

**ASSESSMENT OF DUMPSITE IMPACT ON SOIL AND  
GROUNDWATER QUALITY IN TUDUN WADA, KADUNA**

**BY**

**SANUSI SAIDU**

**DEPARTMENT OF CHEMICAL ENGINEERING  
FACULTY OF ENGINEERING  
AHMADU BELLO UNIVERSITY, ZARIA  
NIGERIA**

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GROUNDWATER QUALITY IN TUDUN WADA, KADUNA**

**BY**

**Sanusi SAIDU, B.Eng. (ABU) 2002  
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AHMADU BELLO UNIVERSITY, ZARIA  
NIGERIA**

**FEBRUARY, 2016**

## **Declaration**

I declare that the work in this Dissertation entitled “ASSESSMENT OF DUMPSITE IMPACT ON SOIL AND GROUNDWATER QUALITY IN TUDUN WADA, KADUNA” has been carried out by me in the Department of Chemical Engineering. The information derived from the literature has been dully acknowledged in the text and list of references provided. No part of this dissertation was previously presented for another degree or diploma at this or any other Institution.

SanusiSaidu (MSc/ENG/13348/2010-11)

\_\_\_\_\_  
Signature

\_\_\_\_\_  
Date

## Certification

This dissertation entitled “ASSESSMENT OF DUMPSITE IMPACT ON THE SOIL AND GROUNDWATER QUALITY IN TUDUN WADA, KADUNA” by Sanusi SAIDU meets the regulations governing the award of the degree of Chemical Engineering of Ahmadu Bello University, and is approved for its contribution to knowledge and literacy presentation.

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Prof. B. O. Aderemi  
Chairman, Supervisory Committee

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Date

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Dr. B. Mukhtar  
Member, Supervisory Committee

---

Date

---

Dr. S. M. Waziri  
Head of Department

---

Date

---

Prof. KabirBala  
Dean, School of postgraduate Studies

---

Date

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## **Abstract**

The assessment of dumpsite impact on soil and groundwater quality in Tudun Wada, Kaduna was carried out. Eight samples of soil and groundwater respectively were collected using grid sampling method and analysed by using Atomic Absorption spectrometer, colony counter, data logging spectrometer and oxygen meter, in Kaduna State Environmental Protection Authority (KEPA) laboratory. The results of the water samples obtained showed that most of the physicochemical parameters of the samples analysed such as temperature, pH, conductivity, TDS, dissolved oxygen, BOD, total alkalinity, chloride content, total hardness, sulphate, nitrate, phosphate, copper, cadmium, chromium, iron, lead and zinc were within the permissible limit by the World Health Organisation (WHO) and Nigerian Standard Drinking Water Quality (NSDWQ), while some parameters such as total dissolved solid and biochemical oxygen demand varied with the spartial position from the dumpsite, others such as sulphate and total hardness showed no regular distribution with regards to the distance from the dumpsite but are rather seeing as a function of geological formation of the area. On the other hand, the microbial parameters analysed, total coliform and hetetrophic count were found to be above the permissible limit which are for samples A1 to A8 were between 100 cfu/ml to 15 cfu/ml for the coliform count instead of 10 cfu/ml by the WHO and NSDWQ, while the hetetrophic count for samples A1 to A3 were between 152 cfu/ml to 110 cfu/ml instead of 100 cfu/ml permissible limit by the WHO. The community may be prone to microbial or pathogenic epidemic, if proper measures were not taken.

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## **Abbreviations**

BOD = Biological Oxygen Demand

DO = Dissolved Oxygen

EC = Electric Conductivity

EIA = Environmental Impact Assessment

EIS = Environmental Impact Studies

FEPA = Federal Environmental Protection Authority

FMEvn = Federal Ministry of Environment

HIA = Health Impact Assessment

HPC = Heterotrophic Plate Count

IEE = Initial Environmental Examination

KEPA = Kaduna state Environmental Protection Authority

NSDWQ = Nigerian Standard Drinking Water Quality

SEA = Strategic Environmental Assessment

SIA = Social Impact Assessment

TC = Total Coliform Count

TDS = Total Dissolved Solid

TOD = Total Oxygen Demand

ToR = Terms Of Reference

UNEP = United Nation Environmental Program

WHO = World Health Organisation

## CHAPTER ONE

### INTRODUCTION

#### 1.1 Background of Study

The sustenance of life depends greatly on water, therefore, the demand for potable water increases continually in line with world population growth. Recently, many African cities have undergone unprecedented growth in population through migration from rural areas which has led to the growth of cities into sprawling “mega-cities” with large areas of unplanned sub-standard housing with few services. The unplanned expansion of such cities leads to a serious pollution threat to the groundwater and uncontrolled industrial and commercial activity add to the pollution threat (UNEP, 2002). This has been a major problem in developing countries; provision of drinking water has become expensive and difficult. The main source of potable water in many of these cities is groundwater, commonly from shallow hand-dug wells and deeper water supply boreholes. In Nigeria, like many other developing countries, open waste dumping system has been the major management option of solid waste disposal. In previous years, management system has been based on collection and dumping out of the city boundaries in conformity with the concept of “out of sight out of mind” (Arukwe *et al.*, 2012). But in recent times, the siting and development of residential quarters near waste sites are common due to shortage of building land to cope with the increasing rate of migration and consequent population explosion (Ikemet *et al.*, 2002).

Dumpsites have been identified as one of the major threats to groundwater resources, receiving a mixture of municipal, commercial and mixed industrial wastes. The depressions into which solid wastes are often dumped include valleys and excavations. Studies on the

effects of unlined waste dumps on the host soil and underlying shallow aquifers have shown that soil and groundwater system can be polluted due to poorly designed waste disposal facilities (Amadi *et al.*, 2012). Uncontrolled waste dumpsites threaten the groundwater supply as movement of leachates from dumpsites through the soil and the aquifers pose a risk to the environment and human health. Waste placed in dumpsites or open dumps are subjected to groundwater underflow or infiltration from precipitation (Moret *et al.*, 2006). The presence and potential exposures of the community to groundwater contaminants may contribute to the predilection of human health impacts, from simple poisoning to cancer, heart diseases and teratogenic abnormalities (Su, 2008).

Release of pollutants through leachates from both functional and abandoned dumpsites pose a high risk to nearby soil and groundwater if not adequately managed (Ikeme *et al.*, 2002). Leachate percolating into the groundwater is a mixture of highly complex contaminants such as potentially toxic metals (lead, mercury, cadmium, chromium etc) ; persistent organic pollutants (POPs) (dioxins, furans, polycyclic aromatic hydrocarbons (PAHs), polybrominated diphenyl ethers PBDEs); inorganic compounds (such as ammonium, sulphates, chlorides) and as well as bacterial contamination – total coliform and faecal coliform (Moret *et al.*, 2006; Longe and Balogun, 2010; Oyeku and Eludoyin, 2010; Agrawa *et al.*, 2011 and Galarpe and Parilla, 2012). Therefore considering possible impact to surrounding environment brought by dumpsites is inevitable.

Despite the enormous resources and efforts that have been committed to waste management, refuse collection and disposal remains a major problem in Kaduna metropolis. Kaduna is one of the most populous cities in Nigeria; hence enormous pressure

is put on the environment due to huge amounts of solidwaste generated daily. The residents make a heavy demand on resources and at the same time, generate large quantities of solid waste. Generally, these wastes are not treated; they are transferred to the several dumpsites, where they are openly burnt. The overwhelming environmental significance and impact of leachates on soil and nearby groundwater and surface water has become a great concern because of its serious threat to the quality of life of human beings that depends largely on water to sustain their livelihood.

Kaduna and its environs is littered with several dumpsites among which are those located at Kurmin Mashi, Kakuri, Sabon Gari and Tudun Wada. This research work is to cover that of Tudun Wada as a result of its proximity to the residential houses, the population density of the area and also its old age of waste accumulation. Therefore, soil samples and groundwater from Tudun Wada around a dumpsite are assessed for the level of soil pollution and groundwater contamination through leachates percolation from the dumpsite.

## **1.2 Statement of the Problem**

Environmental impact assessment of potential health hazards facilities on their immediate environment ought to be a routine exercise by appropriate bodies such as KEPA to proactively prevent outbreak of preventable diseases. However, the unprecedented rate of growth of such facilities in Kaduna is so overwhelming, thereby requiring the intervention of unsolicited but enlightened workers such as the academics for this routine monitoring.

### **1.3 Justification of the study**

Effect of extent of environmental contamination of the groundwater and immediate soil in the area of study will be established by the work. Mitigation and amelioration measures will be suggested, hence negative health issues related to water and soil pollution will be minimized as a result of the work.

### **1.4 Aim and objectives of the study**

The aim of this research is to assess the impacts of a refuse dumpsite in Tudun Wada, Kaduna on the quality of groundwater and arable soil within the area.

The Objectives are:

1. The assessment of the level of impact of the dumpsite on the quality of the immediate soil and groundwater.
2. Suggestion of mitigation and amelioration measures.

### **1.5 Scope of the study**

This research is to cover the assessment of impacts of the refuse dumpsite in Tudun Wada, Kaduna on the quality of its surrounding soil and groundwater and to provide remediation and amelioration measures were the following parameters will be analyze, pH, conductivity, Total dissolved solid, Dissolved Oxygen, Biological Oxygen Demand, Total alkalinity, Chloride content, Total hardness, Nitrate, Phosphate, Copper, Cadmium, Chromium, Iron, Lead, Zinc, Total coliform count and Heterotrophic plate count.

## CHAPTER TWO

### LITERATURE REVIEW

#### 2.1 Landfill

Landfill has been widely used for municipal solid waste (MSW) disposal all over the world. Especially in developing countries, it is considered to be a reliable and cost effective method if adequate land is available. However, improper management and operation of landfill could create severe environmental impacts such as groundwater pollution and nuisance odor. Basic principle of conventional landfill design is to contain or store the wastes so that the exposure to human and environment could be minimized. (EPA 2001)

#### 2.2 Solid Waste Leachate

Solid waste is useless, unwanted or discarded material normally in the solid state that arises from human activity. As water percolates through the landfill, contaminants are leached from the solid waste, within a landfill, a complex sequence of physical, chemical, and biological mediated events occur through solid waste which arise leachate. As a result of consequence of these processes, refuse is degraded as shown in Figure 2.1 (EPA 2001)

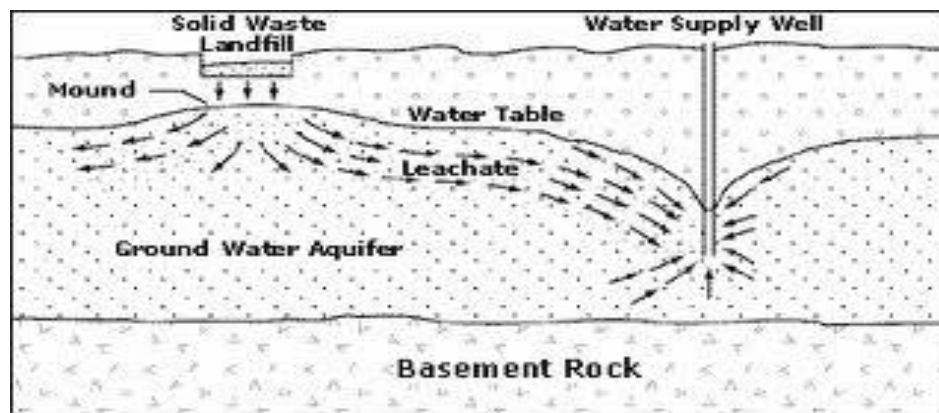


Figure 2.1 Schematic descriptions of leachate formation and groundwater movement (EPA 2001)

## **2.3 Types of Solid Waste**

Solid waste can be divided by source into five categories which are municipal solid waste, industrial solid waste, sewage sludge, agricultural wastes, and mining waste (Bishop, 2000).

### **2.3.1 Municipal solid wastes (MSW):**

These are solid waste from single family and multifamily residences, hotels which consist of residential wastes (garbage, yard wastes, ashes from heating unit, and bulky wastes), commercial and institutional wastes (construction and demolition wastes), street refuse, dead animals, abandoned vehicles, and so on (Bishop, 2000).

### **2.3.2 Industrial solid waste:**

These are solid wastes generally arise from two sources: process wastes remaining after manufacturing a product; and commercial institutional wastes from office activities, cafeterias, laboratories, and the like (Bishop, 2000).

### **2.3.3 Sewage sludge:**

This is the sludge left over after treating water or wastewater that must be handled properly to ensure public safety and minimize environmental damage (Bishop, 2000).

### **2.3.4 Agricultural wastes:**

These consist of both crop residues that cannot be returned to the soil, and manure from animal feeding facilities (Bishop, 2000).

### **2.3.5 Mining waste:**

The mining industry produces such large amounts of solid waste that special emphasis should be given to this material. Unplanned spoil heaps impair the landscape, threaten land slides and pollute ground water (Al-Nori 1999).

## **2.4 Refuse Disposal**

The refuse can be disposed by various methods: some of these methods are sanitary land filling, burning or incineration, barging it out into the sea, composting by bacterial agency (Veslined, 2000).

Actual actions in the disposal of the solid waste in the landfills are:

1-Dump or tip “Open placement of solid waste”, where this dump site is considered collection places, where the solid waste is collected on the surface of the earth and kept on it without any process or transportation to final disposal place landfill, or incineration (Veslined, 2002).

2-Sanitary landfill, which is one of the safety ways of the final disposal of solid wastes, which protect human beings and nature resources especially ground water (Veslined, 2002).

### **2.4.1 Dumping of solid wastes**

In general, solid waste includes garbage, domestic refuse and discarded solid materials such as those from commercial, industrial and agricultural operations. They contain increasing amounts of paper, cardboards, plastics, glass, old construction material, packaging material and toxic or otherwise hazardous substances. Since a significant amount of urban solid

waste tends to be paper and food waste, the majority is recyclable or biodegradable in landfills. Similarly, most agricultural waste is recycled and mining waste is left on site.

The portion of solid waste that is hazardous such as oils, battery metals, heavy metals from smelting industries and organic solvents are the ones we have to pay particular attention to. These can in the long run, get deposited on the soils of the surrounding area and pollute it by altering its chemical and biological properties. They also contaminate drinking water aquifer sources. More than 90% of hazardous waste is produced by chemical, petroleum and metal-related industries and small businesses such as dry cleaners and gas stations contribute as well.

Solid Waste disposal was brought to the forefront of public attention by the notorious Love Canal case in USA in 1978. Toxic chemicals leached from oozing storage drums into the soil underneath homes, causing an unusually large number of birth defects, cancers and respiratory, nervous and kidney diseases.

#### **2.4.2 Domestic and municipal solid waste disposal**

Solid waste generated by private homes, businesses, industries, and public buildings can be disposed of in the direct vicinity of these places or be collected and deposited at solid waste disposal sites. In many cases, these disposal sites may just be pieces of open land that have been fenced off, excavations and old mining areas, or isolated ravines and valleys. In the case that no proper sanitary measures have been taken at the site, leachate may form and infiltrate into the subsoil. Leachate is the contaminant-loaded liquid that is formed at the base of the disposal site when infiltrating and percolating rainwater is available in sufficient quantity. In the case that concentrated leachate, which may be enriched with toxic metals and organic compounds, intrudes the subsoil and reaches the water table, the risk of

groundwater contamination is imminent. The leachate usually contains inorganic components including chlorides, sulfates, carbonates, nitrogen components including chlorides, sulfates, carbonates, nitrogen compounds, and metals, and a wide range of organic compounds. The U.S. Environmental Protection Agency analysed 20 leachate samples from municipal waste disposal sites in the U.S.A. (Table 2.5). The table shows the main analyses done on the leachates and the large variations in concentrations of the individual dissolved components.

Table 2.5 Selected leachate components in municipal waste disposal sites (Source: U.S. EPA, 2001)

Component	Range (mg/l)	Component	Range (mg/l)
Alkalinity (CaCO <sub>3</sub> )	0 – 20,850	Magnesium	17 – 15,600
BOD (5 days)	81 – 33,360	Nitrogen (NH <sub>4</sub> )	0 – 1,106
COD	40 – 89,520	Sodium	0 – 7,700
Calcium	60 – 7,200	Sulfate	1 – 1,558
Copper	0 – 9.9	TDS	584 – 44,900
Chloride	4.7 – 2,500	Zinc	0 – 370
Iron, total	0 – 2,820	pHi	3.7 – 8.5
Total dissolved solids	1,500	Iron	0.3
Arsenic	0.01	Lead	0.01
Cadmium	0.003	Manganese	0.05
Chloride	250	Nitrate	50
Chromium	0.05	Selenium	0.01
Copper	2	Sulfate	250
Fluoride	1.5	Zinc	3

## 2.5 Soil

Soil is the thin layer of organic and inorganic materials that covers the Earth's rocky surface. The organic portion, which is derived from the decayed remains of plants and animals, is concentrated in the dark uppermost topsoil. The inorganic portion made up of rock fragments, was formed over thousands of years by physical and chemical weathering of bedrock. Productive soils are necessary for agriculture to supply the world with sufficient food. (Emilola *et al* 2014)

### 2.5.1 Soil Pollution

Soil pollution is defined as the build-up in soils of persistent toxic compounds, chemicals, salts, radioactive materials, or disease causing agents, which have adverse effects on plant growth and animal health (Emilola *et al* 2014).

There are many different ways that soil can become polluted, such as:

- Seepage from a landfill
- Discharge of industrial waste into the soil
- Percolation of contaminated water into the soil
- Rupture of underground storage tanks
- Excess application of pesticides, herbicides or fertilizer
- Solid waste seepage

The most common chemicals involved in causing soil pollution are:

- Petroleum hydrocarbons
- Heavy metals
- Pesticides
- Solvents

### 2.5.2 Soil pollution due to urbanisation

Urban activities generate large quantities of city wastes including several Biodegradable materials (like vegetables, animal wastes, papers, wooden pieces, carcasses, plant twigs, leaves, cloth wastes as well as sweepings) and many non-biodegradable materials (such as plastic bags, plastic bottles, plastic wastes, glass bottles, glass pieces, stone / cement pieces). On a rough estimate Indian cities are producing solid city wastes to the tune of 50,000 - 80,000 metric tons every day. If left uncollected and decomposed, they are a cause of several problems such as (UNEP 2002).

- clogging of drains: Causing serious drainage problems including the burst / leakage of drainage lines leading to health problems.
- barrier to movement of water: Solid wastes have seriously damaged the normal movement of water thus creating problem of inundation, damage to foundation of buildings as well as public health hazards.
- foul smell: Generated by dumping the wastes at a place.
- increased microbial activities: Microbial decomposition of organic wastes generate large quantities of methane besides many chemicals to pollute the soil and water flowing on its surface
- when such solid wastes are hospital wastes, they create many health problems; as they may have dangerous pathogen within them besides dangerous medicines, injections.

Underground soil in cities is likely to be polluted by

- chemicals released by industrial wastes and industrial wastes
- decomposed and partially decomposed materials of sanitary wastes

Many dangerous chemicals like cadmium, chromium, lead, arsenic, selenium products are likely to be deposited in underground soil. Similarly underground soils polluted by sanitary wastes generate many harmful chemicals. These can damage the normal activities and ecological balance in the underground soil.

## **2.6 Groundwater**

The ‘looming water crisis’ is becoming a major issue on the world agenda for the twenty-first century. The World Water Council presented the ‘World Water Vision’ during the Second World Water Forum and Ministerial Conference at The Hague in March 2000 (Lawson 2011). The Vision reported that 1.2 billion people or one fifth of the world population do not have access to safe drinking water, while half of the world population lack adequate sanitation. The Vision document further states that ‘rapidly growing cities, burgeoning industries, and rapidly rising use of chemicals in agriculture have undermined the quality of many rivers, lakes, and aquifers’ and also emphasises that ‘the impacts of agriculture on water quality are less visible overtime but at least as dangerous (as industrial), because many of the fertilisers, pesticides, and herbicides used to improve agricultural productivity slowly accumulate in groundwater aquifers and natural ecosystems.’

The importance of groundwater is gaining recognition, because this resource:

- represents some 98 percent of the planet’s freshwater resources (polar ice excluded),
- supplies more than 1.5 billion urban dwellers with water,
- is extensively used for low-cost rural water supply,
- is increasingly developed for both large- and small-scale irrigation,

- is generally reliable in periods of drought because of its large storage capacity,
- is cheap to develop because of its widespread occurrence and its generally good natural quality.

The term quality of groundwater refers to its physical, chemical, and biological characteristics as they relate to the intended use of water. Groundwater quality is threatened mainly by human activities, although harmful substances are sometimes introduced by natural processes. Sustainable groundwater management must be based not only on prevention of the overexploitation of groundwater resources but also on prevention of contamination, because unlike treatment at the point of use, prevention protects all of the resource.

Usually, economic activities are classified as primary activities, which produce commodities (mining, agriculture); secondary or industrial activities (energy production, manufacturing, building, etc.); and services (including transport). In addition, activities of private households play a role.

In principle, waste sites can be isolated from the environment. This, however, is not possible with diffuse sources of contamination, which are either introduced into the air and subsequently rained out, or are used in agriculture and partly infiltrate into the subsurface. (Kofoworola 2007)

### **2.6.1 Natural composition of groundwater**

The chemical composition of groundwater mainly depends on the composition of the initial porewater; the composition of infiltrating water and subsurface inflow that replaces the pore water; the composition and physical properties of the soil and rock; the chemical interaction between rock, pore water, and infiltrating water; and microbiological processes.

From the moment rain falls on the ground and begins to infiltrate and pass through the soil and rock, the water dissolves the host materials, and minerals are added to the groundwater flowing through. In general, the amount of Total Dissolved Solids (TDS) increases with the residence time of groundwater.

The dissolved constituents in groundwater take part in the geochemical cycle, which starts with the weathering of rocks. Weathering breaks up rock minerals and released elements react with water and enter into solution. In addition, the vegetative litter releases organic and mineral substances to the soil and groundwater as part of the biochemical cycle. The weathering is more intense in a warm and humid climate than in a dry and cool one. Rocks can be broken up either by mechanical forces, e.g. frost action (physical weathering) or transformed by chemical reactions, e.g. hydrolysis (chemical weathering). The disintegration of rocks by physical weathering increases the infiltration capacity and the surface area of the contact between rock and air and rock and water. Chemical weathering is most active above the water table, in the unsaturated zone.

Because the above mentioned processes vary from place to place or change in the course of time, groundwater greatly varies in composition. However, the number of major dissolved constituents in groundwater is quite limited and natural variations are not as great as might be expected from the complex mineral and organic material through which the water has passed and from the complexity of processes involved (Longe 2007). Of the 22 elements that form 99.80 percent of the mass of the combined upper lithosphere, oceans, and atmosphere, only seven elements occur normally in groundwater in concentrations greater than 1 milligram per litre (mg/l) and form 95 percent of the chemical composition of groundwater. In addition, there are eight secondary constituents that regularly occur in groundwater, although in lower concentrations (0.01–10 mg/l) than the major ones (Table

2.1). Besides these more abundant elements, there are about 40 minor (<1 mg/l) and trace (<1 µg/l) elements, the occurrence of which depends on the local situation with respect to the rock and pore water composition, pH, and redox potential. Eighteen of the more important ones are included in Table 2.1

Table 2.1 Chemical constituents in groundwater (UNEP 2002)

Major constituents	Secondary constituents	Selected minor and trace constituents	
Calcium (Ca)	Potassium (K)	Aluminium (Al)	Molybdenum (Mo)
Magnesium (Mg)	Iron (Fe)	Arsenic (As)	Nickel (Ni)
Sodium (Na)	Manganese (Mn)	Barium (Ba)	Phosphate (PO <sub>4</sub> <sup>2-</sup> )
Bicarbonate (HCO <sub>3</sub> )	Strontium (Sr)	Cadmium (Cd)	Radium (Ra)
Chloride (Cl <sup>-</sup> )	Boron (B)	Chromium (Cr)	Selenium (Se)
Sulfate (SO <sub>4</sub> )	Fluoride (F)	Cobalt (Co)	Silver (Ag)
Silica (SiO <sub>2</sub> )	Carbonate (CO <sub>3</sub> )	Copper (Cu)	Uranium (U)
	Nitrate (NO <sub>3</sub> )	Lead (Pb)	Zinc (Zn)
		Mercury (Hg)	Sulfide (H <sub>2</sub> S, HS)

### 2.6.2 groundwater contamination

This is the Introduction into water of any substance in undesirable concentration not normally present in water, e.g. microorganisms, chemicals, waste or sewage, which renders the water unfit for its intended use.

### 2.6.3 Classification of groundwater contamination sources

The sources and causes of groundwater contamination are numerous, and are as diverse as human activities (Lawson and Enekwechi 2007). With the growing number of potential contamination sources, attempts to classify them have also been increasing. Agencies and scientists in the field of groundwater contamination have often followed their own categorisation. A large number of source classification methods have been developed and

subclassifications have also been prepared. Table 2.2 shows the various ways of classifying contamination sources.

Table 2.2 Methods for classification of groundwater contamination sources (EPA 2001)

Classification	Examples
By way of release	Discharge sources; transport sources
By origin	Domestic sources; agricultural sources
By chemical type	Heavy metals; hydrocarbons; pesticides
By location	Above ground surface; below surface
By character	Point, diffuse, and line sources

An early categorisation of groundwater contamination sources was developed by the U.S. Environmental Protection Agency (2001). The sources were divided into four categories considering the way in which the contaminants were released. For example, Category I included systems, facilities, and activities designed to discharge substances. In 1984, the U.S. Office of Technology Assessment revised this classification (Ugwuh 2009) and expanded it into six categories (Table 2.3). An especially significant improvement was the addition of naturally-occurring sources.

The source classification by origin has been used most often throughout the last decades.

Already at the start of the 1970s, Longe (1987) suggested a simple classification consisting of industrial sources, domestic contamination, agricultural sources, and environmental contamination. Nowadays, the classifications by origin are more extensive and subclassifications, by origin and/or by type of chemical compound, are common. For instance, municipal waste may form a major category of groundwater contamination sources. Subcategories such as solid (municipal) waste and liquid (municipal) waste may be

defined, and further differentiated by chemical character of the waste into inorganic solid waste and organic waste.

A principal classification in terms of chemical type or location has been considered by some scientists. Chemical and biological type classifications may include broad categories such as inorganic and organic compounds, bacteriological species, etc. Inorganic substances may be further subdivided into heavy metals, halogens, radioactive compounds, etc. A classification by location refers to the original location of the sources, e.g. above ground surface, in the unsaturated zone, or in the saturated zone (Lawson, 2007). Classifications by chemical or biological type and by location, are usually reserved to set up subclassifications for groundwater contamination sources.

In addition, the behaviour of the contaminant in the saturated zone may also be a key element for subcategorisation. Some contaminants dissolve in the water and travel along with the groundwater flow in the form of a plume. Others are known to 'float' on groundwater (e.g. petrol), and a third category 'sinks' rather directly to the bottom of a groundwater system (dense non-aqueous phase liquids, such as chlorinated hydrocarbons).

Finally, a classification based on character usually refers to a distinction between point, line, and diffuse (non-point) sources. At point sources, the contaminants are confined to a restricted area of well-defined dimensions. Examples are sites for solid waste, leaking petrol station tanks, or injection wells. Line and diffuse sources spread contaminants over larger distances or areas.

These sources may include contaminants in a river, a road, a leaking pipeline, and agricultural contamination whereby large areas may be affected by fertilisers or pesticides. To some extent, this classification became popular in countries with rapidly growing agricultural and industrial outputs. The increased application of agriculture-based

contaminants and air contamination by industry emphasised the threats from diffuse sources, which subsequently led to the formulation of a character-based classification of contaminants.

In this guideline which the contamination source classification based on origin will be adhered to. The widely accepted use, the ease of physical recognition, and flexibility have been the major reasons for its selection (Table 2.3). Moreover, the origin-based classification is thought to fit well into the concepts of the users of this guideline, including hydrogeologists, engineers, and officials working at national, regional, and provincial levels. Contamination sources were divided into six categories, and their normal character and location described. The major contamination sources of the six categories listed in Table 2.3 are discussed.

Table 2.3 Summary of groundwater contamination sources by origin UNEP 2002

Category	Source type	Usual character	Normal location
Natural sources	Inorganic substances Trace metals Radionuclides Organic compounds Microorganisms	Not applicable	Not applicable
Agriculture and forestry	Fertilisers	Diffuse	Surface
	Pesticides	Diffuse	Surface
	Animal waste	Diffuse/Point	Surface/Unsaturated
	Animal feedlots	Point	Surface
	Irrigation return flow	Diffuse	Surface
	Stockpiles	Point	Surface
Urbanisation	Solid waste sites	Point	Surface/Unsaturated
	On-site sanitation	Point	Surface/Unsaturated
	Wastewater, effluent	Point and line	Surface/Unsaturated
	Salvage and junk yards	Point	Surface/Unsaturated
	Leaking underground storage tanks	Point	Unsaturated Zone
	Runoff, leaks, spills	Point and line	Surface

Mining/Industry	Mine tailings	Point	Surface/Unsaturated
	Mine water	Point and line	Variou
	Solid waste	Point	Surface/Unsaturated
	Wastewater, effluent	Point and line	Surface/Unsaturated
	Injection wells	Point	Below water table
	Spills, leaks	Point	Surface
Water mismanagement	Well-field design	Point	Below water table
	Upconing	Point	Below water table
	Seawater intrusion	Line	Below water table
	Faulty well construction	Point	Below water table
	Abandoned wells	Point	Below water table
	Irrigation practices	Diffused	Below water table
Miscellaneous	Airborne sources	Diffused	Surface
	Surface water	Line	Below water table
	Transport sector	Point and line	Surface/Unsaturated
	Natural disasters	Point and line	Surface/Unsaturated
Cemeteries	Point	Unsaturated Zone	

safety. Most natural, potentially hazardous, sources produce contaminant concentrations that are well below the maximum permissible levels listed in Table 2.4. And some naturally-occurring contaminants are quite innocuous, causing only aesthetic, taste, or odour problems (e.g. iron and manganese).

#### 2.6.4 Inorganic sources

The major inorganic ions in groundwater include sodium, potassium, calcium, magnesium, silica, bicarbonate, sulfate, and chloride (Table 2.1). The distribution of these constituents largely depends on the type of geological formations in contact with the groundwater flowing through.

Most of them are rarely harmful to health but some may cause physical inconveniences if digested in large concentrations (e.g. sulfate). High concentrations of calcium and magnesium compounds cause hardness of water. For people suffering from diseases of the

heart or kidneys, it is recommended to avoid drinking water with high concentrations of sodium.

The major ions form the majority of chemical compounds found in groundwater. The summed ion concentration of minerals dissolved in water is referred to as total dissolved solids (TDS). There is no evidence of adverse health effects at TDS levels over 1,000 mg/l, although at about 1,200 mg/l taste problems are likely to arise, and at levels over 1,500 mg/l, gastrointestinal irritation may occur. (Ugwuh, 2009)

Certain minor inorganic constituents may be present in groundwater and may render it unfit for human consumption. Perhaps the two best known examples of such constituents are arsenic and fluoride. Arsenic may be released into groundwater through the reduction of arsenic-containing iron hydroxide coatings on sand grains, which are present in some fluvial and deltaic river sediments. The consumption of ground-water with excessive arsenic levels is toxic and may eventually lead to the loss of limbs, cancer, or death. Fluoride may be present in groundwater by the disintegration and dissolution of igneous and metamorphic rocks containing minerals such as amphiboles and micas (Ikem, 2002). The drinking of groundwater with high concentrations of fluoride may cause mottled teeth and disturb the growth of bones in children. Extremely high concentrations of fluoride are toxic and could lead to death. The recommended limits for arsenic and fluoride are listed in Table 2.4.

#### **2.6.5 Trace metals**

Concentrations of trace metals, including aluminium, cadmium, chromium, cobalt, copper, lead, nickel, silver, zinc, etc., are usually extremely small in groundwater. Trace metals are normally associated with igneous and metamorphic rocks, and in particular, with ore bodies.

Weathering of these rocks, including oxidation and leaching, may give rise to elevated trace metal levels in groundwater. However, trace metals may also be brought into the groundwater system by human activities. Naturally-occurring elevated concentrations of trace metals in groundwater (maximum limits are listed in Table 2.4) may locally make this resource unfit for human consumption or affect the natural ecosystem.

Table 2.4 Maximum permissible concentrations of potentially harmful or objectionable substances in drinking water.(EPA 2001)

Constituent	Concentration(mg/l)	Constituent	Concentration(mg/l)
Total dissolved solids	1,500	Iron	0.3
Arsenic	0.01	Lead	0.01
Cadmium	0.003	Manganese	0.05
Chloride	250	Nitrate	50
Chromium	0.05	Selenium	0.01
Copper	2	Sulfate	250
Fluoride	1.5	Zinc	3

During the last few decades, urbanisation has taken on an alarming expansion, especially in the developing world. Capitals and small country towns have increased in size tremendously and facilities for the disposal of waste, wastewater, stockpiling, etc. have not always been implemented in a satisfactory manner. Therefore, there are numerous known cases of waste, stockpiles, leaking tanks and pipelines, and accidents damaging the urban environment. Not only the urban area itself is threatened, but also the subsurface framework, including the groundwater resources (Emilola, 2014). The most common sources of groundwater contamination in urban areas are included.

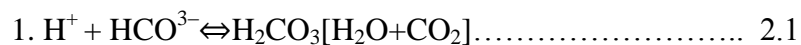
### 2.6.6 Alkalinity

The alkalinity of natural water is generally due to the presence of bicarbonates formed in reactions in the soils through which the water percolates. It is a measure of the capacity of the water to neutralise acids and it reflects its so-called buffer capacity (its inherent resistance to pH change). A poorly-buffered water will have a low or very low alkalinity and will be susceptible to pH reduction by, for example, "acid rain." At times, however, river alkalinity values of up to 400 mg/l CaCO<sub>3</sub> may be found; they are without significance in the context of the quality of the water.

There is little known sanitary significance attaching to alkalinity (even up to 400 mg/l CaCO<sub>3</sub>), though unpalatability may result in highly alkaline waters.

Alkalinity in natural waters may also be attributable to carbonates and hydroxides. Sometimes analysis is carried out to distinguish between the alkalinity elements and this is done by using different indicators in the titration procedure and by making appropriate calculations. The indicators most commonly employed are phenolphthalein (colour change around pH 8.3) and methyl orange (colour change around pH 4.5), resulting in the additional terms phenolphthalein alkalinity and methyl orange alkalinity; the latter is synonymous with total alkalinity. (Gallarpeet *al* 2012)

Alkalinity is involved in the consequential effects of eutrophication [over-enrichment] of waters. Where a high degree of photosynthesis occurs, as discussed below under "Oxygen, Dissolved" (q.v.), there is a high consumption of carbon dioxide by algae. As any free carbon dioxide initially available is consumed, more is produced in a series of related chemical equilibrium reactions, as follows:



3.  $\text{H}_2\text{O} \rightleftharpoons \text{H}^+ + \text{OH}^-$  .....2.3

As the carbon dioxide is consumed by photosynthesis, more is produced (reaction 1, left to right) by the action of bicarbonate ions, present as alkalinity, and hydrogen ions to give undissociated carbonic acid (carbon dioxide and water). Any carbonate ions present will then react with more hydrogen ions to replace the bicarbonate consumed (reaction 2, again left to right). Both these reactions consume hydrogen ions, more of which are produced as in reaction 3 (equilibrium again to the right). A net overall effect is the production of hydroxyl ions and an increase in the pH. It is not uncommon for extreme photosynthetic activity to produce pH levels high enough to cause serious damage (even death) to fish.

**2.6.7 Chloride**

Chloride exists in all natural waters, the concentrations varying very widely and reaching a maximum in sea water (up to 35,000 mg/l Cl). In fresh waters the sources include soil and rock formations, sea spray and waste discharges. Sewage contains large amounts of chloride, as do some industrial effluents. Chloride does not pose a health hazard to humans and the principal consideration is in relation to palatability. At levels above 250 mg/l Cl water will begin to taste salty and will become increasingly objectionable as the concentration rises further. However, external circumstances govern acceptability and in some arid areas waters containing up to 2,000 mg/l Cl are consumed, though not by people unfamiliar with such concentrations. High chloride levels may similarly render freshwater unsuitable for agricultural irrigation. (Moret *al* 2006)

### **2.6.8 Cadmium**

In ores, including those of zinc. Cadmium in water is due nearly exclusively to industrial discharges (e.g. from electroplating, paint-making, manufacture of plastics etc) and landfill leachates. Very highly toxic, hence severe restrictions on its concentrations in waters.

The metal is very strongly adsorbed on muds, humus and organic matter, leading to the possibility of entry to the food chain via fish and fish food, and subsequent accumulation in tissue. The principal physiological effects of cadmium are bone damage, chronic kidney disease, cancer and hypertension. The metal is also highly toxic to aquatic life.

### **2.6.9 Chromium**

Natural occurrence is in ore, but chromium arises in surface waters from discharges from electroplating, tanning, textile, paint and dyeing plants.

Chromium is toxic, to a degree which varies with the form in which it occurs, whether as the trivalent  $\text{Cr}_{\text{III}}$  or the hexavalent  $\text{Cr}_{\text{VI}}$  form. The latter is considered the more hazardous but because it is difficult to distinguish by analysis the figures quoted below refer mainly to the total chromium concentrations.

The element is an essential dietary requirement - in limited amounts - and a deficiency can lead to disruption of glucose metabolism. Indeed, it has been reported that chromium deficiency is of greater nutritional concern than overexposure. However, it is considered that the element is carcinogenic (at high concentrations), though much more evidence of this is needed, and it can act as a skin irritant. Hence its limitation in domestic water supplies.

The deaths of livestock resulting from watering in chromium-contaminated water have been reported from time to time. (Ugwuh 2009)

#### 2.6.10 Total coliforms and faecal

The risk to consumers of infection from drinking polluted water will vary very widely from instance to instance because the numbers of pathogenic organisms (i.e. the actual disease-causing organisms) in contaminated waters will show great variations. The number of pathogens in a sewage contaminated water is a function of the number of persons (so-called "carriers") who excrete such organisms.

As the latter is an unknown quantity, and as the positive identification of specific bacteria may be a very difficult task (and not one suited to the routine bacteriological screening of a water on public health grounds) an indirect approach is universally adopted.

To ensure a high factor of safety, the practice has been to monitor indicator organisms which, by definition, should be (i) easily detected and identified, (ii) of the same origin as the pathogens (i.e. from the human or animal intestine), (iii) present in far greater numbers than the pathogens, and (iv) present whenever the pathogens are likely to be present. In addition, they should show the same or better survival characteristics than the pathogens and, of course, they must not be in themselves pathogenic. To date the universal indicator organisms have been the coliforms, specifically *Escherichia coli*. These bacteria are of definite faecal origin (human and animal) and they are excreted in vast numbers. Their presence in a water supply is proof that faecal contamination has occurred and it is therefore a definite indication of the risk that pathogens may be present. The absence of these faecal coliforms indicates strongly the probability that pathogens are absent.

Because not all coliform organisms (or organisms which show the same test behaviour as coliforms) are of faecal origin, some types being able to grow in soil, a second analysis is

carried out for the presence of total coliforms, giving an indication of the general level of microbiological contamination of a water. Each microbiological test procedure is designed around some distinctive, characteristic property of the group of organisms under study. In the case of the coliforms this is the ability to grow aerobically on an agar/bile-salt medium and to ferment lactose, producing acid and gas, within 48 hours at 37°C. E. coli are distinguished by further individual properties.

As indicated above, two distinct analytical procedures are used routinely. The first is a multiple tube technique in which several replicates of each of three different dilutions of sample are incubated in test-tubes containing the appropriate medium. After incubation the number of positive results is noted, i.e. the number of tubes at each dilution in which the production of gas etc. is observed, and the result - the Most Probable Number of organisms in 100 ml of sample, commonly known as the MPN - is obtained from probability tables. It is presumed that each "positive" indication is due to the presence of coliforms and the test is known as the "presumptive coliform test." Concurrent Most Probable Number determinations are made for faecal and total coliforms (at different incubation temperatures) and the results reported separately.

In the MPN technique actual numbers of coliforms are not being determined, as they are in the second commonly used procedure - Membrane Filtration. Here, measured amounts of sample are passed through sterilised filter membranes. The micro-organisms present are retained on the membranes which are transferred to a suitable medium for culturing separately at the appropriate temperatures. The numbers of resulting colonies are counted to give presumptive E. coli and total coliform counts. The term presumptive is applied as additional tests would be required to verify that the organisms showed all the reactions

characteristic of the coliform group. However, if these extra tests are omitted and waters assessed on the basis of presumptive tests only there is an even greater margin of safety, as a "worst-case" situation is assumed to apply.

The philosophy which has been adopted universally is to use the coliforms as definite indicators of sewage (faecal) pollution and to apply strict limits on their presence in water sources and supplies. The interpretation of the results of analysis may be summarised as follows:

Where *E. Coli* are present in large numbers the inference is that heavy, recent pollution by human or animal wastes has occurred; if the *B. coli* numbers are low it is inferred that pollution from the same source(s) is either less recent or less severe. If coliforms not including *E. Coli* are observed the indication is that either the pollution is recent and non-faecal in origin or of remote, faecal origin such that the intestinal conformers have not survived. (Su 2008).

However, if any coliforms at all are found in a treated drinking water supply, following chlorination, it should be concluded that either inadequate treatment is being applied or else that contamination has been introduced during distribution of the water, or in the sampling or handling of the sample(s). Any indication at all of contamination, however apparently mild, must be regarded as a matter of gravity and the circumstances investigated promptly.

#### 2.6.11 Conductivity

Also referred to as electrical conductivity and, not wholly accurately, as specific conductance, the conductivity of a water is an expression of its ability to conduct an electric current. As

this property is related to the ionic content of the sample which is in turn a function of the dissolved (ionisable) solids concentration, the relevance of easily performed conductivity measurements is apparent. In itself conductivity is a property of little interest to a water analyst but it is an invaluable indicator of the range into which hardness and alkalinity values are likely to fall, and also of the order of the dissolved solids content of the water. While a certain proportion of the dissolved solids (for example, those which are of vegetable origin) will not be ionised (and hence will not be reflected in the conductivity figures) for many surface waters the following Approximation will apply:

$$\text{Conductivity } (\mu\text{S/cm}) \times 2/3 = \text{Total Dissolved Solids (mg/l)} \dots\dots\dots 2.4$$

In samples from a source which is regularly tested a rapid conductivity analysis may be an adequate replacement for other, longer determinations.

#### 2.6.12 Copper

This element is present naturally in metalliferous areas but more often its presence in waters is due to attack on copper piping. Rarely, its occurrence may be due to its use as an algicide. Unless used with great care for algal control there is a grave risk of fish kills, as it is as a toxicant to fish that copper is of greatest interest. In recent years there has been at least one major fish kill attributed to the improper use of copper as an algal toxicant. Copper is an element the toxicity of which to fish varies widely with the hardness of the water.

### 2.6.13 Hardness

Hardness is a natural characteristic of water which can enhance its palatability and consumer acceptability for drinking purposes. Health studies in several countries in recent years indicate that mortality rates from heart diseases are lower in areas with hard water.

Originally taken to be the capacity of a water to destroy the lather of soap, hardness was determined formerly by titration with soap solution. Nowadays, the analysis comprises the determination of calcium and magnesium which are the main constituents of hardness. Although barium, strontium and iron can also contribute to hardness, their concentrations are normally so low in this context that they can be ignored. Thus, total hardness is taken to comprise the calcium and magnesium concentrations expressed as mg/l CaCO<sub>3</sub>. The widespread abundance of these metals in rock formations leads often to very considerable hardness levels in surface and ground waters. (Oyeku 2010)

The following is one of several such arbitrary classifications of waters by hardness

Soft	up to 50 mg/l CaCO <sub>3</sub>	Moderately Hard	151-250 mg/l CaCO <sub>3</sub>
Moderately Soft	51-100 mg/l CaCO <sub>3</sub>	Hard	251-350 mg/l CaCO <sub>3</sub>
Slightly Hard	101 - 150 mg/l CaCO <sub>3</sub>	Excessively Hard	over 350 mg/l CaCO <sub>3</sub> .

A variety of additional terms is used to describe different aspects of hardness. These are frequently encountered and are summarised briefly below:

**Calcium Hardness** is the expression of the results of the measurement of calcium only, as mg/l CaCO<sub>3</sub>.

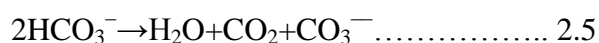
**Carbonate Hardness** is the hardness derived from the solubilisation of calcium or magnesium carbonate (by conversion of the carbonate to bicarbonate). This hardness is removed by heating .

**Magnesium Hardness** The difference between total hardness and calcium hardness is taken as the magnesium hardness (all figures as mg/l CaCO<sub>3</sub>).

**Non-carbonate Hardness** is the hardness due to the solution of calcium chloride or magnesium sulphate, for example.

**Permanent Hardness** This is equivalent to non-carbonate hardness in that it cannot be reduced or removed by heating.

**Temporary Hardness** The same as carbonate hardness, this form may be removed by heating the waters, when chemical reactions occur as follows:



Calcium Carbonate (insoluble)

This is in fact what happens in most cases when the temporary hardness is deposited as scale in boilers, etc.

**Total Hardness** is the expression of the results of direct measurement (principally of calcium and magnesium) expressed as mg/l CaCO<sub>3</sub>.

#### 2.6.14 Heavy metals

Principally from effluent discharges, or from distribution piping, or from geological formations. Toxic to humans (to a degree varying greatly from metal to metal) and to fish (the hazard levels for which are generally very much lower). Easily accumulable in fish and other tissue and hence liable to enter food chain.

The parameters in this very important category comprise principally those listed below. Arsenic, though non-metallic, is included for convenience as it is toxic and is generally referred to as a constituent of this group. All the elements listed below are discussed under

separate paragraphs in this volume but the general class "Heavy Metals" has been included for completeness as references to the group are very common indeed. The term "heavy metals" is rather inaccurate and, indeed, could be misleading. It arises from the high atomic weights of several metals in the broad group, although other metals regarded as in the same group have low atomic weights. Nonetheless, the term both is widely current and a useful descriptor. The following is a listing of the more commonly referred metals in this class:

Antimony	Cobalt	Nickel	Tin
Arsenic	Copper	Selenium	Titanium
Beryllium	Lead	Silver	Uranium
Cadmium	Mercury	Tellurium	Vanadium
Chromium	Molybdenum	Thallium	Zinc.

The individual substances are all more or less toxic to either man or fish or both, and their presence is highly undesirable in raw or finished public waters or in fishery waters, salmonid or cyprinid.

#### 2.6.15 Iron

The objections to iron are primarily organoleptic, but there has been recent medical concern about high levels in drinking water. Iron is present in significant amounts in soils and rocks, principally in insoluble forms. However, many complex reactions which occur naturally in ground formations can give rise to more soluble forms of iron which will therefore be present in water passing through such formations. Appreciable amounts of iron may therefore be present in ground waters. Severe problems can be caused in drinking water supplies by the presence of iron although there is normally no harmful effect on persons consuming waters with significant amounts of iron. Rather, the problems are primarily

aesthetic, as the soluble (reduced) ferrous ( $\text{Fe}^{++}$ ) iron is oxidized in air to the insoluble ferric ( $\text{Fe}^{+++}$ ) form, resulting in colour or turbidity (or, in severe cases, precipitate formation). Laundry becomes stained if washed in water with excessive iron, and vegetables likewise become discoloured on cooking. Taste problems may also occur. When waters rich in iron are used to make tea (in which tannins are present) there may be an action giving rise to off-colours which may in severe cases resemble that of ink. Problems have been reported also with the addition of such waters to whiskey.

#### 2.6.16 Lead

Leaching from ores; effluent discharges; attack on water pipes. Toxic cumulative poison. Lead is one of the most commonly determined heavy metals. Because it accumulates in body tissue it follows that strict limits on its presence in raw and finished drinking waters must be imposed. Particular attention is paid to this element as in many older houses extensive use is made of lead piping and there is a danger of lead being brought into solution ("plumbosolvency"). Levels may be quite marked in samples taken first thing in the morning when the initial yield will be of water which has been standing in such pipes for perhaps twelve hours. Hence the recommendation that drinking water pipes be flushed briefly in the morning before the water is consumed.

### 2.6.17 Nitrate

Oxidation of ammonia: agricultural fertiliser run-off. Hazard to infants above 11 mg/l N (50 mg/l  $\text{NO}_3$ ). Relatively little of the nitrate found in natural waters is of mineral origin, most coming from organic and inorganic sources, the former including waste discharges and the latter comprising chiefly artificial fertilisers. However, bacterial oxidation and fixing of nitrogen by plants can both produce nitrate. Interest is centred on nitrate concentrations for various reasons. Most importantly, high nitrate levels in waters to be used for drinking will render them hazardous to infants as they induce the "blue baby" syndrome (methaemoglobinaemia). The nitrate itself is not a direct toxicant but is a health hazard because of its conversion to nitrite which reacts with blood haemoglobin to cause methaemoglobinaemia.

Also of increasing importance is the degree to which fertiliser run-off can contribute to eutrophication problems in lakes. Sewage is rich in nitrogenous matter which through bacterial action may ultimately appear in the aquatic environment as nitrate. Hence, the presence of nitrate in ground waters, for example, is cause for suspicion of past sewage pollution or of excess levels of fertilisers or manure slurries spread on land. (High nitrite levels would indicate more recent pollution as nitrite is an intermediate stage in the ammonia-to-nitrate oxidation). In rivers high

levels of nitrate are more likely to indicate significant run-off from agricultural land than anything else and the parameter is not of primary importance per se. However, it should be noted that there is a general tendency for nitrate concentrations in rivers to increase as a result of enhanced nutrient run-off; this may ultimately lessen their utility as potential sources of public water supply. Nitrite concentrations in rivers are rarely more than 1 - 2 per cent of the nitrate level so that it may therefore be acceptable to carry out the

analytically convenient determination of nitrate + nitrite at the same time. This determination is correctly referred to as total oxidized nitrogen.

#### 2.6.18 Biochemical oxygen demand

Natural or introduced organic matter in water. No direct health implications, but an important indicator of overall water quality. When organic matter is discharged into a watercourse it serves as a food source for the bacteria present there. These will sooner or later commence the breakdown of this matter to less complex organic substances and ultimately to simple compounds such as carbon dioxide and water. If previously unpolluted, the receiving water will be saturated with dissolved oxygen (DO), or nearly so, and the bacteria present in the water will be aerobic types. Thus the bacterial breakdown of the organic matter added will be an aerobic process - the bacteria will multiply, degrading the waste and utilising the DO as they do so. If the quantity of waste present is sufficiently large, the rate of bacterial uptake of oxygen will outstrip that at which the DO is replenished from the atmosphere and from photosynthesis, and ultimately the receiving water will become anaerobic.

Bacterial degradation of the waste will continue but now the products will be offensive in nature - for example, hydrogen sulphide. Even if the uptake of oxygen is not sufficient to result in anaerobic conditions there will be other undesirable effects as the DO level falls, notably damage to fisheries and, ultimately, fish deaths. Where levels are around 50 per cent saturation for significant periods there may be adverse, though non-lethal, effects on game fish. Coarse fish will be likewise affected if levels are regularly around 30 per cent saturation.

Because of the potential danger to the oxygen levels in receiving waters from waste discharges considerable emphasis is placed in the laboratory on the estimation of the oxygen demand of wastes: i.e. the amount of oxygen which will be required in their breakdown. This is done chemically and biologically, by a variety of tests which are also employed to assess the actual effects of waste discharges on receiving water, as discussed below. As in most cases the oxygen demand of a waste on the DO level of a receiving water results from biological action, it follows that the most important analytical method should also depend on a biological process, to measure the Biochemical Oxygen Demand or (BOD). The principle of this test, which was devised some 85 years ago, is straightforward. The (five-day) BOD of a water is the amount of dissolved oxygen taken up by bacteria in degrading oxidisable matter in the sample, measured after 5 days incubation in the dark at 20°C. The BOD is simply the amount by which the DO level has dropped during the incubation period. This technique is the basis of BOD analyses for all types of sample even though considerable extensions of procedure are necessary in dealing with wastewaters and polluted surface waters.

The Eighth Report of the Royal Commission on Sewage Disposal (1912) contained a classification of river waters based on BOD levels which has been very widely quoted in the ensuing years. In some respects the classification was too precise in that it tried to distinguish between clean waters, very clean waters and so on. Current scientific opinion is that such a rigid approach is unjustified and that waters with a BOD falling within the range of 0 - 4 mg/l O<sub>2</sub> are of satisfactory quality for salmonid fish and thus for other beneficial uses. If an upper limit for BOD of 4 mg/l O<sub>2</sub> is adopted as a criterion of satisfactory quality then it is possible to assess the degree to which waters are polluted by reference to this datum. It is most important to remember, however, that a BOD figure for a receiving water

indicates the maximum extent to which the oxygen level may be depleted by the organic matter present. In reality, no appreciable deoxygenation may occur because of factors such as low temperatures, reaeration at weirs or shallows, dilution by tributaries and so on. Conversely, in some waters which do not have high BOD levels, but which are eutrophic, there may be severe night-time DO depletions caused by algal respiration. Notwithstanding the many often contradictory considerations which govern the interpretation of BOD data the analysis is one of the most important elements in river quality surveillance and it seems unlikely to be superseded for a long time yet. (Veeslind *et al* 2002)

Somewhat different considerations apply to the BOD analysis of effluents. BOD data are normally required for one of two purposes. Firstly, it is necessary to know the strength of a waste which is to be treated by biological means, as in an oxidation ditch or percolating filter. This is essential so that adequate treatment capacity may be provided for in the design of the plant. Secondly, where wastes are being discharged to receiving waters a knowledge of their strength and the magnitude of the river discharge will permit the dilution to be calculated and hence the maximum potential change in the river BOD at the boundary of the mixing zone. A factor which must be borne in mind in obtaining and in assessing BOD results is nitrification. This is the oxidation of ammonia to nitrate by suitable micro-organisms and if the process is occurring under test conditions high oxygen uptake values will be recorded. For normal river waters the onset of nitrification under BOD test conditions does not occur within the 5-day period of the analysis but in the case of waters or wastewaters containing nitrifying organisms this phenomenon will take place much more promptly. Unless suitable precautions are taken the result is an apparently very high BOD level which, if the analysis is being used to check the performance of a waste

treatment works (with respect to the removal of organic matter), for example, may lead to serious errors in the interpretation and use of the data.

The recommendations of the Royal Commission referred to above also dealt with the quality of sewage effluents and they included the so-called "20/30" effluent standard (i.e. an effluent of BOD value 20 mg/l O<sub>2</sub> and suspended solids 30 mg/l) which has been widely used and misused since. It is often forgotten that the standards were based on the premise that in no case would the BOD value of the river receiving the discharge be increased to more than 4 mg/l O<sub>2</sub>. The "20/30" standard was suggested as one which would, even in cases of limited available dilution, ensure that the resultant river BOD would be less than 4 mg/l O<sub>2</sub>. It was in no way advocated as the ultimate goal of all treatment processes, the thinking being that it was more important to specify a limit for the river after receiving a discharge than to fix general effluent standards.

#### 2.6.19 Dissolved oxygen

The importance of (DO) has already been touched upon in the discussion of BOD. The prime requirements for DO arise in connection with fishlife and it is generally true that if water quality is suitable for fish it will also meet the criteria for most if not all other beneficial uses and be of good ecological status, as required by the Water Framework Directive. The cardinal point about the solubility of oxygen in water is that it has an inverse relationship with temperature, as shown in Table 2.6. The consequence is that the actual concentrations of DO in a river will be lowest in summertime when it is usually the case that the risk of damage to a water supply source or of environmental pollution is greatest, especially in areas developed as tourist centres or where such farming operations as silage-making are carried on.

Table 2.6 Solubility Of Oxygen In Water In Contactwith Water-Saturated Air At 760 Mm Hg Oxygen Concentrations In Mg/Litre Corresponding To 100% Saturation (EPA 2001)

Temp	DO	Temp	DO	Temp	DO	Temp	DO	Temp	DO
°C	mg/l	°C	mg/l	°C	mg/l	°C	mg/l	°C	mg/l
0	14.6	5	12.8	10	11.3	15	10.2	20	9.2
1	14.2	6	12.5	11	11.1	16	10.0	21	9.0
2	13.8	7	12.2	12	10.8	17	9.7	22	8.8
3	13.5	8	11.9	13	10.6	18	9.5	23	8.7
4	13.1	9	11.6	14	10.4	19	9.4	24	8.5

The saturation concentration of 9.2 mg/l O<sub>2</sub>at 20°C (around the normal Irish summertemperature) is not a large quantity and, although it is fully adequate to support the fauna andflora of an unpolluted river, it will be depleted very rapidly (even after allowing for naturalre-aeration over weirs, rocks and so on) by the bacterial degradation of even a small amount oforganic matter.

Because such biological activity takes place in receiving waters it is essential that DO levelsare measuredin situ by instrumental means, or at least that chemical reagents are added at onceto the samples to "fix" the DO for a reliable subsequent laboratory analysis. Delayed DO valuesobtained from analysis of unfixed samples are meaningless and are potentially grossly misleading.As indicated above (under "Oxygen Demand, Biochemical"), salmonid fish will begin to be affectedas DO levels drop to around 50 per cent saturation; cyprinid fish are likewise affected at levels inthe vicinity of 30 per cent. In many instances

of fish kills the mortality is directly due to asphyxiation as the DO levels fall massively because of organic pollution. Should levels around zero persist then anaerobic (or septic) conditions will set in and any remaining organic matter will undergo anaerobic decomposition to yield products such as methane and ammonia. Coupled with this will be the reduction of sulphates present to sulphide and the consequent emission of offensive odours. Restoration of aerobic conditions will cure the last mentioned problem.

The effects of eutrophication are closely related to the DO regime in both rivers and lakes. Where there are dense growths of phytoplankton, photosynthesis will take place during the extended daylight periods of summertime, resulting in the production of oxygen which may lead to water DO levels far in excess of 100 per cent saturation. An excess of DO is not a problem in itself but it indicates that the daytime conditions may be mirrored by an equally large undersaturation of oxygen at night-time when photosynthesis ceases and plant respiration supervenes with the consumption of oxygen. The DO concentrations may, therefore, follow something like a "sine wave" pattern with the troughs occurring in the early hours of the morning, just before dawn. Where the amplitude of this "sine wave" is great the DO minimum may be such as to cause fish kills. It should be remembered that the magnitude of this so-called diurnal variation will be greatest where there are both eutrophication and organic pollution effects. But while a high day-time DO may not (in the absence of organic pollution) be matched by a critically low night-time level it is indicative nonetheless of less than satisfactory conditions.

#### 2.6.20 pH

Physical characteristic of all waters/solutions. None - except that extreme values will show excessive acidity/alkalinity, with organoleptic consequences. By definition pH is the

negative logarithm of the hydrogen ion concentration of a solution and it is thus a measure of whether the liquid is acid or alkaline. The pH scale (derived from the ionisation constant of water) ranges from 0 (very acid) to 14 (very alkaline). The range of natural pH in fresh waters extends from around 4.5, for acid, peaty upland waters, to over 10.0 in waters where there is intense photosynthetic activity by algae. However, the most frequently encountered range is 6.5-8.0.

In waters with low dissolved solids, which consequently have a low buffering capacity (i.e. low internal resistance to pH change), changes in pH induced by external causes may be quite dramatic. Extremes of pH can affect the palatability of a water but the corrosive effect on distribution systems is a more urgent problem. The effect of pH on fish is also an important consideration and values which depart increasingly from the normally found levels will have a more and more marked effect on fish, leading ultimately to mortality. The range of pH suitable for fisheries is considered to be 5.0-9.0, though 6.5-8.5 is preferable

#### 2.6.21 Phosphates

Phosphorus occurs widely in nature in plants, in micro-organisms, in animal wastes and so on. It is widely used as an agricultural fertiliser and as a major constituent of detergents, particularly those for domestic use. Run-off and sewage discharges are thus important contributors of phosphorus to surface waters. The significance of phosphorus is principally in regard to the phenomenon of eutrophication (over-enrichment) of lakes and, to a lesser extent, rivers.

Phosphorus gaining access to such water bodies, along with nitrogen as nitrate, promotes the growth of algae and other plants leading to blooms, littoral slimes, diurnal dissolved oxygen variations of great magnitude and related problems.

There is considerable debate as to the availability of the various forms of phosphorus (orthophosphate, polyphosphate, organic phosphate and so on) for the growth of algae although it is considered that orthophosphate is the most readily used form. Phosphorus may be in true solution, in colloidal suspension or adsorbed onto particulate matter, and it is very difficult to differentiate between the various fractions by separation (e.g. filtration) or analysis. A useful parameter is orthophosphate (strictly, total filtrable and non-filtrable orthophosphate) which is the phosphate responding to the analytical procedure without any pre-treatment such as hydrolysis or oxidative digestion. Caution must be exercised in considering the results of phosphorus analysis as the element exists in bound and unbound forms which are very difficult to separate totally in analysis. There is always the likelihood, for example, of some of the bound polyphosphate forms being changed by hydrolysis to orthophosphate under the actual analytical conditions. However, the determination of orthophosphate as specified is of great use in highlighting the presence of one of the most important nutrients and the results are of special interest in waters receiving sewage discharges.

The importance of controlling phosphorus levels in the Irish aquatic environment is highlighted by the publication (in May 1997) by the Minister for the Environment and Local Government of a 10-year strategy paper entitled *Managing Ireland's Rivers and Lakes – A Catchment-Based Strategy Against Eutrophication*. This document deals with the topic of phosphorus levels (expressed as mg/l median Molybdate-Reactive Phosphate [MRP]) and it sets out interim statutory standards, in terms of MRP, for the year 2007 for water in several quality classes, rivers and lakes being treated separately.

#### 2.6.22 Total dissolved solids

Natural or added solutes present in a water. Principally organoleptic implications. The parameter is determined as for total solids except that the sample is filtered through a defined medium (membrane or glass fibre paper; cf. "Solids, Suspended") beforehand. The term Total Filtrable Solids is also used. It is often convenient and acceptable to use the very rapid determination of conductivity (q.v.) to give an estimation of the total dissolved solids.

#### 2.6.23 Sulphate

Rocks, geological formations, discharges and so on. Excess sulphate has a laxative effect, especially in combination with magnesium and/or sodium. Sulphates exist in nearly all natural waters, the concentrations varying according to the nature of the terrain through which they flow. They are often derived from the sulphides of heavy metals (iron, nickel, copper and lead). Iron sulphides are present in sedimentary rocks from which they can be oxidised to sulphate in humid climates; the latter may then leach into watercourses so that ground waters are often excessively high in sulphates. As magnesium and sodium are present in many waters their combination with sulphate will have an enhanced laxative effect of greater or lesser magnitude depending on concentration. The utility of a water for domestic purposes will therefore be severely limited by high sulphate concentrations, hence the limit of 250 mg/l  $\text{SO}_4$ .

#### 2.6.24 Temperature

Generally it is the climatologically influenced (in the absence of thermal discharges). The natural variation in temperature found in Irish surface waters is of the order of 25°C - from freezing point to a summer maximum of around 25°C occasionally. Thermal pollution

would, of course, alter the position, possibly very significantly. The effect of temperature, and especially changes in temperature, on living organisms can be critical and the subject is a very wide and complex one. Where biochemical reactions are concerned, as in the uptake of oxygen by bacteria, a rise of 10°C in temperature leads to an approximate doubling of the rate of reaction. Conversely, such reactions are retarded by cooling, hence the recommendation often made that waters be cooled to 4°C in the interval between sampling and analysis.

Another most important factor is that some key constituents of a water either change their form (as in the ionisation of ammonia) or alter their concentration (as with dissolved oxygen) when temperature changes. In fact, the primary interest in the temperature of surface waters is due to the inverse relationship between it and oxygen solubility (See "Table 2.6"). However, elevated temperatures and, more importantly, steep temperature gradients can have directly harmful effects on fish. It is for the latter reason that changes in temperature are subject to limits.

#### 2.6.25 Zinc

These exist as a result of natural geological occurrence and from wastes. Inhalation of zinc-containing fumes can cause a variety of physiological effects, but the principal significance of excessive amounts in water is that emetic effects occur. Zinc is essential to man but if ingested in gross amounts it has an emetic effect. However, the concern in water supply arises in regard to taste not toxicity, and quite high levels are permissible. In fishery water, in contrast, the toxic action is much more important and very much lower limits have been imposed.

## CHAPTER THREE

### MATERIALS, EQUIPMENT AND METHODS

#### 3.1 Apparatus and Equipment

This chapter presents the list of equipment and materials that were used in the course of this research and also the methodology. Table 3.1 shows lists of materials and equipment used, all the equipment were accessed at KEPA.

Table 3.1 Equipment/Apparatus used in the research

S/NO	APPARATUS/EQUIPMENT	MODEL/TYPE	SOURCE
1	TDS meter	Portable Pen 110v-250v	KEPA, Kaduna
2	pH/mV/Temp meter	Extech 407228	KEPA, Kaduna
3	Oxygen Meter	Extech 407510 7x3x1.3inc	KEPA, Kaduna
4	Portable data logging	RDXL 120S 30V 50/60Hz	KEPA, Kaduna
5	Spectrometer	560 Suntex	KEPA, Kaduna
6	Colony Counter	SC6+ 70W 50/60Hz	KEPA, Kaduna
7	Atomic Absorption Spectrometer	1251-DFDMRXM 1000V	KEPA, Kaduna
8	Weighing Balance	OHAUS USA/Scout(330g)	KEPA, Kaduna
9	Heavy duty Blender	Vitamix 5300s 1000v 50Hz	KEPA, Kaduna
10	Oven	Hot-Air, Temp range 50-100	KEPA, Kaduna
11	Glass wares/	500ml, 250ml, 1L, etc TLS	KEPA, Kaduna
12	Measuring Cylinder	Pula, yugoslavia Pyrex	KEPA, Kaduna
		250mL, 25mL, TLS Pula, Yugoslavia.(Pyrex)	KEPA, Kaduna

### 3.2 Site Location and Description

The dumpsite is located at a Latitude of 10.5125° and Longitude of 7.4111° ,Tudun Wada, Kaduna South Local Government Area of Kaduna State.The dumpsite is surrounded by residential houses as shown in Plate 1 and 2.



Plate 1. Satellite image of kaduna town with tudunwada settlement as an insert.



Plate 2.Satellite Image of Tudun Wada with point of sample collection.

### 3.3 Stakeholders Meeting

This was carried out at the ward’s head office in the presence of the ward head, the representative of KEPA, the environmental health workers and members of the resident within the area. A lot of issues were discussed with regards to the impact of dumpsite on the quality of soil and groundwater on how it affects the environmental health and permission was granted to access the water samples in their houses by the resident.

### 3.4 Samples Collection

The soil samples for this research work were collected from the dumpsite to a distance of 689m, at a depth of 0-15cm and 15-30cm, the two samples were mixed, a total of eight soil and groundwater samples were collected, the groundwater samples were collected from various wells using a grid method of sampling, all these samples were collected in the month of March during the dry season.

Table 3.2 Soil and groundwater samples distribution from dumpsite

SAMPLES	Distance from dumpsite (m)
A1	15.24
A2	30.48
A3	45.72
A4	76.20
A5	228.60
A6	243.84
A7	304.80
A8	457.20

### 3.5 Samples Preparation

The soil samples collected from eight points using a euger from the dumpsite were transferred into polythene bags, after which they were transported to the laboratory for analysis. Soil samples were then spread in a petri dish and dried in an oven at 105°C for 4 hours. The dried soil samples were then ground and passed through an aluminum sieve with 2mm mesh. Soil samples < 2mm were stored in polythene bags prior to analysis.

Water samples were collected from 8 hand dug wells; The 8 samples were collected from the dumpsite at different proximities (between 13 and 689 meters) to the dumpsite using the grid sampling method. All the wells were functional, active, located away from toilets, have not undergone any chemical treatment and were continuously used for drinking and domestic purposes. Samples were obtained using same material normally used by the households to draw water from the wells. Water samples were collected in 1L plastic bottles and stored in the refrigerator prior to analysis using the standard procedure (APHA, 2005).

### **3.6 Analysis of Soil Samples**

Digestion of soil samples were done using aqua regia and heavy metal contents of each digest were determined by an Atomic Absorption Spectrometer (Perkin-Elmer Analyst 200). pH values of the soil samples were determined in  $\text{CaCl}_2$  solutions using a Mettler Toledo Seven Easy pH Meter. Total Organic Carbon of the soil samples were determined by the Walkley-Black Titrimetric Method.

### **3.7 Analysis of Water Samples**

The physical, chemical and bacteriological parameters were determined in each water sample. The pH of the samples were determined electrometrically using a Mettler Toledo Seven Easy pH Meter. Electrical Conductivity (EC) were determined using a conductivity meter. Total solids (TS), Total Dissolved Solids (TDS) and Total Suspended Solids (TSS) were determined gravimetrically. The Acidity, Alkalinity, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD) was determined by titrimetric method. Nitrates, Phosphates and Sulphates were determined by UV spectrophotometry (APHA, 2005).

Toxicmetals concentrations were determined by acid digestion using nitric acid and further analysed with Perkin Elmer A Analyst 200 Flame Atomic Absorption Spectrometer. Total Coliform (TC) counts were determined using membrane filter method. Total heterotrophic plate count (HPC) were determined by plating out 0.1ml of  $10^{-1}$  and  $10^{-2}$  dilutions series of water sample on nutrient agar plate for total heterotrophic bacteria and on potato dextrose agar plate for total heterotrophic fungi respectively. For bacteria analysis, two replicates were made and incubated aerobically at  $37^{\circ}\text{C} \pm 2^{\circ}\text{C}$  for 24 - 48hrs, for fungi analysis, two replicates were incubated aerobically at  $22^{\circ}\text{C} - 28^{\circ}\text{C}$  for 5 - 7 days. At the end of incubation, the colonies that developed were screened, counted and identified based on their morphological and biochemical properties (APHA, 2005).

## CHAPTER FOUR

### RESULTS AND DISCUSSION

#### 4.1 Water Analysis

##### 4.1.1 pH value of the water samples

Figure 4.1 Shows the variation of pH values along the distance of the water samples from the dumpsite. The pH values are within a range of 6.89 to 7.53 with a slight jump in sample A2 which could be as a result of the nature of the geological formation of the soil at that location.

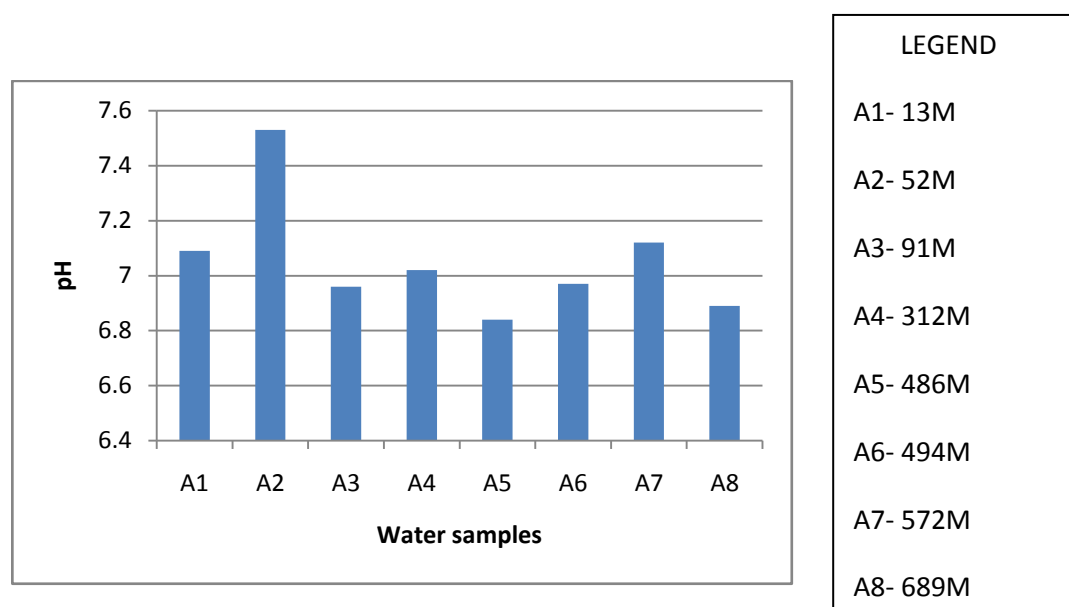


Figure 4.1 pH Variation with distance of the water samples from the dumpsite

##### 4.1.2 Conductivity analysis of the water samples

The conductivities of the water samples are presented in Fig 4.2. The conductivity indicates the amount of concentrated (ionisable) solute in a solvent, and from the values of conductivity of the water samples it shows that there is a trend from sample A1 to sample A8 indicating a decrease in conductivity which could be due to the leachate from the dumpsite which was richer in metals ions in the sample close to the dumpsite than those far from it as it is shown in Figure 4.2

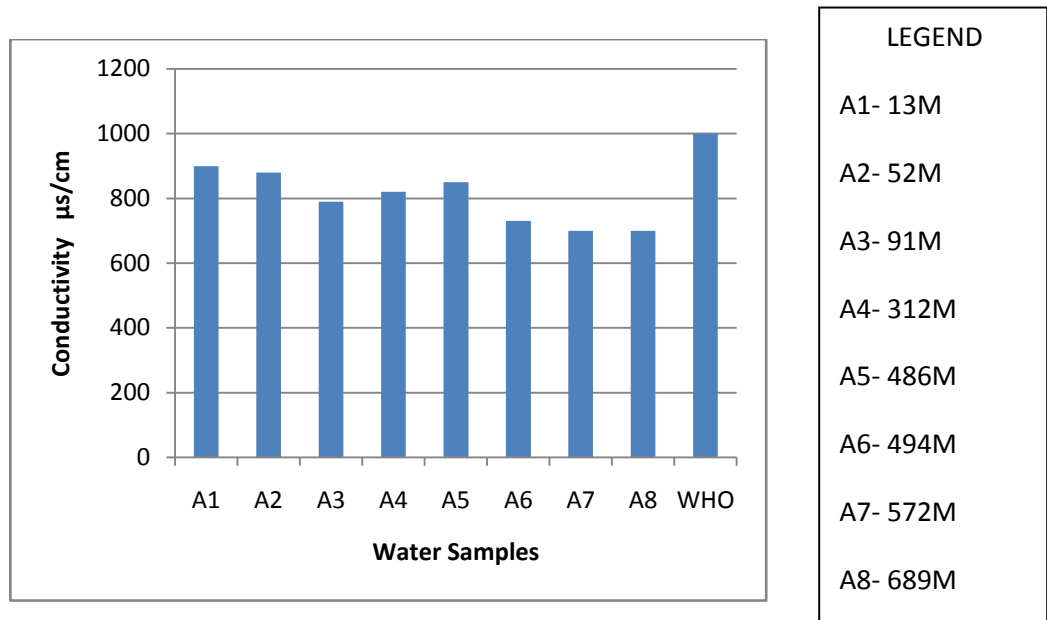


Figure 4.2 Conductivity variation with distance of the water samples from the dumpsite

#### 4.1.3 Dissolved oxygen analysis of the water samples

The Dissolved Oxygen is the indication of the amount of oxygen consumed by microorganism in the water, Figure 4.3 shows an increasing in dissolved oxygen from sample A1 to sample A8 indicating that sample A1 has a lower value of DO compared to the other sample meaning it contains more microorganism than the other samples.

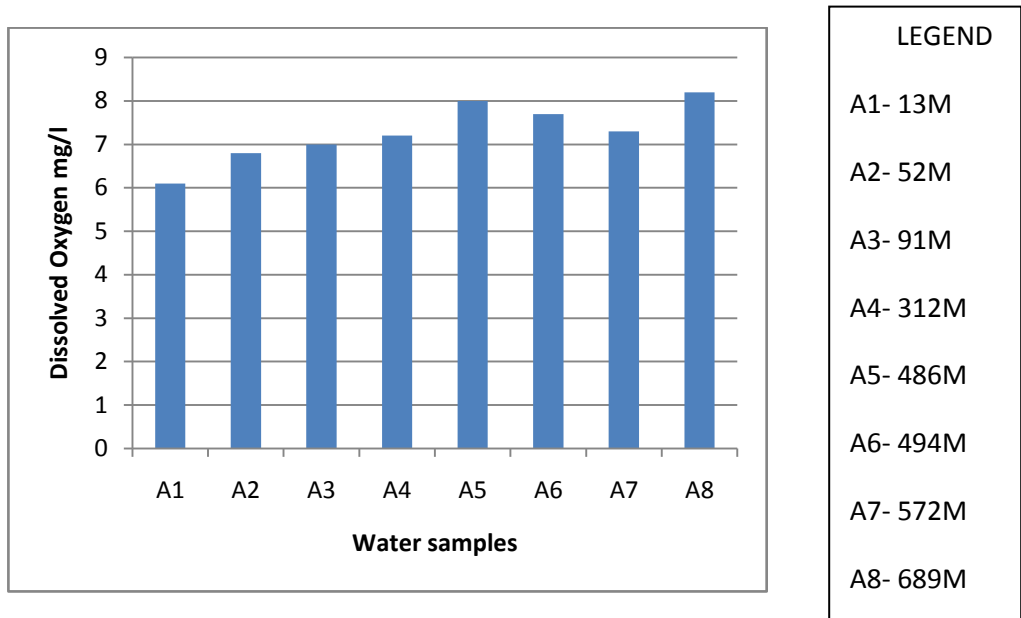


Figure 4.3 Dissolved Oxygen variation with distance of the water samples from the dumpsite

#### 4.1.4 Total dissolved solid analysis in water samples

The total dissolved solid is a parameter that indicates the amount of dissolved solid in a water. Figure 4.4 shows the total dissolved solid values for sample A1 to sample A8 with a decreasing trend from 400mg/l to 240mg/l indicating that the samples close to the dumpsite have higher values of TDS than the samples far from the dumpsite but all the samples are within the permissible limit of WHO.

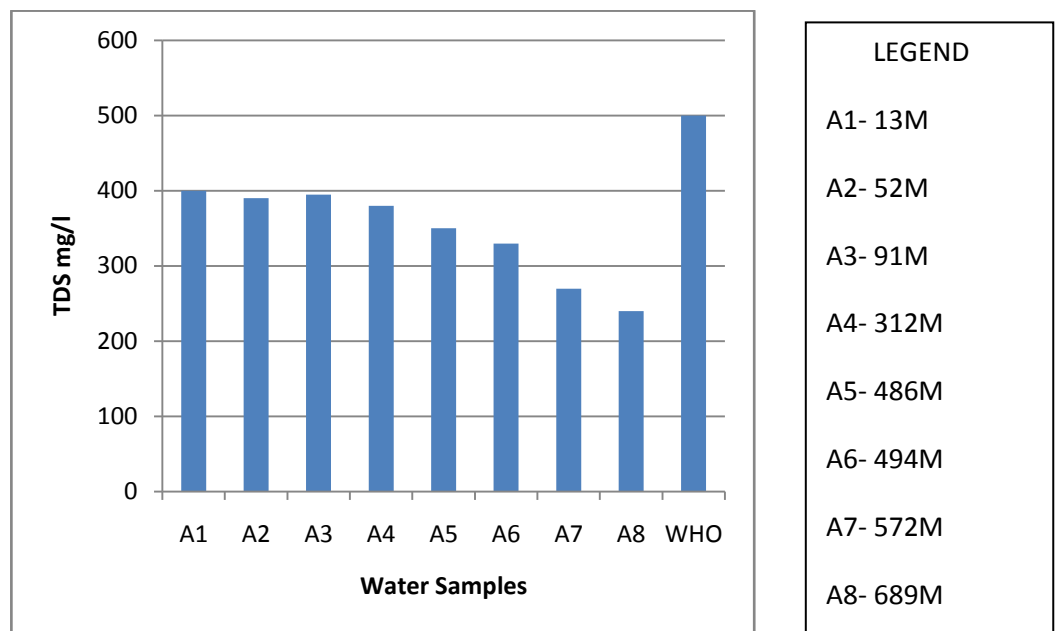


Figure 4.4 TDS variation with distance of the water samples from the dumpsite

#### 4.1.5 Total Alkalinity analysis in water samples

The total alkalinity indicates the basicity of a water and this is based on two bicarbonates of Mg and Ca. Figure 4.5 shows that, Total Alkalinity values has no any particular order, which could be due to the nature of the geological formation of the location having a high value of one of the bicarbonates.

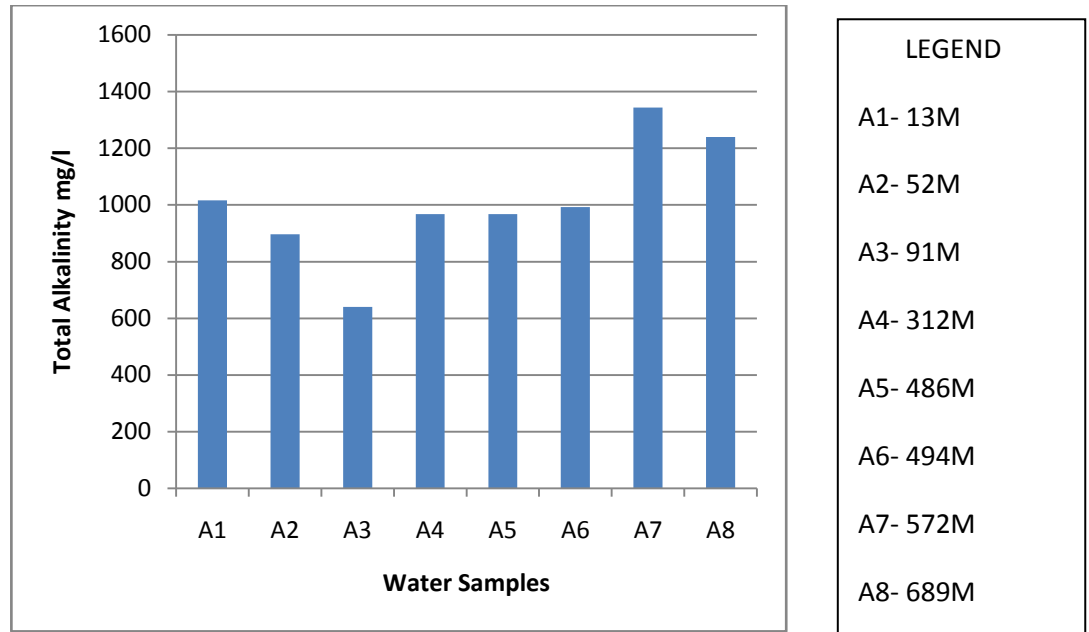


Figure 4.5.Total Alkalinity variation with distance of the water samples from the dumpsite

#### 4.1.6 BOD analysis in water samples

The biological oxygen demand is an indicator of the amount of oxygen needed by the microorganism and it was obtained after it had been cultured for five days.Italso indicated the presence of microorganisms in the water. Figure 4.6 shows the BOD values ranging from 4.5mg/l to 3mg/l indicating that the samples close to the dumpsite havehigher values of BOD than the samples close to the dumpsite which gives a slightly decreasing from sample A1 to sample A8, all the samples are within the permissible limit of the WHO.

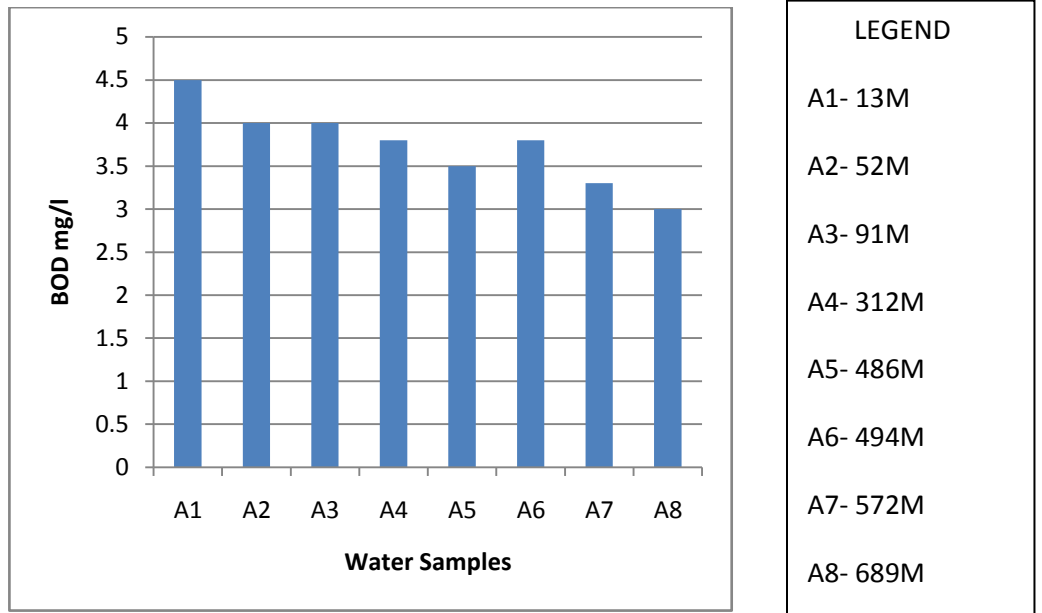


Figure 4.6 BOD variation with distance of the water samples from the dumpsite

#### 4.1.7 Sulphate analysis in water samples

Figure 4.7 shows the variation of sulphate with the water samples which ranges from 17mg/l to 45mg/l with no particular trend; This could be as a result of the nature of the geological formations of the locations and all the samples values are within the permissible limit of the WHO which is 100mg/l.

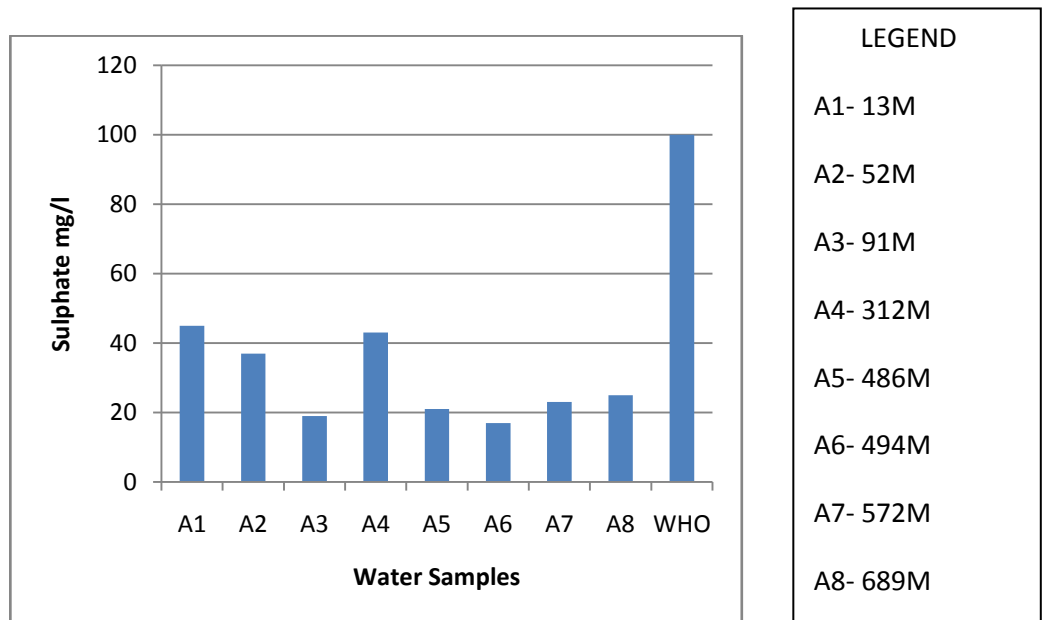


Figure 4.7 Sulphate variation with distance of the water samples from the dumpsite

#### 4.1.8 Total hardness analysis in water samples

The total hardness of water indicates the presence of soluble limestone in water and this is as a result of the presence of concentration of calcium and magnesium expressed in mg/l of  $\text{CaCO}_3$ . In Figure 4.8 there is no trend rather the values of the parameter ranges from 90mg/l to 120mg/l in a fluctuating manner, which could be as result of the geological formations of the locations and all the values are within the permissible limit of the WHO, which is 150mg/l.

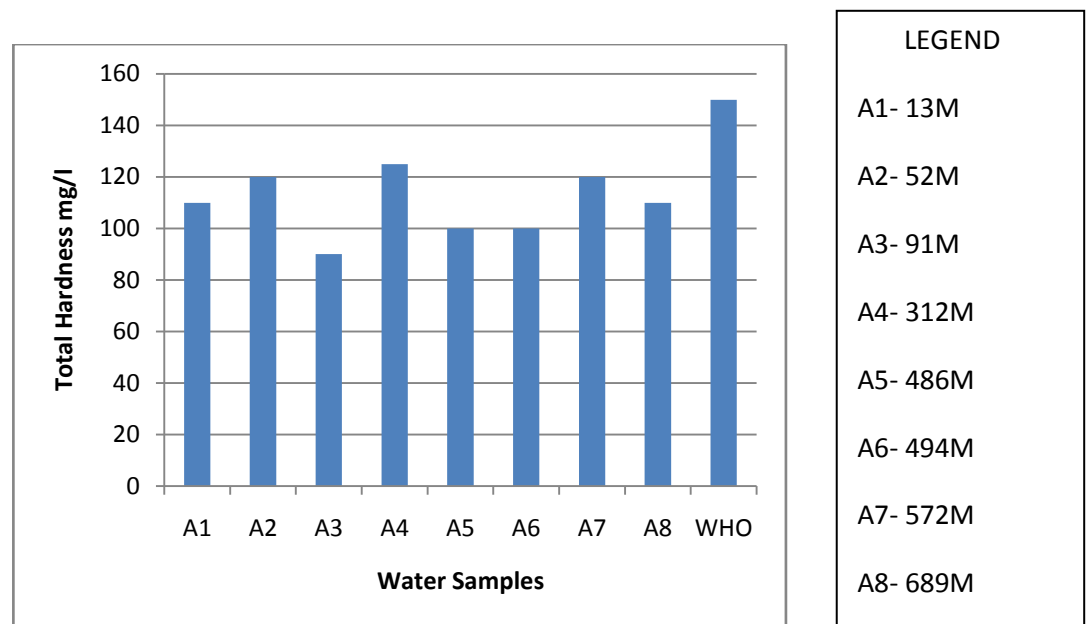


Figure 4.8 Total Hardness variation with distance of the water samples from the dumpsite

#### 4.1.9 Phosphate analysis in water samples

Figure 4.9 Show the variation of phosphate with the values ranging from 0.07mg/l to 0.49mg/l, which decreases from sample A1 to sample A3 from there the values are fluctuating. The initial decrease could be as a result of the impact of the dumpsite while the sudden increase could be due to the geological formation of the locations.

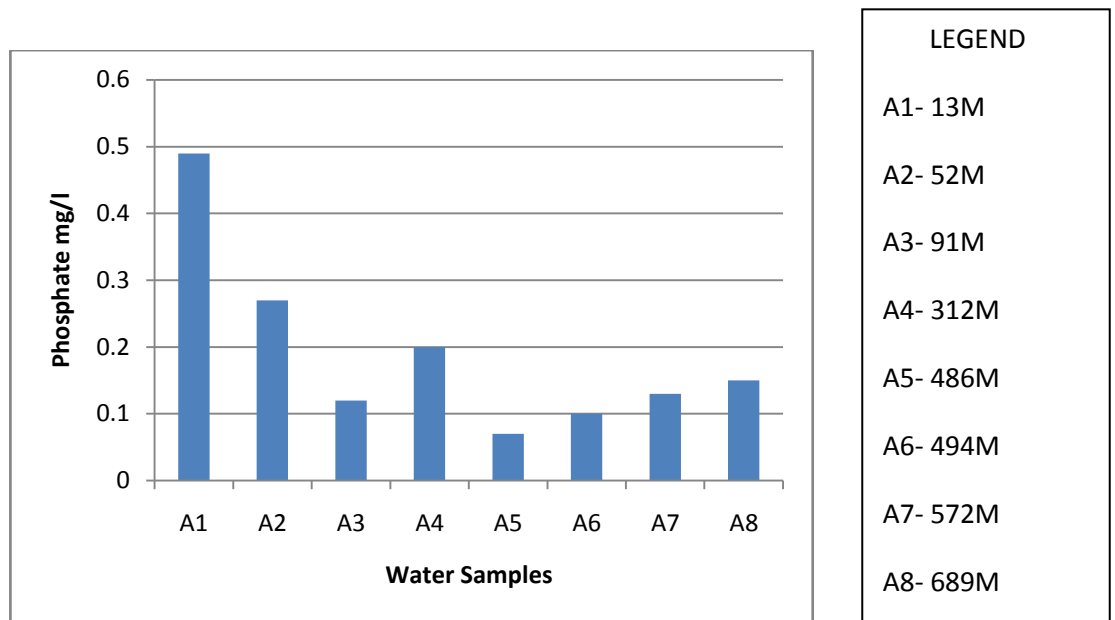


Figure 4.9 Phosphate variation with distance of the water samples from the dumpsite

#### 4.1.10 Nitrate analysis in water samples

Figure 4.10 shows how nitrate values range from 18 mg/l to 28 mg/l, with a trend decreasing from sample A1 close to the dumpsite which indicates the impact of the dumpsite on the value of the nitrate before it starts fluctuating, which could be due to the cumulative impact of the dumpsite and the geological formation of the locations.

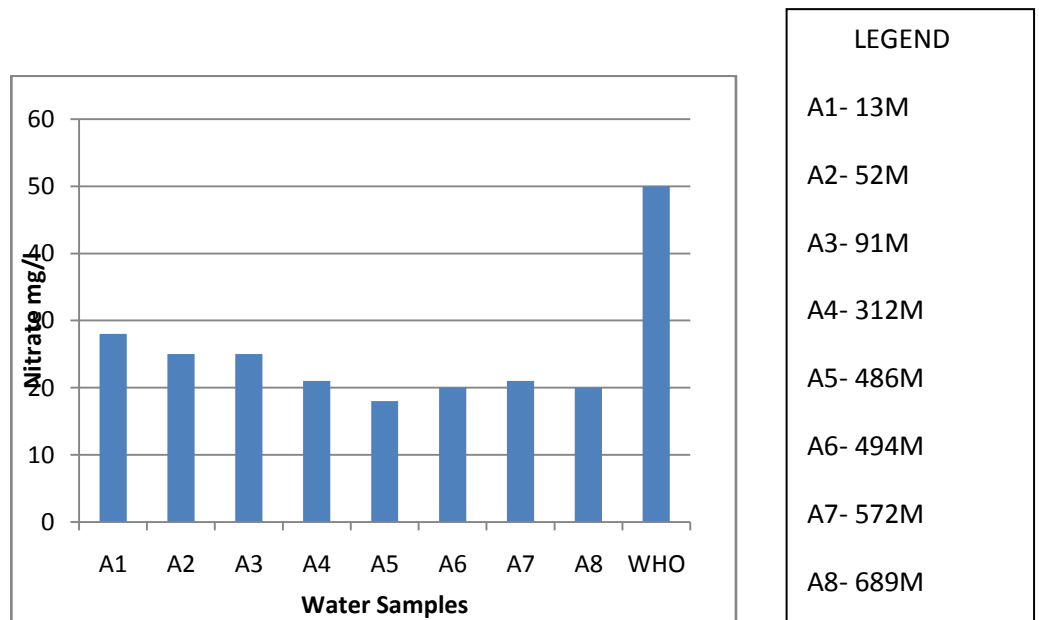


Figure 4.10 Nitrate variation with distance of the water samples from the dumpsite

#### 4.1.11 Cadmium analysis in water samples

The variation of Cadmium with water samples shows that only traces of the parameter in the samples were detected which ranges from 0.001mg/l to 0.0017mg/l; This is because the dumpsite is mainly made up domestic wastes as cadmium are mostly associated with the industrial waste, hence it was found in traces and all the values are within the permissible limit of the WHO which is 0.003 mg/l as shown in Figure 4.11

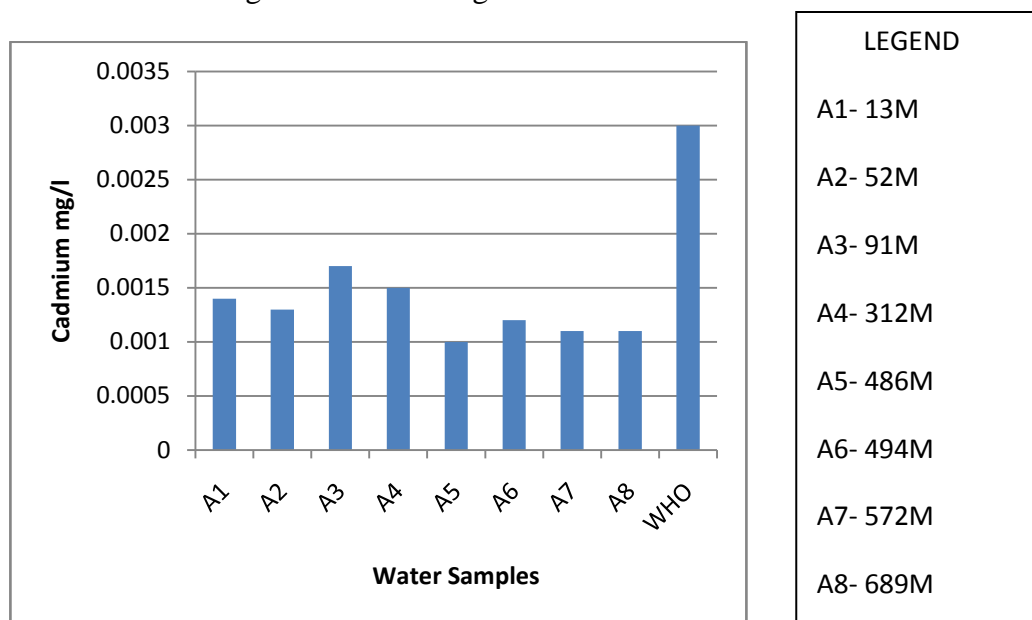
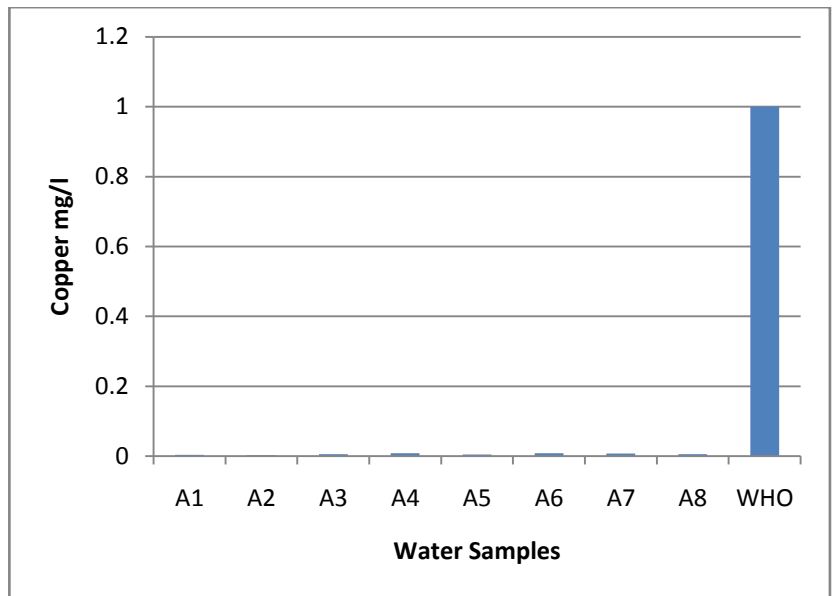


Figure 4.11 Cadmium variation with distance of the water samples from the dumpsite

#### 4.1.12 Copper analysis in water samples

The copper variation with water samples distance from the dumpsite shows that only traces of copper are detected from the samples and it ranges from 0.0027mg/l to 0.0081mg/l. This shows that the dumpsite is made of up domestic waste not industrial waste as shown in Figure 4.11.

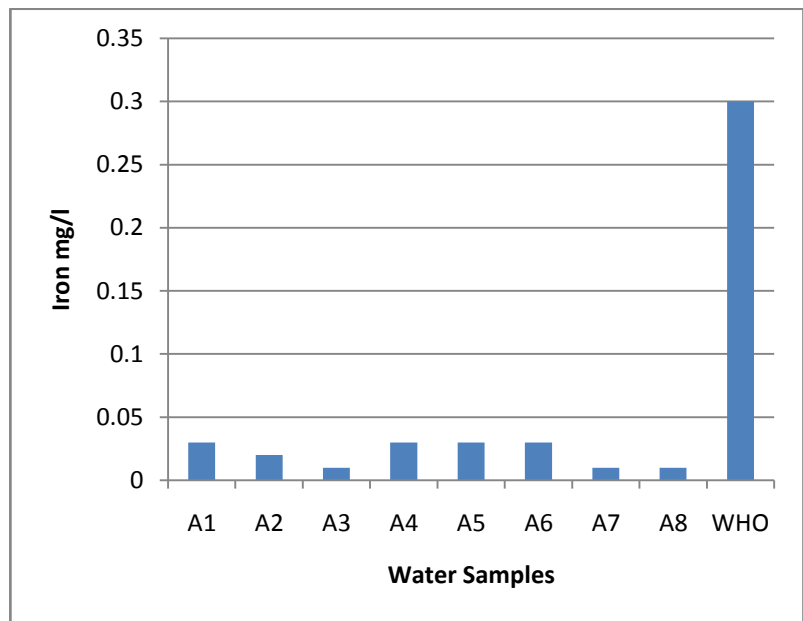


LEGEND	
A1-	13M
A2-	52M
A3-	91M
A4-	312M
A5-	486M
A6-	494M
A7-	572M
A8-	689M

Figure 4.12Copper variation with distance of the water samples from the dumpsite

#### 4.1.13 Iron analysis in water samples

The Iron variation with water samples indicates the values of the parameter ranging from 0.01mg/l to 0.03mg/l, with no particular order or trend, this could be as a result of the dumpsite as its mainly comprised of a domestic waste. And the values are within the permissible limit of the WHO, as can be seen in Figure 4.13



LEGEND	
A1-	13M
A2-	52M
A3-	91M
A4-	312M
A5-	486M
A6-	494M
A7-	572M
A8-	689M

Figure 4.13.Iron variation with distance of the water samples from the dumpsite

#### 4.1.14 Chromium analysis in water samples

The chromium variation with the water samples indicates the chromium values in all the parameter in all the water samples, which contain a very small amount of it ranging from 0.001mg/l to 0.0032mg/l. The small value of the parameter is because the dumpsite is mainly made up of domestic waste and all the values are within the permissible limit of the WHO, which is 0.05mg/l as shown in Figure 4.14

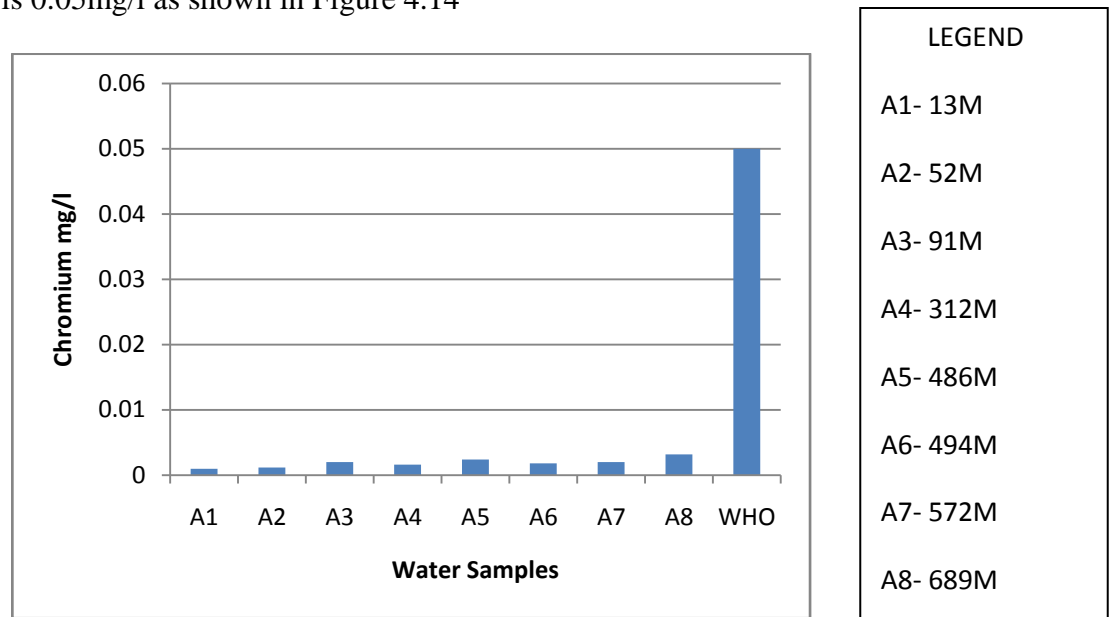


Figure 4.14 Chromium variation with distance of the water samples from the dumpsite

#### 4.1.15 Zinc analysis in water samples

Figure 4.15 shows the zinc variation with water samples which ranges from 0.09mg/l to 2.8mg/l with a decreasing trend from sample A1 to sample A8, the high value of the parameter in sample A1, which is close to the waste is as a result of the impact of the dumpsite while the samples far from the dumpsite has a lesser impact as this can be seen in Figure 4.15

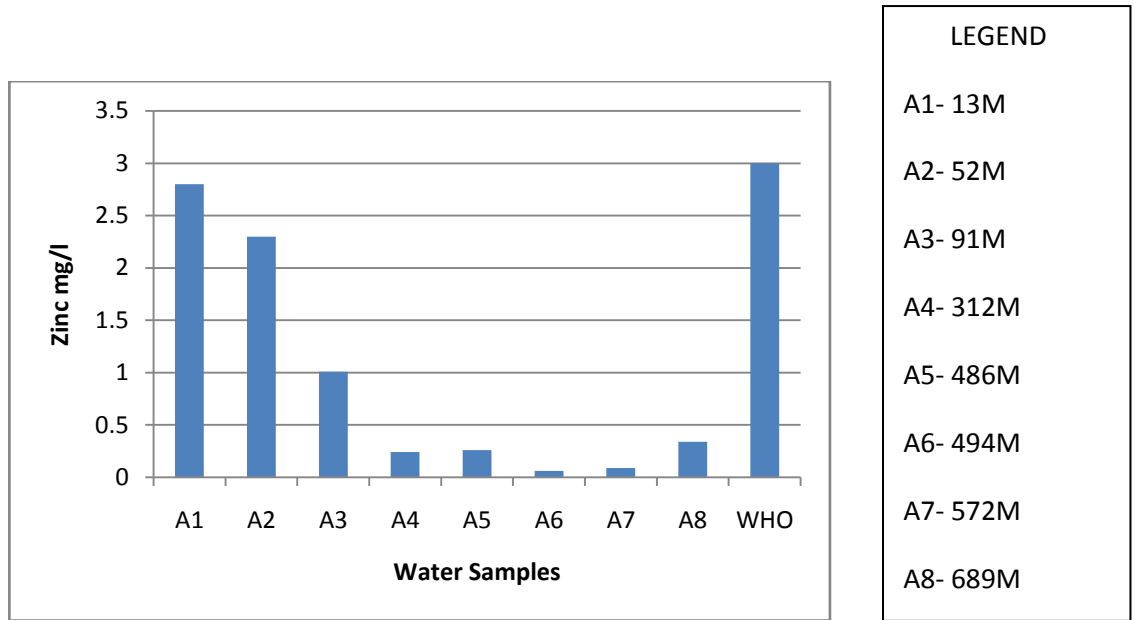


Figure 4.15 Zinc variation with distance of the water samples from the dumpsite

#### 4.1.16 Lead analysis in water samples

The lead variation with the water samples indicates value of the parameter in the samples, there is no any trend from Figure 4.16 which shows much variation in the samples; The values of the parameter ranges from 0.0021mg/l to 0.003mg/l. These lead traces could be as a result of the geological formations of the locations as the dumpsite mainly contains domestic waste, all the values are within the permissible limit of the WHO which is 0.01mg/l.

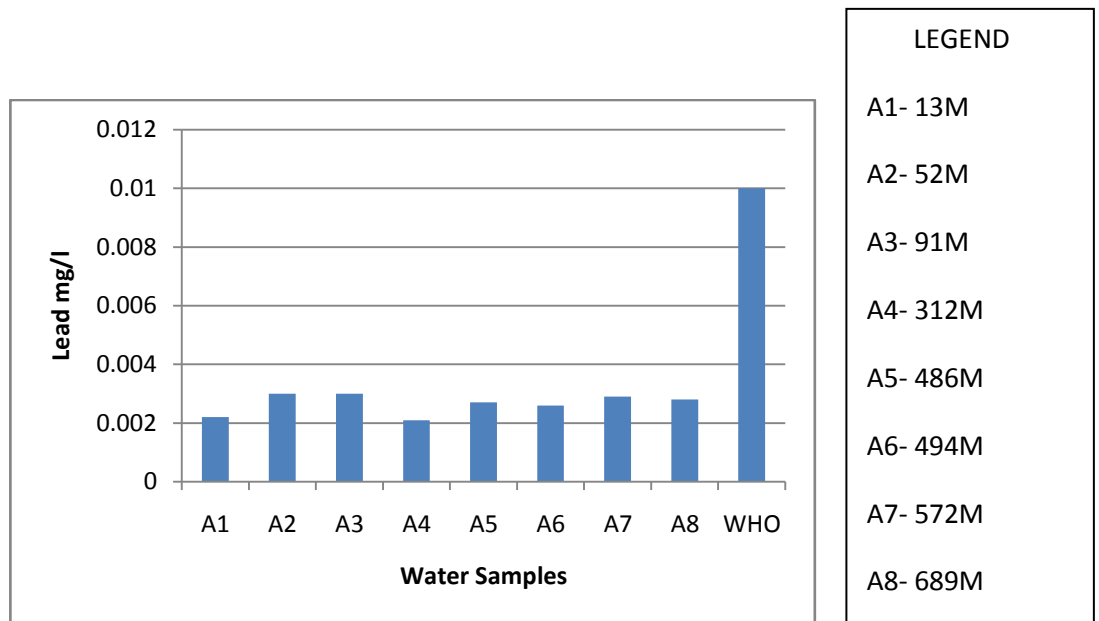


Figure 4.16 Lead variation with distance of the water samples from the dumpsite

#### 4.1.17 Total coliform analysis in water samples

The presence of pathogens is normally indicated by the total colony which shows the presence of microorganism, Figure 4.17 shows the total coliform variation with the water samples where the total colony value ranges from 15ctu/ml to 100ctu/ml with a decreasing trend from sample A1, a point close to the dumpsite, to sample A8 which is far away from the dumpsite indicating a significant impact of the dumpsite on the total coliforms and all the values are above the permissible limit by WHO.

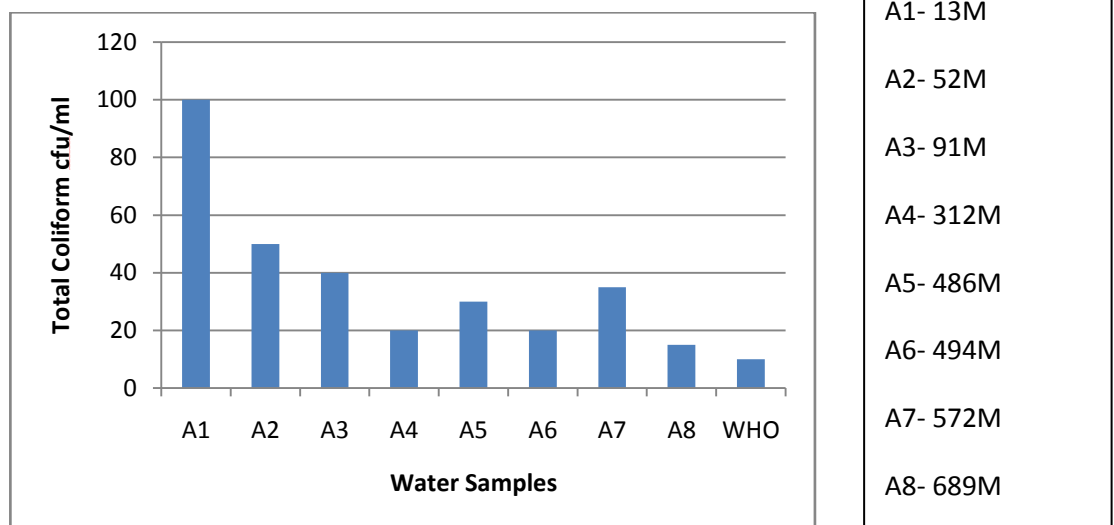


Figure 4.17 Total Coliform variation with distance of the water samples from the dumpsite

#### 4.1.18 HPC analysis in water samples

Heterotrophs are a group of microorganisms (bacteria, moulds and yeasts) that use organic carbon sources to grow and can be found in all types of water. In fact, the majority of bacteria found in drinking water systems are considered heterotrophs. Heterotrophic plate count (HPC) is a method that measures heterotrophic bacteria. At a point (distances) close to the dumpsite the coliform counts were relatively higher than the point far from the dumpsite with low values, with samples A1 to A3 having values higher than the WHO permissible limit and samples A4 to A8 lower than the WHO permissible limit, as shown in Figure 4.18

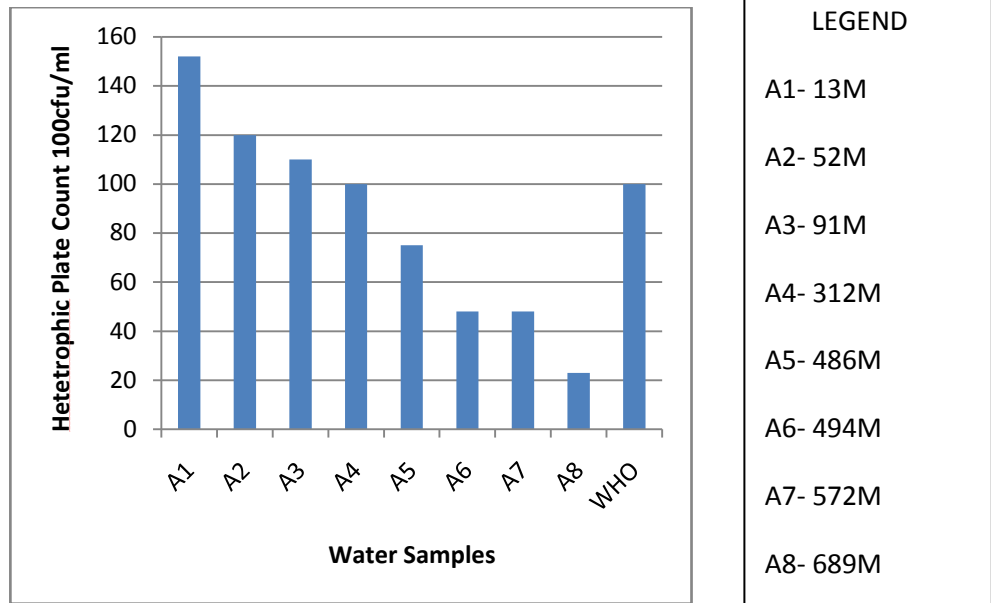


Figure 4.18. HPC variation with distance of the water samples from the dumpsite

This is a strong indication that wells located within 150 m away from the dumpsite are susceptible to microbial (pathogens) contamination. The natural filtration capacity of the surrounding soil to remediate leachates from dumpsite is only effective after a distance of >150m.

## 4.2 Soil analysis

Table 4.1: Physiochemical properties of the soil samples

PARAMETERS	A1	A2	A3	A4	A5	A6	A7	A8
pH	7.45	7.48	7.38	7.48	7.56	7.53	7.62	7.38
Bulk density g/ml	1.25	0.76	1.04	1.35	1.35	1.15	1.1	1.23
Copper ppm	0.0055	0.0048	0.0052	0.0031	0.0051	0.0048	0.0026	0.0025
Lead ppm	0.0301	0.0221	0.0212	0.0155	0.0266	0.0144	0.0151	0.0066
Cadmium ppm	0.0041	0.0021	0.0031	0.002	0.0039	0.0032	0.001	0.0001
Chromium ppm	0.0018	0.0021	0.002	0.0019	0.0019	0.0023	0.002	0.0021
Zinc ppm	3.61	2.3	3.3	2.21	2.5	3.1	3	2.76
Iron ppm	0.06	0.03	0.02	0.02	0.03	0.01	0.015	0.015
Organic Content%	4.9	4.5	4.8	3.13	2.5	1.77	1.75	1.8

The results of the soil analysis were presented in table 4.1, which shows that the physicochemical properties of the soil parameters analysed were found to be in traces; This could be as a result of the dumpsite is made up of domestic waste as the parameters analysed are mostly associated with industrial waste and these parameters are copper, lead, cadmium, chromium, zinc and Iron.

The results of the pH variation with that distance of the soil samples from table 4.1 shows that the soil samples pH ranges from 7.38 to 7.62 indicating that the soil samples are neutral.

Table 4.1 also shows the results of the organic content of the soil indicating that it ranges from 4.9 % to 1.75% indicating that the soil samples closed to the dumpsite are richer in organic content than those away from the dumpsite.

### **4.3 Mitigation and amelioration measures**

1. Indiscriminate dumping of solid waste directly on the ground should be stopped
2. In case the site is to be made a central solid waste collection centre, then plastic, metallic or concrete containers should be provided
3. Sign post should be placed to serve as notice to the community
4. The already existing dumpsite should be cleared and managed by professional solid waste managers.
5. The stakeholder that is the community and the law enforcement agencies should always monitor the site.
6. Based on total coliform count of the water samples and the organic contents of the soil samples, houses that depend on groundwater should not be allowed within a radius of 150 m to dumpsite.
7. Law enforcement agencies such as KEPA, environmental health workers in conjunction with the police should always carryout surveillance around the area to stop perpetrators.
8. Sensitization seminars should be emphasized to enlighten the communities on the effect of taking contaminated water.
9. The water from the affected wells should always be treated particularly if it is to be consumed.
10. The wells should also be provided with cover and lined with concrete ring to reduce pollution effects.

## CHAPTER FIVE

### CONCLUSIONS AND RECOMMENDATIONS

#### 5.1 Conclusions

Analysis has been carried out on groundwater and soil samples at various distances from the dumpsite in Tudun Wada, Kaduna and the following conclusions are drawn:

- The results showed that physicochemical parameters of both the water and soil samples, temperature, pH, Conductivity, TDS, Dissolved Oxygen, BOD, Total alkalinity, Chloride Content, Total Hardness, Sulphate, Nitrate, Phosphate, are within the WHO and NSDWQ permissible limit.
- The heavy metals parameters of the water and soil samples, Copper, Cadmium, Chromium, Iron, Lead and Zinc are also within the WHO and NSDWQ permissible limit and the low values are as a result of the dumpsite been mainly made up of domestic waste.
- The microbial parameters Total Coliform and Heterotrophic count have a high potential impact as most of the values are higher than the WHO and NSDWQ permissible limit.
- The Conductivity analysis of the water samples shows that it decreases along the distance of the water samples from the dumpsite, from 900 mg/l to 730 mg/l.
- The dissolved oxygen analysis of the water samples shows that the dissolved oxygen in the water samples increases along the distance from the dumpsite from 6.1 mg/l to 8.2 mg/l.
- TDS analysis of the water samples also indicates that the TDS of the water samples decreases along the distance from the dumpsite from 400 mg/l to 240 mg/l.

- BOD analysis of the water samples indicates that the BOD of the water samples decreases along the distance from the dumpsite from 4.5 mg/l to 3.0 mg/l.
- Phosphate analysis of the water samples also indicates that the Phosphate in the water samples decreases along the distance from the dumpsite from 0.49 mg/l to 0.1 mg/l.
- The Zinc analysis also shows that the zinc in the water samples decreases along the distance from the dumpsite from 2.8 mg/l to 0.6 mg/l.
- The total coliform counts analysis of the water samples indicates that the TC in the water samples decreases along the distance from the dumpsite from 100 cfu/ml to 15 cfu/ml.
- The heterotrophic plate count of the water samples shows that the HPC in the water samples decreases along the distance from 152cfu/ml to 23cfu/ml.
- The total organic content of the soil samples also shows that the total organic contents of the samples decrease along the distance from the dumpsite from 4.9 % to 1.75 %.

## **5.2 Recommendations**

- Based on the analysis carried out, a sensitization seminar should be organized in order to enlighten the members of that community the potential health impact of dumpsite very close to residential quarters.
- Based on total coliform count of the water samples and the organic contents of the soil samples, houses that depend on groundwater should not be allowed within a radius of 150 m to dumpsite.

- Further work should be carry out to cover both the dry and raining season as leaching is most expected during raining season.
- Further work should be carried out to cover other parameters that were not cover in this work such as Pathogenic Staphylococci, etc.

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## APPENDICES

### Appendix A

APPENDIX A1: Physiochemical Properties of The Water Samples

PARAMETERS	A1	A2	A3	A4	A5	A6	A7	A8	WHO
Temperature	24.1	20.1	27.4	23.4	24.4	24.6	23.4	24.9	NS
pH	7.09	7.53	6.96	7.02	6.84	6.97	7.12	6.89	6.5-8.5
Conductivity	900	880	790	820	850	730	700	700	1000
TDS	400	390	395	380	350	330	270	240	500
Dissolved Oxygen	6.1	6.8	7	7.2	8	7.7	7.3	8.2	NS
BOD	4.5	4	4	3.8	3.5	3.8	3.3	3	NS
Total alkalinity	1016	896	640	968	968	992	1344	1240	NS
Chloride Content	402.49	584.98	402.49	447.49	384.99	289.99	434.99	174.99	250
Total Hardness	110	120	90	125	100	100	120	110	150
Sulphate	45	37	19	43	21	17	23	25	100
Nitrate	28	25	25	21	18	20	21	20	50
Phosphate	0.49	0.27	0.12	0.2	0.07	0.1	0.13	0.15	NS

APPENDIX A2: Physiochemical Properties of The Water Samples

PARAMETERS	A1	A2	A3	A4	A5	A6	A7	A8	WHO
Copper	0.0034	0.0027	0.0051	0.0081	0.0048	0.0081	0.0077	0.0059	1
Cadmium	0.0034	0.0083	0.0077	0.0065	0.007	0.0044	0.006	0.0059	0.003
Chromium	0.001	0.0012	0.002	0.0016	0.0024	0.0018	0.002	0.0032	0.05
Iron	0.01	0.02	0.01	0.06	0.04	0.03	0.01	0.01	0.3
Lead	0.0022	0.003	0.003	0.0021	0.0007	0.0026	0.0029	0.0061	0.1
Zinc	2.8	2.3	1.01	0.24	0.26	0.06	0.09	0.34	3

APPENDIX A3: Microbials Properties of The Water Samples

PARAMETERS	A1	A2	A3	A4	A5	A6	A7	A8	WHO
TC	100	50	40	20	30	20	35	15	10
HPC	152	120	110	100	75	48	48	23	100

APPENDIX A4: Physiochemical Properties of The Soil Samples

PARAMETERS	A1	A2	A3	A4	A5	A6	A7	A8
pH	7.45	7.48	7.38	7.48	7.56	7.53	7.62	7.38
Bulk density g/ml	1.25	0.76	1.04	1.35	1.35	1.15	1.1	1.23
Copper ppm	0.0055	0.0048	0.0052	0.0031	0.0051	0.0048	0.0026	0.0025
Lead ppm	0.0301	0.0221	0.0212	0.0155	0.0266	0.0144	0.0151	0.0066
Cadmium ppm	0.0041	0.0021	0.0031	0.002	0.0039	0.0032	0.001	0.0001
Chromium ppm	0.0018	0.0021	0.002	0.0019	0.0019	0.0023	0.002	0.0021
Zinc ppm	3.61	2.3	3.3	2.21	2.5	3.1	3	2.76
Iron ppm	0.06	0.03	0.02	0.02	0.03	0.01	0.015	0.015
Organic Content%	4.9	4.5	4.8	3.13	2.5	1.77	1.75	1.8

## Appendix B

### LABORATORY EQUIPMENT AND SAMPLES PHOTO



APPENDIX B1 Soil samples in petrish dish



APPENDIX B2 Water samples in sample bottle



APPENDIX B3 Heavy duty blender



APPENDIX B4 Drying Oven



APPENDIX B5 Atomic Absorption Spectrometer



APPENDIX B6 Colony Counter



APPENDIX B7 Portable data logging Spectrometer



APPENDIX B8 Oxygen Meter



APPENDIX B9 pH/mV/Temp meter



APPENDIX B10 TDS meter



APPENDIX B11 Weighing balance machine