EVALUATION OF THE IMPACT OF THE NEKEDE DUMPSITE ON SURROUNDING GROUNDWATER QUALITY IN OWERRI WEST, IMO STATE, NIGERIA.

BY

IZIBEYA DIEMEWULU, B. Tech. 20164024058 (M.Sc., FUTO)

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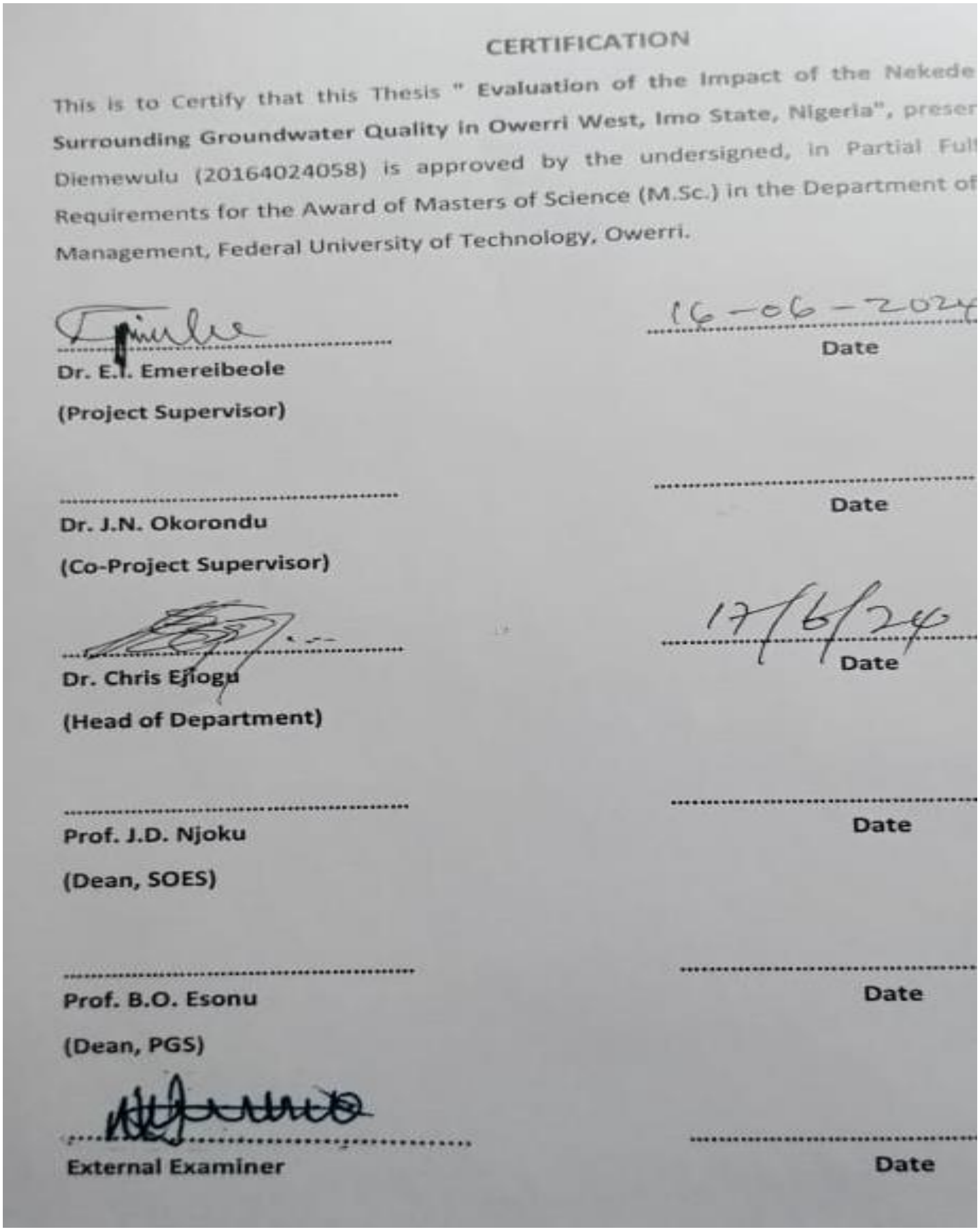

CERTIFICATION

This is to Certify that this Thesis " **Evaluation of the Impact of the Nekede**
Surrounding Groundwater Quality in Owerri West, Imo State, Nigeria", preser
Diemewulu (20164024058) is approved by the undersigned, in Partial Ful
Requirements for the Award of Masters of Science (M.Sc.) in the Department of
Management, Federal University of Technology, Owerri.

Dr. E.I. Emereibeole **(Project Supervisor)**	16-06-2024 **Date**
Dr. J.N. Okorondu **(Co-Project Supervisor)**	**Date**
Dr. Chris Ejiogu **(Head of Department)**	17/6/24 **Date**
Prof. J.D. Njoku **(Dean, SOES)**	**Date**
Prof. B.O. Esonu **(Dean, PGS)**	**Date**
External Examiner	**Date**

DEDICATION

I dedicate this work to God Almighty.

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ABSTRACT

This study evaluated the impact of municipal solid waste on groundwater quality around the Nekede dumpsite, Owerri West, Imo State, Nigeria. The Nekede waste dump is about two (2) hecters in area and has existed for many years and can pose pollution hazard to surface and groundwater resources through leachate infiltration. Several families abstract water for domestic usage from boreholes in this areas with resultant exposure to several water-borne challenges. 50kg of waste were classified into different categories and their percent composition determined. Water samples were also collected from four (4) different boreholes within 50m radius of the waste dump and analysed using standard procedures. Results obtained revealed that the waste in the dumpsite were majorly composed of metals (36.66% by mass). The pH of the borehole water sampled were slightly acidic, indicating possible waste interaction with the underlying aquifers. The Electrical Conductivity (EC) values ranged between 24-490μScm^{-1}. BH1, the borehole nearest to the waste dump recorded the highest conductivity value of 490 μscm^{-}1 which is above the WHO regulatory standard for a portable water. Lead (Pb), Iron (Fe), Nickel (Ni), and Chromium (Cr) concentrations were all found to be above the WHO regulatory limits. These results suggest a possible pollutant input from the waste dump, implying that the selected boreholes were impacted by the waste dump. The VES data of Nekede dumpsite showed a thickness value of 35m to 183m and the aquifer resistivity values ranged from 1000Ωm to 5850Ωm, the aquifer map also revealed an unconfined/ semi unconfined aquifer formation with sandy soil from top to bottom and layers of clay of 3.3m to 5.9m thickness. This formation is highly vulnerable to groundwater pollution due to high rate of leachate infiltration. This research have shown that Nekede dumpsite is a threat to the surrounding groundwater due to possible seepage of leachate from the dumpsite. This work has shown that regulation of drilling of boreholes in the study area and its environs has become inevitable to protect the public from water borne diseases.

CHAPTER ONE

1.0 INTRODUCTION

1.1 BACKGROUND TO THE STUDY

Waste (or wastes) are unwanted or unusable materials. Waste is any substance which is discarded after primary use, or is worthless, defective and of no use. Waste can also be defined as any unnecessary resource use or release of substances into the water, land or air that could harm human health or the environment. Waste encompasses various types of waste, from construction scraps and demolition debris to tank residues, chemical or oil spills, air emissions and wastewater leaks.

The Waste comprised of biodegraded and non-biodegraded wastes which contaminate the soil around the selected sites and possible source of water supply through surface and groundwater contamination.

In Nigeria, Imo state to be precise, most domestic and commercial waste go a long way to adversely affect the rural and urban areas. Pollution problems associated with incidents of used oil or waste oil spills around automobile-repair workshops, resulting in metal contamination of topsoil, have been subject of many reports.

The impact of these wastes groundwater quality can be devastating, depending on the composition of the heterogeneous mixture and method of disposal. The generation of waste is a function of human activities, therefore, proper waste disposal become steadily imperative with no compromise if only a healthy society and generation is to be achieved. Agricultural soils exposed to incessant disposition of solid waste are liable to become contaminated due to influx of heavy metals, which subsequently through intrusion intercept and affect the groundwater quality (Mohammad & Chukwuma, 2011).

Groundwater is one of the most important natural resources which contribute to the global freshwater supply. In Nigeria, groundwater provides much of the public and domestic water supply, supports agricultural and industrial economies, and contributes its flow to rivers, lakes and wetlands; and this helps in maintaining balance in the ecosystem (Aizebeokhai, 2011). Groundwater is the primary source of potable water in most parts of Nigeria, particularly in rural areas, which rely on domestic (private) hand-dug wells (Aizebeokhai, 2011). According to (Kumar *et*, *al* (2013), groundwater is one of the primary sources of water for human consumption, agriculture and industrial uses. In recent years, an increasing threat to ground water quality due to human activities has become of great importance. The adverse effects on ground water quality are the results of man's activity at ground surface, unintentionally by agriculture, domestic and industrial effluents, unexpectedly by sub-surface or surface disposal of sewage and industrial wastes. Uncontrolled urban growth and its resultant effect, especially in developing nations like Nigeria, can adversely affect the quality of underlying groundwater if not properly controlled (Putra & Baier, 2008). With a rapid population growth of about 2.5% per annum, the demand for water supply has progressively increased over the last three decades. The provision of safe drinking water has deteriorated.

Solid waste dumpsites which have been identified as one of the major threats to groundwater resources receive a mixture of municipal, commercial and mixed industrial wastes. Moreover, studies on the effects of unlined waste dumps on the host soil and underlying shallow aquifers have shown that soil and groundwater systems can be polluted due to poorly designed waste disposal facilities (Amadi et al., 2012). Groundwater contamination in a dumpsite facility occurs mainly due to the contaminant potential of leachate from the waste body. These leachates are solutions, essentially organic or inorganic complexes of biodegradation components of solid wastes flowing from the refuse dumps, saturated with rainwater (Kassenga & Mbluligwe, 2009).

1.2 STATEMENT OF THE PROBLEM

The problem of rapid urbanization has led to increase in municipal solid waste generation because of increasing population and some socio-economic factors in Nigeria. (Butu & Mshelia, 2014). Majority of the municipal solid waste disposal sites in Nigeria are still open dumps. Moreover, in most cases the landfills are not properly engineered and operated to accepted world standards. Improper management of solid waste areas has resulted in serious ecological, environmental and health problems. Such practices contribution to widespread environmental pollution as well as spread of diseases (Susu & Salami, 2011). Solid waste disposal by landfill poses a threat to groundwater and surface water quality through the formation of polluting liquids known as leachate (Mohammed et al., 2013).

According to Kola-Olusanya (2011) the risk of groundwater pollution is increasing both from disposal of solid waste and the widespread use of potentially polluting chemicals in agriculture.

The dumpsite which is located along Owerri-aba, close to Nekede Mechanic village Imo state, Nigeria, is about two (2) hecters in area has pose prompt pollution hazard to groundwater source. The contaminant plumes percolate into the aquifer through leachate infiltration and successfully disperse transversely into the aquiferious zone.

several boreholes in this area are drawing from this threatened aquifer with resultant exposure to several water-borne challenges.

in line with World Health Organization (WHO), about 80% of all the World's diseases are caused by water, the use of befoul water and poor sanitary conditions result to increased vulnerability to water borne diseases including diarrhea, which leads to deaths of more than 70,000 citizens annually.

Figure 1: A section of the landfill site along old Aba Road.

1.3 AIM AND OBJECTIVES

The aim of this study is to investigate the impact of municipal solid waste on groundwater quality around the Nekede dumpsite, Owerri West, Imo State, Nigeria. This will be achieved through the following objectives;

i. To classify the waste types in the Nekede dumpsite.
ii. To determine the physico-chemical characteristics of boreholes water samples from around the Nekede-Aba road dumpsite.
iii. To determine aquifer layers in the study area using Vertical Electrical Soundings (VES).

iv. To analyze results obtained with statistical tools.

v. To compare results with regulatory standards (WHO).

1.4 SIGNIFICANCE OF THE STUDY

Understanding the quality of groundwater is a very important factor in determining whether the source could be used to supply suitable water for human consumption and use. As a scarce resource, groundwater requires continuous monitoring through quality assessments and management for sustainable use against contamination. Groundwater is the primary source of potable water in most part of Imo metropolis, which relies on domestic (private) hand-dug wells from the upper aquifer (Bakari, 2014). The ability for municipalities, particularly Imo to ensure reliable protection of public health and the environment through efficient wastes management, there is a need to identify a relationship between the solid waste, soil and groundwater that will help to understand the quality of the groundwater reservoirs in the study area. This study will provide useful knowledge on water quality awareness to reduce problems associated with water and its implications on health-related risks. Application of quality assessments of groundwater in Imo area has important implications in the groundwater’s potential as a resource and can indicate where negative impacts may be mitigated and efficiency of water conservation programs can be evaluated.

1.5 SCOPE OF STUDY

This work is limited to the collection and determination of the physico-chemical properties of four (4) sampled boreholes from locations around Nekede Dumpsite, Aba Road. VES will be used to determine aquifer layers and water table properties of the study area.

CHAPTER TWO

2.0 LITERATURE REVIEW

Waste is defined as unwanted and unusable materials and is regarded as a substance which is of no use to the owner. Wastes in our surroundings is also known as garbage. Garbage is mainly considered as a solid waste that includes wastes from homes (domestic waste), wastes from schools, offices, etc (municipal wastes) and wastes from industries and factories (industrial wastes).

In the recent times, the social and environmental impacts of municipal solid waste (MSW) have received tremendous attention as reported by Calvo, Moreno, Zamorano and Szanto, (2005). Consequently, several policies, strategies, plans and methods have been formulated in MSW management. These policies focus more on waste reduction and waste recovery for reuse, recycling, composting, and incineration for energy generation in addition to landfilling of final rejects (Narayana, 2009). According to Nagendran, Selvam, Joseph and Chiemchaisri, (2006), landfills and/or open dumpsites have been identified as the most adopted method of MSW disposal all over the world. Studies show that currently, sanitary landfill represents a viable and the most used method for solid waste disposal all over the world because it may achieve the reclamation of derelict land (Erses, Fazal, Onaya, & Craig, 2005).

Several scholars such as Saarela, (2003), Abu-Rukah and Kofahi,(2001),Looser, Parriaux, and Bensimon, (1999), Christensen, Jensen, Gron, Filip and Christensen**,** (1998), De Rosa, Rubel, Tudino, Viale, and Lombardo**,**(1996), Flyhammar, (1995), etc. have carried out studies on problems associated with municipal solid waste disposal which includes leachate migration and contamination of groundwater.

According to a study titled municipal solid waste disposal and environmental issues in Kano metropolis, Nigeria, conducted by Butu and Mshelia, (2014), the disposal of Municipal Solid Waste (MSW) is a global concern, most especially in developing countries across the world, where poverty, population growth and high urbanization rates combine with ineffectual and under-funded governments to prevent efficient management of wastes.

Waste management has become increasingly complex due to the increase in human population, industrial and technological revolutions (Akinbile, 2011), and according to Nagendran, Joseph, Esakku, Visvanatha and Norbu (2006), open dumps are the oldest ways of disposing of solid wastes. Although most of such dumps have been closed, in our growing metropolis, some are still being used (Adamu, Dibal & Duhu, 2014). However, these landfills are considered one of the major threats to aquifers and groundwater (Fatta, Papadopoulos & Loizidou, 1999). The scale of this threat depends on the concentration and toxicity of contaminants in leachate, type and permeability of geological strata, depth of water table and the direction of groundwater flow (Al-Khaldi, 2006).

2.1 Waste disposal and landfill

Waste can be loosely defined as any material that is considered to be of no further use to the owner and is, hence, discarded (Taylor & Allen, 2006). However, most discarded wastes can be reused or recycled; one of the principles of most waste management philosophies. What may be of no further use to one person and regarded as waste to be dumped may be of use to the next person. This is the basis of the rag picking trade; the sifting through of refuse at landfills for recovery and resale which is a very fundamental historical waste management practice still functioning in many countries, often conducted on a highly organized commercial basis (Taylor & Allen, 2006).

Wastes are generated universally and are a direct consequence of all human activities. Wastes are generally classified into solid, liquid and gaseous. Gaseous waste is normally vented to the atmosphere, either with or without treatment depending on composition and the specific regulations of the country involved (Al-Sabahi, Rahim & Zuhairi, 2009). Liquid wastes are commonly discharged into sewers or rivers or water bodies or allowed to infiltrate into the ground. Indiscriminate disposal of liquid wastes pose a major pollution threat to both ground and surface water, including aquatic life (Alam & Ahmade, 2013).

Solid wastes are mainly disposed of to landfill, because landfill is the simplest, cheapest and most cost-effective method of disposing of solid wastes (Barrett & Lawlor, 1995). In most low- to medium-income developing nations, almost 100 percent of generated waste goes to landfill. Even in many developed countries, most solid waste is landfilled, (USEPA, 2008). Although the proportion of waste to landfill may in future decrease, the total volumes of municipal solid wastes (MSW) being produced are still increasing significantly, in excess of 3 percent per annum from any developed nations (Douglas, 1992). Landfill is therefore likely to remain a relevant source of groundwater contamination for the foreseeable future (Allen, 2001). Solid waste composition, rate of generation and methods of treatment and disposal vary considerably throughout the world and largely determine the potential of waste to impair groundwater quality (Bhalla, Sainib & Jha, 2014).

2.2 Types of Solid Wastes

Wastes generated by the full extent of human activities range from relatively innocuous substances such as food and paper wastes to toxic substances such as paint, batteries, asbestos, healthcare waste and sewage sludge. Numerous classifications of solid wastes have been proposed (e.g. Tchobanoglous, Thiesen & Vigil, 1993; Ali, Cotton & Westlake, 1999) and the following represents a simple classification of wastes into broad categories according to their origin and risk to human and environmental health:

(i). Household wastes;

(ii). Municipal solid wastes (MSW);

(iii). Commercial and non-hazardous industrial wastes;

(iv). Hazardous (toxic) industrial wastes;

(v). Construction and demolition (C&D) wastes;

(vi). Healthcare wastes (e.g. hospitals, medical research facilities);

(vii). Human and animal wastes; and
(viii). Incinerator wastes.

Household wastes represent wastes generated in the home and collected by municipal wastes collection services. Municipal solid wastes (MSW) include these plus shop and office wastes, food wastes from restaurants, wastes derived from street cleaning, and green (organic) waste generated in parks and gardens.

Storage of waste in a disposal facility serves to minimize the effects of waste on the environment. This is achieved by restricting any effluent derived from the waste to a single location, where emissions can be controlled. If control is lacking or inadequate, disposal facilities may become point sources of groundwater contamination. In many regions, centralized waste disposal has historically occurred by landfilling, wherein local quarries and gravel pits have been filled with waste because, in many cases, they simply constituted an appropriately sized hole in the ground (Butu & Mshelia, 2014). Such locations typically offered little protection against contamination of adjacent groundwater supplies. Legislation, designed to protect usable groundwater, has helped to reduce the incidence of this practice in many high to middle income countries. Modern waste management practices involve disposal of waste in specially sited and engineered sites known as "sanitary landfills"(Barret & Lawlor, 1995).

In the developed nations, the range of wastes usually found in municipal waste landfills would normally include solid wastes, commercial and non-hazardous industrial wastes, construction and demolition (C&D) waste (Lusugga, 1999).Although the C&D waste are most often regarded as being inert and are buried at the site of generation, they have the tendency to pollute groundwater with heavy metals through downward percolating rainwater. Recent waste regulations in some developed countries require all C&D waste to be disposed of in landfills (Clark, Jambeck &Townsend, 2006).

In many countries, waste management legislation tries to differentiate between hazardous and non-hazardous wastes. However, hazardous wastes can generally be defined as wastes with the potency to impair human health or impact negatively on the environment due to their quantity, physical, chemical or infectious characteristics when improperly used, treated, stored, transported or disposed (USEPA, 2005). In many countries, hazardous or toxic industrial wastes, solid incinerator residues, bottom and fly ash are disposed in special hazardous waste landfills. Specialized disposal or incineration may also be practiced for healthcare wastes.

In many developing countries of the world, where uncontrolled open dumps are common, all wastes tend to be dumped together, regardless of their origins or hazardous nature. These wastes produce leachate which can infiltrate to the aquifers through porous geological media. The infiltrated leachate can cause regional groundwater contamination leading to various water quality concerns(Rudakov, & Rudakov, 1999;Moench, 2004).Moreover, the quality of groundwater and microbial communities changes significantly through the degradation of organic contaminants, depletion of electron acceptor and changes of redox zone in the time and space, etc. (Christensen *et al., 1994*; Lyngkilde, & Christensen, 1992).

One of the major problems of leachate from hazardous industrial wastes include its toxicity to the bacteria naturally present in the waste mass and thus delay biodegradation of organic substances in leachate (Esmail, Abdul, Wan, Fadhl & Fares, 2009).

It is a common practice not to dispose human and animal wastes in landfills, although animal carcasses and waste from abattoirs may in some countries be disposed of in dumps and landfills. Although human corpses are not regarded as waste, they degrade in a similar way to other organic waste, and also produce significant quantities of leachate. Majority of corpses are buried in cemeteries, although a significant proportion are cremated (incinerated), the proportion depending on the proportions of different religious groups in the population and their funeral rites. The main health concern with human and animal wastes is the high concentrations of pathogenic organisms associated with this type of waste, and the potential it has to spread disease (DEADP, 2006).

The rate at which waste is generated corresponds roughly with levels of income. In high- income countries of Europe and North America, between 500 and 750 kg of solid waste are produced per person per year (OECD, 1997). In contrast, urban populations in most low- income countries, for example in Nigeria and Côte d'Ivoire, generate between 100 and 200 kg of solid waste per person per year (Attahi, 1999; Onibokun & Kumuyi, 1999). Despite this lower rate, rapid urbanization, particularly in low income developing countries has left little space for disposal of the increasing amounts of waste material being generated in urban settings (Sangodoyin, 1993). As a result, uncontrolled disposal (i.e. "fly tipping") is rife in many countries, and is a diffuse source of groundwater contamination.

2.3 Waste Storage, Treatment and Disposal Sites

The processes of storage, collection, transport, treatment and disposal of wastes all have the potential to pollute the environment and particularly groundwater due to uncontrolled migration of fluids (leachate) derived from the wastes. In addition to the potential for groundwater pollution at sites where wastes are produced and stored prior to collection, sites associated with the treatment and disposal of wastes, where leachate may be generated include landfills (both controlled as sanitary landfill or uncontrolled as open dumps), scrap-yards, cemeteries, waste collection and processing facilities, and composting facilities (Lone, Kumar, Khan, Saxena & Dar, 2012).

Most modern landfills in high to medium income countries require licenses to operate, and must be engineered to prevent groundwater pollution. This generally involves lining the site with an artificial lining system, but liners leak and degrade with time. Even if the site is well engineered and managed, with an artificial lining system installed, and the waste materials are inert, leachate which may have the potential to pollute groundwater will be produced. It is therefore essential to assess the capacity of the underlying geology to protect groundwater in the event of liner failure (Maiti, De, Hazra, Debsarkar & Dutta, 2016).

The likelihood of disposed wastes polluting groundwater depends on the thickness of the unsaturated zone and the attenuation capacity of the over burden (i.e. any loose unconsolidated material which overlies solid bedrock) underlying the site. Another important factor is the total and effective precipitation at the site, since the quantity and concentration of leachate generated is a function of the access of water to the waste. Thus the potential for pollution of groundwater will be least at sites carefully selected to take advantage of the most favorable geological/ hydrogeological conditions (Lee & Jones-Lee, 2004).

Historic landfills (dumps) generally were not subject to the regulations governing modern landfills, and were usually sited for convenience, such as the presence of a pre-existing hole into which the waste could be deposited. The general assumption that an after care period of 30 years is adequate to allow for degradation of waste to an inert state, is now being questioned (Rohrs, Fourier, Blight, 2000). Recent studies (Hjelmar *et al.*, 1995; Wall & Zeiss, 1995; Kruempelbeck and Ehlrig, 1999; Fourie & Blight, 2000;Fourie & Morris, 2003) suggests that wastes may remain active for many decades and even hundreds of years, particularly under moisture-deficient conditions. This includes not only landfills from regions where evaporation exceeds precipitation, but also all lined and capped landfills employing the concept of dry entombment of wastes.

In the past, hazardous and non-hazardous wastes were not distinguished so that hazardous substances may be stored in all of these landfills.

2.4 Groundwater Sources and Potability

Groundwater sources have their origin in the water cycle and are held in aquifers beneath the ground surface. These aquifers can be penetrated by wells to provide a clean water source. Groundwater is an important source of drinking water in many areas, including Nigeria. The potability is based on the levels of contaminants contained in it resulting from its source rock compositions or anthropogenic activities. The protection of groundwater from contamination is a global issue and many resources have been invested in the process of its conservation. Anthropogenic impaction of groundwater quality is exhibited in leachate constituents of groundwater and waste disposal practices are recognized as of paramount importance in groundwater quality (Tamer, Yunes & Samir, 2011).

2.5 Factors influencing contamination of groundwater by disposal of wastes

Wastes deposited in landfills or in refuse dumps immediately become part of the prevailing hydrological system. Fluids derived from rainfall, snow melt and groundwater, together with liquids generated by the wastes through processes of hydrolysis and solubilisation, percolate through the deposit and mobilize other components within the wastes. The resulting leachate, subsequently migrates from the landfill or dump and has the potential to contaminate local groundwater either through direct infiltration on site or by infiltration of leachate-laden runoff off site (Freeze & Cherry, 1979).

The risk posed to groundwater-fed drinking water sources by waste disposal in landfills or dumps can be considered in terms of three controls as described in (i) – (ii) following.

i. Waste Composition and Loading

The composition and volume of disposed wastes vary nationally and regionally in relation to the local human activities, and the quantity and type of products that communities consume (Dharmarathne & Gunatilake, 2013). Discarded wastes in lower income areas are typically rich in food-related wastes, i.e. organic (carbon-rich) substances. Although such wastes are not inherently toxic, decomposition of organic matter can alter the physico-chemical quality of groundwater and enhance the mobility of hazardous chemicals including metals and solvents (Odette & Wu-Jang, 2007).

The proportion of manufactured (e.g. paper) and potentially hazardous (e.g. textiles, metals, plastics) wastes increases in relation to income and degree of industrialization. Wastes disposal leachate from highly industrialized settings may contain a wide range of anthropogenic contaminants. The types of hazardous substances likely to occur in discarded wastes may be assessed from the types of industry, small-scale enterprise and other human activities of a particular area (Vaibhav, Sultan, Pooja & Rajeev, 2015).

Landfilled refuse is rich in microorganisms and mature sites may be compared to large bioreactors in which the organic content of the waste is decomposed anaerobically. Most of the organisms that carry out these processes are harmless saprophytes, but a small percentage of the population may be opportunistically pathogenic microorganisms. Wastes arising from households, medical practices and hospitals, veterinary practices, industrial sites and from environmental sources will contain pathogenic microorganisms (Babanyara, Ibrahim, Garba, Bogoro & Abubakar, 2013).

Whereas wastes from industrial, medical and veterinary sources are more likely to be controlled or to be of known composition, domestic wastes tend to be highly variable and of uncontrolled composition. An analysis of household wastes in the UK showed that over 4 per cent of the wastes comprised disposable nappies (diapers) of which about one-third may be soiled with faeces (Scaglia & Adani, 2008). Domestic wastes such as sanitary pads, tampons and discarded wound dressings also contain bloodstained materials. The potential for pathogens within this mixture of sources is extremely high. Pathogens may also be transported to landfill sites by vermin (rats) and other scavengers, in particular seagulls (Taylor & Allen, 2006).

ii. Leachate production

Most wastes deposited in landfills are not inert. Degradation of many components of waste including food, paper and textiles consumes oxygen thereby changing the redox potential of the liquid present and potentially influencing mobility of other constituents. Plastics, glass and metal compounds tend to be less reactive and degrade more slowly. Under some conditions, metals may, however, become rapidly mobilized (Holmes, 2013).

Percolating rain water provides a medium in which wastes, particularly organics, can undergo degradation processes into simpler substances. These processes include biochemical reactions involving dissolution, hydrolysis, oxidation and reduction, processes controlled to a large extent by microorganisms, primarily bacteria (Hossain, Das and Hossain, 2014).

Mechanisms regulating mass transfer from wastes to leaching water, from which leachate originates can be divided into three groups of processes:

a) Hydrolysis of solid waste and biological degradation;
b) Solubilisation of soluble salts contained in the waste; and
c) Suspension of particulate matter.

The first two groups of processes, which have the greatest influence on the composition of leachate produced, are associated with the stabilization of wastes. Initially, organic matter, in the form of proteins, carbohydrates and fats, is decomposed under aerobic conditions (i.e. oxidized), through a series of hydrolysis reactions (Ostrem, 2004). This will result to the formation of carbon dioxide and water together with nitrates and sulfates via a number of intermediate products such as amino acids, fatty acids and glycerol. Such oxidation reactions are exothermic, so temperatures in the landfill become elevated. Carbon dioxide is released as a gas or is dissolved in water to form carbonic acid (H_2CO_3) which subsequently dissociates to yield the bicarbonate anion (HCO_3) at near neutral pH. Oxygen is one of the most important factors necessary for aerobic degradation of wastes components (Kaplan, 2011). In the contaminated groundwater, aerobic microorganisms consume oxygen in converting organic contaminants to carbon dioxide and water. A study on characterization of microbial populations in landfill leachate during aerobic biodegradation shows that count of aerobes in leachate increased by two orders of magnitude during the first several months of air injection (Boothe, Smith, Gattie & Das, 2001; Rolling, Breukelen & Braster, 2000).

Aerobic decomposition of organic matter depletes the wastes deposit of oxygen (O_2) as buried wastes in the landfill or refuse dump becomes compacted and circulation of air is inhibited (Tiwari, 2014).

As oxygen becomes depleted, it is replaced as the oxidizing agent by in succession, nitrate (NO_3), manganese (as MnO_2), iron (as Fe $(OH)_3$) and sulfate (SO_4^{2-}). In general, the aerobic stage is short, no substantial volumes of leachate are produced, and aerobic conditions are rapidly replaced by anaerobic conditions (Chan, Chong, Law & Hassell, 2009).

The main stages of anaerobic digestion are (i) acidogenic (acid) fermentation, (ii) intermediate anaerobiosis, and (iii) methanogenic fermentation, all three of which can be operating simultaneously in different parts of the landfill (El-Sayrafi, Daghra, Hussein &Swaileh,2011).

Acidogenic fermentation brings about a decrease in leachate pH, high concentrations of volatile acids and considerable concentrations of inorganic ions (e.g. Cl^{-}, SO_4^{2-}, Ca^{2+}, Mg^{2+}, Na^{+}). As the redox potential drops, sulfate is slowly reduced, generating sulfides, which may precipitate iron, manganese and heavy metals that are dissolved by the acid fermentation. Decrease in pH is due to production of volatile fatty acids (VFAs) and to high partial pressures of carbondioxide (CO_2), whilst the increased concentrations of anions and cations results from leaching (lixiviation) of easily soluble organic material present in the waste mass (Dahiya, Sarkar, Swamy, &Venkata,2015).

Breakdown of organic material reduces the redox potential to <330mV, which allows the next stage of the process to become initiated. Leachate from this phase is characterized by high values of biochemical oxygen demand (BOD, commonly > 10,000 mg/L), high BOD_5/COD (chemical oxygen demand) ratios (commonly>0.7), acidic pH values (typically5-6) and ammonia (NH_3) due to hydrolysis, and fermentation in particular of proteins (Anderson, 2001).

Intermediate anaerobiosis commences with a gradual increase in the methane (CH_4) concentration in the gas, coupled with a decrease in H_2, CO_2 and volatile fatty acids. Conversion of the volatile fatty acids leads to an increase in pH values and to alkalinity, with a consequent decrease in the solubility of calcium, iron, manganese and the heavy metals, which are probably precipitated as sulfides. Ammonia is released but is not converted to nitrate in such an anaerobic environment (Marquet, 2000).

Methanogenic fermentation, the final stage in the degradation of organic wastes, operates within the extremely limited pH range of 6-8. At this stage in the degradation process, the composition of leachate is characterized by almost neutral pH, and low concentrations of volatile acids and total dissolved solids (TDS), indicating that solubilisation of the majority of organic components is almost complete, although wastes stabilization will continue for several decades (Yang, 2015). The biogas being produced has a methane content of generally>50percent, whilst ammonia continues to be released by the acidogenic process. Leachate produced at this stage is characterized by relatively low BOD values, and low ratios of BOD/COD (Bajpai, 2017).

Degradation processes convert nitrogen into a reduced form (ammonium), and bring about mobilization of manganese and iron and also liberation of hydrogen sulphide gas. Production of methane indicates strongly reducing conditions with a redox potential in the order–400 mV. Unlike carbon dioxide, methane is poorly soluble in water (Pohland & Kim, 1999).

Due to the decomposition of organic matter, leachate derived from landfills or dumps comprises primarily dissolved organic carbon, largely in the form of fulvic acids (Christensen *et al*. 2001). The solubility of metals in leachate is enhanced through complexation by dissolved organic matter. The solubility of organic contaminants (e.g. solvents) in wastes may also be slightly enhanced through the presence of high levels of organic carbon in leachate. Hydrophobic compounds may be mobilized through leachate, as they adsorb to organic carbon in solution. For example, benzene- and naphthalene- sulphonates comprise between 1 and 30 per cent of the dissolved organic carbon in landfill-leachates recently analyzed in Switzerland (Riediker, Sulter & Giger, 2000).

iii. Leachate migration

In unsealed landfills above an aquifer, water percolating through landfills and refuse dumps often accumulates or 'mound' within or below the landfill as shown in Figure 2.1. This is due to production of leachate by degradation processes operating within the wastes, in addition to the rainwater percolating down through the wastes (Mor, Ravindra, Dahiya & Chandra, 2006).

The increased hydraulic head gradient (fluid pressure) developed promotes downward and outward flow of leachate from the landfill or dump. Downward flow from the landfill threatens underlying groundwater resources whereas outward flow can result in leachate springs yielding water of a poor, often dangerous quality at the periphery of the waste deposit. Observation of leachate springs or poor water quality in adjacent wells/boreholes are indicators that leachate is being produced and is moving. Leachate springs represent a significant risk to public health (Tesfaye, 2007; Patil, Narayanakar, &Virupakshi, 2013).

One method used to reduce the generation of leachate and, hence, hydraulic heads generating flow from a closed landfill is to place a capping of low permeability material (e.g. clay or high density polyethylene - HDPE) over the waste deposit in order to reduce infiltration of rainwater (Bagchi, 2004). Groundwater pollution potential from older capped landfills may therefore be higher than from younger, open landfills.

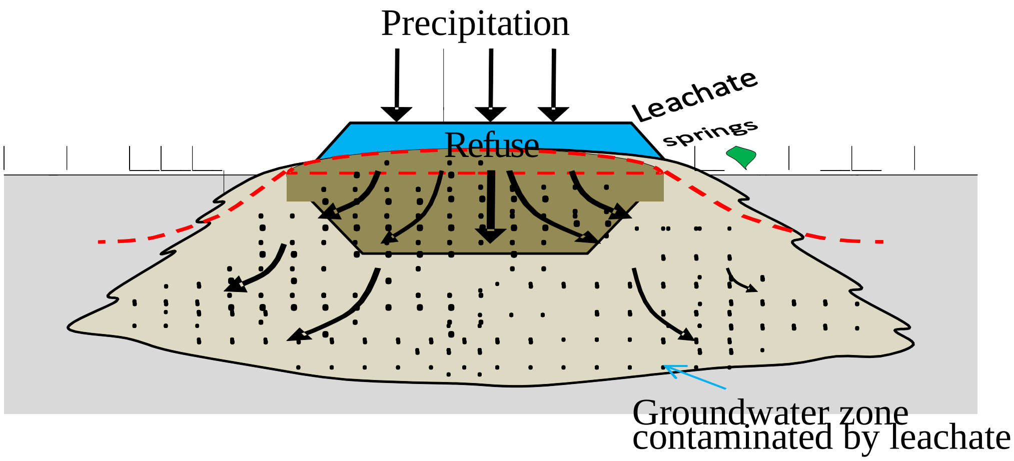

Figure 2.1.Conceptual diagram of leachate migration from a landfill. Source: Freeze and Cherry, (1979).

Leachate migration is also affected by the manner in which waste is deposited. Compaction of waste prior to deposition reduces its permeability, whereas regular application of a topsoil cover between the loadings of waste to landfills induces layering. These characteristics inevitably give rise to preferential flow paths through landfills.

2.6 Leachate effects

Contamination of groundwater and surface water is among the potential and worrisome environmental influences associated with landfill leachate (Kjeldsen *et al.*, 2002). Leachates contain a host of toxic and carcinogenic chemicals, which may cause harm to both humans and the environment (Aderemi, Oriaku, Adewumi & Otitoloju, 2011). Leachate-contaminated groundwater can adversely affect industrial and agricultural activities that depend on well water. For certain industries, contaminated water may affect product quality, decrease equipment lifetime, or require pretreatment of the water supply, all of which cause additional financial expenditures. The use of contaminated water for irrigation can decrease soil productivity, contaminate crops, and move possibly toxic pollutants up the food chain as animals and humans consume crops grown in an area irrigated with contaminated water (Mpofu, 2014).

2.7 Contaminant Transport Theory

Contaminant transport in aquifers cannot be determined if there is no information concerning where the water is moving. The flow of groundwater is dictated by Darcy's law, which states that the velocity of flow is proportional to the hydraulic gradient (Suwai, 2014).

The Darcy's velocity of groundwater flow is defined as follows:

$$\frac{Q}{A} = q = -K\frac{\partial h}{\partial l} \qquad (2.1)$$

Where,

q is the volumetric flow rate per unit area of connected space, $[LT^{-1}]$

K is the hydraulic conductivity, $[LT^{-1}]$

$\frac{\partial h}{\partial l}$ is the hydraulic gradient (change in hydraulic head per unit length) $[LL^{-1}]$

Darcy’s law is valid for laminar flow, which is the case for most porous materials. Darcy’s law is valid for horizontal and vertical flows in the saturated and the unsaturated zone. The direction of the flow depends on the formation of the geological units, the aquifer systems, hydraulic properties, topography, recharge and the presence of water supplies (Fan, Toran & Schlische, 2007).

The speed at which groundwater flow depends on the size of the spaces in the soil or rock and how well the spaces are connected (Abam & Ngah, 2013). Materials are permeable because they have large connected spaces that allow water to flow through them. Groundwater must satisfy the equation of continuity; water is conserved in flow through porous media. The equation of continuity for non-steady state conditions in a confined or unconfined aquifer is given as:

$$\frac{\partial(\rho v_x)}{\partial x} + \frac{\partial(\rho v_y)}{\partial y} + \frac{\partial n(\rho v_z)}{\partial z} = \frac{\partial(\rho \eta)}{\partial t} \qquad (2.2)$$

Where,

ρ is the water density,[ML^{-3}]

$v_{x,y,z}$ is the specific discharge in the longitudinal, lateral, and vertical directions,

[LT^{-1}]

η is the Porosity of the porous medium

t is time, [T]

2.8 Contaminant Solute Transport Mechanism

Advection and dispersion are the two major transport processes that determine the maximum extent of the leachates plume spread and the geometric character of the concentration distribution (Johnson, Brown & Stockman, 2006).

Advection is mass transport due simply to the flow of water in which the mass is dissolved. The direction and rate of transport coincide with the groundwater. Dispersion is a process of fluid mixing that causes a zone of mixing to develop between fluids of one composition that is adjacent to a fluid with a different composition (Duriez, 2005).

Transport and reaction of the contaminant in the porous medium can be represented by the equation below:

$$\frac{\partial C}{\partial t} = \frac{\partial (U_i C)}{\partial x_i} + \frac{\partial}{\partial x_i}\left[D_{ij}\frac{\partial C}{\partial x_j}\right] \pm \sum_{m=1}^{n} \mathrm{r_m}$$

advection dispersion reaction

Where,

C is the Solute concentration, $[ML^{-3}]$

t is the Time, [T]

U_i is velocity in three dimensions, $[LT^{-1}]$

x_i is longitudinal, lateral, and vertical distance, [L]

D_{ij} is dispersion coefficient tensor, $[L^{2}T^{-1}]$

r_m is physical, chemical, and biological reaction rates, $[ML^{-3}T^{-1}]$

Advection is by far the most dominant mass transport process in shaping the plume while hydrodynamic dispersion is usually a second-order process, except in some cases involving fractured rocks (Zinn & Harvey, 2003). The magnitude and direction of advective transport are controlled by: hydraulic conductivity distribution within the flow field, the configuration of the water table, the presence of sources and sinks (e.g. wells), and the shape of a domain (Zinn & Konikow, 2007). All of these parameters are important in controlling the groundwater velocity, which drives advective transport. When there is no dispersion or reactions, the plumes have a uniform concentration equal to the source concentration. A reduction in hydraulic conductivity reduces the extent of the plume by simply reducing the groundwater velocity (Nwachukwu, 2014).

On the other hand, dispersion can cause important changes in the shape of a plume. Dispersion mixes the contaminant with an increasing proportion of the uncontaminated water and as the plume size increases, the maximum concentration decreases (Demenico & Schwarts, 1998).

2.9 Transport of hazardous wastes

The transport of hazardous wastes is largely a function of their physical properties, the physical properties of their surrounding matrix, the physical conditions to which they are subjected and chemical factors (Wuana & Okieimen, 2011).

i. Physical properties of Wastes: the major physical properties of wastes that determine their amenability to transport are volatility, solubility, and the degree to which they are sorbed to solids, including soil and sediments (Alessandro, 2001).The distribution of hazardous waste compounds between the atmosphere and geosphere or hydrosphere is largely a function of compound volatility. Usually, in the hydrosphere, and often in soil, hazardous-wastes compounds are dissolved in water. Therefore, the tendency of water to hold the compound is a factor in its mobility (Manahan, 2013). For instance, although ethanol with a higher vapor pressure and lower boiling point (77.8^{o}C) than toluene (110.6^{o}C) is more retained in water than toluene owing to its higher solubility in water.

ii. Chemical factors: the environmental transport, effects and fates of hazardous-waste compounds are strongly related to their chemical properties. For instance, a toxic heavy-metal cationic species such as Pb^{2+} ion, may be strongly held by negatively charged soil solids. But if the led ad is chelated by EDTA anion, represented by Y^{4-}, it becomes much more mobile as PbY^{2-}, an anionic form (Manahan, 2013).Also oxidation state can be very important in the movement of hazardous substances. The reduced state of iron and manganese, Fe^{2+} and Mn^{2+}, are water-soluble and relatively mobile in the hydrosphere and geosphere (Kawa *et al., 2016)*. However, in their common oxidation states, Fe (III) and Mn (IV), these elements are present as insoluble $Fe_2O_3.xH_2O$ and MnO_2, which have virtually no tendency to move. Furthermore, these iron and manganese oxides will sequester heavy metal ions, such as Pb^{2+} and Cd^{2+}, preventing their transport in soluble form.

2.10 Attenuation

In the unsaturated zone, both air and water fill the pores between soil particles (Fullen & Catt, 2014). The slow movement of leachates in that zone causes attenuation of certain leachate chemicals. Positively charged lead, zinc, cadmium and mercury metals, are easily attenuated. As leachate containing these metals flows through soil, the metals stick or adsorbs to the soil and is removed from the leachate. Other leachate pollutants, such as volatile organic compounds (VOCs) and acids are not easily attenuated, and they move unimpeded through soil. This is shown in Figure 2.2.

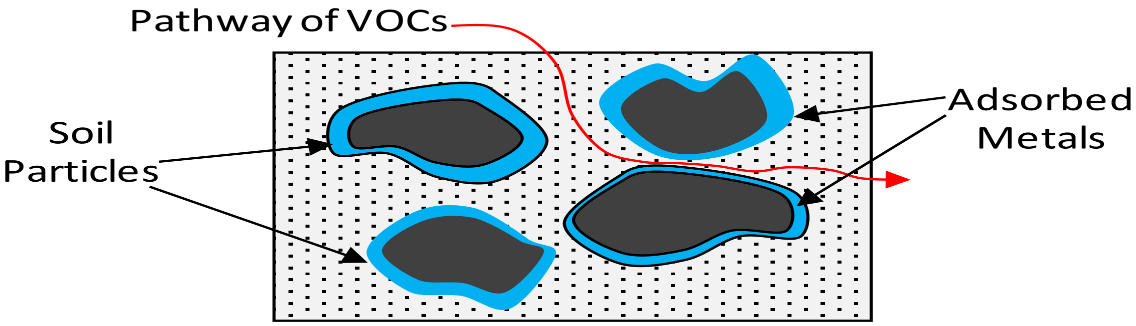

Figure 2.2: Unimpeded movement of VOCs through soil matrix

The composition of a soil and the characteristics of its binding sites affect its attenuation capability. Different soils have different abilities to attenuate and exchange chemicals. Once the binding sites of the soil particles become full, they can hold no more chemicals and henceforth, pollutants will move through the soil towards the groundwater (Maddocks, 2009).

As they fill to capacity, the binding sites become choosier. Only preferentially bound chemicals, or those that form tight bonds with soil, will be attenuated, and chemicals that bind loosely to soil will be replaced as shown in Figure 2.3.

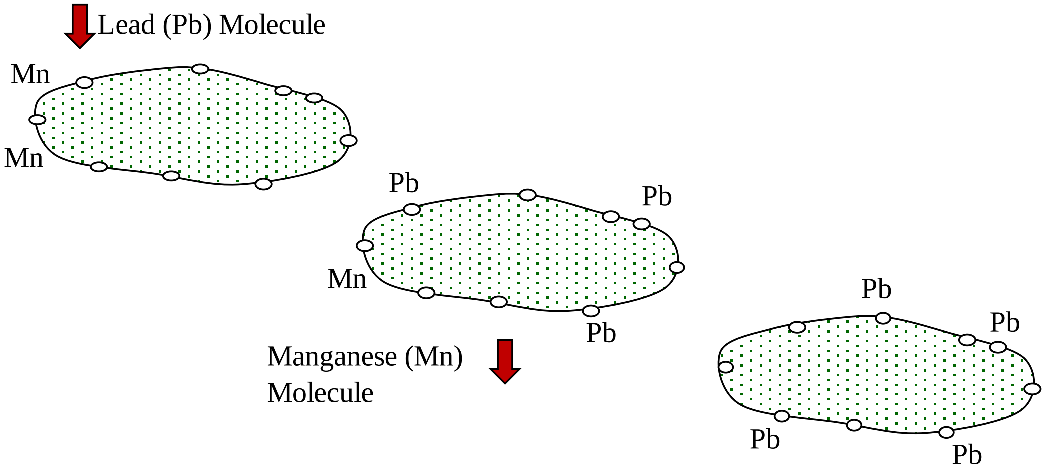

Figure 2.3: Preferential adsorption of Pb over Mn molecules in soil

For example, as leachate flows through soil, lead particles in the leachate can easily replace manganese that is adsorbed on soil because lead is more preferentially bound than manganese. In this situation, lead would be removed from the leachate and stick to the soil, but manganese would leave the soil and re-enter the leachate, posing a continued threat to groundwater. In general, the more rapidly a reaction removes a contaminant, the smaller the plume will be at a given time (ITRCPT, 2008). Ion exchange can also produce the same dramatic attenuation in concentration. In ion exchange processes, the coefficient of selectivity is a determining factor. When the selectivity (preference among ions), is small, there is no exchange and the contaminant moves due to mass transport alone. However, as selectivity increases, the plume becomes smaller as exchange retards spreading. In some instances, the geo-chemical processes have the capability of immobilizing particular contaminants at the source (Wuana & Okieimen, 2011).

A measure of the attenuation can be expressed by the distribution coefficient

$$K_d = C_s/C_w \qquad (2.4)$$

where C_s and C_w are equilibrium concentrations in solid and solution respectively. A more empirical expression is based on the Freudlich equation

$$C_s = K_f C_w^{1/n} \qquad (2.5)$$

where K_f and 1/n are empirical constants.

Several factors determine degree of sorption. They include:

(i) Surface area; sorption is generally higher above the water table in the unsaturated zone of soil due to higher surface area and this zone favors biodegradation process,

(ii) Chemical nature of surface; presence of sorptive clays, hydrous metal oxides and humus (for sorption of organic substances) greatly enhances sorption of substances.

(iii) Chemical nature of the leachate; presence of organic solvents or detergents in leachates will solublize organic materials, increasing their mobility. Also acidic leachates dissolve metal oxides thus preventing sorption of metals in soluble forms. $M(OH)_2(s) + 2H^+ \longrightarrow M^{2+} + 2H_2O$.

MSW is generated from industries, hospitals, schools, and houses (EPA, 2019). MSW is a biomass waste type consisting of glass, food wastes, metals, textiles, wood, plastics, and paper. The methods most used for management of MSW are open dumping and landfilling. Municipal solid wastes (MSW), defined as trash, are highly nonhomogeneous mixture of residential, commercial, and industrial sectors. Typical residential and commercial MSW include clothing, disposable tableware, yard trimmings, cans, office disposable tables, paper, and boxes, whereas institutional and industrial MSW contain restaurant trash, paper, classroom wastes, wood pallets, plastics, corrugated box, and office papers. Although the composition of MSW could be highly variable, it is generally accepted that organic materials are the largest component of municipal solid waste.

Municipal solid waste is considered one of the major global environmental problems, especially in developing countries. Solid waste in general can be classified into industrial or manufacturing, agricultural and forestry, municipal, and other types such as sludge, water canal floating weeds, construction and demolition waste, clinical waste, etc. Municipal solid waste (MSW) is considered the most important solid waste because of its nature and impact on our community and consists of hazardous and non-hazardous waste. It is a fact that solid waste composition differs from one community to another according to their culture and socioeconomic level.

However, solving the problem of MSW in general is very challenging because of its heterogeneous nature. On the other hand, solving the problem in rural and developing countries is more challenging because of two factors: the low socioeconomic level of most of the population and their lack of awareness of the size of the problem as well as the lack of a suitable technology platform needed to face the problem.

2.11 Types of Municipal Solid Waste

a. **Residential:** This comprises of wastes such as food waste, food containers and packaging items, cans, bottles, papers and newspapers, clothes, garden waste, e-wastes, furniture waste, etc.

b. **Institutional wastes (school, university, college, hospital):** This comprises of office waste, food waste, garden waste, furniture waste etc.

c. **Industrial wastes (factory):** This is composed of all sorts of waste generated through industrial activities ranging from office waste, cafeteria waste and processing wastes.

2.12 Open Dump

An open dump refers to a land disposal site where solid waste is disposed of in a manner that does not protect the environment. It is susceptible to open burning, and is exposed to vectors, and scavengers.

Throughout history dumps have been used to solve solid waste problems. In the past, open dumping was used as an inexpensive and often appropriate solution. It served the purpose of keeping waste separated from commercial and residential areas thus limiting exposure to disease and objectionable odors. However, the introduction of more complex products into the waste stream, increased urbanization, and population growth, have all resulted in a huge increase in the negative impacts of open dumps.

Today the use of open dumps does not conform to the increasing public awareness of environmental issues, including the current focus on sustainability and global climate change. Closing, or alternatively upgrading, open dumps is therefore a key issue for many communities. Upgrading these dumps is an essential step in reducing future environmental and public health impacts, as well as avoiding future costs caused by the ongoing mismanagement of waste, that is now so evident at open dumps.

2.13 SANITARY LANDFILL

When precipitation falls on open landfills, water percolates through the garbage and becomes contaminated with suspended and dissolved material, forming leachate. If this is not contained, it can result to groundwater contamination. All modern landfill sites use a combination of impermeable liners, several meters thick, geologically stable sites and collection systems to contain and capture leachate. It can then be treated and disposed of in an environmentally sustainable manner. Once a landfill site is full, it is sealed off to prevent precipitation ingress and new leachate formation. However, liners must have a lifespan, be it several hundred years or more. Eventually, any landfill liner could leak, so the ground around landfills must be tested for leachate to prevent pollutants from contaminating groundwater.

2.13.1 Landfill Leachate

Leachate is generated on account of the infiltration of water into landfills and its percolation through waste as well as by the squeezing of the waste due to self-weight. Thus, leachate can be defined as a liquid that is produced when water or another liquid comes in contact with solid waste. Leachate is a contaminated liquid that contains a number of dissolved and suspended materials.

The important factors that influence leachate quality include waste composition, elapsed time, temperature, moisture, and available oxygen. In general, leachate quality of the same waste type may be different in landfills located in different climatic regions. Landfill operational practices also influence leachate quality.

Leachate is generated on account of the infiltration of water into landfills and its percolation through waste as well as by the squeezing of the waste due to self-weight. Thus, leachate can be defined as a liquid that is produced when water or another liquid meets solid waste.

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CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 THE STUDY AREA

3.1.1 GEOMORPHOLOGY OF STUDY AREA

The study area which includes the Owerri Capital Territory of Imo State in southeastern Nigeria, an area of about 740 km^2, is bounded by latitudes 5°23' and 5°33'N and longitudes 6°57' and 7°08'E. The climate is marked by two main seasons: a wet (rainy) season and a dry season. Most of the mean annual rainfall of about 2152 mm (Monanu & Inyang, 1975) occurs during the wet season, April-October, and is associated with moisture-laden maritime southwest trade winds from the Atlantic Ocean. The temperature ranges from 23 to 26°C.

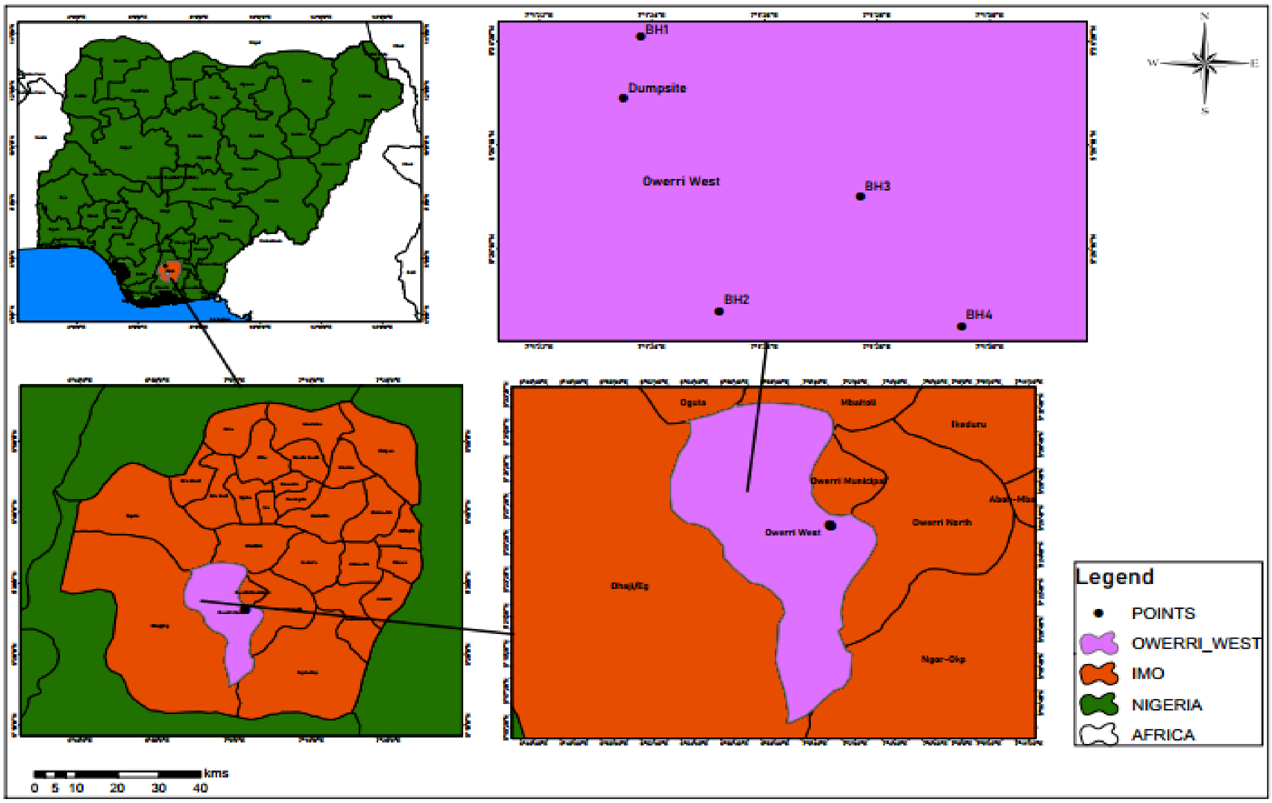


Figure 3:1 Owerri west showing Nekede dumpsite and the four (4) sampling locations.

3.1.2 GEOLOGY OF THE STUDY AREA

Owerri lies entirely within coastal plain sandstones (Benin Formation) which have a thickness of about 800 m. The Benin formation extends from the west across the Niger Delta and southward beyond the present coastline. It is over 90 percent sandstone with minor shale intercalations in some places. It is coarse grained, gravely, locally fine grained, poorly sorted, sub-angular to well-rounded, and bears lignite streaks and wood fragments. The Benin formation is thus partly marine, partly deltaic, partly estuarine and partly lagoonal and fluviolacustrine in origin (Reyment, 1976). Its age ranges from Miocene to recent. The terrain of the area is characterized by two types of land forms: highly undulating ridges and nearly flat topography. Various structural units (point bars, channel fills, natural levees, back swamp deposits and oxbow fills) are identifiable within the formation indicating the variability of the shallow water depositional medium. The otherwise continuous body of the Benin formation is interrupted by the Afam clay member which consists mainly of clay with few intercalated sandstone bodies.

Stratigraphically, the Benin formation is overlain by recent alluvium and recent sediments and underlain by the Agbada formation. Its outcrop lateral equivalent is probably the Ogwashi-Uku-Asaba formation (Figure Geological map of Imo).

3.1.3 HYDROGEOLOGY OF STUDY AREA

The study area is drained by three rivers, the Otamiri, Njaba, and Oramiriukwa, the Nwaorie Stream and the ephemeral Okitankwo Stream (recharge is mainly from surface runoff and groundwater baseflow); peak discharge occurs in September and October (Enuvie *et al,* 1991).

The porous and permeable sands and interfingering sandy clay and gravels of the Benin Formation form a multi-aquifer system in which aquifer units are separated by semi-permeable sandy clay aquitards. Three aquifer units are recognized in the lower Imo River basin (Uma & Egboka 1986). They are an upper water-table (unconfined) aquifer, a middle semi-confined aquifer, and a lower confined aquifer. The base of the upper water-table aquifer is at a maximum depth of 100 m. The middle semi-confined aquifer has an average thickness of 80 m, and the lower confined aquifer has an estimated thickness of more than 600 m. The aquifers have high storativity and transmissivity. Well yields range from 54.2 to 231.5 m h^{-1} (Uma & Egboka, 1986).

3.1.3 TOPOGRAPHY AND LOCATION

Owerri, the capital city of Imo, is in the heart of the Igboland. Owerri consists of three Local Govern Areas including Owerri Municipal, Owerri North and Owerri West; it has an estimated population of about 400,000 as of 2006 and is approximately 40 square miles ($100km^2$) in area. Owerri is border by the Otamiri River to the east and the Nworie River to the south

3.2 CLASSIFICATION OF WASTES FROM THE NEKEDE WASTE DUMP

The waste was classified by sorting and separation of the waste material. The tools and items employed included; wheel barrow, weighing balance, riffle box, portable waste bucket, hand glove, rain boot, rake and spade.

PROCEDURE

i. Waste from the dumpsite was raked and packed into a wheel barrow.
ii. The waste in the wheelbarrow was then measured by the use if weighing balance till 50kg of waste were gotten.
iii. Sorting, separation and categorization of waste materials were performed.
iv. The results obtained were tabulated and the percent composition of each waste type were determined.

3.3 Borehole Sampling

Borehole sampling was made in keeping with standard methods as provided by APHA/AWWA/WPC (2005). Borehole water samples were collected in sterilized polyethylene bottles of two-liter capacity. During sampling, bottles were thoroughly rinsed thrice with the water to be sampled. The samples were transported to the laboratory in an ice bag and were kept in a refrigerator at a temperature below 4 °C till analysis was completed on them.

3.4 Laboratory Procedures

All physicochemical parameters were determined based on Standard Methods for the examination of water and waste water, APHA, (2012).

3.4.1pH

The pH meter was first calibrated using pH buffer 4, pH buffer 9 and distilled deionized water. 50ml of the water sample was poured into a beaker and the probe inserted into the water 10 minutes after the meter was switch on, and the pH reading was recorded when the reading becomes stable.

3.4.2 Conductivity: The conductivity meter was calibrated using the conductivity solution at 25ºC; it was then switched on and inserted into the 50ml water sample. Conductivity value was recorded when the reading becomes stable.

3.4.3 Total Dissolved Solid (TDS): The conductivity meter was also used to take insitu measurement of the total dissolved solids in the borehole water samples. The conductivity value was multiplied by a factor (0.65) to obtain the value for the TDS.

3.4.4 Total Suspended Solids (TSS)

TSS was determined by photometric method using HACK DR/2010 Spectrophotometer at a wavelength of 810nm and programme number of 630.

25ml of the filtered deionized water was poured into a 25ml sample cell bottle as blank. The blank was used to ZERO the spectrophotometer. Then the sample was vigorously shaken and

25ml of the sample was put into the light shield and closed after the blank was removed and the READ button was pressed. The value was then digitally displayed in mg/l.

3.4.5 Turbidity

Turbidity was determined by photometric method using HACK DR/2010 spectrophotometer at a wavelength of 860nm and program number of 750.

Twenty five milliliter of the filtered deionized water was poured into a 25ml sample cell bottle as blank. The blank was used to ZERO the spectrophotometer, then the sample was vigorously shaken and 25ml sample was poured into another 25ml sample cell bottle. The sample was put into the light shield and closed after the blank was removed and the READ button was pressed. The value was then digitally displayed in mg/l.

3.4.8 Dissolved Oxygen:

The dissolved oxygen (DO) was determined using DO meter. The DO meter was calibrated using 5% sodium sulphate solution. The probe of the meter was then inserted into the sample after the meter was put on for about 10 minutes. The reading was recorded in mg/l.

3.4.9 Temperature

The dissolved oxygen meter is a dual purpose meter that can measure both dissolved oxygen and temperature. The instrument was used to take in situ measurement of the borehole water temperature. The reading was recorded in ^{0}C.

3.4.10 Five-Day Biochemical Oxygen Demand (BOD_5)

The $BOD_5$was determined using Dissolved Oxygen (DO) meter. The DO meter was calibrated using 5% sodium sulphate solution. The probe of the meter was then inserted into the sample after the meter was put on for about 10 minutes. The reading was recorded in mg/l as dissolved oxygen for day 1 (DO_1). The sample was then incubated in a 250ml Wrinkler's bottle for a period of 5 days at $20^{o}C$. Then DO of the fifth day (DO_5) was measured by inserting the probe again into the sample. The difference in DO between the DO_5 and DO_1 was recorded as the five-day BOD.

$BOD_5 = DO_1 – DO_5$

3.4.11 Determination of Heavy Metals Using Atomic Absorption Spectrometer (AAS)

Apparatus and accessories

i. FS 240 Varian Atomic absorption spectrophotometer
ii. Nitrous oxide oxidant gas
iii. Acetylene gas
iv. Air oxidant gas
v. Distilled water
vi. Conical flask

Working principle

Atomic absorption spectrometer's working principle is based on the sample being aspirated into the flame and atomized. The AAS's light beam is then directed through the flame into the monochromator, and on to the detector that measures the amount of light absorbed by the atomized element in the flame. Since metals have their own characteristic absorption wavelength, a source lamp composed of that element is used, making the method relatively free from spectral or radiational interferences. The amount of energy of the characteristics wavelength absorbed in the flame is proportional to the concentration of the element in the sample.

Procedure

Standard solutions of known metal concentrations in water with a matrix similar to the sample were prepared. Standards that bracket expected sample concentration and were within the method's working range were used. The samples were thoroughly mixed by shaking and 100ml of each transferred into a glass beaker of 250 ml volume. Each sample was aspirated into the oxidizing air-acetylene flame and the sensitivity for 1% absorption was observed and recorded.

Figure 3.2: A section of the Nekede dumpsite showing wastes of different categories

Source: researcher, (2021).

3.4.12 Determination of Chemical Oxygen Demand (APHA 5220C)

Chemical Oxygen Demand (COD) was used as a measure of the oxygen equivalent of the organic matter content of the sample which was susceptible to oxidation by a strong chemical oxidant. COD was determined using the open reflux method where a sample was refluxed and digested in a strongly acidic solution with a known excess of potassium dichromate ($K_2Cr_2O_7$). After digestion, the excess un- reacted potassium dichromate was titrated using ferrous ammonium sulphate (FAS) with Ferron indicator.

3.4.13 Determination of Acidity (Titrimatry)

Acidity is the capacity of water to neutralize a strong alkali to a particular Ph. It is important because acids contribute to the corrosiveness of the water. They may also influence some chemical and biological processes.

Apparatus: burette, volumetric flask, beaker, pipette

Reagent

0.1m NaOH phenolphthalein indicator.

Procedure

50ml of water sample was measured into conical flask, 30 drops of phenolphthalein indicator were added, the sample solution was then titrated with 0.02N NaOH from the burette until the first permanent pink colour appears.

Calculation

$$\text{Total acidity as CaCO3 (ppm)} = \frac{\text{titrant value} \times \text{molarity of titrant} \times 50000}{\text{Volume of sample}}$$

3.4.14 Determination of Acidity and Total Alkalinity

a. Phenolphtalein indicator: dissolve 0.05g of phenolphthalein powder into 10oml standard flask, add 80ml of ethanol and make it ton mark with distilled water.

b. methyl orange indicator: dissolve 0.05g of methyl orange powder in distilled water and dilute to 100ml.

c. 0.05m HCL

Procedure

Measure 50ml of water sample and add 3 drops of phenolphthaiein indicator, if there is no colour observed, add 2 drops of methyl orange indicator to the same solution and titrate against 0.05m HCL.

Calculation

$$\text{Total alkalinity (mg/l)} = \frac{V_A \times M \times 50{,}000}{V_W(\text{ml})}$$

V_A- Volume of acid used for the titration

M- molarity of acid used

V_W- volume of the sample taken

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 RESULTS

Table 4.1.1 presents the results of waste type classification from the Nekede dump site whereas Table 4.1.2 presents the results of the physiochemical analysis and heavy metals in the selected boreholes around the waste dumpsite. Figure 41.1 is the VES data obtained from Nwagbara et al (2012) whereas Figure 4.1.2 is the geoelectric section of Nekede VES spot within the study area.

Figures 4.1(a,b), 4.2(a,b) 4.3(a,b), 4.4(a,b), 4.5(a,b) and 4.6(a,b) are the bar charts and 3-D plots of results for pH, Electrical Conductivity (EC), Temperature, Turbidity, Total Dissolved Solids (TDS) and Total Suspended Solids from the sampled boreholes respectively. Figures 4.7(a,b), 4.9(a,b) and 4.10(a,b) represents the bar charts and 3-D plots for Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Acidity and Alkalinity results of the sampled boreholes respectively. Furthermore, Figures 4.11(a,b), 4.12(a,b),.4.13(a,b),.4.14(a,b) and 4.15(a,b) are bar charts and 3-D plots for lead (Pb) Copper (Cu), Iron (Fe), Nickel (Ni) and Chromium (Cr) concentrations respectively, in the sampled boreholes.

Table 4.1.1 classification of waste from the Nekede dump site

Waste type	**Composition (kg)**	**%composition**
Paper	0.05	0.10
Food	9.5	19.00
Nylon	2.24	4.48
Glass	8.05	16.10
Metals	18.33	36.66
Woods	5.61	11.22
Plastic	4.02	8.04
Others	2.20	4.40
Total	50	100

Table 4.2 concentrations of physiochemical parameters and heavy metals in boreholes under study.

PARAMETERS	BH1	BH2	BH3	BH4	MEAN VALUE	WHO STD
pH	4.1	4.8	5.4	4.7	4.75	6.5-8.5
EC (µscm^{-}1)	490	24	58	82	163.5	250
Temperature (°C)	28.4	28.4	28.4	28.1	28.325	30
Turbidity (NTU)	0.00	0.00	0.01	0.01	0.005	5.00
TDS (mg/L)	245	11	30	40	81.5	500
TSS (mg/L)	2.0	2.2	2.5	2.0	2.175	3.0
BOD (mg/L)	2.8	3.0	3.1	2.8	2.925	2.0
COD (mg/L)	10	12	8	10	10	80
Acidity (mg/L)	30	20.6	18.5	20	22.275	-
Alkalinity (mg/L)	25.4	24.8	32.6	48.2	32.75	N/G
Pb (mg/L)	0.140	0.256	0.162	0.399	0.239	0.01
Cu (mg/L)	0.246	0.384	0.039	0.296	0.241	2
Fe (mg/L)	1.512	1.615	0.020	3.217	1.591	0.3
Ni (mg/L)	0.524	1.217	0.032	1.428	0.825	0.1
Cr (mg/l)	0.346	0.784	0.539	0.496	0.541	0.05

Key: pH, EC= Electrical Conductivity, Temperature, Turbidity, TDS= total Dissolved Solid, TSS= Total Suspended Solid, BOD= Biochemical Oxygen Demand, COD= Chemical Oxygen Demand, Acidity, Alkalinity, Pb = Lead, Cu = Copper, Fe = Iron, Ni = Nickel, Cr = Chromium.

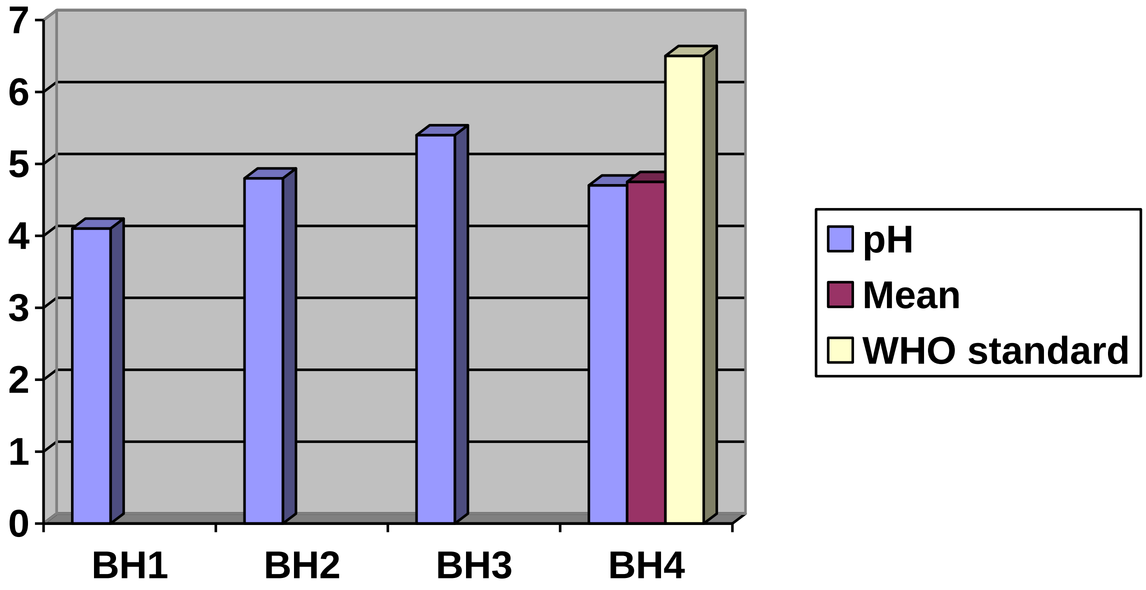


Figure 4.1(a) pH of the boreholes

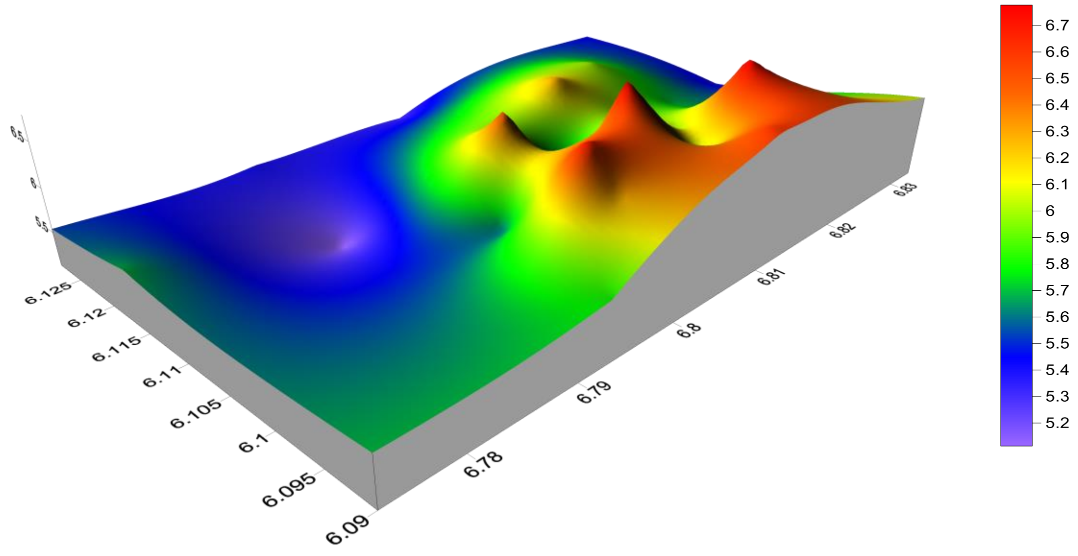


Figure 4.1(b): 3-D model of pH values in the study area

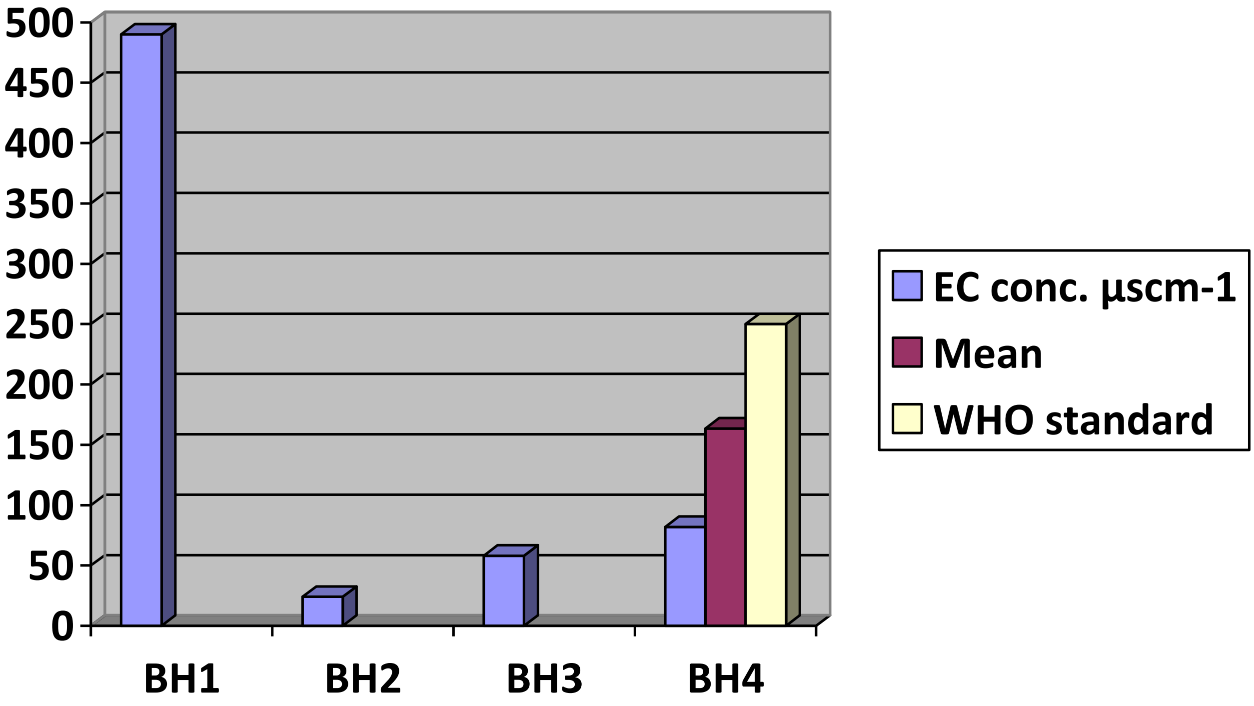


Figure: 4.2(a) EC in S/m of the boreholes

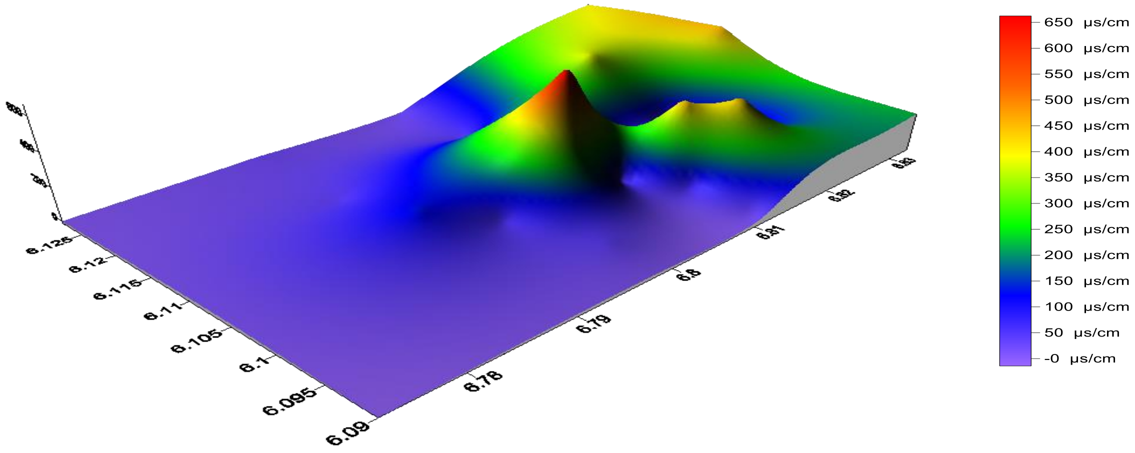


Figure: 4.2(b)3-D model of Electrical conductivity values in the study area

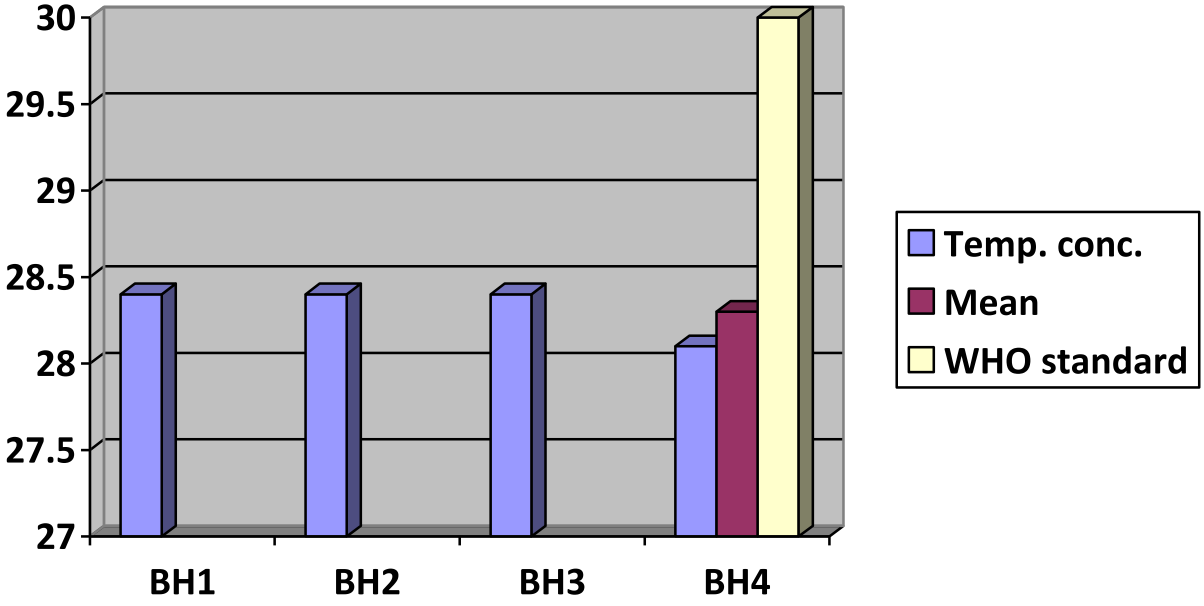


Figure: 4.3(a) Temperature in ºC of the borehole

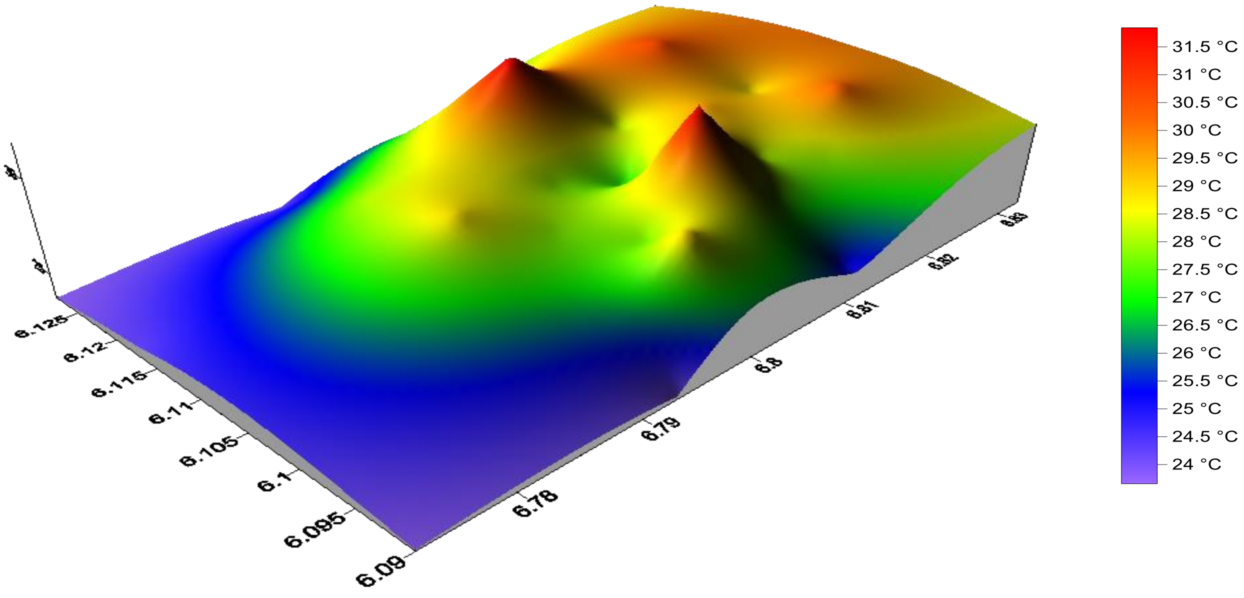


Figure 4.3(b): 3-D model of Temperature values in the study area

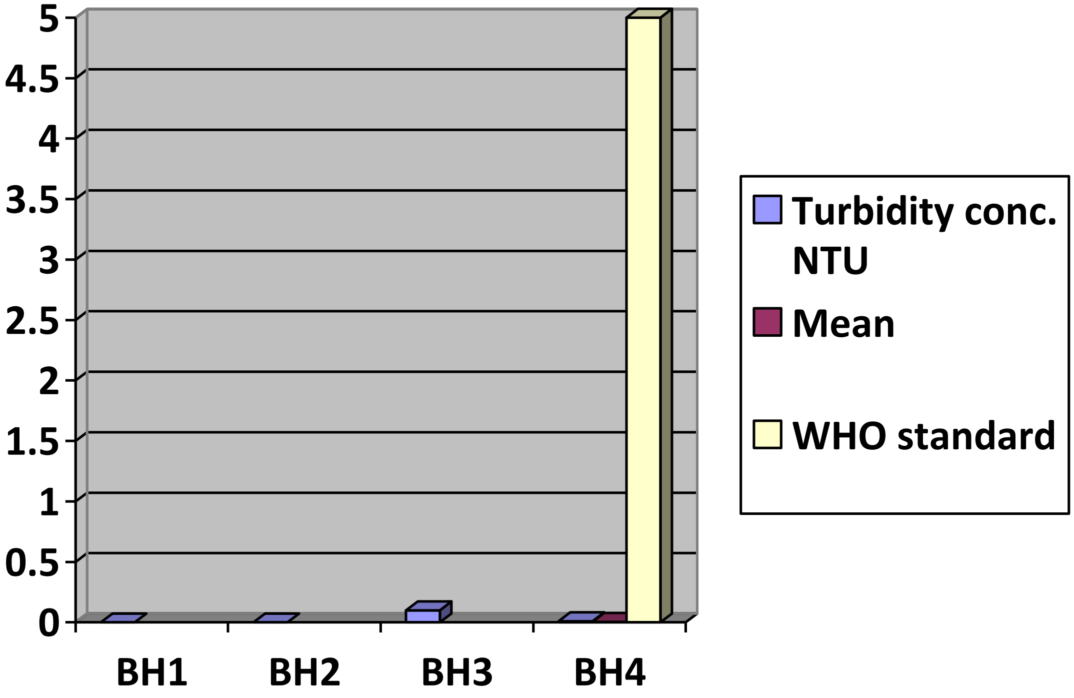


Figure. 4.4(a) Turbidity in NTU of the boreholes

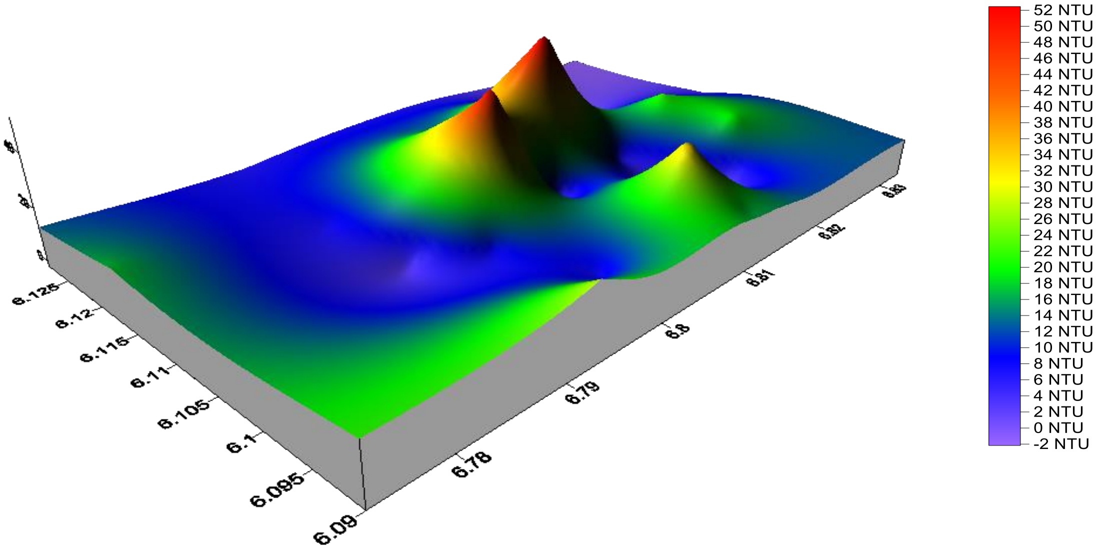


Figure. 4.4(b) 3-D model of Turbidity values in the study area

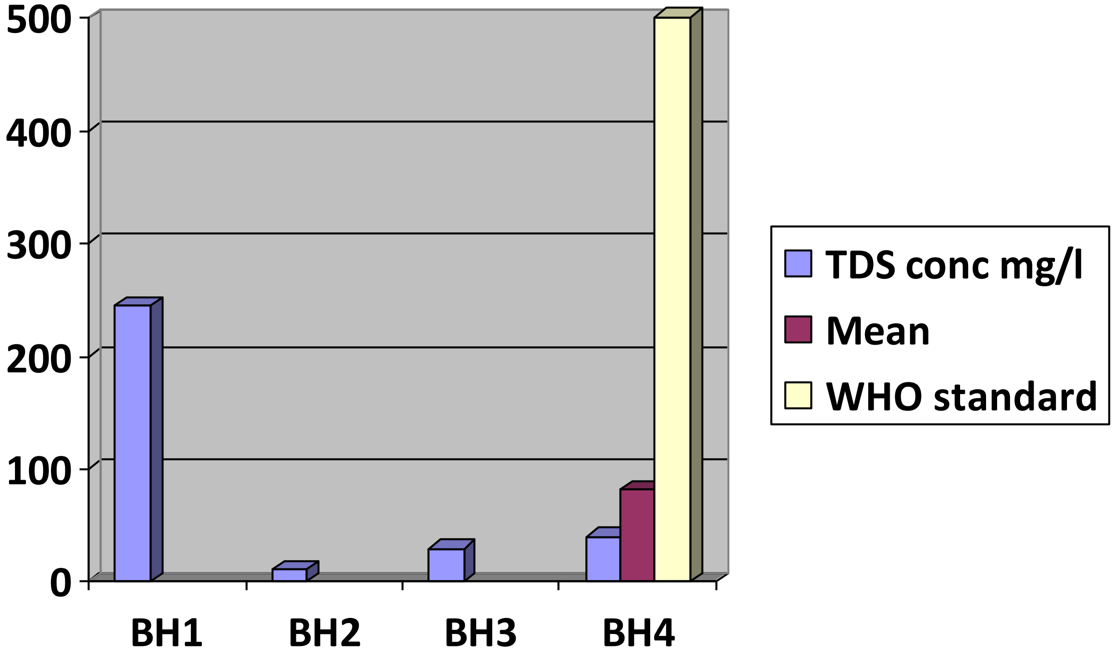


Figure: 4.5(a) TDS inn mg/l of the boreholes

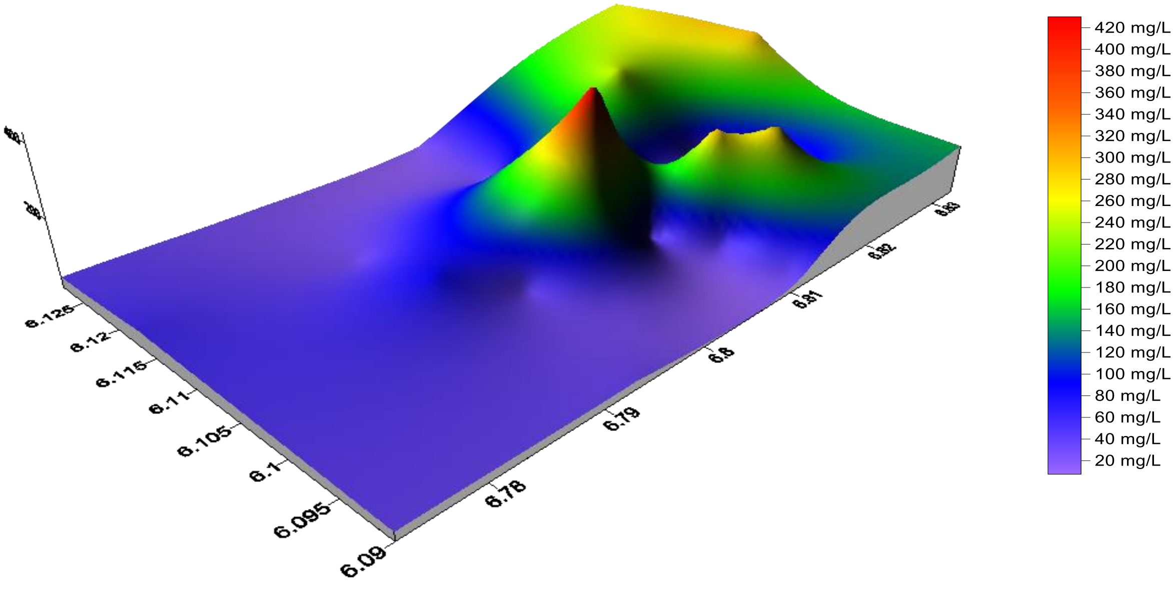


Figure: 4.5(b) 3-D model of TDS values in the study area

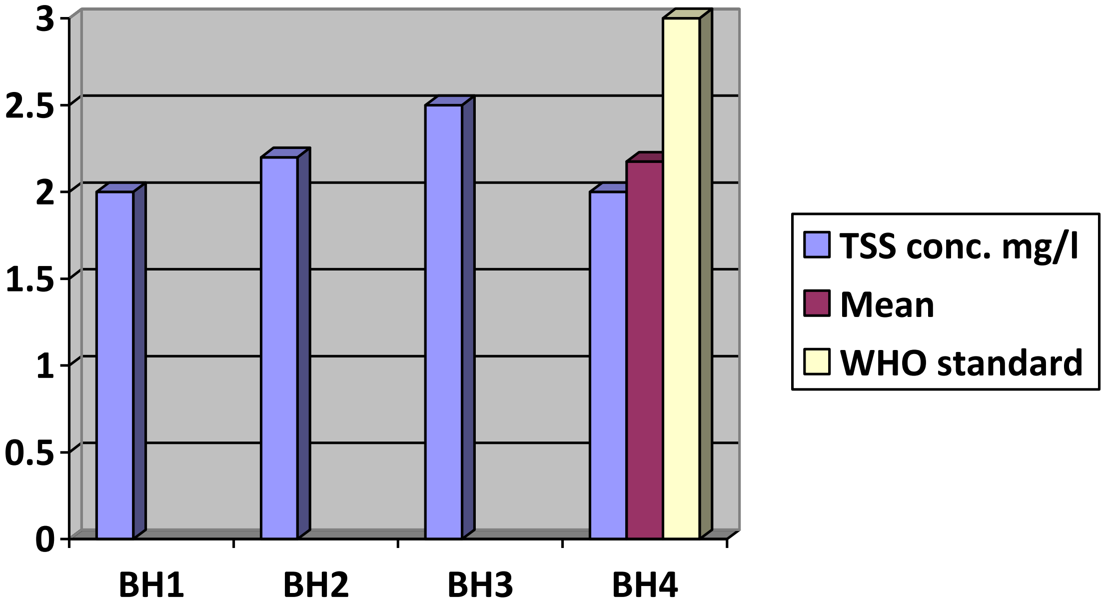


Figure: 4.6(a) TSS in mg/l of the boreholes

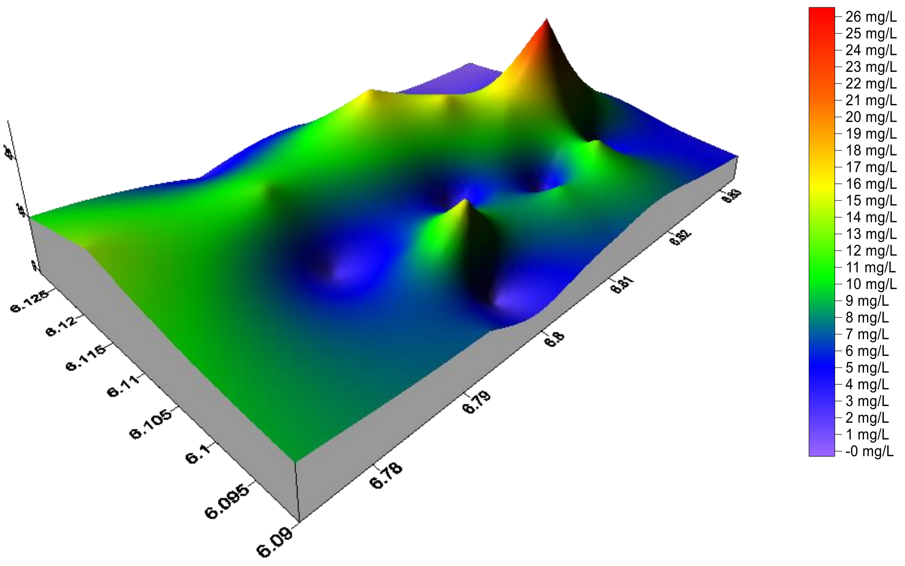


Figure: 4.6(b) 3-D model of TSS values in the study area

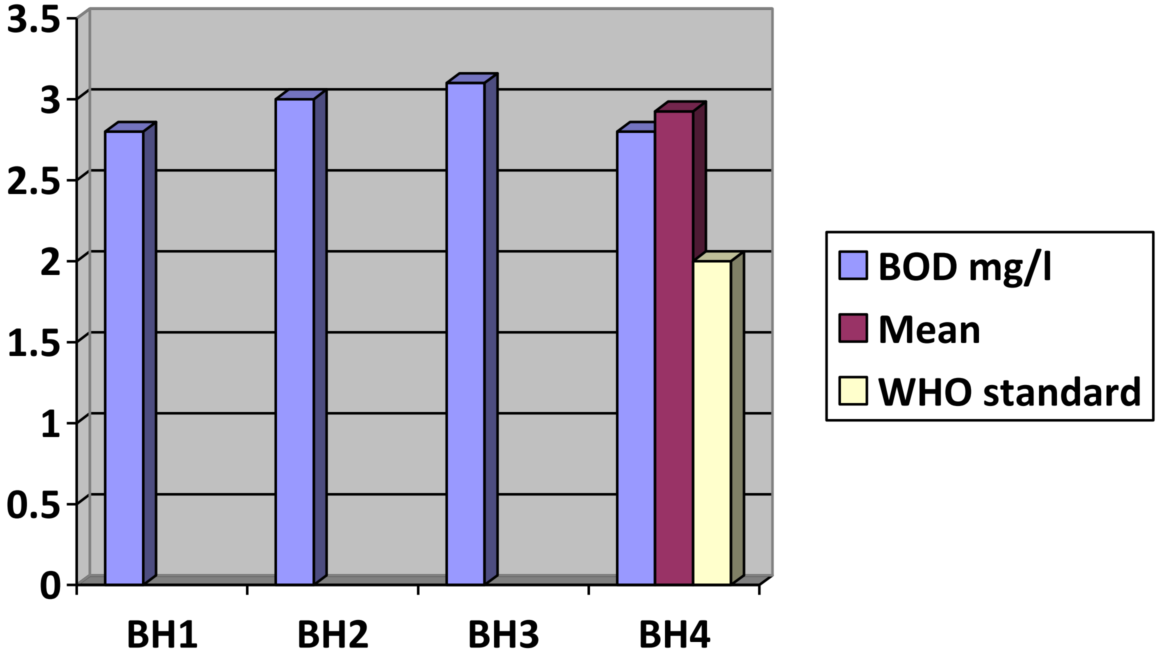


Figure: 4.7(a) BOD in mg/l of the boreholes

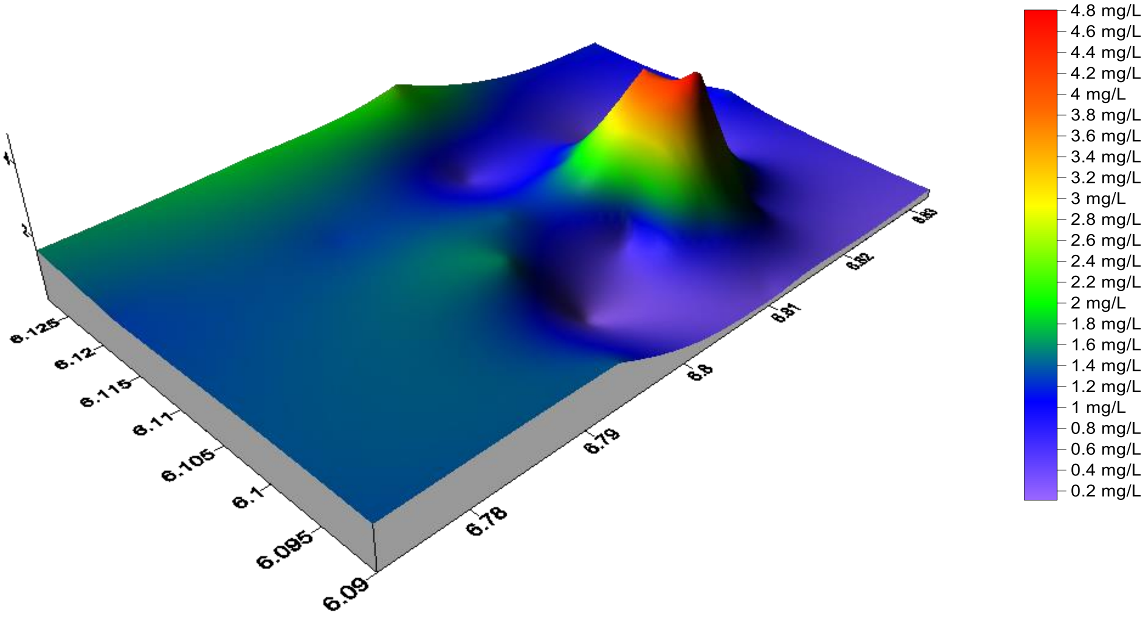


Figure: 4.7(b) 3-D model of BOD values in the study area

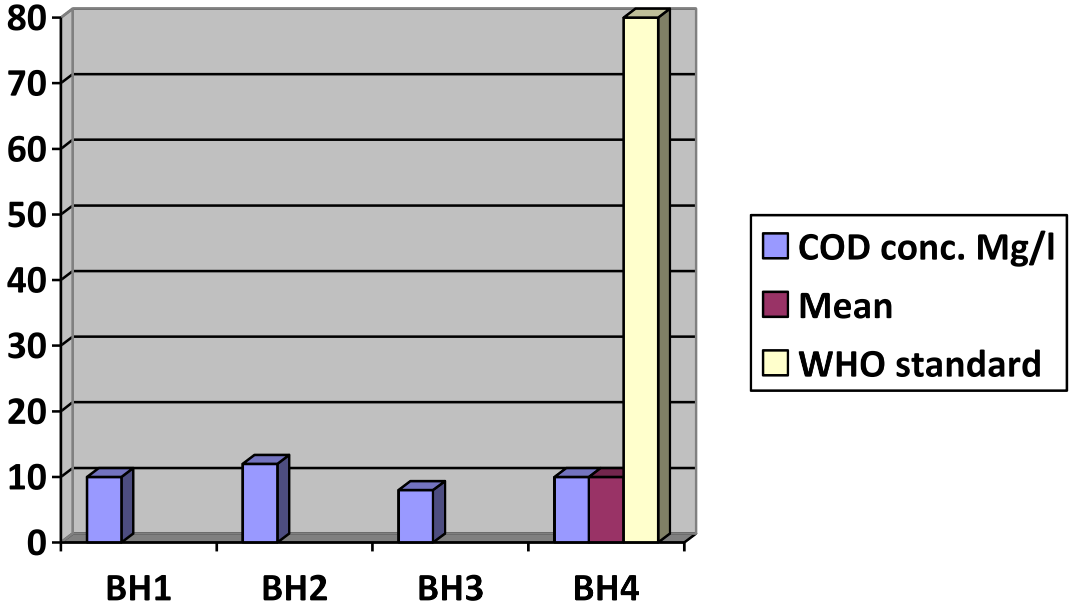


Figure: 4.8(a) COD in mg/l of the boreholes

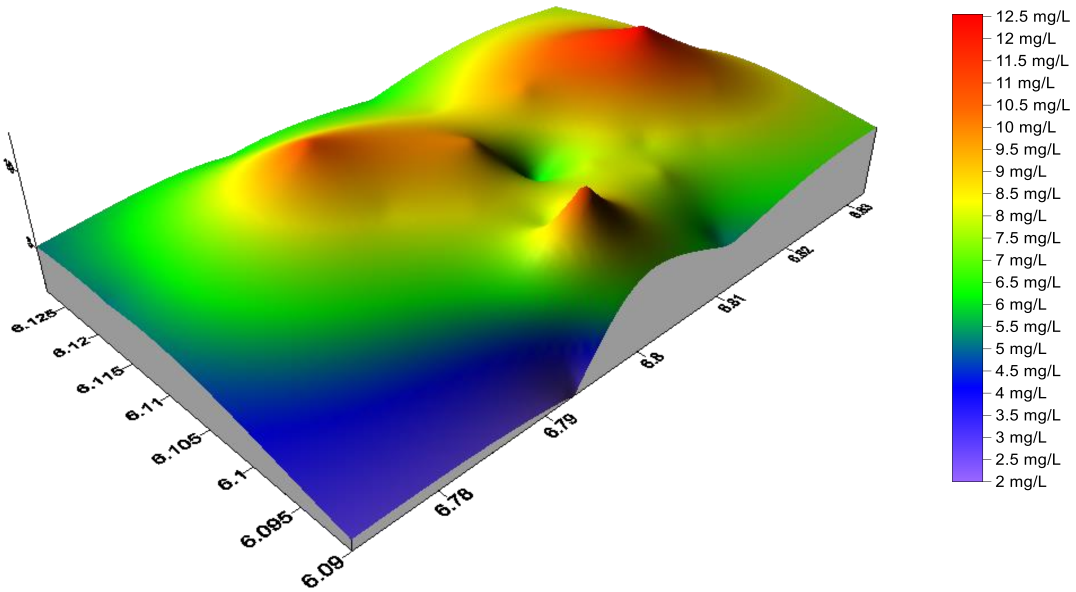


Figure: 4.8(b) 3-D model of COD values in the study area

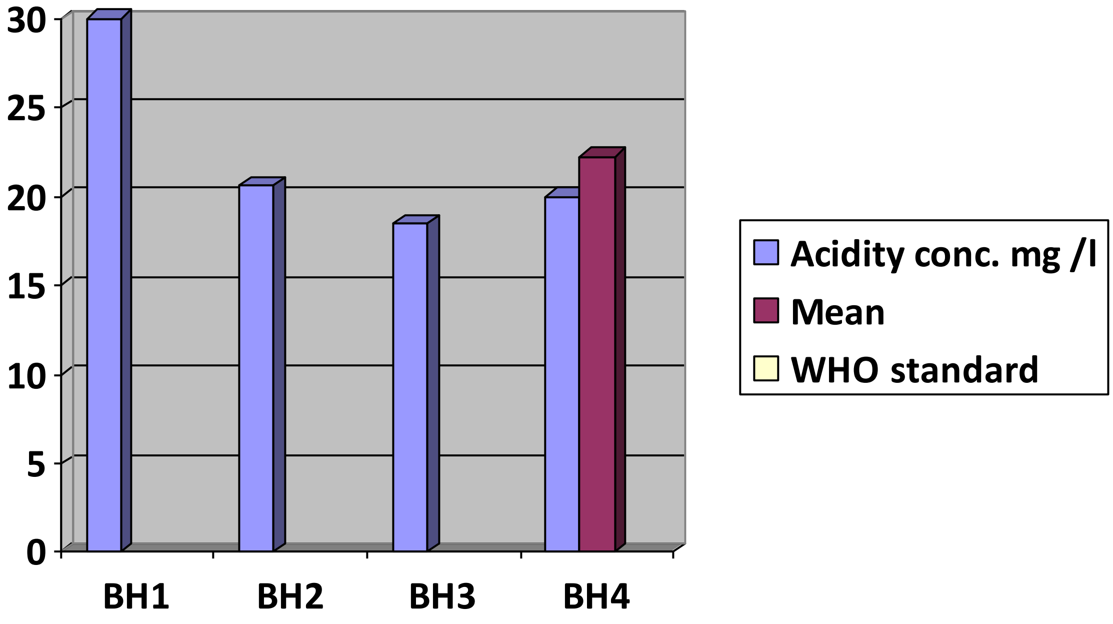


Figure: 4.9(a) Acidity of the boreholes

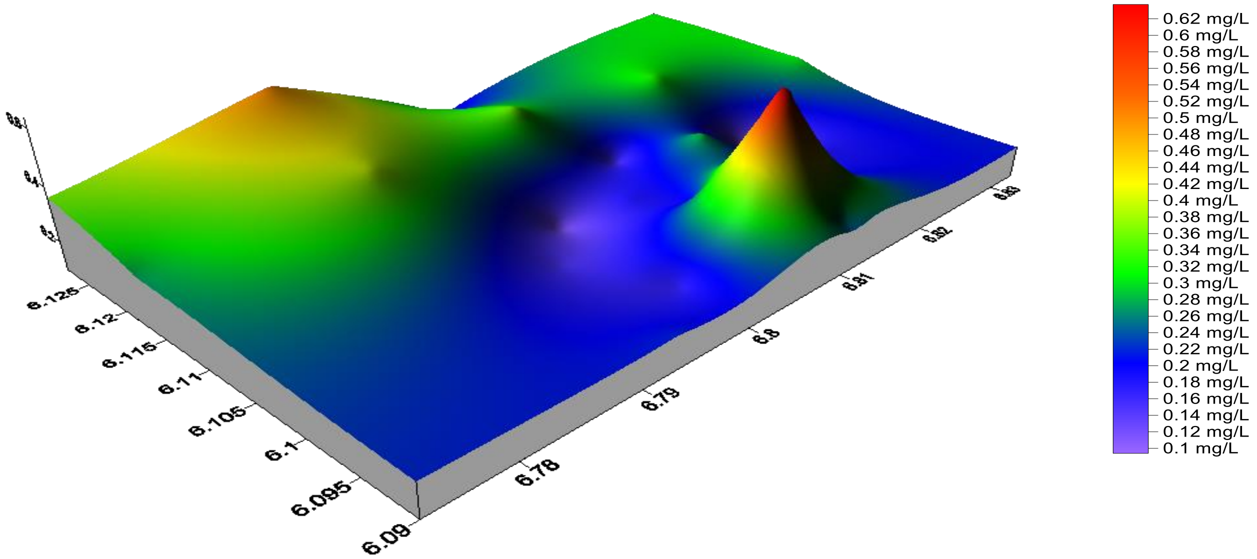


Figure: 4.9(b) 3-D model of Acidity values in the study area

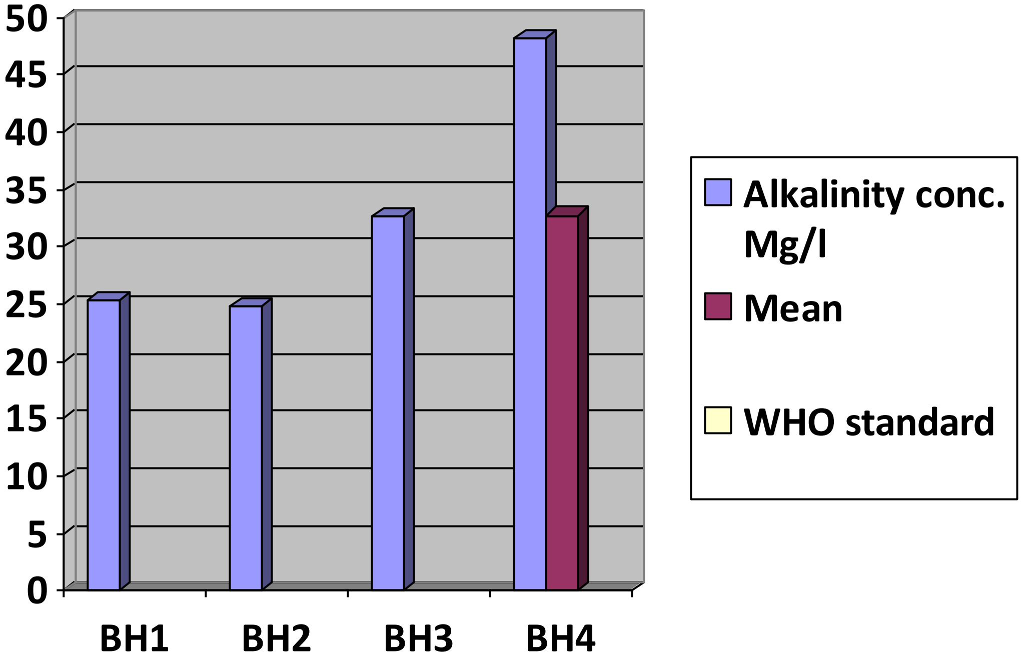


Fig:4.10(a) Alkalinity of the boreholes

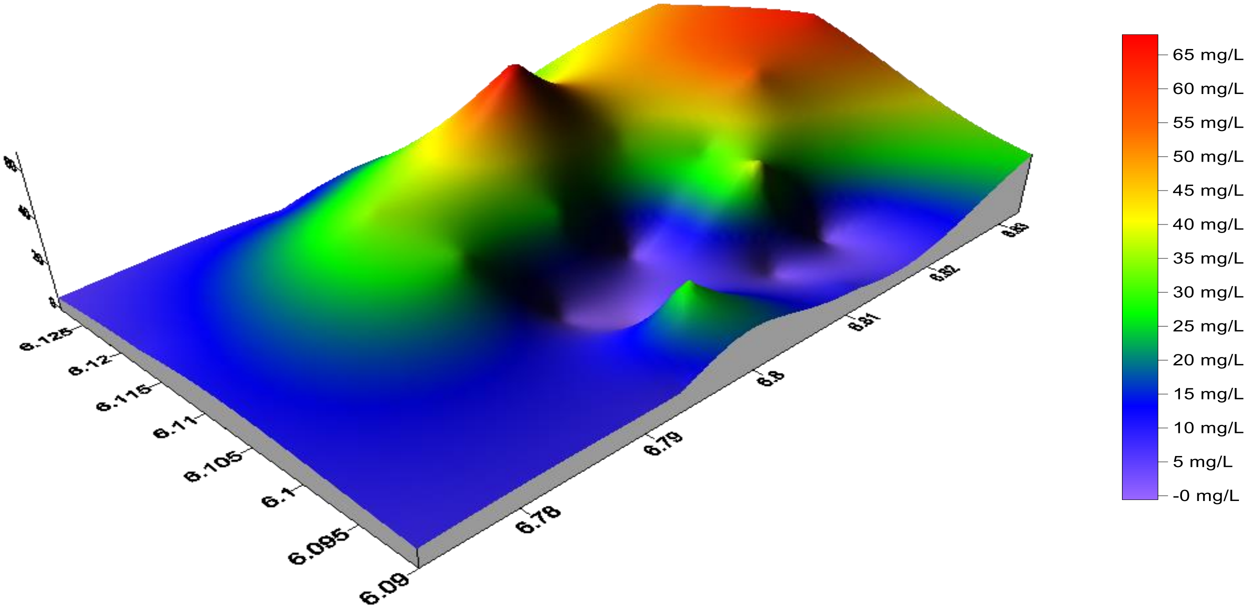


Figure: 4.10(b) 3-D model of Alkalinity values in the study area

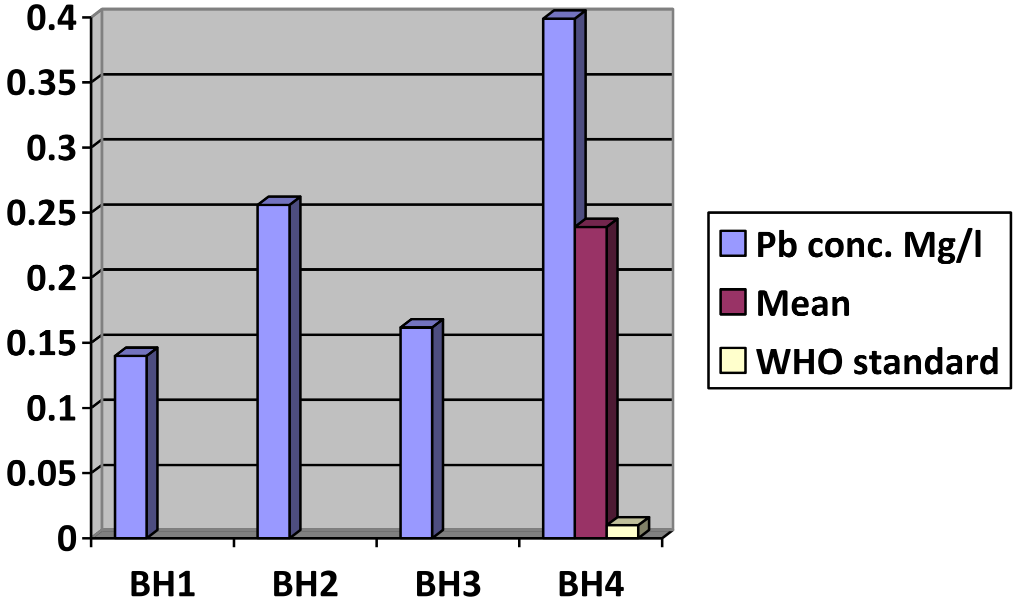


Figure:4.11(a) Pb concentration of the boreholes

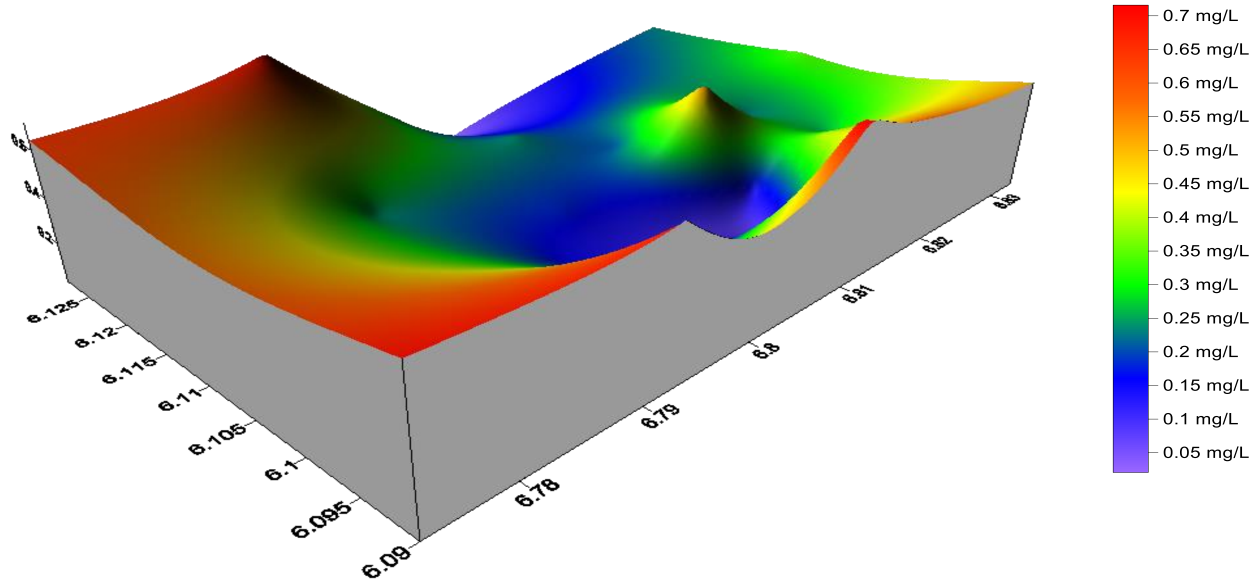


Figure:4.11(b) 3-D model of Lead values in the study area

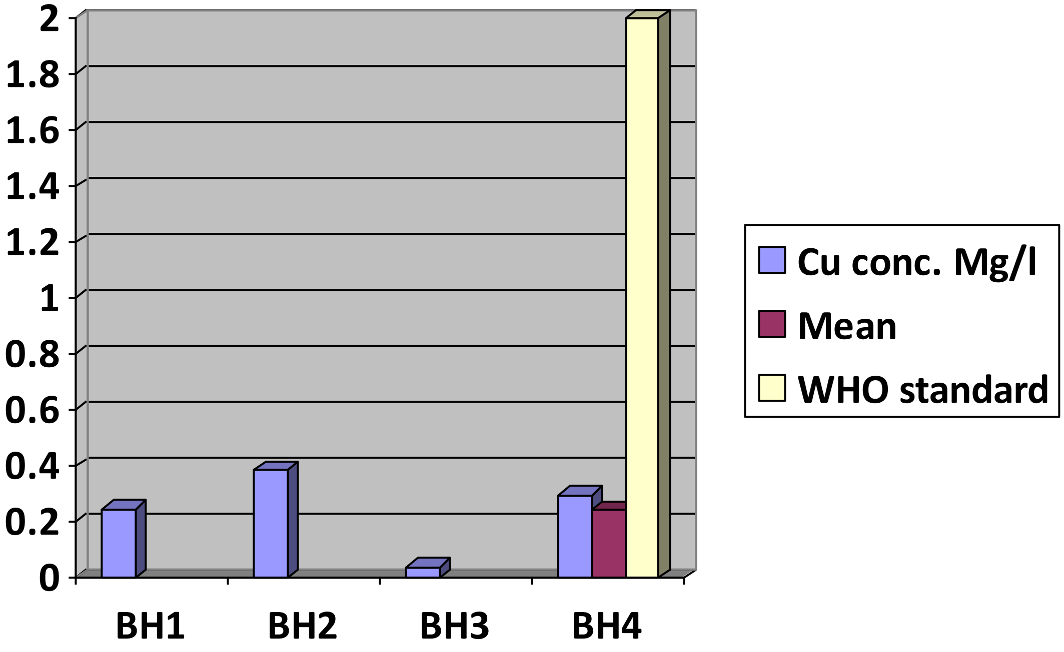


Figure: 4.12(a) Cu concentration of the boreholes

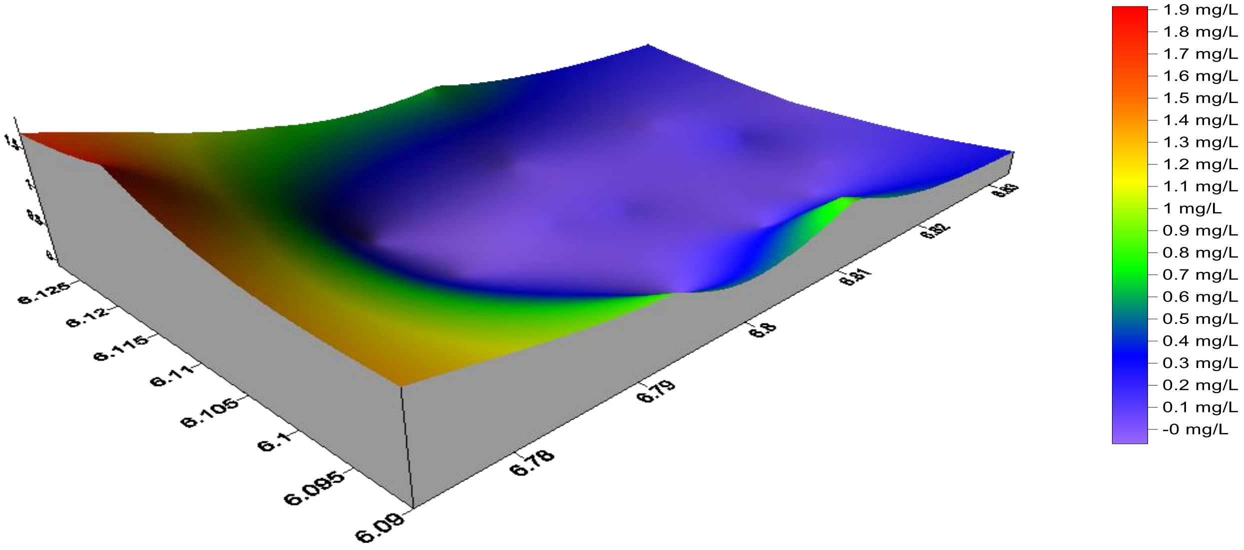


Figure: 4.12(b) 3-D model of Copper values in the study area

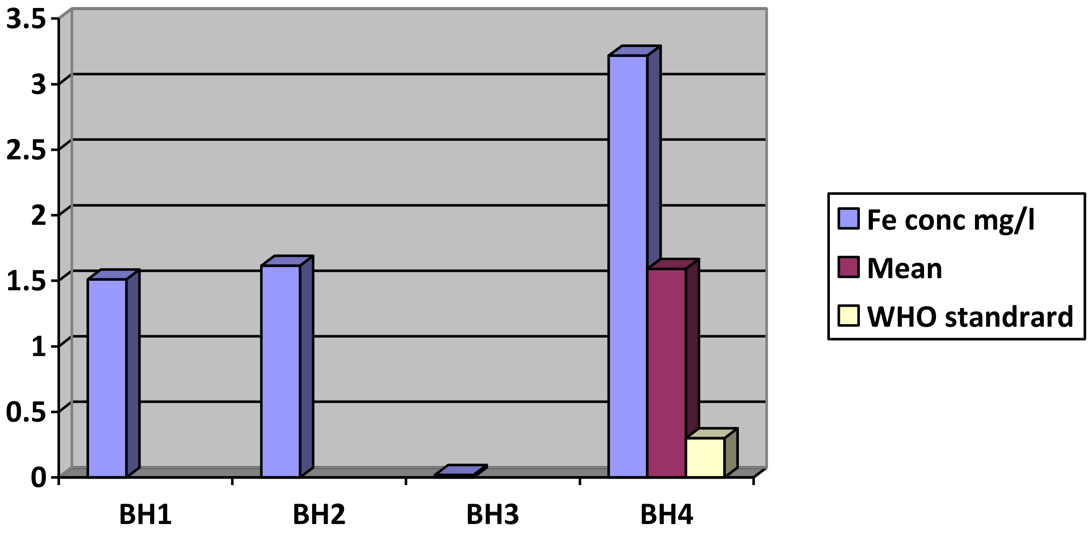


Figure: 4.13(a) Fe concentration of the boreholes

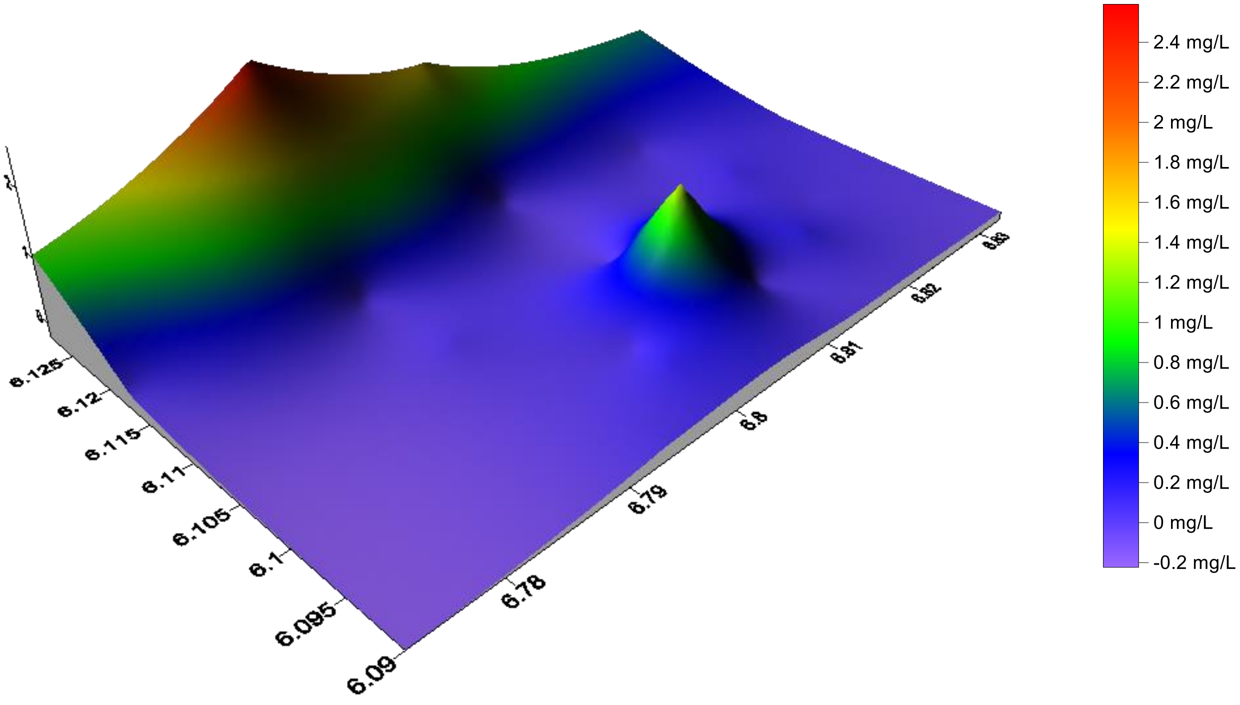


Figure: 4.13(b) 3-D model of Iron values in the study area

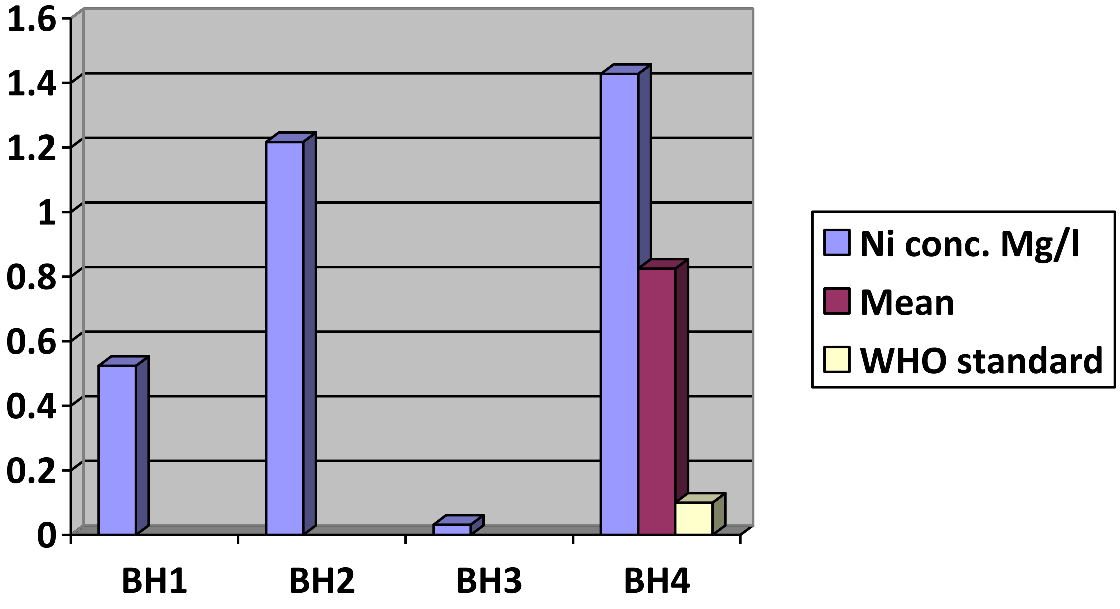


Figure: 4.14(a) Ni concentration of the boreholes

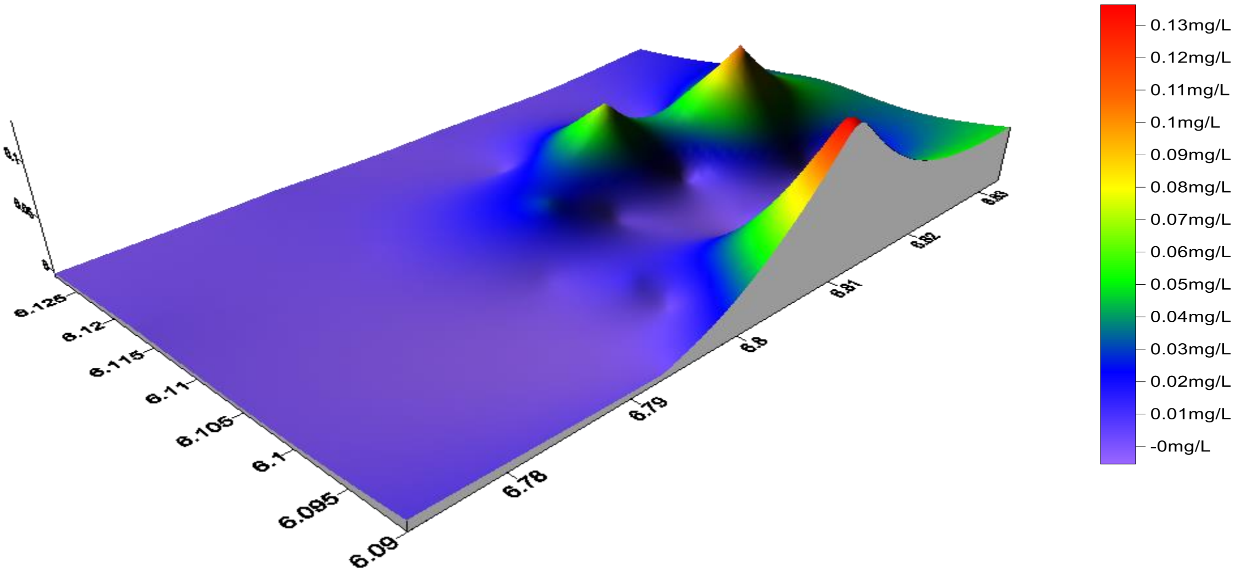


Figure: 4.14(b) 3-D model of Nickel values in the study area

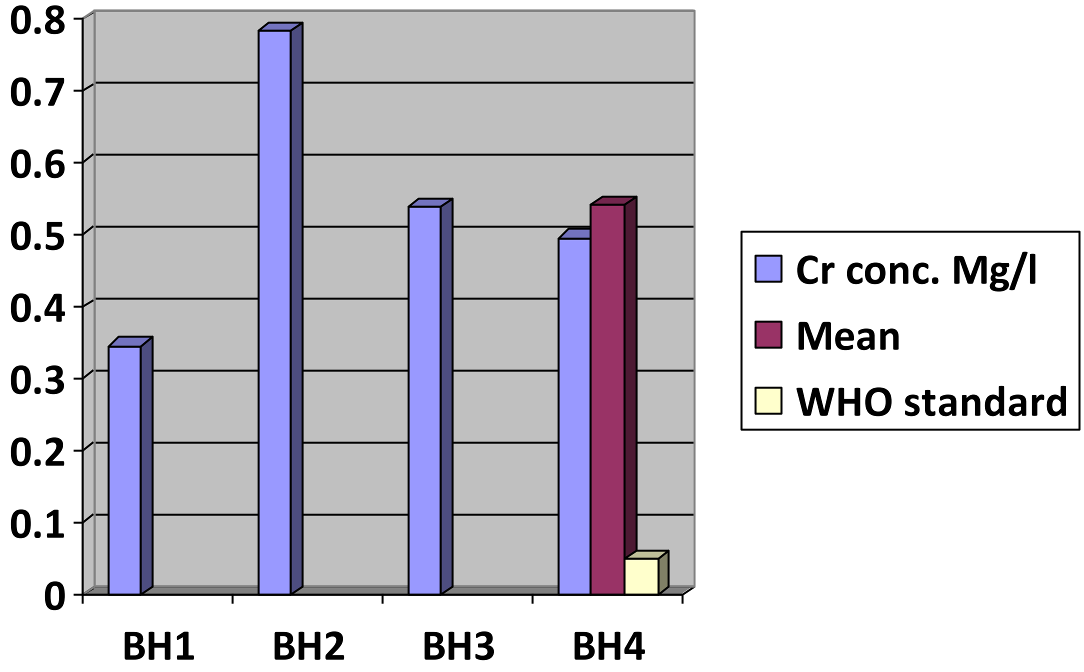


Figure: 4.15(a) Cr concentration of the boreholes

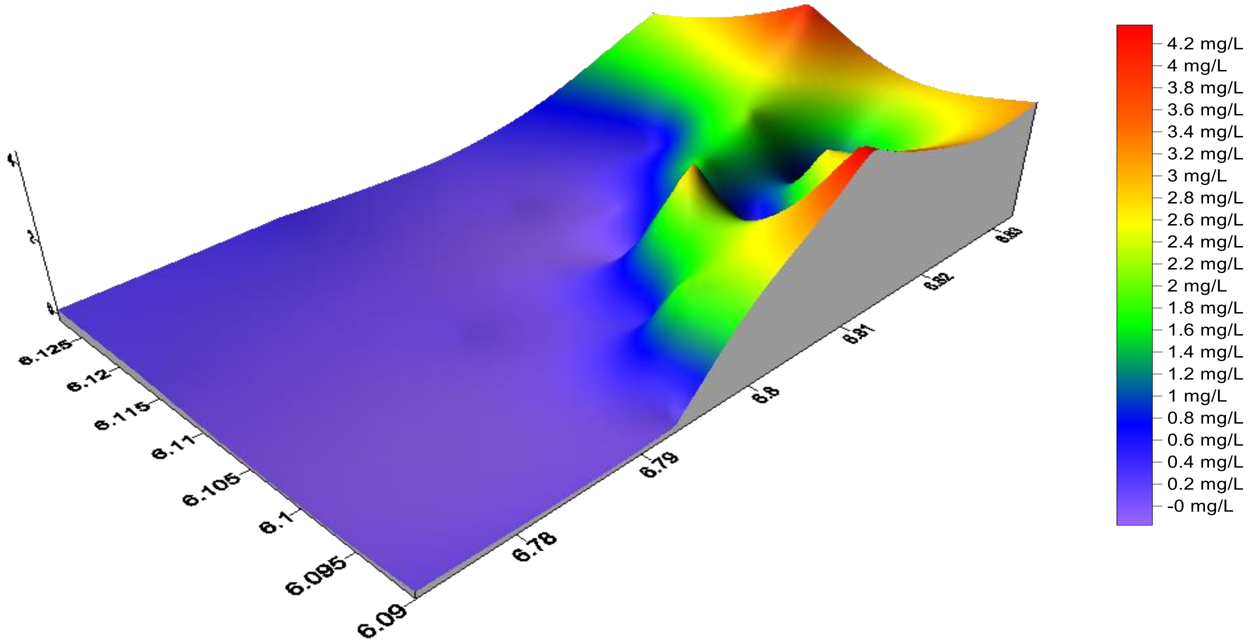
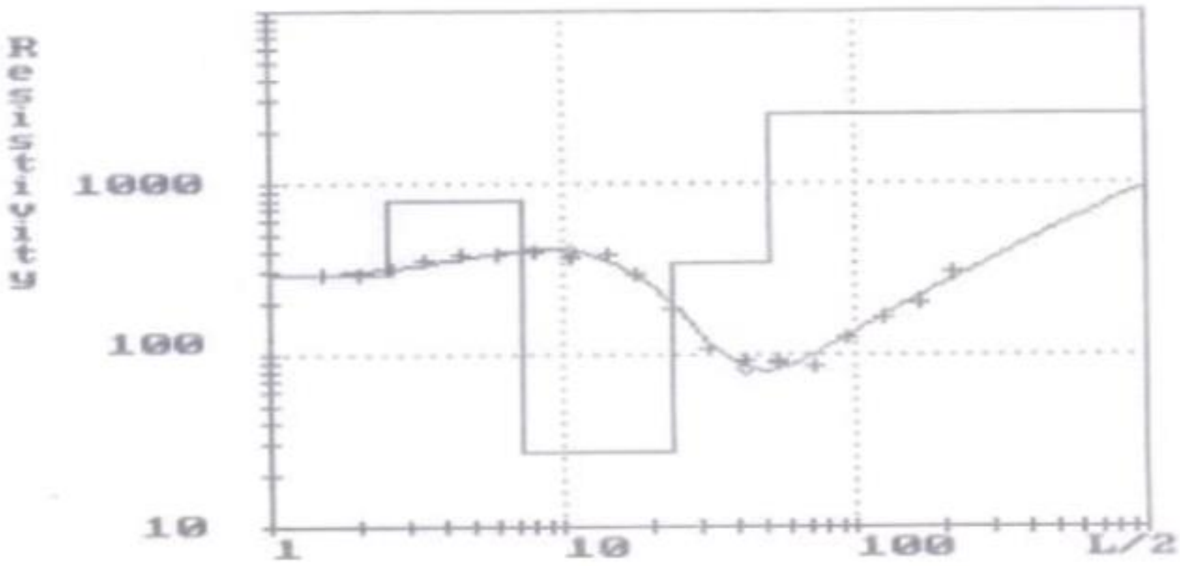


Figure: 4.15(b) 3-D model of Chromium values in the study area



Resistivity (Ohm.m)	Depth (m)
290.0	2.5
790.0	7.2
27.2	23.8
346.0	51.0
2500.0	

Figure 4.16 **VES data collected from the site.**

Source: Nwagbara et al 2012 (electrical resistivity study for vulnerability of groundwater pollution).

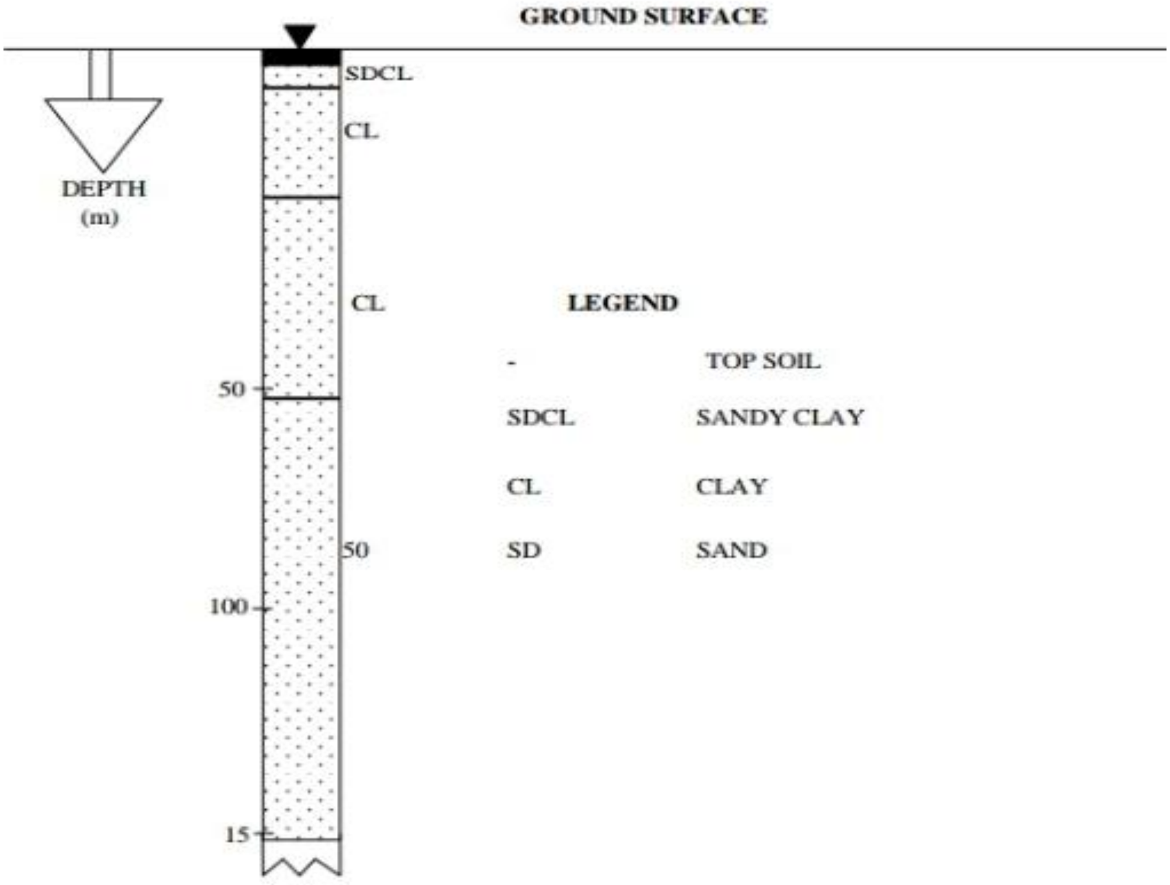


Figure. 4.17: typical geoelectric section (semiconfined aquifer) of Nekede VES spot within the study area.

Source: Nwagbara et al 2012.

4.2 DISCUSSION

Table 4.1 shows that metals constituted the major bulk of wastes (36.66%) in the waste dump while paper constituted the least (0.10%) on mass basis. This result implies that the possibility of metals contaminant of groundwater around the waste dump is very high and could pose a threat of metal pollution to the aquifers.

The VES data of the study area shows that the thickness values of the aquifers vary from 35m to 183m and the aquifer resistivity values ranged from 1000Ωm to 5850Ωm. The aquifer map suggests sandy nature from top to bottom which is an unconfined/semi unconfined aquifers with layers of clay of 3.3m to 5.9m thickness (Nwagbara et al, 2012). This formation is highly vulnerable to groundwater pollution occasioned by high rate of leachate infiltration.

The pH of the borehole water sampled were slightly acidic. This pH condition could encourage high mobility and bioavailability of heavy metals in the groundwater leading to obvious toxic effects to organisms. Furthermore, low pH in water encourages corrosion of metallic installations.

The Electrical Conductivity (EC), is a measure of ionic activity in the water. Its values ranged between 24-490µscm^{-}1 in the boreholes samples. BH1 recorded the highest conductivity value 490 µscm^{-}1 which is above the WHO standard for a portable water. This points to an elevated value of dissolved ions in the water.

The Total Dissolved Solid (TDS) values are within the acceptable range of WHO standard except in BH1 with the value of 245mg/l. this value conforms with the observed high levels of conductivity and pH in the same water sample.

Furthermore, Total Suspended Solid in the four (4) sampled boreholes were within the WHO acceptable level.

The Biochemical Oxygen Demand (BOD) of the borehole samples were above the WHO regulatory standard. High BOD in water bodies affect the amount of dissolved oxygen and spells doom for aquatic lives.

Lead (Pb), Iron (Fe), Nickel (Ni), and Chronuim (Cr) were all found to be above the WHO regulatory limits. These results suggest a possible pollutant input from the waste dump.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

The waste classification of Nekede waste dump revealed that the predominant waste types were paper, food, metals, nylon, glass, wood and other waste. It also shows that Nekede dumpsite has unconfined or semi-unconfined aquifer system because of its thin layers of clay and low thickness as a result of dead organic matters decomposing on the top of the sands and infiltration of heavy metals from the dumpsite making the aquifer porous and permeable to high concentration of contaminates and making the groundwater vulnerable to pollution. BH1 recorded the lowest pH which makes it acidic base on that, the conductivity and total dissolved solids were also high. The four (4) boreholes were contaminated with lead (Pb), iron (Fe), Nickel (Ni) and Chromuim (Cr) as a result of leachate seepage from the waste into the groundwater of the study area especially in BH4 except for Copper (Cu) which is in low concentration in the boreholes.

5.2 RECOMMENDATION

There should be regular groundwater quality evaluation and monitoring and effective strategies for ensuring that WHO standards are maintained for every borehole.

However, indiscriminate drilling of boreholes should be checked and regulated in order to protect the public from infiltration of contaminants from poor handling of waste and unsanitary dumpsites; besides, regulators should ensure that WHO standard are maintained and other governmental regulations are observed in order to maintain good boreholes for human consumption.

The use of sanitary landfills free of environmental pollution and public health risks associated with open waste dumping should be adopted.

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