conditions in ponds and lakes by preventing oxygen from the atmosphere from reaching the water.

2.3.4 Inorganic

Inorganic minerals, metals, and compounds, such as sodium, potassium, calcium, magnesium, cadmium, copper, lead, nickel, and zinc are common in wastewater from both residential and nonresidential sources. They can originate from a variety of sources in the community including industrial and commercial sources, storm water, and inflow and infiltration from cracked pipes and leaky manhole covers. Most inorganic substances are relatively stable, and cannot be broken down easily by organisms in wastewater. Large amounts of many inorganic substances can contaminate soil and water. Some are toxic to animals and humans and may accumulate in the environment. For this reason, extra-treatment steps are often required to remove inorganic materials from industrial wastewater sources. For example, heavy metals which are discharged with many types of industrial wastewaters are difficult to remove by conventional treatment methods. Although acute poisonings from heavy metals in drinking water are rare, potential long term health effects of ingesting small amounts of some inorganic substances over an extended period of time are possible.

2.3.5 Nutrients

Wastewater often contains large amounts of the nutrients nitrogen and phosphorus in the form of nitrate and phosphate, which promote plant growth.

2.3.6 Solids

Solid materials in wastewater can consist of organic and/or inorganic materials and organisms. The solids must be significantly reduced by treatment or they can increase Biological Oxygen Demand (BOD) when discharged to receiving waters and provide places for microorganisms to escape disinfection, they also can clog soil absorption fields in onsite systems.

2.3.7 Gases

Certain gases in wastewater can cause odors, affect treatment, or are potentially dangerous. Mclhanc gas, for example; is a byproduct of anaerobic biological treatment and is highly combustible. Special precautions need to be taken near septic tanks, manholes, treatment plants, and other areas where wastewater gases can collect. In addition to the many substances found in wastewater, there are other characteristics system designers and operators use to evaluate wastewater, for example; the color, odor, and turbidity of wastewater give clues about the amount and type of pollutants present and treatment necessary.

2.4 Liquid and gaseous radioactive effluents transfer in terrestrial food chains

Airborne radionuclides are transported downwind and dispersed by the mixing processes in the atmosphere. They gradually settle on land surfaces as a result of different deposition mechanisms. Plants are contaminated by two main processes: (1) direct deposition on aerial parts of the standing vegetation and (2) indirect contamination by root uptake when radionuclides deposited onto the soil are absorbed by plants along with water and nutrients. In a similar way, radionuclides present in irrigation water reach plants by direct deposition on aerial parts (sprinkling) or via the soil by root absorption. Gaseous radioelements like ^{14}C and ^{3}H (as water vapor or tritiated hydrogen) penetrate the plants through the stomata and are incorporated into organic constituents by photosynthesis and other metabolic processes. Contamination of animals and animal products results from inhalation and ingestion of contaminated soil particles, feed, and water as shown in figure 1.

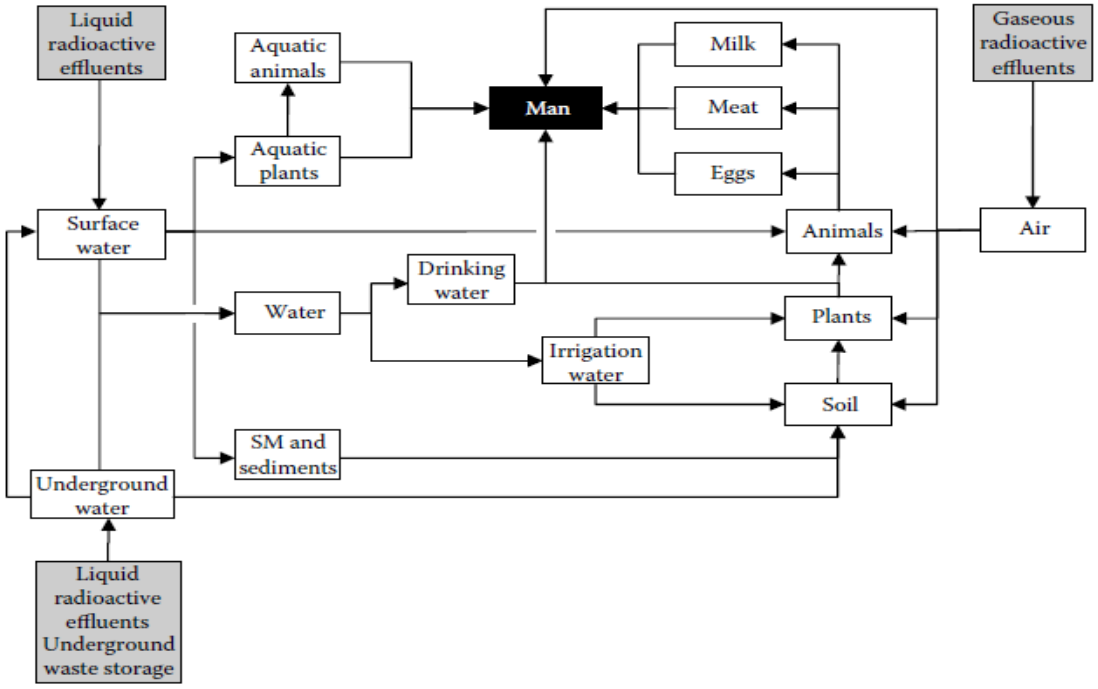


Figure 1: Conceptual model describing the transfer of liquid and gaseous radioactive effluents to man

Source: Taylor and Francis, 2007

2.5 Interactions of Radionuclides with Soil

Soils are heterogeneous systems combining three immiscible phases (solid, liquid, and gaseous) in different and changing proportions depending on the humidity level. Each phase is highly complex and variable in composition and physicochemical properties. Soil characteristics and thickness are also highly variable in space. They are often stratified in layers, termed horizons, lying on parent bedrock. The top layer, or topsoil, is rich in organic material, while underlying strata are essentially inorganic. Inorganic compounds are generally categorized on the basis of their size: clay (less than 2 µm), silt (2 to 20 µm), sands (20 to 2000 µm), gravels (2 to 20 mm), and stones (greater than 20 mm). Soils are dynamic systems; the properties are acquired and modified with time due to the joint actions of natural factors (variations in temperature and humidity, erosion) and farming practices. Radionuclides deposited on the ground or dispersed

within the soil are first dissolved in soil water. Dissolving proceeds via kinetics, depending on the speciation of the radioelement: it is quasi-instantaneous or soluble compounds (e.g., CsI), but can be a longer process when radionuclides are included in insoluble matrices (e.g., fuel particles or vitrified wastes), as radionuclides cannot be leached before weathering processes in the soil have altered the matrix. Once in solution, radionuclides can absorb on the sorption complex by exchange processes; (co-)precipitate as hydroxides, sulfides, carbonates, or insoluble oxides; form complexes with organic molecules; or remain in the water phase in an ionic form. One key property of soil is its ability to absorb ions and to immobilize them to different extents on the solid phase. Soil colloids (clay minerals and organic matter) contain a high specific density of negative charges acting as cation exchange sites. The ability of a soil to adsorb ions is proportional to the density of exchange sites and is expressed by its cation exchange capacity (CEC, in mEq/kg).

Values reported for the CEC range from 0.3 to 1.5 mEq/kg for kaolinite, 1 to 4 mEq/kg for illite, 8 to 15 mEq/kg for montmorillonite, and 30 to 50 mEq/kg for organic compounds. For most ions, adsorption of ions is reversible and equilibrium tends to be achieved between the concentration in the soil solution and on the sorption complex. This equilibrium is generally expressed as the distribution coefficient *K*d (in l/kg), which is the quantity of an element sorbed per unit weight of solids divided by the quantity of the element dissolved per unit volume of water.

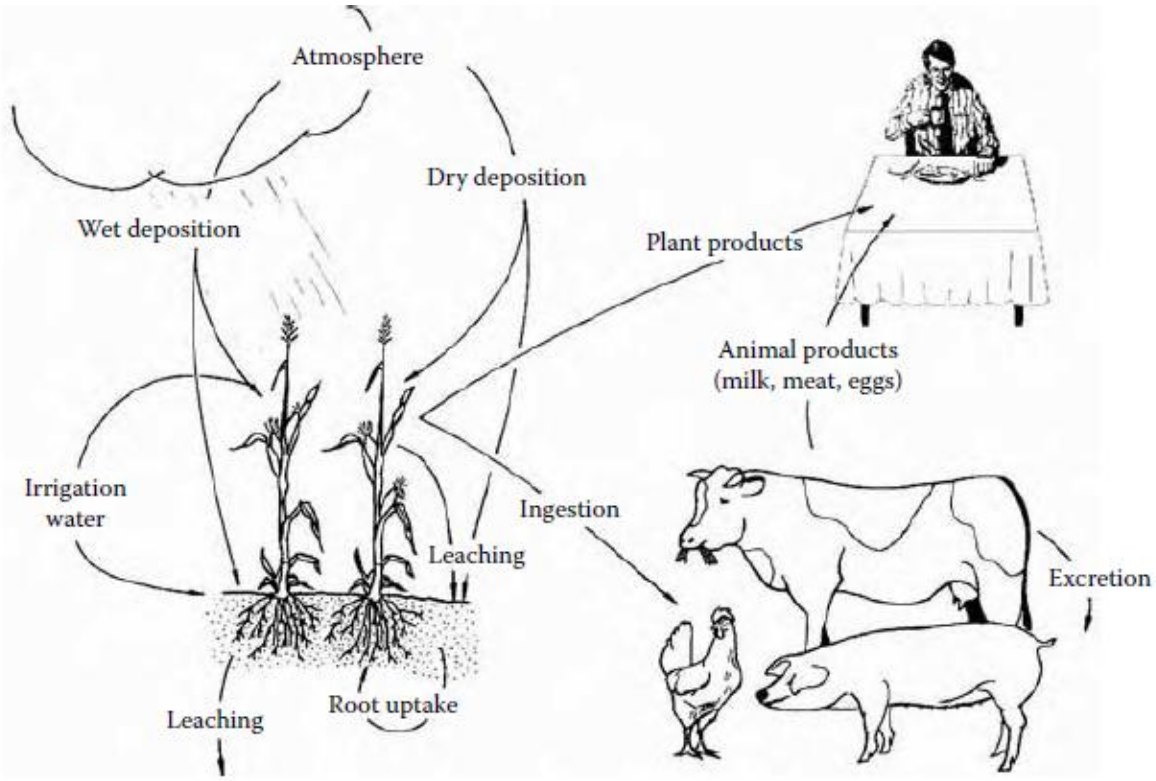


Figure 2: Main pathways for radionuclides to man in continental agricultural food chains.

Source: Taylor and Francis, 2007

2.6 Sources of radioactivity in soil

Radioactivity has two different origins in the environment. Some radionuclides are naturally present in soil, rocks, underground water, oceans, and the atmosphere. Their mobility and potential transfer to the food chain are directly linked to parameters such as their chemical form,

redox conditions of the environment, alteration of minerals and hydrogeological conditions. Chemistry within the rhizosphere is critical in the transfer of radioactivity from soils to plants. Air mass exchange within the atmosphere is also a key parameter for radionuclides produced by cosmic rays in the atmosphere. For technologically enhanced naturally occurring radioactive materials (TENORMs), both soil mineralogy and human parameters (e.g., fertilizers, petroleum or mining industries) are of importance when considering the transfer of radioactivity to the food chain. The distribution of anthropogenic radionuclides in the environment is less associated with the mineralogy of soils, and depends mostly on the presence of authorized or accidental releases from the nuclear power industry, military facilities, and nuclear weapons tests.

2.7 Soil contamination by heavy metals

Soils may become contaminated by the accumulation of heavy metals and metalloids through emissions from the rapidly expanding industries(such as textile, tanning, petrochemicals, pesticides, and pharmaceutical facilities), mine tailings, disposal of high metal wastes, leaded gasoline and paints, land application of fertilizers, animal manures, sewage sludge, pesticides, wastewater irrigation, coal combustion residues, spillage of petrochemicals, and atmospheric deposition (Wuana and Okieimen, 2011).

Soils are the major sink for heavy metals released into the environment through the aforementioned anthropogenic activities and unlike organic contaminants which are oxidized to carbon (IV) oxide by microbial action, most metals do not undergo microbial or chemical degradation, and their total concentration in soils persists for a long time after their introduction (Wuana and Okieimen, 2011).

Heavy metals constitute an ill-defined group of inorganic chemical hazards, and those most commonly found at contaminated sites are lead (Pb), chromium (Cr), arsenic (As), zinc (Zn), cadmium (Cd), copper (Cu), mercury (Hg), and nickel (Ni). Heavy metal contamination of soil may pose risks and hazards to humans and the ecosystem through: direct ingestion or contact with contaminated soil, the food chain (soil-plant-human or soil-plant-animal-human), drinking of contaminated ground water, reduction in food quality (safety and marketability) via phytotoxicity, reduction in land usability for agricultural production causing food insecurity, and land tenure problems (Wuana and Okieimen, 2011).

To determine the level of environmental assessment of pollutants in the soil, we employ the use of risk assessment codes which are useful in assessing the major and toxic metals in soils and sediments. These codes are classified into two broad categories, i.e., single and integrated assessment indices (Filipssona *et al*., 2007; Hussain *et al*., 2015). The single assessment indices is further divided into five categories, i.e., contamination factor, pollution load index, enrichment factor, ecological risk index, and geo-accumulation index. In these indices, the contamination factor is commonly used to find out the variation between the target and reference samples toxicity and their risk for environment (Ameh *et al*., 2011; Hussain *et al*., 2015).

The ecological risk index can measure both toxicity and total concentration of heavy metals in soil and sediments (Sundaray et al. 2011). Geo-accumulation index is a technical method used to quantify the degree of anthropogenic or geogenic contamination and their variation range of concentration in soils. Geo-accumulation index is used to quantify metals in soil and also their health risk grades (Grath *et al*., 2004; Harikumar *et al*., 2009; Hussain *et al.,* 2015).

2.7.1 Contamination factor

Contamination factor (**CF**) is also called single pollution index (**PI**). Contamination factor is the quotient obtained by dividing the concentration of metals related to the target area by reference area. Their results are mostly associated with single pollution load, while their n-root was used for integrated pollution load index. The contamination factor can be calculated through the following formula as suggested by Harikumar *et al.,* (2009).

$$CF = \frac{Cn}{Bn} \text{ ---------- } \mathbf{2}$$

In above equation, **Cn** is the concentration of metals in the target/reference area, and **Bn** is the metals concentration of the control area. And if the contamination factor CF < 1, it refers to low contamination; 1 ≤ CF < 3 means moderate contamination; 3 ≤ CF ≤ 6 indicates considerable contamination and CF > 6 indicates very high contamination.

2.7.2 Geo-accumulation index

Geo-accumulation index is used to quantify the degree of anthropogenic or geogenic accumulated pollutant loads in soil and can be determined through the following formula:

$$\mathbf{Igeo} = \log_2\left(\frac{Cn}{1.5 \times Bn}\right) \text{ ---------- } \mathbf{3}$$

Where Cn and Bn are the determined concentration of metals in the target and reference areas, respectively. The factor 1.5 is possible anthropogenic variations of contaminants in reference areas (Lokeshwari and Chandrappa 2006; Fagbote and Olanipekun 2010).

The intensities for geo-accumulation index (GAI or I_{geo}) of element according to their grading, degrees, and values are classified as: grade zero ($0<I_{geo}\leq1$), which is considered as unpolluted, grade 1 ($1<I_{geo}\leq2$) as slightly polluted, grade 2 ($2<I_{geo}\leq3$) as moderate polluted, grade 3 (3<Igeo≤4) moderate to severely polluted, grade 4 ($4<I_{geo}\leq5$) as severely polluted, while grade 5 ($I_{geo}>5$) as severely to extremely polluted.

2.7.3 Ecological risk factor

Ecological risk index (**ERI**) is critical to measure both risk factor and metals concentrations in soil. The potential ecological risk index can be determined through the following formula:

$$\boldsymbol{Er = (Tr \times CF)} \quad \text{----------} \quad \mathbf{4}$$

Where **Er** is the potential ecological risk factor/index, **r** represents the toxic-response factor, and **CF** represents contamination factor (measured through Section 3.1).

2.7.4 Enrichment factor

The enrichment factor (**EF**) was calculated for the level of elemental enrichment in soil and sediments in terms of their anthropogenic and geogenic origins. Enrichment factor is a common approach to assess the impacted soil and can be calculated through following formula as suggested by Huu *et al.,* (2010); Atgn *et al.,* (2000):

$$\boldsymbol{EF = \left(\frac{Cn}{Cm}\right) \div \left(\frac{Cb}{Cx}\right)} \quad \text{----------} \quad \mathbf{5}$$

where **Cn** is the concentration of elements in the target area, and **Cm** is the rare concentration (lowest possible concentration in the target area) of element in the target area, whereas **Cb** is the

concentration of element in reference area, and **Cx** is a rare concentration (lowest possible concentration in the reference area) of element in the reference area.

2.7.5 Pollution load index

Pollution load index (**PLI**) is simple statistical technique used to determine elemental contents in soil beyond the reference concentration and provide comprehensive information about the metals toxicity in respective samples (Tomlinson *et al.,* 1996; Yang *et al.,* 2011). Pollution load index can be determined through the following formula:

$$PLI = \sqrt[n]{CF1 \times CF2 \times CF3 \times \ldots \times CFn} \quad \text{---------} \quad \mathbf{6}$$

Where **PLI** represents the pollution load index, **BCF** is the contamination factor, and **Bn** is the number of elements. The **PLI** >1 indicates polluted, while **PLI** <1 indicates no pollution.

2.7.6 Weighted average of pollution index (PIw_{avg})

Weighted average of pollution index (PIw_{avg}) is a simple statistical technique used for toxic and major elements importance (toxicity) in the target area. A weighted average of pollution index was defined by Qingjie and Jun (2008) and is calculated as:

$$PIwavrg = \sum_{i=1}^{m} \mathbf{WiPi} \quad \text{----------} \quad \mathbf{7}$$

Where **Pi** is the single pollution index of metals **i**, **Wi** is the weight of **Pi**, and **m** is the count of heavy metals species. The weight values for major and toxic metals are 1–5 as suggested by Qingjie and Jun (2008).

2.8 Concept of radioactivity

2.8.1 Radioactivity and radiation

For any nucleous to be stable, there a limit range of neutrons it can accommodate when compared to its atomic number. If there are too few or too many neutrons in the nucleus, the atom (isotope) is unstable. It tries to gain stability by emitting energy in the form of radiation as such it is said to radioactive. Hence, radioactivity is the spontaneous emission of radiation (energy) from an unstable atom. And radiation is a form of energy (chemical in nature) given off by a radioactive materials and travels in form of waves (X,ɣ) or particles (α, β). Radioactivity is divided into two categories namely: -

- Natural radioactivity:- when an unstable nuclei spontaneously disintegrates in nature i.e by itself.
- Artificial radioactivity:- when the unstable nuclei is been prepared in the lab. e.g operation of a nuclear reactor, production of x-rays, radioactive ore mining and milling, nuclear weapon testing e.t.c

Since radioactivity involves nuclear transformations that result in the formation of new elements, these transformations are usually accompanied by one or several different mechanisms, including alpha particle emission, beta particle and positron emission, and electron capture. Each of these reactions may or may not be accompanied by gamma radiation (Cember, 1996). Radioactivity and radioactive properties of nuclides are determined by nuclear considerations only, and are independent of the chemical and physical states of the radioisotopes. Radioactive properties of an radioisotopes therefore cannot be changed by any means, and are unique to the respective radionuclides.

2.8.2 Decay constant (λ)

The principal fundamental law of radioactivity states that: the average number of nuclei disintegrating per unit time (activity), is proportional to the total number N of the nuclei at any given time. i.e

$$\frac{dN}{dt} \propto N \quad or \quad \frac{dN}{dt} = -\lambda t, \qquad A = /-\lambda N/ \quad \text{----------} 8$$

λ= decay constant

N= number of atoms present in the nuclei, $N = \frac{mN_A}{M}$

M= molar mass of the sample

N_A= Avogadro's number

m= mass of the sample

$$\text{Now} \quad \frac{dN}{N} = -\lambda dt \qquad \text{or} \qquad \int_{N_0}^{N} \frac{1}{N} dN = -\lambda \int_0^t dt$$

$\ln[N]_{N_0}^{N} = -\lambda t, \quad \ln\frac{\mathrm{N}}{\mathrm{N_0}} = -\lambda \mathrm{t}, \quad$ and taking ln on both sides gives

$$\frac{N}{N_0} = e^{-\lambda t} \ , \qquad N = N_0 e^{-\lambda t} \ \text{or} \qquad A = A_0 e^{-\lambda t} \quad \text{----------} 9$$

Where:

N=number of nuclei at time t

N_0= number of nuclei at time $t = 0$

$t =$ elapse time

2.8.3 Half-life ($t_{1/2}$)

Half-time is the time it takes a radioactive substance to decay/disintegrate to half of its original value.

Now from equation 9, put $N = \frac{N_0}{2}$ and $t = T_{1/2}$, we will have

$$\frac{N_0}{2} = N_0 e^{-\lambda T_{1/2}}, \quad \frac{1}{2} = e^{-\lambda T_{1/2}}, \quad 2 = e^{\lambda T_{1/2}},$$

Which when taken ln on both sides gives

$$T_{1/2} = \frac{ln2}{\lambda} = \frac{0.693}{\lambda} \text{ ---------- } 10$$

The half-life of a radio nuclei vary greatly among different types of atoms, from less than a second to billions of years. For example, it will take about 4.5 billion years for half of the atoms in a mass of ^{238}U to spontaneously disintegrate, but only 24,000 years for half of the atoms in a mass of ^{239}Pu to spontaneously disintegrate. In contrast, ^{131}I, commonly used in medicine, has a half-life of only 8 days.

A plot of number of atoms against half-life is shown in figure 3 below

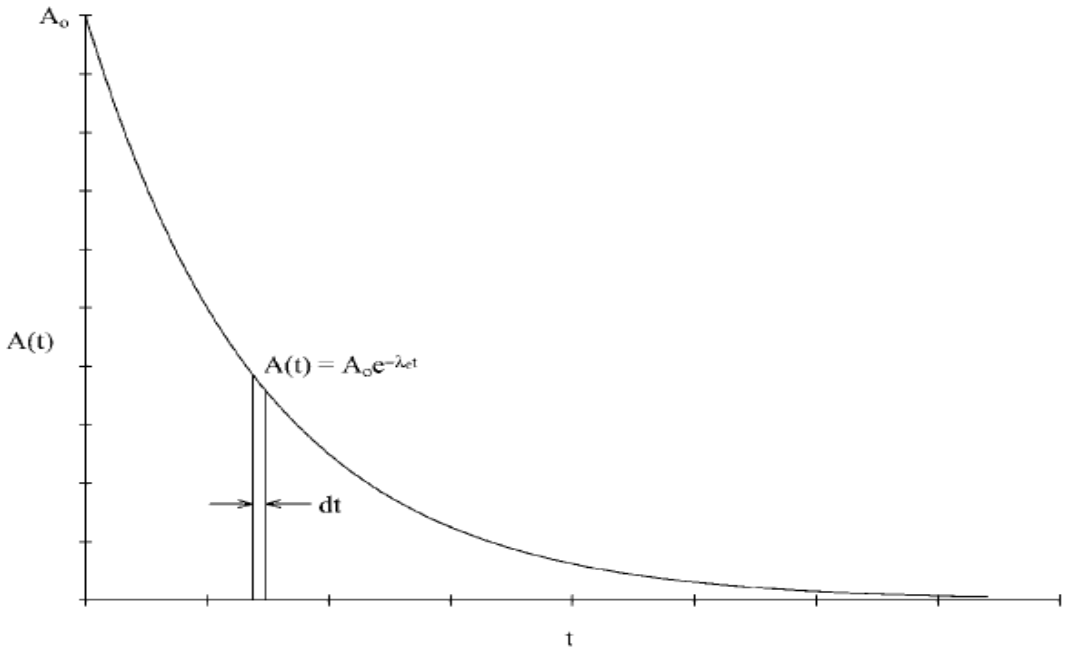


Figure 3: A typical radioactive curve

The unit of activity is the disintegration per seconds (dps) known as the Becqurel (Bq). Another important unit of activity is the Curie (Ci); as $1\ Ci = 3.7 \times 10^{10} Bq$ which is the activity of $1g$ of $Radium - 226$.

2.8.4 Radioactive decay series

Radioactive series refers to any four independent sets of unstable heavy atomic nuclei that decay through a sequence of alpha and beta decays until a stable nucleus is achieved. While many naturally occurring elements have radioactive isotopes, only potassium, and the uranium and thorium decay series have radioisotopes that produces gamma rays of sufficient energy and intensity to be measured by gamma ray spectrometry. This is because they are relatively abundant in the natural environment. Others such as vanadium-50, do exist but contribute insignificantly (Ibeanu, 2002), which according to Eisenbud (1973), may be due to their low abundance. Uranium, radium and thorium occur in three natural decay series headed by uranium- 238, uranium-235 and

thorium-232 respectively. In nature the radionuclide in these three series are approximately in a state of secular equilibrium, in which the activities of radionuclide within each series are nearly equal.

The isotopes ^{238}U, ^{235}U and ^{232}Th do not decay directly to a stable product, but achieve ultimate stability through a succession of α and β- decays, including several minor closed branches. The uranium-series (^{238}U), actinium-series (^{235}U) and thorium-series (^{232}Th) are shown in figure 4.

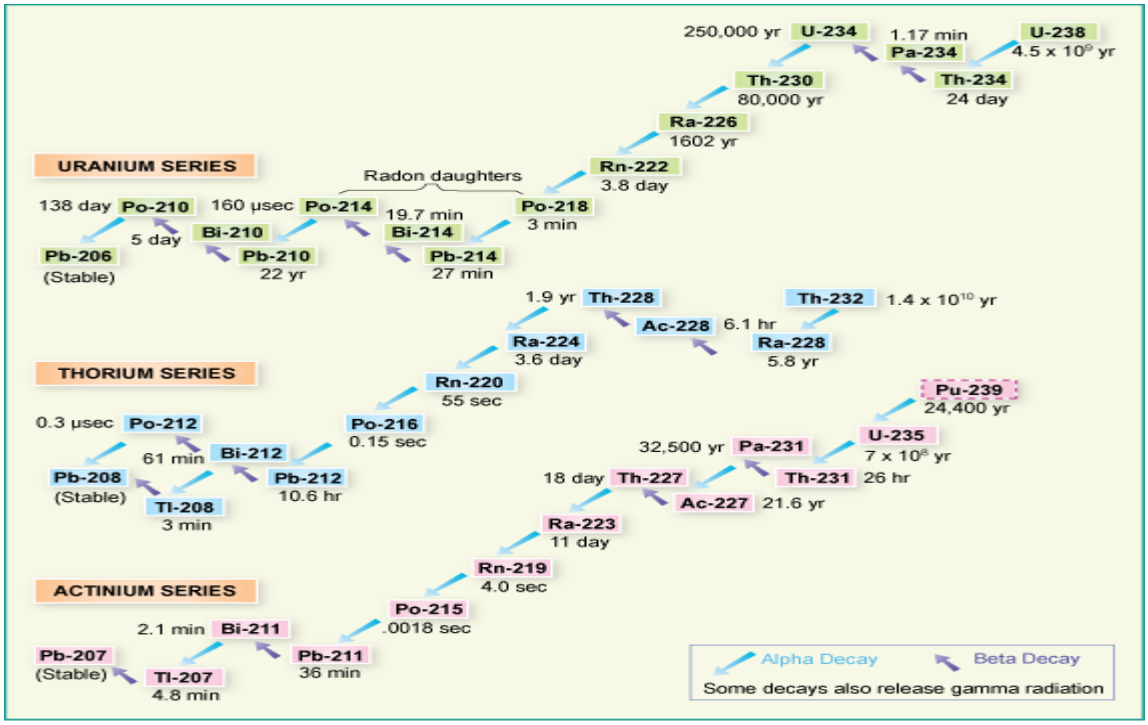


Figure 4: U-235, U-238 and Th-232 Decay Series

(**Source**: World Nuclear Association, WNA) Wednesday, July 08, 2015

2.8.5.0 Radioactive equilibrium

Radioactive equilibrium is the term used to explain the state when the member of the radioactive series decay at the same rate as they are produced (Prince, 1979). The three predominant cases of the state of equilibrium are the secular, transient and no equilibrium.

2.8.5.1 Secular Equilibrium

If the period of observation (or calculation) is such that the activity of the parent nuclide remains essentially unchanged, then the activity of the radioactive product (commonly referred to as the radioactive daughter) in the equation for the second member of a radioactive series can be simplified as follows:

$$A(t) = A_1(1 - e^{-\lambda_2 t}) \text{ ---------- } 11$$

It should be noted that this is accurate only if the parent is much longer lived than the product. When this condition is satisfied, the product activity will grow to a level that is essentially identical to that of the parent, as shown in Figure 5, and the activities of the parent and the product show no appreciable change during many half-lives of the product. This condition is called **secular equilibrium**. The build-up of ^{90}Y from the transformation of ^{90}Sr is a good example of secular equilibrium as in the growth of ^{222}Rn from the transformation of ^{226}Ra. In both instances, the activity of the product will increase until it is the same as that of the parent (i.e., it is in equilibrium with the parent); the activity of the product reaches a value of 99% of the parent activity after about 6.7 half-lives of the product nuclide and is effectively in equilibrium with the parent at this

and subsequent times.

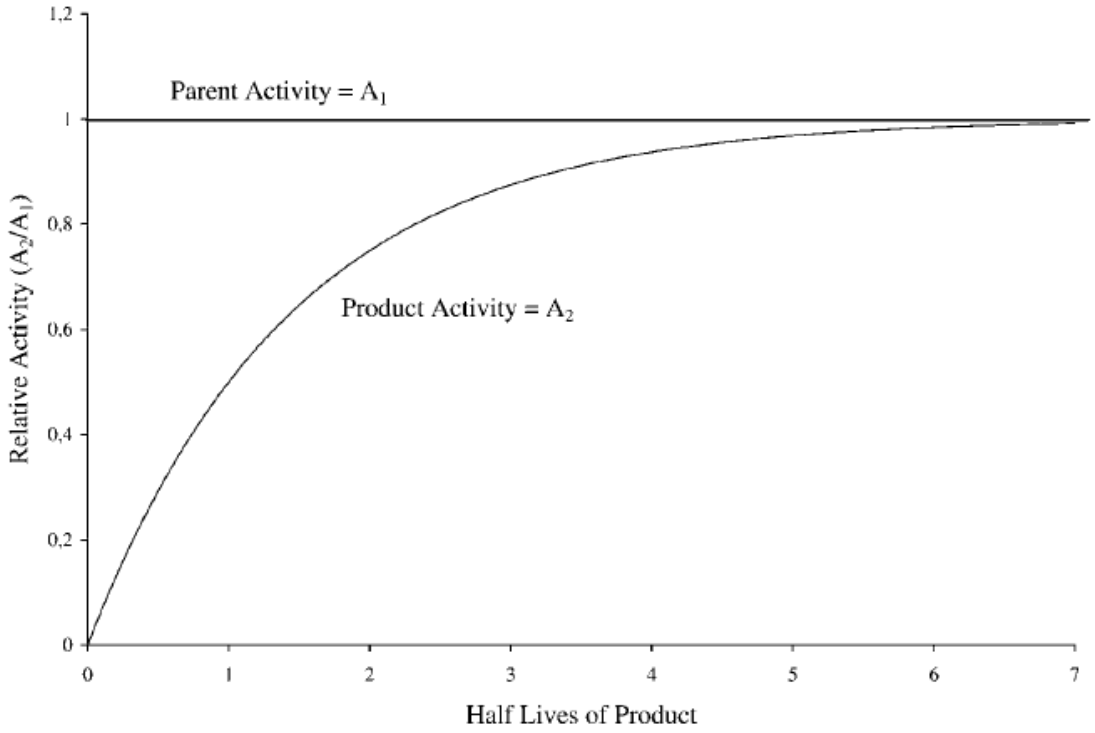


Figure 5: Example of secular equilibrium in which the parent activity remains essentially unchanged whiles the short-lived product (activity = 0 at t = 0) activity builds up to 99% of the parent activity in about 6.7 half-lives.

2.8.5.2 Transient Equilibrium

A condition called transient equilibrium results between a radioactive parent and a radioactive product if the parent is longer-lived than the product ($\lambda_1 > \lambda_2$), but the half-life of the parent is such that its activity diminishes appreciably during the period of consideration. If no product activity exists at t = 0, the activity of the product is given by

$$A_2(t) = \frac{T_1}{T_1 - T_2} A_1 (e^{-\lambda_1 t} - e^{-\lambda_2 t})$$

For values of t above 6.7 half-lives or so, $e^{-\lambda_2 t}$ becomes negligible compared with $e^{-\lambda_1 t}$ and the activity of the product is essentially

$$A_2(t) = \frac{T_1}{T_1 - T_2} A_1 e^{-\lambda_1 t}$$

Thus, the product eventually diminishes with the same half-life as the parent. When this condition exists, the two nuclides are said to be in transient equilibrium, and the product activity is greater than that of the parent by the factor $T_1/(T_1 - T_2)$. And since $A_1 e^{-\lambda_1 t}$ is just the activity of the parent at time **t**, the product activity can be obtained easily by determining the parent activity $A_1(t)$ at time **t** and multiplying it by $T_1/(T_1 - T_2)$ if it is known that transient equilibrium has been established. This is done by determining that the in growth time has exceeded the time when the product activity has reached its maximum value, and achieved just after, but not before, the activity of the product nuclide ^{132}I crosses over the activity curve for ^{132}Te as shown below.

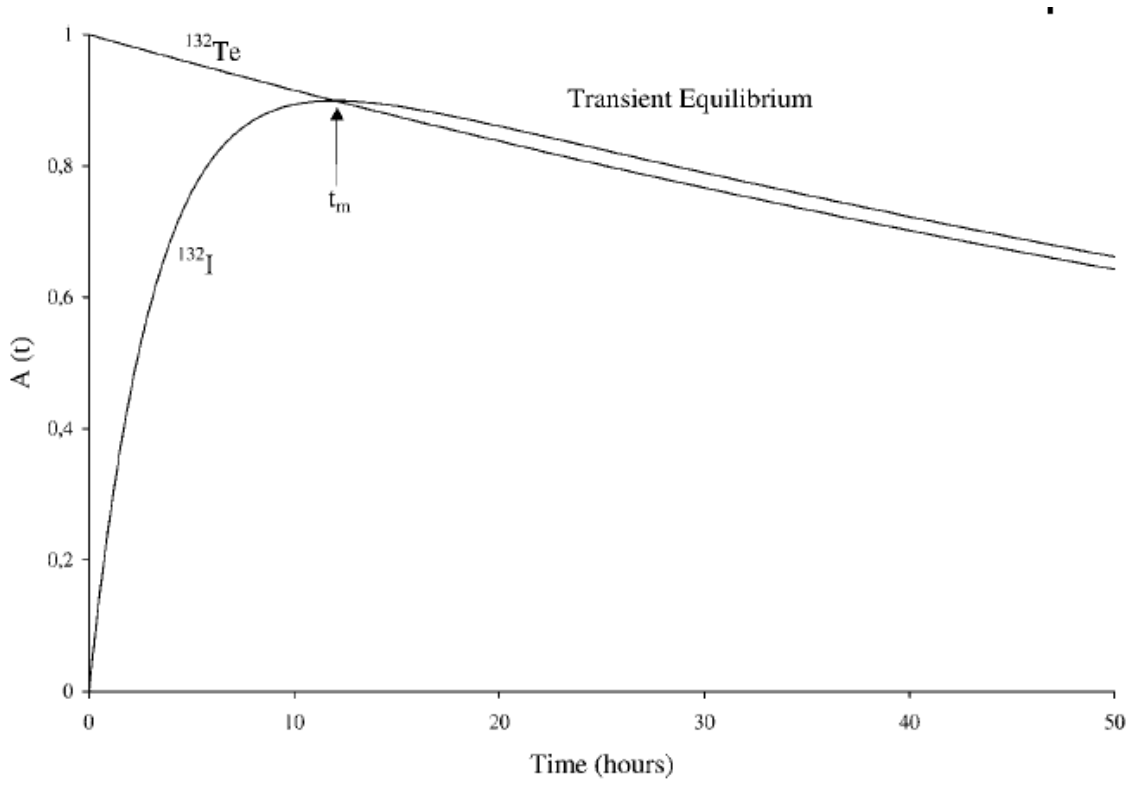


Figure 6: Activity of ^{132}I produced from initially pure ^{132}Te undergoing radioactive transformation to ^{132}I, showing the establishment of transient equilibrium.

When the parent has a shorter half-life than the product ($\lambda_1 > \lambda_2$), no state of equilibrium is attained. If the parent and product are separated initially, then as the parent undergoes transformation the number of product atoms will increase, pass through a maximum, and the product activity will eventually be a function of its own unique half-life(Choppin *et al*, 2002,Turner,2007, Lapp and Andrews, 1972, Cember and Johnson, 2009).

2.8.6 Applications of radioactivity

The knowledge of radioactivity has been gaining wider acceptance and has proven useful in diverse field of applications in many areas to include:-

- ✓ Archaeology for Carbon dating to determine the age of rocks and other fossils
- ✓ Medicine as either radiotherapy in tumour killing of cancers, or as diagnostic radiology in routine X-ray examinations
- ✓ Agriculture in food preservation and processing
- ✓ Industry for nuclear power generation
- ✓ Academy for research as tracer technique e.g in neutron activation analysis NAA
- ✓ Oil and gas for well logging in mineral exploration

2.9 Sources of Heavy Metals in Soils

Heavy metals are elements with atomic number greater than or equals 20 or with mass number of 40 and above. Their major sources into the soil are weathering of rock and anthropogenic activities (Turpeinen, 2002). Heavy metals occur naturally in the soil environment from the pedogenetic processes of weathering of parent materials at levels that are regarded as *trace*

(<1000 mg kg^{-1}) and rarely toxic due to the disturbance and acceleration of nature's slowly occurring geochemical cycle of metals by man and above defined background values high enough to cause risks to human health, plants and animals, ecosystems, or other media. Although the level of pollution is sufficiently low that crops are still able to grow, if it is accumulated in the edible parts of the crop to levels that exceed food safety standards, they can enter the body and pose a risk to human health (Wuana and Okieimen, 2011; Xueli *et al*., 2012).

The chief sources of heavy metals contamination to the soil are:-

- ✓ Large quantities of fertilizers regularly added to soils in intensive farming systems to provide adequate N, P, and K for crop growth as the compounds used to supply these elements contain trace amounts of heavy metals (e.g., Cd and Pb) as impurities, which, after continued fertilizer, application may significantly increase their content in the soil. Application of these phosphatic fertilizers inadvertently adds Cd and other potentially toxic elements to the soil, including F, Hg, and Pb.
- ✓ *Biosolids and Manures*(e.g., livestock manures, composts, and municipal sewage sludge) inadvertently leads to the accumulation of heavy metals such as As, Cd, Cr, Cu, Pb, Hg, Ni, Se, Mo, Zn, Tl, Sb, and so forth, in the soil as these are frequently apply to crops and pastures either as solids or slurries.

  And if repeatedly applied to restricted areas of land, can cause considerable build-up of these metals in the soil in the long run.
- ✓ *Wastewater:*-The application of municipal and industrial wastewater and related effluents to land is a common practice in many parts of the world. Worldwide, it is estimated that 20 million hectares of arable land are irrigated with wastewater and it

accounts for 50 percent of the vegetable supply to urban areas in most developing nations. Farmers generally are not bothered about environmental benefits or hazards since they are primarily interested in maximizing the yields and profits. Although the metal concentrations in wastewater effluents are usually relatively low, long-term irrigation of land with such waters can eventually result in heavy metal accumulation in the soil.

- ✓ *Mining and Milling Processes* of metal ores coupled with industrial wastes have bequeathed many countries, the legacy of wide distribution of metal contaminants in soil. Extensive Pb and Zn ore mining and smelting have not only resulted in contamination of soil that poses risk to human and ecological health, but have also not restore soil productivity. Although some few have little benefits to agriculture or forestry, many are potentially hazardous because of their high toxic contents of heavy metals (Cr, Pb, and Zn) when disposed off on land.

2.10 Effects of soil contamination by heavy metals on farm crops

Most of crops and vegetables irrigated with wastewater may be contaminated even though the ability to absorb heavy metals differs from one crop to another, and between varieties of the same crop species. Sugarcane is a C4 plant with good photosynthetic capability that is cultivated extensively in Nigeria. In recent years, researchers around the world have studied the use of sugarcane to remediate the contaminated soil because of it poor accumulator of some metals such as copper (Cu), cadmium (Cd), and selenium (Sl). When Cd content in the soil is less than 50

mg kg^{-1}, the low amount accumulated in cane juice means it is safe for consumption otherwise not safe (Xueli *et al*., 2012).

Soils normally contain low background levels of heavy metals. Excessive levels of heavy metals can be hazardous to man, animals and plants. Heavy metals regulated by the EPA are arsenic, cadmium, copper, lead, nickel, selenium, and Zinc. The limits of some heavy metals for non contaminated soil and plants and garden are given in Table 4.

Table 4: Typical and unsafe heavy metal soil levels

Heavy metal	Typical background levels for non contaminated soil (ppm)	Unsafe for leafy or root vegetables (ppm)	Unsafe for gardens and children contact (ppm)
Cadmium	0.1 - 1.0	>10	50
Copper	1 - 50	>200	500
Lead	10 - 70	>500	1000
Nickel	0.5 - 50	>200	500
Zinc	9 - 125	>200	500

Source: Amin and Lygh, 2013

Heavy metal toxicity may results into a number of health problems including a damaged or reduced mental and central nervous function, lower energy levels, and damage to blood composition, lungs, kidneys, liver, and other vital organs. Long-term exposure may result in a slowly progressing physical, muscular, and neurological degenerative process, that mimic

Alzheimer's disease, Parkinson's disease, muscular dystrophy, and multiple sclerosis. Allergies are not uncommon and repeated long-term contact with some metals or their compounds may even cause cancer (Amin, Ibrar and Alam 2014).

Heavy metals on the basis of their health importance can be classified into four major groups, as essential, like Cu, Zn, CO, Cr, Mn and Fe, which are micronutrients and are toxic when taken in excess; non essential like Ba, Al, Li and Zr, less toxic like Sn and Al, and highly toxic like Hg and Cd. The toxicity limit and recommended or safe intake of some of heavy metals for human health is given in Table 5.

Table 5: Toxic limit/recommended/safe intake of heavy metals

Heavy metal	Toxic limit	Recommended intake/Safe intake
Arsenic	3 mg/day for 2 - 3 weeks	15 - 25 micro g/day (adults)
Cadmium	200 micro/kg of fresh weight	15 - 50 micro g/day (adults), 2 - 25 micro g/day children
Lead	>500 micro g/L (Blood)	20 - 280 micro g/day (adults), 10 - 275 micro g/day children
Zinc	150 micro/day	15 micro g/day

Source: Amin, Ibrar and Alam 2014

Research has proven that long term use of sewage effluent for irrigation contaminates soil and crops to such an extent that it becomes toxic to plants and causes deterioration of soil. This contains considerable amount of potentially harmful substances including soluble salts like Fe^{2+},

Cu^{2+}, Zn^{2+}, Mn^{2+}, Ni^{2+} and Pb^{2+}. Additions of these heavy metals are Undesirable (Amin, Ibrar, and Alam 2014).

Table 6: Recommended maximum concentration (mg L^{-1}) of heavy metals for use of effluents in agriculture.

Trace element	Concentration(mg/L)
Cu	0.2
Pb	0.025

Co	0.5
Cr	0.1
Ni	1.2
Fe	5.0
Mn	0.2
Cd	0.01
Zn	2.0
As	0.003

Source: - WHO 2007, Antil, 2011, USEPA and ANEFA, 1991

2.11 Ecology of Sugarcane

Sugarcane (*Saccharum spp.*) is a tropical crop that usually takes between 8 – 12 months to reach its maturity. Matured cane which may be green, yellow, purplish or reddish considered ripe when sugar content is at its maximum is grown commercially in many parts of tropical and sub-tropical regions of the world and it is the main source of sugar produced for both export and domestic consumption. Sugarcane is a crop that makes a high demand on essential plant nutrients as its production practices throughout the world vary depending on soil types, climatic factors and custom. The climate is characterized in most of the sugar plantation estates in Nigeria by a pronounced break between dry and wet season and the

water deficit from December to March necessitates the use of irrigation during these periods of the year (Girei and Giroh, 2012; Adekola and Akinpelu, 2002).

As a result of high demand of sugarcane on essential nutrients, it is possible that trace elements if present in the irrigation water or soil could eventually be absorbed and may result in important concentrations of these elements in the sugarcane juice hence the need to understand the possible effect or influence of the physicochemical quality of the irrigation water and also of the soil on the quality of sugarcane juice. Monitoring of the level of trace elements, and especially the most toxic ones such as cadmium and lead, in sugarcane juice and other farm crops becomes important since they are included in the list of metals considered important by the Global Environment Monitoring System (GEMS) by the United Nations Environmental Programme (Adekola and Akinpelu, 2002).

Sugarcane requires ample supply of water, 1200 - 1500 mm per annum and in freely drained soils, a high precipitation can be tolerated. Since duration of rainy season is important in sugarcane growth, adequate moisture and temperature becomes the two most important ecological requirements that are essential for the efficient growth and productivity of sugarcane crop. If excess water is not immediately drained at the sprouting stage, it will result in rotting of stem cuttings called setts, usually used for the next season's plantings. On the other hand, if rainfall is insufficient during the season, supplementary irrigation becomes necessary to ensure effective development of stems. In this context, water stress occurring in the plant during stem elongation severely reduces sugarcane production (Tarimo and Takamura, 1998).

Insolation in a sugarcane plantation is controlled not only by day length and humidity, but also by cloudiness of the sky. Solar radiation is particularly important in sugarcane because absorption of mineral nutrients from the soil is enhanced by the presence of light during the day time and absorption of water from the soil is equally dependent upon solar energy. It is imperative, therefore, that the greater the exposure of sugarcane to sunlight, the greater the yield. These ecological requirements of sugarcane make Nigeria and many other tropical countries best suited for its production. Furthermore, When the growing season is long enough, proper plant arrangement in rows promotes optimum exposure to solar radiation and hence, greater production (Tarimo and Takamura, 1998).

2.12 Uptake of toxic trace metals and micro nutrients by sugarcane

Long-term use of industrial effluents for irrigation may cause the concentrations of the trace metals Cd, Cu, Zn, Pb, and Mn to increase in surface soil, which may affect food quality and safety. Bioaccumulation of certain trace elements (Cd, Pb, and Cu) in vegetables and fruits to toxic levels are related to high prevalence of upper gastrointestinal cancer since these trace metals were judged to have a potential for bioaccumulation in sugarcane juice and risks to human health when consuming the juice (Damodharan and Reddy, 2014)

The need for controlling the irrigation with waste water or effluents, for improvement of the sugarcane quality will ultimately help to prevent exposure of humans to toxic metals; and to achieve this, knowledge of metal transfer factors that allows predicting their potential uptake by

plants in a particular area will be investigated to ascertain the extent of concentrations of trace metals in sugarcane which correlates with their concentrations in waste water effluents used for irrigation and in soil ((Damodharan and Reddy, 2014; Miller *et al*., 1992).

To portray quantitatively the transfer of an element from soil to plant, the soil–plant Transfer Factor (**TF**) of Concentration Ratio that expresses the ratio of contaminant concentration in plant parts to concentration in dry soil is used. **TF** is calculated as follows:

$$\mathbf{T.F} = \frac{\mathbf{Conc.plant}}{\mathbf{Conc.soil}} \quad \text{----------} \quad \mathbf{15}$$

Where, **Conc. plant** and **Conc. Soil** are the cane juice and soil concentrations, respectively.

When a **TF** is < 1, it shows that the plant can only absorb but not accumulate trace metals,

Whereas when a **TF** is > 1, it shows that plant can accumulate metals (Bose *et al*., 2008).

2.13 Uses and nutritional values of sugarcane

Nigeria has a land potential of over 500,000 hectares suitable for sugarcane cultivation that exist in about 40 different locations across the country and which is capable of producing 30 million metric tons of sugarcane or about 3 million metric tons of refined sugar. The type of sugar produced by sugarcane is called sucrose which is used as a sweetening agent for foods and in the manufacture of cakes, candies, preservatives, soft drinks, alcohol, molasses, baggasse “Jaggery” (Mazarkwaila), sweets (Alewa) and numerous other foods. Generally, sugarcane for domestic

consumption in Nigeria is more than that produced for industrial use for obvious reasons. Thus, chewing cane account for more than 46 percent of the total cane production (Daniel, 2014; Girei and Giroh, 2012).Bagasse represents about 12% of the original cane. The various uses of bagasse include industrial fuel and as soil additives (Adekola and Akinpelu, 2002).

The Sugarcane juice per serving contain Energy-111.13 kJ (26.56 kcal), Carbohydrates-97.5%, Protein-0.96%, Calcium- 0.04%, Iron-1.3%, Potassium-0.15%, Sodium-0.06% (DSP,2013).Sugarcane has essentially four growth phases:- Germination phase, Tillering phase, Grand growth phase, Maturity and ripening phase.

2.14 Review of some previous work

Recent studies have reported the presence and effects of some heavy metals in sugarcane as a result of wastewater use for irrigating farmlands across the globe (Damodharan and Reddy, 2014; Adekola and Akinpelu, 2002; Verma, *et al*., 2010; Kapungwe, 2013; Damodharan, and Reddy, 2012; Xueli *et al*., 2012; Velmurugan *et al*.,2009; Al-Khashman, *et al*., 2013; Akenga, *et al*., 2014; Pujar *et al*., 2012; Muchuweti, *et al*., 2013).

Soil analysis carried out for selected macro and micronutrients in some major sugarcane producing areas reveals that the level of phosphates and nitrates were below the required standards. The results indicate generally that macronutrient levels of phosphates and nitrates were low and below the required minimum levels for normal plant. Micronutrients were within the limits for normal plant growth which shows that low phosphate and nitrate

content in the soils is a contributor to the low sugarcane yields experienced in the area (Akenga *et al*., 2014).

Assessment of physico-chemical and heavy metal concentration in soil samples taken at various locations showed that monitoring of micronutrients (trace elements) in the soil provides efficient way to assess the qualitative and quantitative differences in metal concentrations at distinct locations since different uptake tendency of growing plants in the fields relies on the micronutrient deficiency or excess, and the higher values are indicative of anthropogenic inputs, either due to excess application of fertilizers or to industrial or mining activities (Pujar *et al.,* 2012).

Studies on heavy metal content in vegetables irrigated with mixtures of wastewater and sewage sludge in Harare indicated that the crops analysed were heavily contaminated with the four regulated elements Cd, Cu, Pb and Zn; and substantially exceed maximum values considered safe for human consumption even though the vegetable still looking apparently healthy and growing well. This may not only result in environmental contamination, but also lead to elevated heavy metal uptake by crops, which may affect food quality and safety (Muchuweti *et al*., 2013)

The study of chemical composition as well as analysis for temperature, conductivity, dissolved oxygen, pH, major cations, major anions and trace elements of wastewater treatment carried out at the Petra Wastewater Treatment Plant effluent in the southern region of Jordan showed that the water quality was characterized by its high salinity hazard and low Sodium Hazard which can be considered as marginal for human consumption. Moreover, concentrations of trace metals in treated wastewater were found to be low and within guidelines for irrigational purposes due to low level of industrial activities in the study area (Al-Khashman, 2013).

Assessments of comparison in the uptake of toxic metals and micro nutrients concentrations by sugarcane in treated effluent exceeded the permissible limits of the Indian standards and WHO/FAO expert committee recommendations. While their concentrations in juice of sugarcane grown in fields irrigated with bore-well water were within the limits of safety. The TF values for trace metals varied greatly between irrigated water to crop and soil to crop ratio which make the plant roots damaged by Pb contamination in soil and become weaker in absorbing other nutrients (Damodharan and Reddy, 2014).

Analysis of the multistatistical approaches for environmental geochemical assessment of pollutants indicated that the soil of Gadoon Amazai Industrial Estate of Pakistan, is highly affected by the release of effluents containing toxic and heavy metals from the various industries. These toxic metals can cause environmental problems in ecosystem of the area due to the release of toxic and heavy metals from the contaminated soil to the ground water system and also in the plants and vegetation grown in the soil (Hussain *et al.*, 2015).

Results of analysis of some trace elements in juice and bagasse of two varieties of sugarcane, location soil and irrigation water from Bacita Sugar Estate, indicates that levels of Mn and Cu are generally very low in the juice, bagasse and irrigation water, while Cd and Pb are rarely detected in most of the samples. Comparison of these levels of trace elements in irrigation water with WHO and United States Environmental Protection Agency maximum permissible levels for both drinking and irrigation purposes indicates that Bacita irrigation water is not potable but suitable for irrigation of farmlands. These results therefore show that the quality of the irrigation water could most probably influence the quality of the cane juice as well as the bagasse (Adekola and Akinpelu, 2002).

Evaluation of the impact assessments on application of sugar industry treated wastewater effluent on Sugarcane growth at two experimental farms, conclude that the possible accumulation of various nutrients and heavy metals in both soil and water may cause potential problems after long term reclaimed wastewater irrigation. Nevertheless, it suggested that risk assessment should be conducted prior to effluent irrigation to keep the safe application of wastewater for landscape and agriculture and make its reuse safer (Damodharan, and Reddy, 2012).

CHAPTER THREE

MATERIALS AND METHOD

3.1 Location of the study area

Jibia is a town and Local Government headquarters located about 43Km West of Katsina, in Katsina State. It is located on the central plain of Hausa land of Northern Nigeria and lies between Latitude 13^{0} 05^{1} 30^{11}**N** and Longitude 07^{0} $13^{1}35^{11}$**E** with a population of about 167435 people. It is situated on the extreme part of Northern Nigeria, bordering Niger Republic to the North, Katsina and Kaita Local Government Areas to the North East, and to the South by Batsari and Batagarawa Local Government Areas. The major occupation of the people in this area is agriculture which provide job to about 85% of the total population in various agricultural practices such as farming, livestock rearing and poultry etc, while the remaining 15% are engaged in other occupations such as trading, carpentry and blacksmithing etc. The area is dominated mainly by Hausa and Fulani (El-Ladan and Maiwada, 2014; Suleiman and Abdul, 2013; Katsina, 2003).

In terms of climatic condition, the total annual rainfall is around 600-700mm, mean annual temperature of about 25^{o}C. The area is characterized by high temperature of about 43^{o}C, constant low relative humidity 50% and shorter raining season. The wet season starts in May and ends inearly October and dry seasons last longer from November to April (Yusuf and Abdulkadir, 2012).



Figure 7: Administrative Map of Katsina State (Study area)

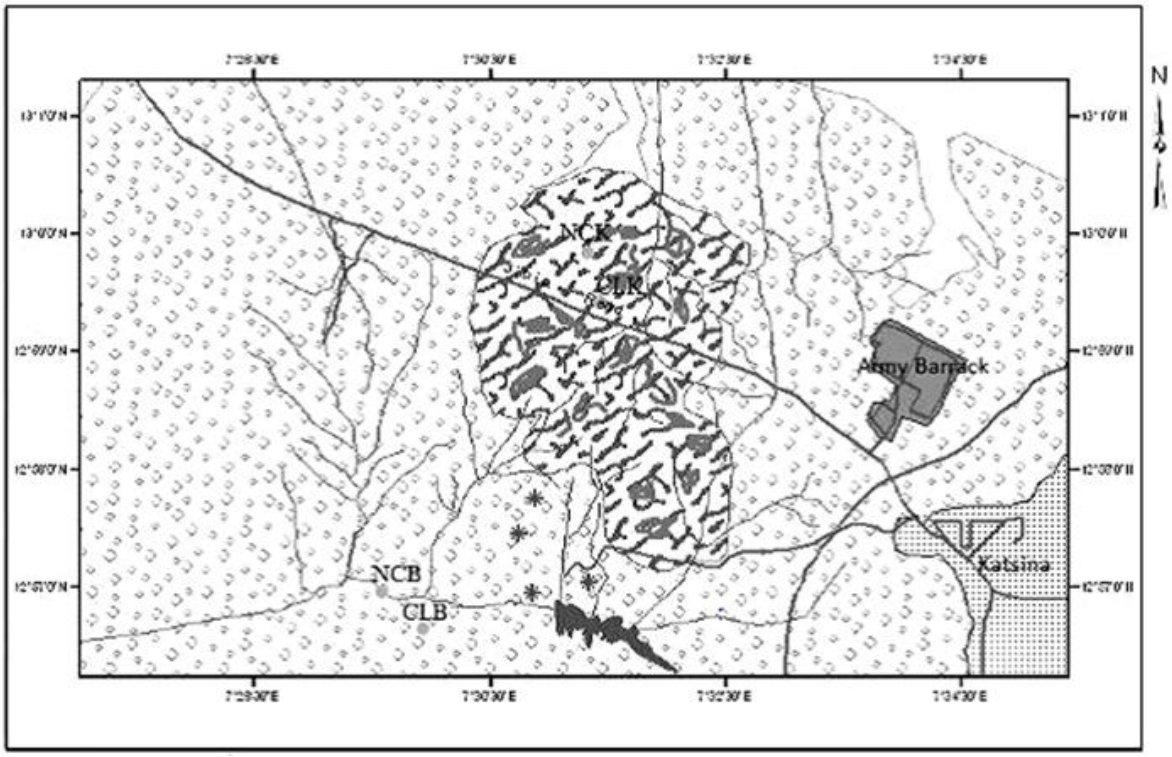


Figure 8: Samples collection points

The experimental sites are located in Jibia water treatment plant backyard where the effluent from the treatment plant is been collected directly for irrigation farming of sugarcane; And a farm land in ward B where normal water is used for irrigation of sugarcane farmland both from Jibia district in Jibia local government of Katsina State.

3.2 Samples collection and Identification

A total of twenty one replicate samples from the two study areas made up of soil and water were well representatively collected for the analysis using appropriate methods and quality-assurance measures to ensure that the field sites selected and the samples collected accurately represent the environment intended for the study and to fulfill data-quality objectives. Standard precautionary measures were adopted to avoid cross contamination of the samples. Well labeled sterile plastic containers were used to collect the wastewater samples, and be tightly closed immediately for onward transportation at low temperature to the laboratory for elemental analysis.The soils samples were collected into black polythene bags. The water and soil samples were obtained from both the reference and control sites covering a total area of $130m \times 95m$ that was partitioned into 44m x 32m grid points labeled L-T. Grid points L-N, O-Q, and R-T were all parallel to the direction of flow of the effluent; while L-R, M-S, and N-T were perpendicular to the effluent flow; at $5m$ away from the point source and at $40m$ to each other as shown in Figure (9). Obtained samples were labeled R1, R2, R3, R4, R5, R6, R7, R8, R9, R10; and C1, C2, C3, C4, C5 respectively. Soil samples were collected at the middle of each grid from depths of 10, 20, 30 and 40cm using hand auger. Control samples were collected just some few metres away from another farmland that uses different water source but having the same geological settings as the reference site. A total of twenty one samples were taken with 10 samples being from control field.

L	M	N
O	P	Q
R	S	T

Figure 9: Grid of the sampled area

3.3 Samples preservation

In order to ensure the integrity of the samples that were collected, all possible sources of contamination during each phase of sample collection (and processing) was substantially avoided. Concentrated HNO_3 acid was added in drops in order to preserve the wastewater samples against any bacterial infections. All digested solutions of soil and irrigation water were analysed for Zinc(Zn), Copper(Cu), Cadmium(Cd), Iron(Fe) and Arsenic(As) by atomic absorption spectrometry technique (PyeUnicam Model PU91 OOX flame atomic absorption spectrophotometer); and the gross alpha – beta radioactivity measurements was done using proportional counter MCB-2000 BDP model.

3.4 Location of the experiment

The elemental analysis of the trace elements was carried out at the Multipurpose Laboratory, Chemistry department, Ahmadu Bello University, Zaria. While the Gross alpha and Beta measurements were carried out at the Centre for Energy Research and Training (CERT) Ahmadu Bello University, Zaria.

3.5.0 Materials for Gross alpha and beta measurements

The following are the equipment and materials that was used for the gross alpha/beta radioactivity measurements in both samples.

3.5.1 Equipment

- Single channel, gas free portable MPC 2000 gross Alpha/Beta counter
- Hot plate
- $100ml - 1500ml$ laboratory Beakers (Pyrex)
- $2L$ plastic containers
- Graduated measuring cylinder of capacity $100cm^3$
- Porcelain Dish of capacity $50ml$
- Sterilized spatula
- Plastic containers
- Placket ($3cm$ stainless steel)
- Experimental weighing balance
- Gloves
- Acetone needle and Syringe
- Masking tape

3.5.2 Chemicals

- Concentrated Nitric acid ($HN0_3$) of concentration $1.5g/ml$
- Fresh distilled water
- Vinyl acetate

At various experimental stages of the work, above mentioned materials were used in the following ways:-

For sampling: A well cleaned 2L plastic container for collecting water samples, Geographical Positioning System (GPS) for measuring the geographical co-ordinates, and Nitric acid.

For sample preparation: Hot plate for evaporation, vinyl Acetate, Ethanol for even spread of the sample in the planchette.

For preparation of alpha standards, KCl for beta standards, de-ionized water and the planchette of about 0.5m in diameter and 0.002m thickness, made of stainless steel to resist corrosion from samples and reagents that may be placed in them.

3.5.3 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 as shown below.



Figure 10: Proportional counter MPC-2000-DP model

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) 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.

3.5.4 Gas-filled detectors: proportional counters and principle of operation

A gas-filled radiation detectors uses argon, propane, or air which is enclosed in a chamber that has an electrical potential applied across it. During ionization, the ion pairs move to the anode and cathode under the influence of this electrical potential difference. As the electrons move through the circuit connecting anode and cathode, they create a signal that is measured to provide an output signal which can be related to various parameters (count rate, radiation dose rate, etc.). As the applied voltage across the chamber changes, the response of the chamber to ionizing radiation also changes (Karam, 2000).

Proportional counters operate in a region of the response curve in which the output signal is proportional to the energy deposited in the gas and to the applied voltage. This means that, for a constant voltage, the output pulse will be higher as the energy of the interaction increases. Since most alpha radiation has a much higher energy than beta radiation, a proportional counter can be used to simultaneously measure both alpha and beta radiation by sorting pulses into one of two "bins" – the high-energy alpha bin and the lower-energy beta bin – by means of a pulse height discriminator. Proportional counters are frequently used in the laboratory and, less frequently, in the field. Field surveys for tritium, for example, are almost always performed using a hand-held proportional counter. In the laboratory, proportional counters are often used for gross alpha-beta measurements, a screening measurement. The most common type of proportional counter is a gas-flow device, in which a constant flow of gas (usually propane) passes through the detector chamber. In such devices, it is important to monitor the level of gas in the tank so that the proportional counter works properly (Karam, 2000).

3.5.5 Equipment Standard

For this research work, plutonium- 239 sources was used as the alpha standard. Been a sealed calibration source, it was used to determine the efficiency of the proportional counter; While the beta standard was strontium- 90. The alpha and beta standards were used to calibrate the proportional counter.

3.6.0 Preparation and method for Gross Alpha and Beta analysis

3.6.1.0 Sample preparations

Samples of both water and soil were obtained from each site and acidified with Conc. HNO_3 solution in order to reduce the pH to less than 2 and to retain the radioactivity content in the samples, minimized precipitation and absorption by the walls of the container as well as to prevent the growth of micro-organisms; and then air tight. The water samples were evaporated with the residues being kept in the desiccators until they were ready for counting. Evaporation was done using hot plates, without stirring and at moderate heat in an open 600ml beaker that lasted for about 16hrs to complete the evaporation of one liter of each sample.

In the process of evaporation, when the level of sample in the beaker was about 50ml, it was then transferred into a petri-dish and placed under infrared light source to completely dry the residue. 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 which about 0.077g 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. The Volume *V*, of sample that will produce 0.077g was calculated using the relationship

$$0.077\text{g} \times V_T = T_R \text{V} \quad \text{----------} \quad 17$$

V_T = Volume that produce the total residue

T_R = Weight of the total residue

V = Volume that will give 0.077g

Volume of water that gave the total residue could be obtained from the relationship

$$V = \frac{V_T}{T_R} \times R_{\text{p}} \quad \text{----------} \quad 18$$

V_T = Volume of water = 1 litre,

T_R = total residue obtained from V_T in mg

R_P = residue transferred to Placket.

Sample preparation efficiency could be obtained from the relation:

$$\text{Sample preparation efficiency} = \frac{weightofresidue}{0.077g} \times 100\% \quad \text{----------} \quad 19$$

$$\text{Sample efficiency} = \frac{R_P}{T_R} \times 100\% \quad \text{----------} \quad 20$$

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)

3.6.1.1 Gross Alpha and Beta Counting

A non-gas proportional counter with model MPC – 2000-DP, SERIAL NO: 01872140 single channel analyzer (Protean Instrument Cooperation) was used for the gross alpha and beta counting. For this purpose, the sample was placed in a 5cm diameter stainless steel planchette and later placed in a sample carrier which was then placed on the sample drawer and closed. By setting some factors such as the current time, number of cycles and the operational voltage, the counting was done automatically according to the selected count mode with the appropriate sample information (channel efficiency and background count rate, volume of sample used and sample efficiency) were selected and the operating voltage being 1650 V. The system which was calibrated for alpha and beta energies by preparing standard samples which contains equal concentrations of 241Am (931Bq) and Sr-90 (931Bq), has detector efficiencies to be 87.95% for alpha and 42.06% for beta; while detector background count rate were $\mathbf{0.13}\ \boldsymbol{cpm}$ for alpha and $\mathbf{76.30}\ \boldsymbol{cpm}$ for beta respectively. These characteristics (detector efficiency and background count rate) data 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 was evaluated using:

$$MDA(Bq/l) = \frac{L_d}{VT \times 60} \text{ ---------- 21}$$

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

Where V = the volume of sample (l)

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

ε= the efficiency and

C_B = the background count rate (count per minute)

3.6.1.2 Gross alpha counting

A high voltage of 1650V was used in a selective counting for gross alpha measurement in 5 cycles of 2700 sec per cycle. The alpha count rate and alpha activity were calculated using the formula (ISO, 1992).

The alpha activity $(\alpha) = \frac{\text{rate } (\alpha) - \text{Bgd}(\alpha)}{\text{Channel efficiency} \times \text{Sample efficiency} \times \text{Volume}} \times 0.0167$ ----- 22

The alpha count rate $(\alpha) = \frac{Raw\ (\alpha) count}{Counttime}$ ---------- 23

3.6.1.3 Gross beta counting

Also, a high voltage of 1650V was used and samples were counted for 5 cycles of 2700 sec per cycle. The beta count rate as well as the beta activity were calculated using the formula (ISO, 1992).

The beta activity (β) = $\frac{\text{rate }(\beta) - \text{Bgd}(\beta)}{\text{Channel efficiency} \times \text{Sample efficiency} \times \text{Volume}} \times 0.0167$ - - - - - - - - 24

The beta count rate (β) = $\frac{Raw\ (\beta) count}{Count\ time}$ - - - - - - - - - - - - - - - - - - 25

3.6.2 Data presentation

The activity concentration (C) in Becquerel per litre for gross alpha/ beta was calculated using the expression

$$C\ (Bq/l) = \frac{\text{Net count}}{CE \times SE \times SV} \times 0.0167 \quad \text{- - - - - - - - - - - - - 26}$$

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

Where: Net count = Sample count rate – Background count rate

The sample count rate = $\frac{Raw\ sample\ count}{Count\ time}$ - - - - - - - - - - - - - - 27

Where

C = activity in Becquerel per Litre,

SE = sample efficiency

CE = channel efficiency

SV = Volume of water

3.7.0 Data Analysis for Gross alpha and beta activity

3.7.1 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.

$$E_{avg}(\alpha/\beta) = \sum_{i}^{R(\alpha/\beta)} A_{i(\alpha/\beta)}) \times DCF_{i(\alpha/\beta)} \times 730 \text{ - - - - - - - - - - - - - - - - - } 28$$

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 for ingestion of the individual natural radionuclides for an adult taken from UNSCEAR (2000) report. A daily water intake of 2L/day is assumed (EPA, 2000–05) thus resulting in annual consumption rate of 730 Litre per year.

3.7.2 Statistical Analysis: statistical operations such as estimation of standard deviations and the mean, as well as statistical graphs were used to analyze the results.

3.7.3 Standard Deviation: The standard deviation, δ, which measures the activity of the sample is computed (ISO 9697: 1992 (E)) as

$$\delta = \sqrt{\frac{R_b}{t_o}} + \frac{R_a}{t_o} \times \frac{14.4 \times m \times 1.02}{(R_b - R_o) \times 1000 \times V} \text{ ---------- 29}$$

Where:

R_b=observed sample count rate (S^{-1})

R_o=background count rate (S^{-1}),

V=volume of sample in liters,

m=mass in milligrams of ignited residue from volume V; represent the specific activity of 40K in KCl. 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.

3.8.0 Atomic absorption spectrometry (AAS) technique

Atomic Absorption Spectrometry (AAS) is an analytical technique that measures the concentrations of elements. Atomic absorption spectroscopy can be used to analyze the concentration of over 62 different metals in a solution and is so sensitive that it can measure down to parts per billion of a gram (ug/dm^{-3}) in a sample. The technique makes use of the wavelengths of light specifically absorbed by an element. They correspond to the energies needed to promote

electrons from one energy level to another, higher, energy level. In AAS, the sample is atomised – i.e converted into ground state free atoms in the vapour state – and a beam of electromagnetic radiation emitted from excited lead atoms is passed through the vaporised sample. Some of the radiation is absorbed by the lead atoms in the sample (Gennaro, 2009).



Figure 11: Unicam Solar AAS- 969 model

An atomic absorption spectrophotometer consists of a light source, a sample compartment and a detector. In this method, light from a source is directed through the sample to a detector. The source of light is a lamp whose cathode is composed of the element being measured. Each element requires a different lamp.

3.8.1 Samples preparation for AAS Analysis

Water samples were digested using appropriate chemicals and the soil samples were air-dried at ambient laboratory temperature after being grounded with mortar and pestle, sieved to pass through 2 mm sieve, and stored for AAS analysis. Highly sensitive chemical balance (SNRK96452 model) measure $0.5g$ of samples that was placed in a Teflon beaker and then transferred to a fume-cupboard for digestion by adding $10mL$ and $5mL$ of concentrated nitric and perchloric acids respectively; by maintaining oven temperature of 200^0C for an hour before leaching it with $5cm^3$nitric acid.

Digested samples were then filtered and made up to 100 mL with deionized water. A blank determination was treated in the Atomic Absorption Spectrometer but without sample. Solution of samples were then taken and aspirated into Atomic Adsorption Spectrophotometer (Unicam Solar AAS- 969 model) for analyzing metals. Blank determination was also carried out as in a similar way as described above except for the omission of the sample. A calibration graph was plotted for each element using measured absorbance and the corresponding concentration. The calibration curve was used to determine the concentration of the metal.

CHAPTER FOUR

RESULT AND DISCUSSION

4.1 Reference samples data results

Reference water (RW) gross alpha activity and gross beta activity measurements: (0.0315 ± 0.00354) Bq/dm^3 and (0.2162 ± 0.0236) Bq/dm^3 respectively.

Table 7: Distribution of radioactivity measurement of gross alpha and beta in soil samples from reference area. RS= reference soil

Sample ID	Gross Alpha Activity (Bq/kg)	Gross Beta Activity (Bq/kg)
RS1	63.07±2.176	2312.67±153.0
RS2	52.62±5.402	1146.43±68.4
RS3	78.59±1.520	3463.57±24.7
RS4	69.45±3.121	2011.43±11.5
RS5	39.76±1.482	1321.93±432.0
RS6	61.96±1.680	2147.04±29.5
RS7	57.95±2.071	1978.45±64.9
RS8	54.79±1.530	987.23±40.5
RS9	83.51±2.831	1024.58±15.2
RS10	68.48±3.281	1387.47±130.0

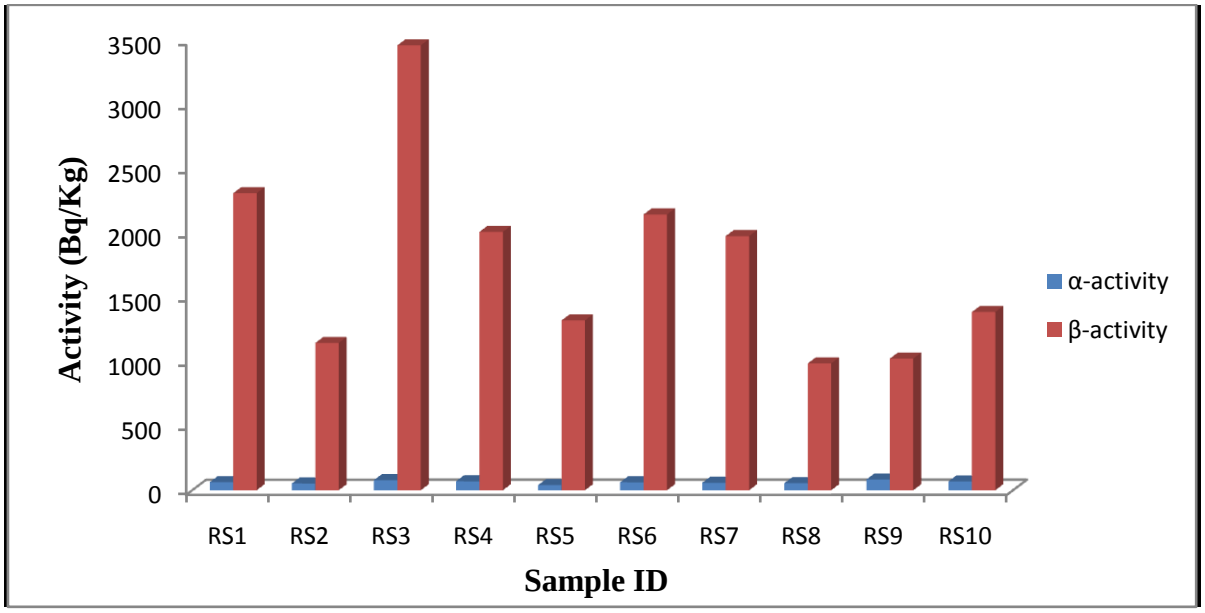


Figure 12: Distribution of Activity in soil samples from reference area

Table 7 shows distribution of radioactivity measurements of gross alpha/beta in the soil samples from reference area. The mean activity in soil samples ranged between (65.5274±12.9064)Bq/kg and (1836.17±768.5978)Bq/kg for gross alpha and beta respectively. Figure 10 shows the plot of gross alpha and beta activities in the soil for the sampled locations. As seen from the graphs, there exists a poor linear correlation between gross alpha and beta activities in the soil sample thus implying that different radio nuclides might be responsible for low measurements of alpha activity.

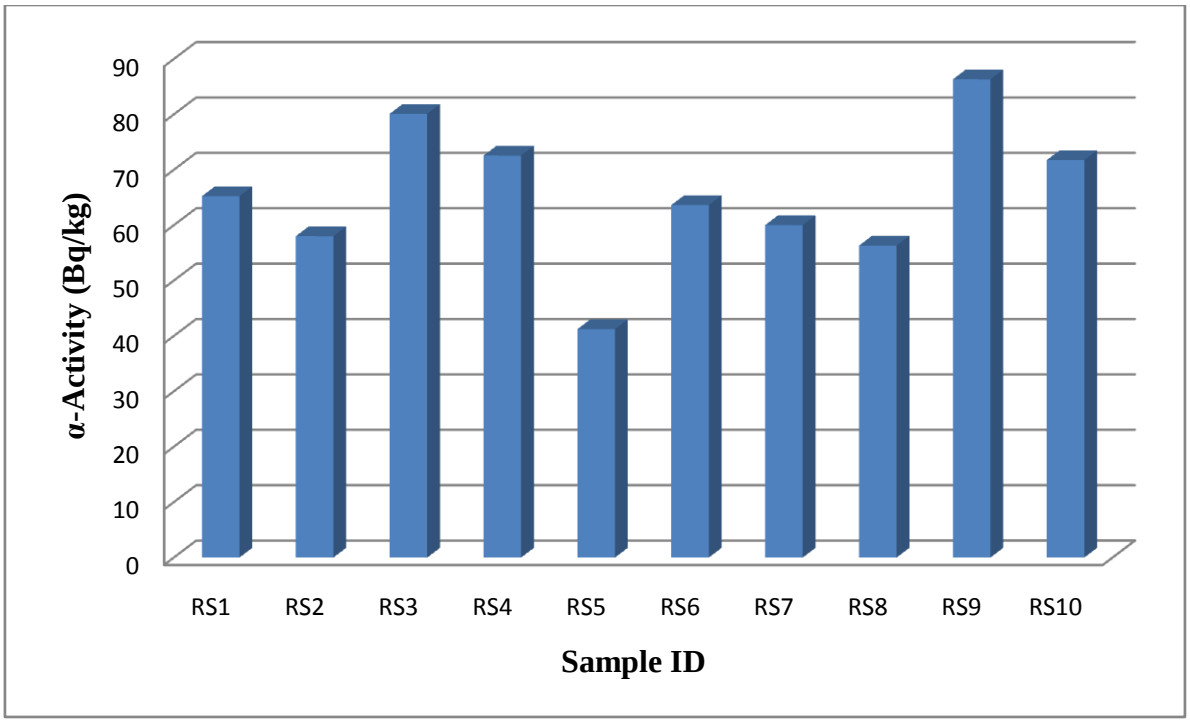


Figure 13: Distribution of α-Activity in soil samples from reference area

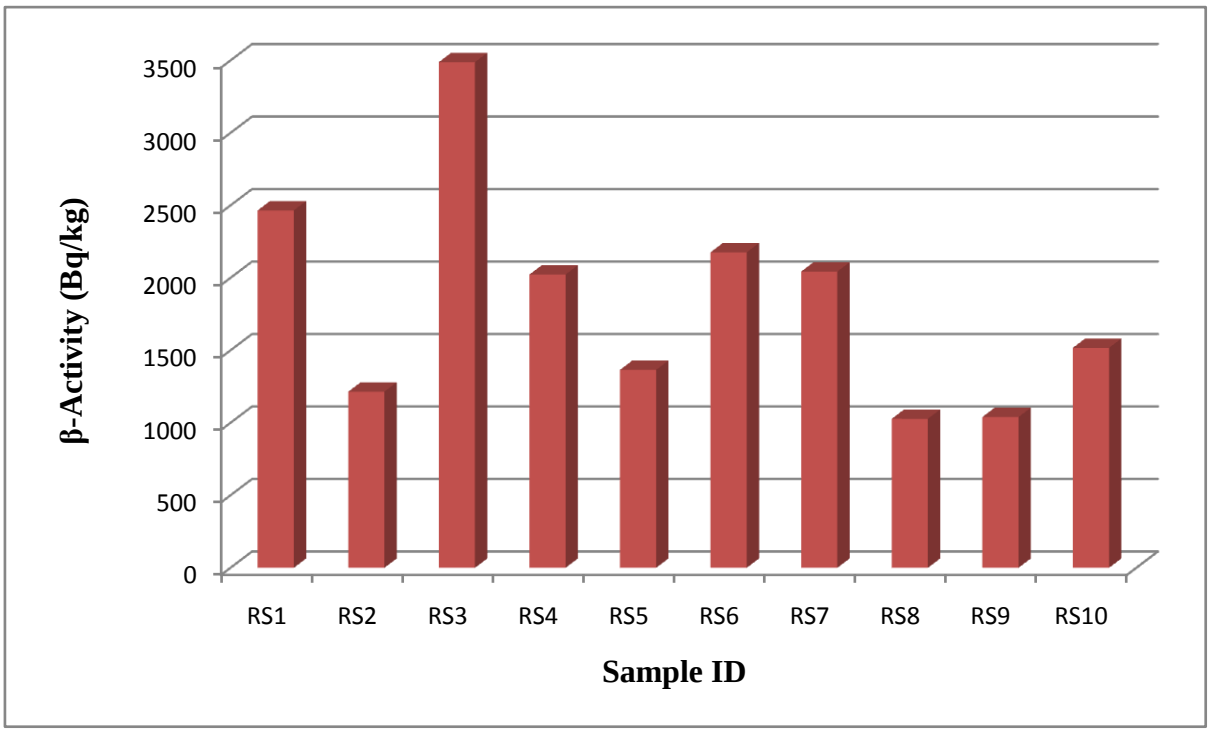


Figure 14: Distribution of β-Activity in soil samples from reference area

Figures 13 and 14 show distribution of activities in the soil samples of the reference area. The maximum activity recorded was (83.51±2.831) Bq/kg and (3463.57±24.70) Bq/kg for both alpha and beta activities respectively; while (39.76±1.482) Bq/kg and (987.23±40.55) Bq/kg were recorded as minimum for the same alpha and beta activities respectively.

4.2 Control samples data results

Table 9: Distribution of radioactivity measurement of gross alpha and beta in soil samples from control area: **CS= Control Soil**

Sample ID	Gross Alpha Activity (Bq/kg)	Gross Beta Activity (Bq/kg)
CS1	51.34±12.5	723.74±25.6
CS2	43.67±15.3	414.58±15.6
CS3	39.05±14.6	453.71±37.2

CS4	46.64±17.3	564.38±47.4
CS5	53.21±14.9	693.93±63.1

Table 10: Distribution of radioactivity measurement of gross alpha and beta in water samples from control area: **CW= Control Water**

Sample ID	Gross Alpha Activity (Bq/dm^3)	Gross Beta Activity (Bq/dm^3)
CW1	0.03677±0.002	0.0692±0.001
CW2	0.08164±0.006	0.3684±0.004
CW3	0.00368±0.001	0.3486±0.001
CW4	0.01245±0.002	0.5657±0.001
CW5	0.0068±0.004	0.04684±0.003

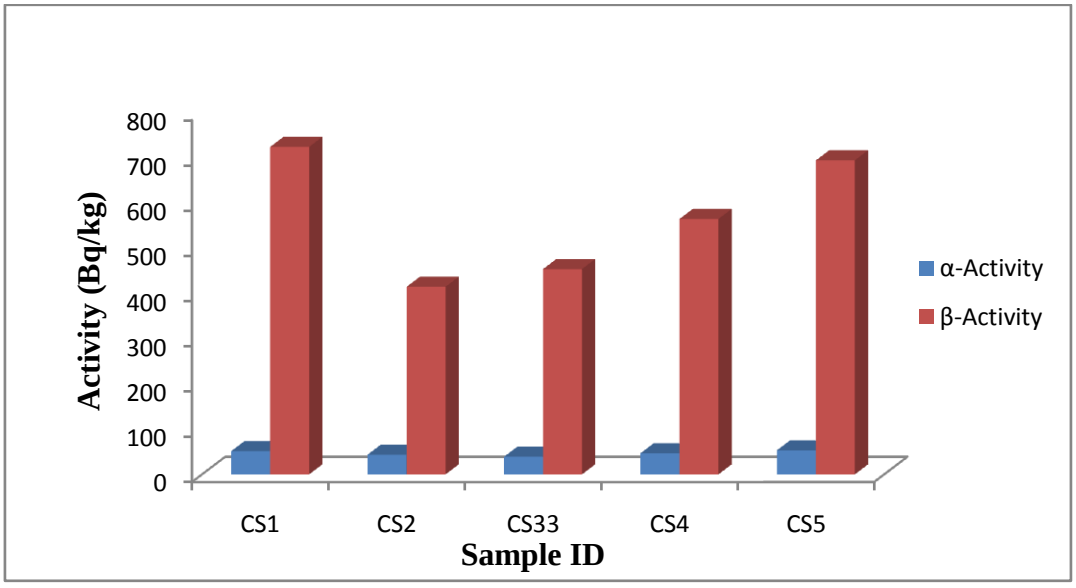


Figure 15: Distribution of Activity in soil samples from control area

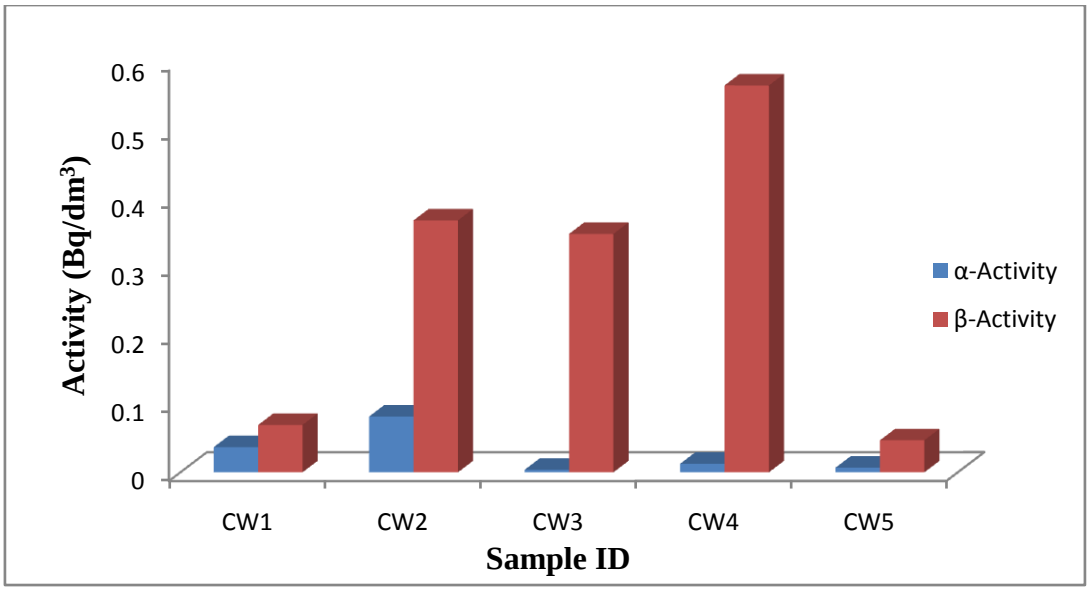


Figure 16: Distribution of Activity in water samples from control area

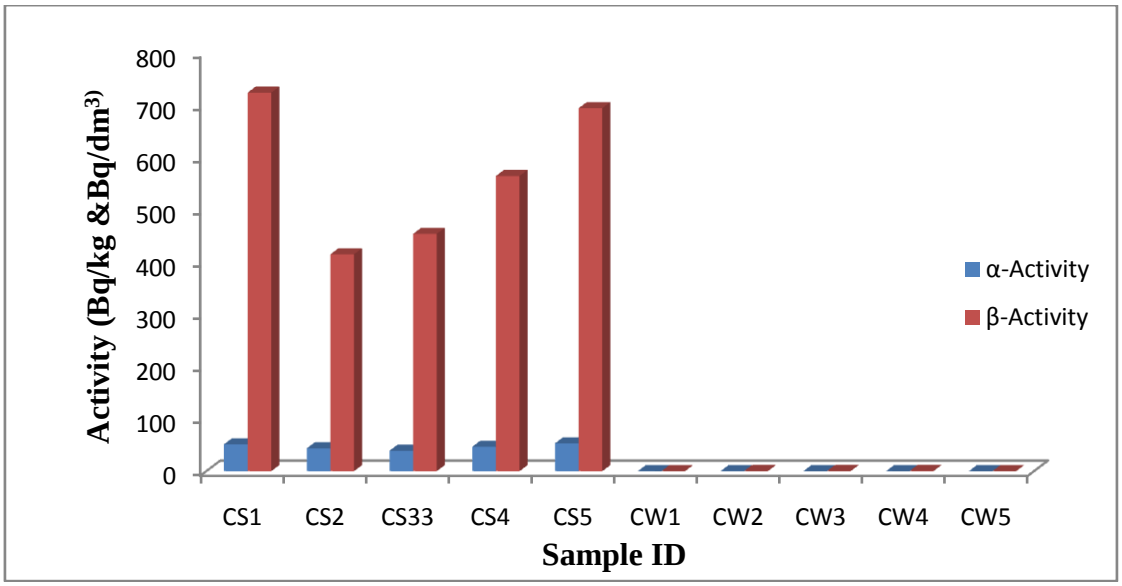


Figure 17: Distribution of α/β Activity in soil and water samples from control area.

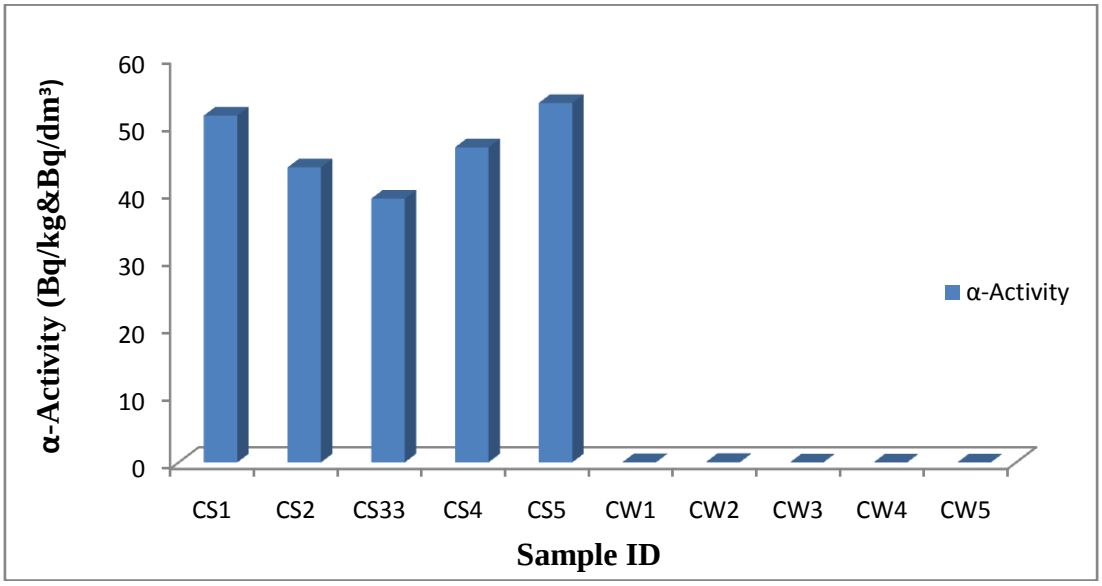


Figure 18: Distribution of α -Activity in soil and water samples from control area.

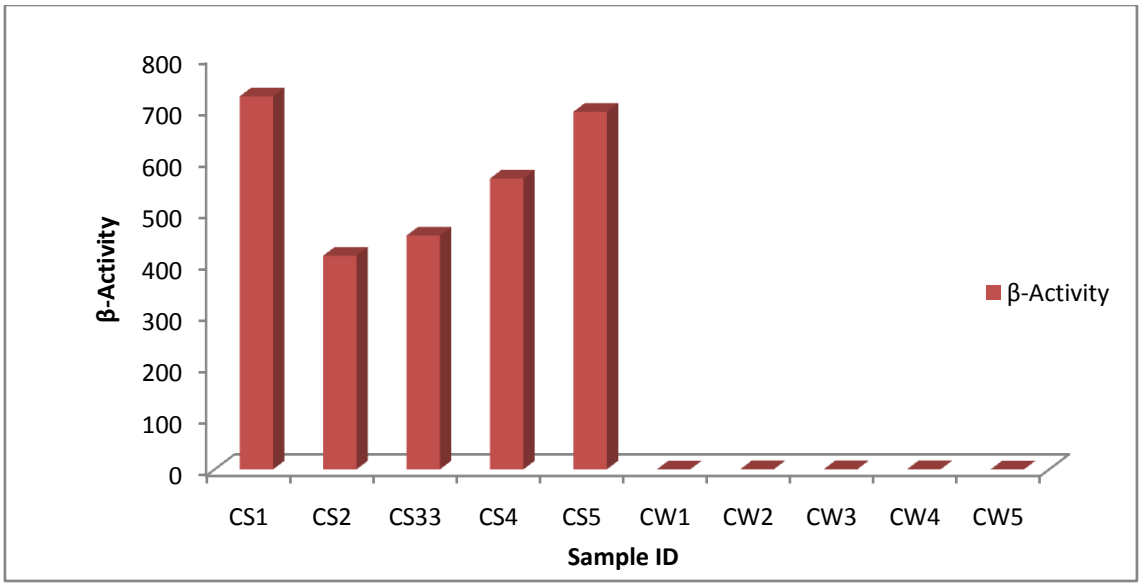


Figure 19: β-Activity distribution in both soil and water samples from control area.

Tables 9 and 10 show distribution in the radioactivity measurements of gross alpha/beta in water and soil samples from control area. The mean activity in soil and water samples ranged between (61.702±5.544)Bq/kg and (605.84±149.953) Bq/kg; and (0.03127±0.0034) Bq/dm^3 and (0.2817±0.002)Bq/dm^3 for gross alpha and beta activities respectively. Figure 17 shows the plot of gross alpha and beta activities in the soil and water for the sampled locations. As seen from the graphs, there exists a poor linear correlation between gross alpha and beta activities in the soil and water samples thus implying that water samples accumulate less radionucleides compared to its soil counterpart.

4.3 Elemental distribution of heavy metals in soil sample

Table 11: Distribution of heavy metal concentration(mg/kg) at different depth of reference area

Depth/location	Zn	Cu	Cd	As	Fe
10cm					
L	0.253	0.632	0.338	0.326	294.517
M	0.459	0.671	0.321	0.237	241.794
N	0.225	1.587	0.283	0.421	318.649
O	0.336	0.946	0.315	0.342	199.431
P	0.323	0.995	0.109	0.452	296.768
Q	0.217	0.733	0.563	0.431	241.427
20cm					
O	0.391	1.024	0.404	0.461	327.493
P	0.281	0.781	0.274	0.521	274.921
Q	0.278	0.684	0.321	0.432	285.732
R	0.229	0.859	0.375	0.481	246.351
S	0.423	0.794	0.364	0.361	286.702
T	0.387	0.685	0.185	0.456	274.941
30cm					
L	0.413	0.784	0.286	0.412	251.804
O	0.372	0.683	0.402	0.497	284.637
R	0.327	0.492	0.361	0.510	312.804
M	0.243	1.034	0.278	0.351	258.405
P	0.285	0.956	0.372	0.621	284.936
S	0.329	0.473	0.394	1.023	318.846
40cm					
M	0.284	0.831	0.317	0.921	321.903

P	0.315	0.658	0.289	1.041	285.523
S	0.359	0.731	0.410	1.162	262.314
N	0.289	0.835	0.275	0.742	284.031
Q	0.641	0.652	0.326	0.694	273.746
T	0.241	0.693	0.281	0.623	284.312

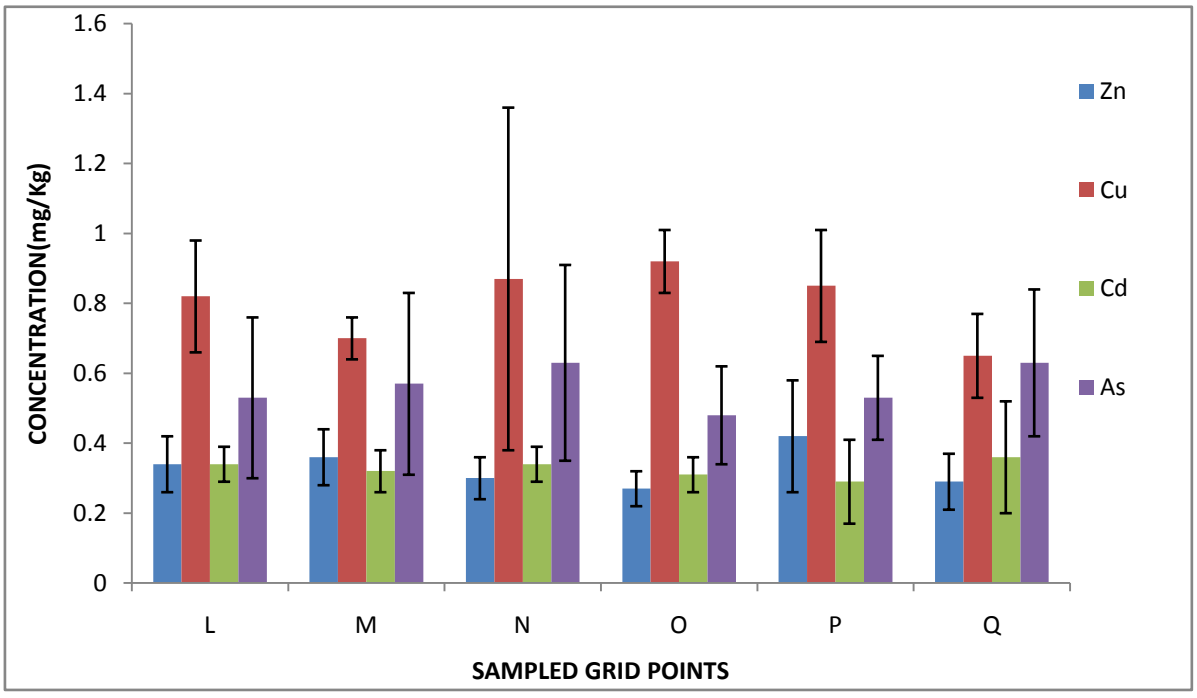


Figure 20: Concentration of Zn, Cu, Cd, and As in Sampled grid points of reference area

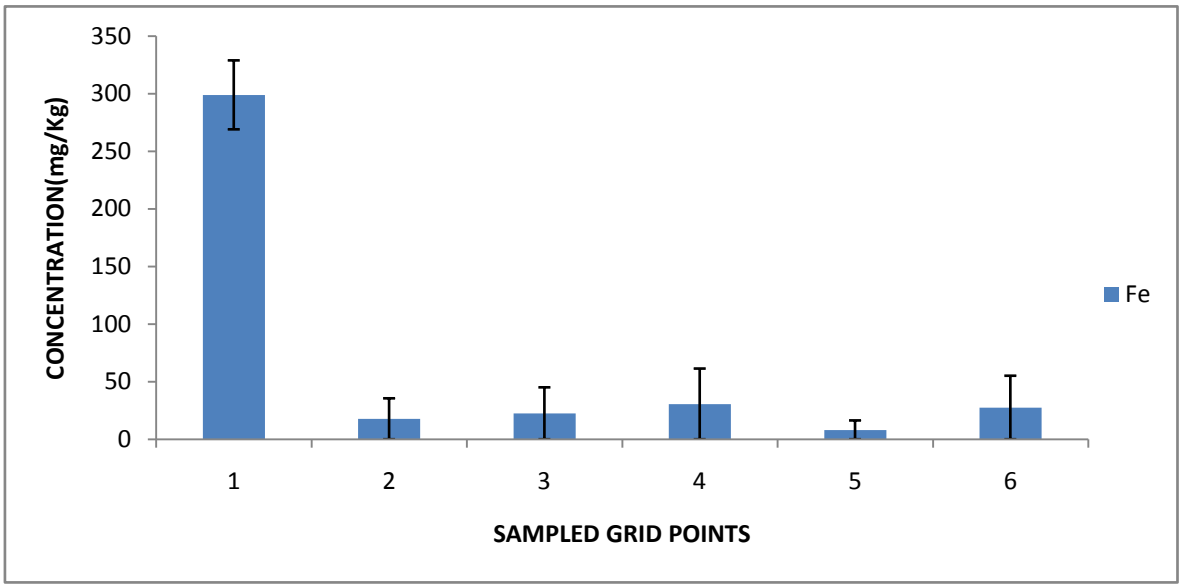


Figure 21: Concentration of Fe in Sampled grid points

Table 12: Distribution of heavy metal concentration at different depth of control area

Depth/location	Zn	Cu	Cd	As	Fe
10cm					
L	0.191	0.582	0.236	0.296	289.463
M	0.239	0.508	0.215	0.421	237.830
N	0.201	0.432	0.235	1.683	296.693
O	0.131	0.776	0.249	0.843	216.063
P	0.151	0.758	0.435	0.472	271.053
Q	0.102	0.713	0.482	1.043	198.461
20cm					
O	0.246	0.693	0.298	0.943	249.391
P	0.206	0.593	0.216	0.743	242.473

Q	0.194	0.493	0.314	1.590	256.296
R	0.319	0.872	0.316	0.397	261.392
S	0.215	0.673	0.293	0.843	301.428
T	0.147	0.538	0.483	1.432	282.130
30cm					
L	0.217	0.578	0.271	0.313	253.241
O	0.204	0.823	0.251	0.521	226.392
R	0.310	0.627	0.314	0.842	216.934
M	0.281	0.721	0.261	0.614	273.216
P	0.270	0.792	0.304	0.231	253.801
40cm					
M	0.319	0.526	0.294	0.191	271.563
P	0.274	0.621	0.262	1.047	247.234
S	0.267	0.637	0.352	0.593	261.327
N	0.197	0.683	0.271	0.493	265.486
Q	0.283	0.724	0.216	0.184	231.284
T	0.273	0.823	0.321	1.326	217.321

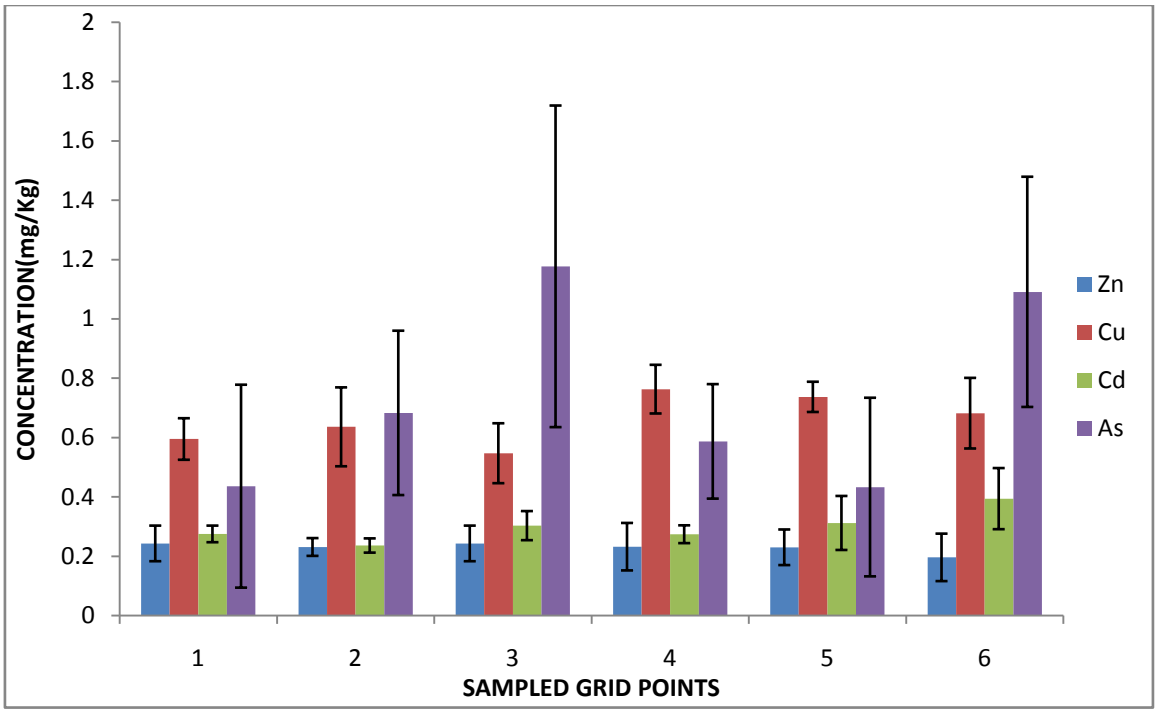


Figure 22: Concentration of Zn, Cu, Cd, and As in Sampled grid points of control area

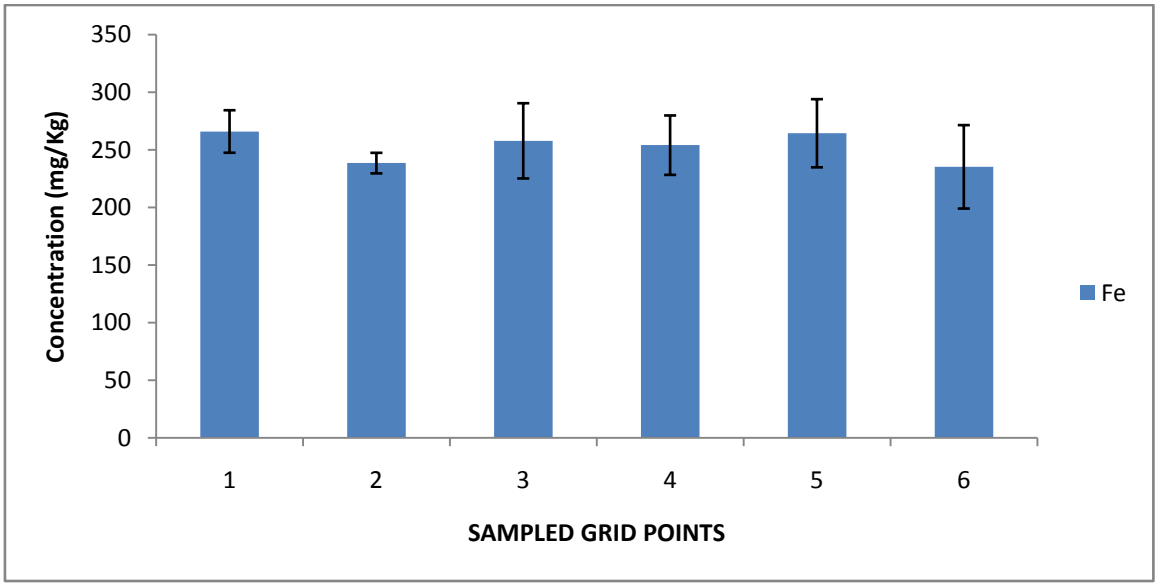


Figure 23: Concentration of Fe in Sampled grid points

Tables 11 and 12 list the concentrations in mg/kg of the heavy metals in the soil at various grid points L-T in both reference and control areas. Most samples were found to be fairly above the maximum permissible levels in some grid points. Tables 13 and 14 show heavy metals concentration in the sampled soils ranging from (0.302 - 0.355)Zn, (265.46 - 285.31)Fe; And (0.927 - 0.778)Cu, (0.322 - 0.316)Cd, (0.368 - 0.864)As increasingly and decreasingly respectively. This trend may perhaps be due to the fact that Zn, Fe and Cu are nutritionally essential metals which are required by both soil and crops in good quantity for proper metabolism and functioning; while Cd and As are trace elements with no known benefits and cause toxicity to both soil and plant. Furthermore, measured concentration of these metals varied by element, sampling location and depth. Maximum concentration of hazards metals such as Cd and As were < 0.5 mg/kg and ≤ 1.432 mg/kg respectively; and those of macro-nutrients metals such as Cu, Fe and Zn were between (0.927 - 0.737), (285.31 - 265.46) and (0.355 - 0.302) respectively. For the more toxic metals, the maximum total concentration in the soil samples were found at 40cm depth except for Cd which had it maximum concentration at 10cm depth.

Table 13: Mean distribution of heavy metal concentration (mg/kg) in reference area at various depth.

Depth(cm)	Zn	Cu	Cd	As	Fe
10	0.302	0.927	0.322	0.368	265.46
20	0.322	0.805	0.321	0.452	282.69
30	0.328	0.737	0.349	0.569	285.24
40	0.355	0.778	0.316	0.864	285.31

Table 14: Statistical distribution of heavy metal concentration(mg/kg) from the reference area

Element	Mean	Minimum	Maximum	S.D
Zn	0.327	0.302	0.355	0.021869
Cu	0.812	0.737	0.927	0.081761
Cd	0.327	0.316	0.349	0.01494

As	0.563	0.368	0.864	0.216782
Fe	279.675	265.46	285.31	9.554735

Table 14 shows the statistical distribution of soil samples analysed for heavy metals (Zn, Cu, Cd, As, Fe). It was found that: of all the samples, Iron (Fe) has highest mean value, followed by copper (Cu), then Arsenic (As), Zinc (Zn) and Cadmium (Cd); (279.679, 0.812, 0.563, 0.329 and 0.327) mg/kg respectively. When compared with WHO standard, they are all slightly above the recommended values. The reason for this extremity in values might be due to the accumulation of some salts in the effluents that was use for irrigation in the farmland.

Table 15: Mean distribution of heavy metal concentration(mg/kg) in control area

Depth(cm)	Zn	Cu	Cd	As	Fe
10	0.169	0.628	0.309	0.793	251.594
20	0.221	0.644	0.320	0.991	265.518
30	0.214	0.590	0.234	0.435	203.931
40	0.261	0.699	0.286	0.639	249.036

Table 16: Statistical distribution of heavy metal concentration(mg/kg) in control area

Element	Mean	Minimum	Maximum	S.D
Zn	0.216	0.169	0.261	0.0377
Cu	0.640	0.590	0.669	0.0452
Cd	0.287	0.234	0.320	0.0382
As	0.715	0.435	0.991	0.2356
Fe	242.520	203.931	265.518	26.7258

Table 17: Distribution of contamination factor (C.F) and pollution load index (PLI)

Depth/location	Zn	Cu	Cd	As	Fe	PLI

10cm						
L	1.324	1.086	1.432	1.101	1.017	1.181
M	1.922	1.321	1.493	0.563	1.249	1.216
N	1.125	3.674	1.204	0.251	1.339	1.107
O	2.563	1.219	1.265	0.405	1.374	1.170
P	2.149	1.313	0.251	0.758	0.672	0.815
Q	2.135	1.028	1.168	0.432	0.891	0.997
20cm						
O	1.593	1.478	1.356	1.489	1.314	1.442
P	1.364	1.317	1.269	1.701	1.134	1.344
Q	1.434	1.387	1.022	1.272	1.115	1.235
R	1.183	0.985	1.187	1.212	0.942	1.095
S	1.353	0.985	1.187	1.212	0.942	1.095
T	2.634	1.273	0.383	1.318	0.975	1.105
30cm						
L	1.904	1.356	1.055	1.316	1.331	1.366
O	1.828	0.826	1.602	0.954	0.994	1.179
R	1.054	1.785	1.149	0.606	1.382	1.125
M	0.867	1.434	0.885	0.417	1.191	0.885
P	1.053	1.207	1.436	0.101	1.043	0.719
S	1.647	1.164	1.439	1.263	1.326	1.357
40cm						
M	0.892	1.580	1.078	1.482	1.549	1.283
P	1.152	1.064	1.103	0.994	1.004	1.061
S	1.362	1.148	1.105	1.959	1.632	1.407

N	2.221	0.978	1.627	1.505	1.068	1.415
Q	1.473	1.228	1.509	1.408	1.183	1.353
T	0.884	0.842	1.875	1.474	1.308	1.218

Table 17 shows computation of the environmental hazard indices which play important information on the extent and degree of multi-element contamination and can be applied to the evaluation of soils before their use in agriculture and production of food crops. To effectively know the measure of degree of overall contamination by all the metals, the pollution load index (PLI) was calculated using equation 6 for each grid sampled area as shown above. From the results presented in table 17, it was observed that at various depth most grid samples were polluted (PLI>1).

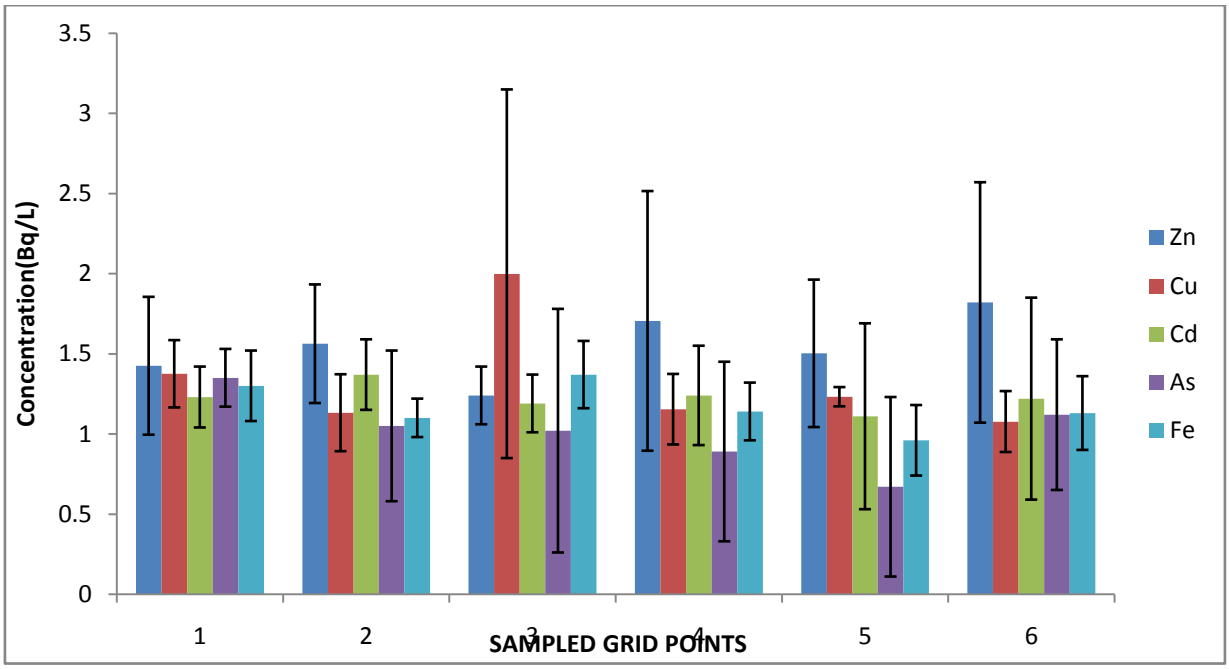


Figure 24: Concentration of Zn, Cu. Cd, As and Fe in Sampled grid points

Figure 23 is a plot of the variation of pollution load index with depth. Form the graph, the pollution load index (PLI) decreases (1.442 – 0.719) with depth (0 - 40cm) which confirm that the study area is probably facing some environmental pollution especially with dangerous heavy metals (As, Cu, Cd, As, Fe, Zn).

Table 18: Mean distribution of PLI

Depth(cm)	Mean PLI	Maximum	Minimum
10	1.081	1.216	0.818
20	1.219	1.442	0.958
30	1.105	1.366	0.719
40	1.290	1.415	1.061

4.4 Elemental distribution of heavy metals in water samples

Table 19: Distribution of heavy metal concentration(mg/L) from reference area

Sample ID	Zn	Cu	Cd	As	Fe
L	0.025	0.142	0.136	0.014	1.251
M	0.031	0.151	0.128	0.018	1.195
N	0.029	0.125	0.146	0.009	1.273
O	0.042	0.186	0.121	0.020	1.292
P	0.030	0.096	0.131	0.012	1.280
Q	0.041	0.187	0.143	0.018	1.295
R	0.021	0.163	0.129	0.019	1.301
S	0.032	0.132	0.140	0.012	1.285

T	0.028	0.162	0.136	0.014	1.273
Maximum	0.042	0.187	0.146	0.020	1.301
Minimum	0.021	0.096	0.121	0.009	1.195
Mean	0.031	0.149	0.134	0.015	1.272
S.D	0.007	0.030	0.008	0.004	0.032

Table 20: Distribution of heavy metal concentration(mg/L) from control area

Sample ID	Zn	Cu	Cd	As	Fe

L	0.019	0.139	0.124	0.012	1.213
M	0.022	0.148	0.115	0.014	1.164
N	0.013	0.119	0.113	0.003	1.175
O	0.037	0.164	0.111	0.018	1.239
P	0.027	0.063	0.111	0.011	1.230
Q	0.034	0.173	0.112	0.005	1.273
R	0.019	0.158	0.118	0.012	1.300
S	0.024	0.127	0.121	0.007	1.262
T	0.026	0.146	0.112	0.009	1.269
Maximum	0.037	0.173	0.124	0.018	1.300
Minimum	0.013	0.063	0.111	0.003	1.164
Mean	0.025	0.137	0.115	0.010	1.236
S.D	0.0075	0.033	0.005	0.005	0.046

Tables 19 and 20 show mean concentration (mg/L) of heavy metals in the irrigation water from the reference and control areas. The mean concentration were 0.033, 0.149, 0.134, 0.015 and1.272 for Zn, Cu, Cd, As and Fe respectively for the reference area; while 0.025, 0.137, 0.115, 0.010 and 1.236 are the corresponding mean concentrations for Zn, Cu, Cd, As and Fe in the control area.

Among the detected heavy metals in the referenced area, only As and Cd exceeded the permissible limit set by FAO (1989); and this can result to soil or plants pollution.

Furthermore, heavy metals detected from the control area fall within the maximum allowable concentration (MAC) for irrigation water except for Iron (Fe) which was below the MAC level at points M and N as shown the table. In all irrigation water samples from the two sites, it can be seen that the concentration of the samples were above the detectable limits with their maximum and minimum in mg/L being: 0.042, 0.187, 0.146, 0.02, 1.301; and 0.021, 0.096, 0.121, 0.009, 1.195 in the referenced area; while 0.037, 0.173, 0.124, 0.018, 1.30; and 0.013, 0.063, 0.111, 0.003, 1.164 in the control area respectively.

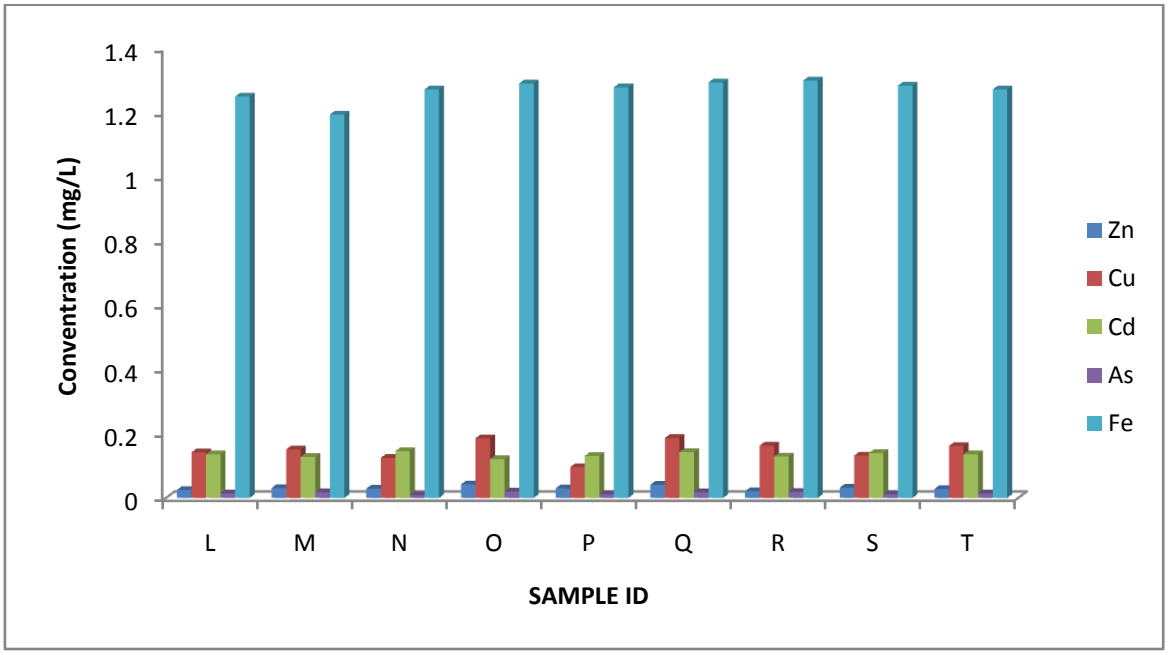


Figure 25: Concentration of heavy metal distribution in reference area.

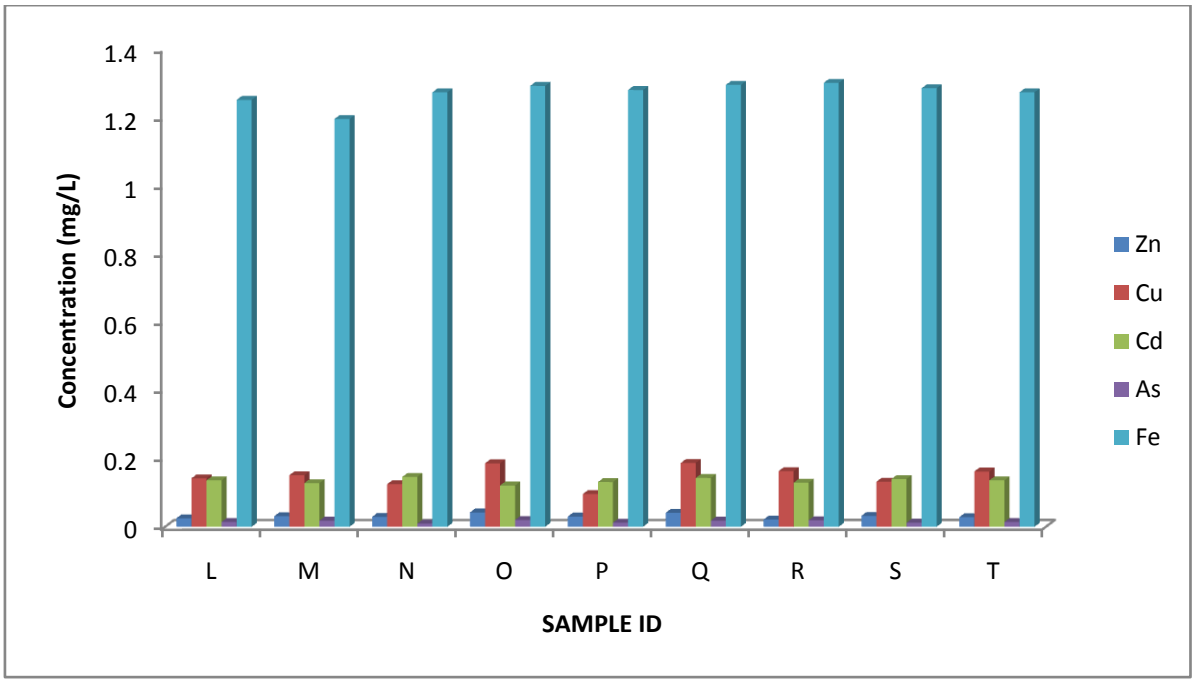


Figure 26: Concentration of heavy metal distribution in control area.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATION

5.1 Summary

This study was conducted to determine the radioactivity concentration and heavy metal assessment in soil and water on a sugarcane farm land irrigated with effluent from Jibia water treatment plant using a proportional counter detector and the Atomic absorption spectrometry (AAS) technique. In this study, a total of twenty one samples made up of soil and water from both reference and control areas were collected and analyzed for gross alpha/beta activity and five heavy metals concentration (Zn, Cu, Cd, As and Fe) using standard procedures. The results show that for the gross alpha/beta analyses, the reference samples had their highest alpha/beta activities to be (83.51 and 3463.57)Bq/kg; (0.08604 and 0.5657)Bq/dm^3 Table 7 for both soil and water samples respectively. While the control area recorded (53.21 and 723.74)Bq/kg; (0.08164 and 0.5657)Bq/dm^3 Table 8 for the same soil and water samples respectively. The study revealed that the gross beta activity in the reference area was relatively higher than their corresponding alpha values from the same locations which gave an indication of anthropogenic activity that has elevated or enhances the level of radionuclides in the area. Similarly, the measured alpha and beta activity in soils samples are above some reported values in similar environment but are still within WHO recommended maximum permissible limit for irrigation purpose. Although the research findings revealed the effluent is radoiologically safe for irrigation activity and may not pose some serious health hazards to the crop grown, continuous application of it may lead to accumulation of plant nutrients and heavy metals to undesirable high levels in the crops and thereby reducing their quality and nutritional value as forage crops for animal feeding.

Similarly, the results obtained from the AAS elemental analysis that determine the concentration of heavy metals in soil and water samples show a wide dispersive range of (0.302 – 0.355 mg/kg)Zn, (0.737 – 0.927 mg/kg)Cu, (0.316 – 0.349 mg/kg)Cd, (0.368 – 0.864 mg/kg)As and (265.46 – 285.31 mg/kg)Fe in the reference area Table 13; While the control area recorded (0.169 - 0.269 mg/kg)Zn, (0.590 – 0.669 mg/kg)Cu, (0.234 – 0.320 mg/kg)Cd, (0.435 – 0.991 mg/kg)As, and (203.931 – 265.518 mg/kg)Fe Table 15 respectively. Obtained soil samples concentrations (mg/kg) were used to compute environmental hazard indices such as contamination factor (C.F), and pollution load index (PLI) in the reference area as shown in Table15. These hazards indices concept especially PLI, gives important information on the extent and degree of multi-element contamination and can be applied to the evaluation of soils before their use in agriculture and production of food crops.

5.2 Conclusion

The study revealed that heavy metal concentration in water and soil samples from the effluent of Jibia water treatment plant was within the permissible limits set by WHO and the area can be considered safe for irrigation farming of sugarcane, tomato, cabbage, spinach, lettuce and other selected wild plants; since vegetables plants generally require these elements in appreciable quantities.

5.3 Recommendation

- More research work should be carried out to study the accumulation of heavy metals in the crops which are irrigated by the effluent water of Jibia water treatment plant.
- The sugarcane and any other plant grown in this area should also be analyzed by calculating its transfer factor (TF).
- A periodic monitoring of crop quality parameters is required when using wastewater for irrigation and this should be carried out.

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