EFFECTS OF LANDFILL SITES ON GROUNDWATER QUALITY IN IGANDO, ALIMOSHO LOCALGOVERNMENT AREA, LAGOS STATE

by

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Ms. Ifeoma J. Oyiboka

DEDICATION

This work is dedicated to God Almighty, my beloved husband and loving family.

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ABSTRACT

With increasing population comes the concern for waste disposal. The absence of sanitary disposal methods has left most city residents with open landfills as their only source of waste disposal. The resulting leachate formed from the decomposition of these waste materials is highly polluting and finds its way to the underground water supply. The study investigated the effects of open landfill sites on the underground water quality by examining the physical and chemical properties of underground water in hand-dug wells around the Solous landfill sites in Igando, Alimosho Local Government Area of Lagos State. Solous landfill is the second largest landfill by landmass and volume of waste in Lagos State.

Systematic random sampling was used for data gathering. Eighteen hand-dug wells were sampled at increasing distances from the landfill site. Physical, chemical and microbiological parameters were analysed at the Lagos State Environmental Protection Agency (LASEPA). Soil samples were also taken from both the A (0 – 30cm) and B (30 – 60cm) horizons of the water sampling points to determine the soil texture (silt, clay and loamy composition) and to show the impact of soil texture on ground water quality within the sampled area. The level of contamination of groundwater was also determined using the Contamination Index method.

The results showed high degree of conformance with W.H.O standard with respect to the microbiological properties of the sampled groundwater. However, coliform tests indicated the potential presence of pathogens. Of the seven (7) physical parameters tested, conductivity was higher in one sample. The study of chemical properties from the eighteen wells showed five (5) parameters (dissolved oxygen, total alkalinity, iron, lead, nitrates and copper) above W.H.O limits in some samples. The water may therefore not be safe for human consumption and there is a serious need to monitor the groundwater quality in the area.

The level of contamination of groundwater was also determined using the Contamination Index method. Areas of high and medium contamination were discovered. There was no area with low contamination level in the area sampled. Contamination levels were mapped to show the exact levels of contamination in the study area. The results of the soil analysis showed that the study area had soil that was mostly sandy in nature which may suggest an increase in parameters over time with significant health implications for the people who depend on surrounding wells for domestic use. The study also showed no significant variation in water quality with increasing distance from the dump site. Findings also indicated that the water around Solous 1 was of better quality for domestic use than groundwater around Solous 2 and 3 due to temporal reduction of contaminant concentration.

There is therefore a need for adequate and proper planning, design and construction, and strategic management disposal of waste, as well as the implementation of a better sustainable environmental sanitation practice.

Key terms:

Landfill; Biodegradable; Contamination Index; Infiltration; Leachate; Physico-chemical; Sanitary; Groundwater; Borehole

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GLOSSARY

Acronyms	Definition
APHA	American Public Health Association
LASEPA	Lagos State Environmental Protection Agency
LAWMA	Lagos State Waste Management Authority
NIS	Nigerian Industrial Standard
NPC	National Population Commission
NSDWQ	Nigerian Standard for Drinking Water Quality
WHO	World Health Organisation
WQI	Water Quality Index
U.S. EPA	United States Environmental Protection Agency
U.S.G.S	United State Geological Survey

CHAPTER ONE

BACKGROUND TO THE STUDY

1.1 Introduction

Water is the most abundant environmental resource on earth but its accessibility is based on quality and quantity, as well as space and time. It may be available in various forms and quantity but its use for various purposes is the subject of quality. About 70% of the human body and about 60-70% of plant cells is made up of water (Smith and Edger, 2006). It is one of the determinants of human settlement, existence and activities on the earth. Its quantity is fixed but dynamic in formation and storage. Of all the environmental concerns that developing countries face, the lack of adequate, good quality water remains the most serious (Markandya, 2004). Once contaminated, groundwater may forever remain polluted without remedy or treatment. Water is one of the determinants of human earth system. Diseases may spring up through water pollution, especially groundwater contamination, and rapidly spread beyond human expectation because of its flow mechanism (Afolayan *et al.*, 2012). One of the major factors that make the earth habitable for humans is the presence of water. Forming the major component of plant and animal cells, it is the basis of life and therefore the development of water resources is an important component in the integrated development of any area.

Water is critical to our daily lives and is an extraordinary compound in nature. It covers 71% of Earth (USGS, 2014). Water is the most important resource of a country, and of the entire society, since no life is possible without water. It has this unique position among other natural resources, because a country can survive in the absence of any other resource, except water (Garg, 2009). According to the National Water Policy (2002), in the planning and operation of systems, water allocation priorities should be broadly as follows: drinking, irrigation, hydropower, ecology, agro-industries and non-agricultural industries, navigation and other uses.

About 68.7% of the fresh water is tied up in polar ice caps and glaciers, and a further 30.1% is underground as groundwater, most of which is not available for use (Gleick, 1996). Rivers and lakes constitute a mere 0.32%, atmospheric moisture 0.03% and soil moisture 0.05%.The major sources of water are surface water (oceans, rivers, streams, seas and brooks), groundwater, snow and ice, and lakes. However their exploration and exploitation varies from place to place based on their state of existence. Groundwater plays a vital role for urban and agricultural water supply. It accounts for about 0.5% of total hydrosphere, approximately 6.73 x10km^3 in volume (Ayoade, 2003). It constitutes a major portion of the earth's water circulatory system known as hydrological cycle and occurs in permeable geologic formation known as aquifers i.e. formations having structure that can store and transmit water at rates fast enough to supply reasonable amounts to wells (Afolayan *et al.*, 2012).

Wastes of different types, mostly solid wastes are the major input of dumpsites/landfills. With respect to the hydrological analysis of groundwater, it flows from areas of higher topography towards areas of lower topography, thereby bringing about the examination of the degradable material which form leachate and contaminate the groundwater of the study area.

Landfill practice is the disposal of solid wastes by infilling depressions on land. The depressions into which solid wastes are often dumped include valleys (abandoned) sites of quarries, excavations, or sometimes a selected portion within the residential and commercial areas in many urban settlements where the capacity to collect, process, dispose of, or re-use solid waste in a cost-efficient, safe manner is often limited. The practice of landfill system as a method of waste disposal in many developing countries is usually far from standard recommendations (Mull, 2005; Adewole, 2009; Eludoyin & Oyeku, 2010). A standardized landfill system involves carefully selected location, and is usually constructed and maintained by means of engineering techniques, ensuring minimized pollution of air, water and soil and risks to man and animals. It involves placing waste in lined pit or a mound (Sanitary landfills) with appropriate means of leachate and landfill gas control (Alloway & Ayres 1997; Eludoyin & Oyeku 2010). Land filling of municipal solid waste is a common waste management practice and one of the cheapest methods for organized waste management in many parts of the world (El-Fadel *et al.*, 1997; Jhamanani *et al.*, 2009; Longe & Balogun, 2010). Increasing urbanization results in an increased generation of waste materials and landfills become the most convenient way of disposal. Most of these landfills are mere 'holes in the ground" do not qualify as sanitary means of solid waste disposal. Most of the areas around the Solous dumpsites depend either on dug-up wells or bore-holes which may likely be affected by the generated leachate through waste decomposition from the dumpsites despite the provision of pipe-borne water by government. According to Papadopoulou *et al.* 2007, as the natural environment can no longer digest the produced wastes, the development of solid waste management has contributed to their automated collection, treatment and disposal. One of the most common waste disposal methods is landfilling, a controlled method of disposing solid wastes on land with the dual purpose of eliminating public health and environmental hazards and minimizing nuisances without contaminating surface or subsurface water resource.

There are three major landfills and two temporary landfill sites serving the area of Lagos State. The Olushosun landfill site is the largest, situated in the Northern part of Lagos within Ikeja Local Government Area, and receives approximately 40% of total waste deposits from Lagos (LAWMA, 2011).

The Solous landfills, I, II and III, may be regarded as the second most functional landfill in Lagos State after the Olusosun landfill in Ketu. This is because of its location within the largest Local Government Area of the State. For the teeming population of the surrounding community, groundwater is the major source of water supply. Despite the provision of pipe-borne public water by Lagos State Water Cooperation mini water works, some households still prefer their personal wells and bore holes. Owing to this fact, the possibility of the generated leachate affecting the hydrology of the area deserves proper investigation through experimental analysis.

1.2 Research Problems

Landfills have served many years as ultimate disposal site for all types of waste; municipal solid waste, industrial sewage and hazardous waste. Physical, chemical and biological processes interact simultaneously to bring about the overall decomposition of the wastes. One of the by-products of this mechanism is chemically laden leachate. Leachate is produced by the action of rainwater aiding bacteria in the process of decomposition. Leachate is typically composed of dissolved organic matter, inorganic macro components (such as chlorides, iron, aluminum, zinc and ammonia), heavy metals and xenobiotic organic compounds such as halogenated organics. Other chemicals including pesticides, solvents and heavy metals may also be present. Leachates are a potential hazardous waste from landfill sites. If not dealt with properly they can cause pollution to groundwater, health problems and affect the environment. It is therefore important that leachates are treated and contained to prevent these occurrences (Kostova, 2006).

The city of Lagos with its teeming population has less than 50 Water Supply Boards to cater to it in terms of water treatment and distribution. It therefore relies rely mostly on bore holes and hand dug wells for its water needs. The major environmental problem experienced around the Solous landfill areas is the contamination of groundwater via discharged leachate. Areas near landfills have great possibility of groundwater contamination because of the potential pollution source of leachate originating from the nearby site. Such contamination of groundwater resource poses a substantial risk to local resource users and to the natural environment. The impact of landfill leachate on the surface and groundwater has given rise to a number of studies in recent years (Mor *et al.,* 2006). It is therefore important to study the water quality in areas especially those around these landfill sites to examine its impact on groundwater quality.

1.3 Justification of the Study

Seasonality is the first criteria of the period of this research work because it plays prominent role in waste degradation and groundwater migration. Similar studies have also been carried out in the past during the rainy season and this study monitors the sites to compare results over time. This serves as the basis of the fieldwork being carried out in August, 2011 unlike either during the dry season when there is no water ingression or during the excess rainfall which can easily dilute and reduce parameter concentration. The study will also recommend measures with which local authorities can continue to reduce pollutant levels over time. The selected variables were based on their long life span and being the common pollutants within the landfill, as well as their degree of concentration in relation to groundwater migration. They have been regarded as being responsible for various health problems, being non-biodegradable, as well as their possibility of accumulation in the food web. Despite the provision of pipe borne water by state government in areas of the landfill, people still rely more on their dug-up wells which are easily contaminated through seepage. Low literacy levels may have influenced their choice of preference for dug-up wells. Some physical parameters like taste, colour and odour are the main indicators of water pollution to the people without taking into consideration the other physical, chemical and biological variables of water.

1.4 Hypotheses

H_0: There is no significant relationship between the location of the dumpsite and groundwater quality.

H_1: There is a significant relationship between the location of the dumpsite and groundwater quality.

H_0: There is no significant relationship between distance from dumpsite and ground water quality.

H_1: There is a significant relationship between distance from dumpsite and ground water quality.

H_o: There is no significant difference in the quality of a water sample in the area compared with the water quality standard of the World Health organization.

H_1: There is a significant difference in the quality of a water sample in the area compared with the water quality standard of the World Health organization.

1.5 Aim and Objectives

The aim of the research is to examine the effect of the location of dumpsites on the underground water quality in Igando, Alimosho Local Government Area of Lagos State. The study will particularly:

- Examine the effect of distance from dumpsite on the physical, chemical and heavy metal properties of sampled groundwater.
- Determine and map the extent of contamination in the study area.
- Determine the effect of soil physical properties on the ground water quality in the study area.
- Examine if there is variation in water quality among sampled groundwater sources
- Compare the difference in the quality of sampled water with WHO and NSDWQ water quality standards.

1.6 Limitation of the Study

Assessing the variability in leachate composition and leachate migration from old landfills needs an integrated approach. Historical information (including old maps, aerial photographs, interviews, etc.) creates a valuable basis for understanding the variability. Also, information on the hydrology of the dumpsite and the adjacent part of the polluted aquifer is needed. Detailed information of the site like depth could not be extracted from the appropriate authority due to the fact that the sites were not originally planned and designed for the purpose of waste management. As a result of proximity of the examined dumpsites, there were problems of spatial boundary location. The Solous dumpsites are interconnected and to establish surface hydrological boundary in between them posed a very serious task. However, surface delineation of landfill areas may not coincide with the underground water basin. Most of the inhabitants refused to cooperate due to their suspicion that the researcher was an agent to State Government set out to expose their non-compliance with the instructions of the Lagos State Water Corporation.

The lack of standard laboratories as well as the high cost of testing each sample affected the number of samples tested. A long distance was travelled to avail the services of the Lagos State Environmental Protection Agency to test the water samples and soil samples were tested out of state resulting in additional transport costs. Period of observation, that is rainy season, might also checkmate the results from the parameters.

1.7 Definition of Terms

Aerobic: Waste decomposition in oxygen-present environment.

Anaerobic: Waste decomposition in oxygen-absent environment.

Biodegradable: Able to be broken down by natural biological processes.

Dumpsites: Also known as traditional landfills are excavated pieces of land or pits where waste materials are stored.

Groundwater: Water that infiltrates and is stored in the spaces between particles in the earth.

Hydraulic head: Measurement of liquid pressure used to determine the hydraulic gradient between two or more points

Infiltration. This is the process of water movement from soil surface into the other soil layers.

Landfill: An old and easiest method of waste disposal that involves burying the waste in specially constructed sites.

Leachate: Contaminant-laden water that flows from landfills or other contaminated sites.

Physico-chemical: Combination of both physical and chemical parameters.

Percolation: The process by which water permeates the soil or porous rock into the subsurface environment.

Plume: The column of effluent moving through water

Sanitary landfill: A designed and engineered method of disposing of solid wastes to reduce groundwater pollution.

Scavenger: A person who sifts through refuse to collect items perceived to be useful

CHAPTER TWO

LITERATURE REVIEW

2.1 Sustainable Water Development

The earth's water cycle links the planet's fresh water and oceans. About 70% of human body is made up of water and about 60-70% of plant cell (Smith and Edger, 2006). 97% of the earth's water is in the ocean and the ocean supplies almost all the water that falls on land as rain and snow. Of the small portion that is freshwater, about a third is groundwater and a mere 0.3% in accessible surface waters (Gleick, 1996).

Water contamination either natural or anthropogenic is the major problem of water especially in developing countries. Once contaminated, water, especially groundwater may remain polluted without remedy or treatment. Water in its liquid form is the material that makes life possible on Earth. All living organisms are composed of cells that contain at least 60% of water (Jackson, 1985). It is the basis of life and therefore the development of water resources is an important component in the integrated development of any area.

Water is critical to our daily lives and is an extraordinary compound in nature. Water is the most important resource of a country, and indeed society, since no life is possible without water. It has this unique position among other natural resources, because a country can survive in the absence of any other resources, except water (Garg, 2009). According to the National Water Policy (2002), in the planning and operation of systems, water allocation priorities should be broadly as follows: drinking, irrigation, hydropower, ecology, agro-industries and non-agricultural industries, navigation and other uses.

Water occurs naturally in various location and forms in the earth-atmosphere system, in liquid, solid as well as gaseous form. It occurs in the atmosphere mainly as vapour (gaseous), and as gas, solid or liquid on and beneath the earth surface. It is continually changing in three state of matter such as liquid to solid (freezing), liquid to gas (evaporation), gas to liquid (condensation). The total global water in liquid and gaseous forms is about 1360×10^{6} km^{3} of which only 2.8% is fresh water. About 75% of this fresh water is tied up in polar ice cap and glacier and a further 25% is underground as groundwater, most of which is not available for use. Rivers and lakes constitute a mere 0.32%, atmospheric moisture 0.03% and soil moisture 0.05% (Gleick, 1996). Therefore, the major sources of water are surface water (oceans, rivers, streams, seas and brooks), groundwater, snow and ice, and lake. Overexploitation of both surface and groundwater has been the result of rapid urbanization, population growth and development. Urban areas within Igando in Alimosho Local Government Area are characterized by different water sources with the most common source being bore-holes and wells. Over 75% of houses within this area have a well as their main source of water. Level of economic development influences the consumption rate of water in any society. Areas with a higher level of economic development would require more water for industrial and agricultural uses. A sustainable water supply network covers all the activities related to the provision of potable water.

Sustainable development is of increasing importance for the water supply to urban areas as water shortages are expected in the near future. To achieve sustainable water supply, raise awareness on the issue of environmental pollution as well as the need to develop new sources of water. However, various water management strategies have been adopted in developed even in developing countries. The idea of water treatment is very common in developing countries of Africa.

Groundwater quality comprises of the physical, chemical and biological properties. Temperature, colour, taste, turbidity and odour make up the list of physical water quality parameters (Harter, 2003). Examples of water chemical properties include: alkalinity, acidity, pH and total hardness. More attention is focused on chemical and biological quality since groundwater within Igando is tasteless, odourless and colourless. Increase in population and subsequent unplanned urbanization in Lagos has resulted in environmental conditions with groundwater being impacted by disposal resulting from domestic and industrial activities. Landfills have historically been the primary method of waste disposal because this method is the most convenient and because the threat of groundwater contamination was not initially recognized (Smith & Edger, 2006). The major environmental problem experienced around the landfill is the subsequent contamination of groundwater via discharged leachate (Afolayan *et al*., 2012). Groundwater recharge is the replenishment of an aquifer with water from the land surface (Bhattacharya, 2010). When groundwater becomes polluted, the risk of surface water contamination also increases due to the interconnectivity between groundwater and surface water. Landfills have served many years as ultimate disposal site for all types of waste; municipal solid waste, industrial sewage and hazardous waste. Modern landfills have liners at the base, which act as barriers to leachate migration. However, it is widely acknowledged that such liners deteriorate over time and ultimately fail to prevent the movement of leachate into an aquifer (Jagloo, 2002). Physical, chemical and biological processes interact simultaneously to bring about the overall decomposition of the wastes. One of the by-products of this interaction is chemically laden leachate. Although, it can take years before ground water pollution reveals itself, the chemical in the leachates often react in unanticipated ways to affect the ecosystem at large.

Landfill may be analyzed as a closed and open system. Either in engineered or ordinary landfill and dumpsite, waste of different nature serves as input and leachate as output. Through leachate plume and migration, past eradicated diseases may outbreak over time due to the degradation of buried wastes that initially caused such diseases. Without adequate and proper waste management, health related problems would be recurring, such as in the form of seasonal shedding and sprouting of a deciduous forest (Joseph *et al.*, 2006; LAWMA, 2010).

The quality of surface water within a region is governed by both natural processes (such as precipitation rate, weathering processes and soil erosion) and anthropogenic effects (such as urban, industrial and agricultural activities and the human exploitation of water resources). Jarvie *et al* 1998; Liao *et al.*, 2007; Mahvi *et al.*, 2005; Nouri *et al.*, 2008; Pejman *et al.*, 2009). According to Kholoud *et al.* (2009) heavy metals are good indicators of contamination in urban soils and street dust. They appear in gasoline car components, oil lubricants, industrial, incinerator emissions, and municipal wastewater discharge. Contamination with heavy metals is of major concern because of their toxicity and threat to human life and the environment. Children living in urban areas are at a higher risk of exposure due to unintentional hand-mouth interaction while playing in the city streets.

2.2 Differences between Landfills and Dumpsites

A sanitary landfill is an engineered system while a dump is a random site that allows the collection of waste. In most cases, construction of sanitary landfills do occur where groundwater and runoff is not the problem. Local municipalities and residents must be considered. Avoidance of burning, well trained staff and modern equipment must be provided.

According to Emelda (2011) waste disposal is one of the biggest problems that the world is facing. In man's everyday life, he produces waste materials which, if not properly managed, can lead to health and environmental problems. Governments are faced with finding the most effective waste disposal and management systems to use. A few decades ago when the human population was not as large as it is today, waste disposal was easily managed. People used dumps which are excavated pieces of land or pits where waste materials are stored. Most households, especially those in rural areas, have dumps while urban communities have a common dump for their residents. Dumps are not regulated by the government and they lack processing control. They can be found anywhere and may or not be covered with soil. They are also not monitored and the chances of the liquid produced by solid waste contaminating the water supply are great.

Open dumps can attract pests such as flies and rats and emit bad odours which are hazardous to man. Because of this, dumps are considered illegal and have since been replaced with landfills. Communal dumps have been converted to landfills which are regulated by the government.

The ideal landfill is one which is confined to a small area and is covered with layers of soil. It is also required to have a liner at the bottom of the pit to prevent leachate or the liquid from solid waste to seep through and contaminate the water supply.

Additionally, a landfill must have groundwater testing, leachate treatment systems, and it must be covered with soil daily to avoid the emission of unpleasant odours and invasion of pests. Once a landfill is filled, a new one is created. Old landfills can be sources of toxins which are caused by the inability of waste materials to rot naturally. Because landfills are good sources of recyclable materials, they draw scavengers who face the risk of being buried under the pile of rubbish if they are careless. While dumps and landfills are used to address the waste problems, in the long run they can become health and environmental hazards.

In summary, a dump is an excavated piece of land used as storage for waste materials while a landfill is also an excavated piece of land for waste storage but is regulated by the government. It is smaller than a landfill. Dumps do not have leachate collection and treatment systems while a landfill does.

A landfill has a liner at the bottom to trap the liquid produced by solid waste while a dump does not have a liner. Landfills are covered daily with soil to deter pests and prevent bad smells from being released into the air. It also helps to control the speed of rot as water and air do not readily enter the landfill. Dumps on the other hand, are hardly covered speeding up the rot process and releasing toxic gases into the air.

A sanitary landfill holds municipal solid waste, construction debris, and some type of agricultural and industrial waste. Liners prevent leachate from dripping out of a well-designed landfill. Landfills are basically designed in such a way that the garbage is stored without damaging the environment. Whereas, an open dump or dumpsite is essentially a large hole in the ground into which rubbish is dumped. The hole may be disused quarry, open cast mine or clay pit which is then used as a place to dump rubbish.

2.3 Landfill Systems in the Developing World

Landfills have been referred to as the ultimate means of survival for the less privileged people in developing countries of the world, especially in Africa. It also serves as alternative source of raw material for recycling, thereby giving substance to the adage that “One man’s meat is another’s poison”. These categories of people, called scavengers perceive waste in another perspective differing from the majority. They recognize waste as wealth and also as being the source of their means of survival. Competition even exists among the scavengers, to the extent that certain “payments” are made to the dump manager to grant access to the dumpsite for scavenging, especially in Lagos dumpsites. Different landfill systems exist globally. With respect to Africa as a continent the open dump approach is the primitive stage of landfill development and remains the predominant waste disposal option in most African countries. A default strategy for municipal solid waste management, open dump involves indiscriminate disposal of waste and limited measures to control operation, including those related to environmental effects of landfills (Lars & Gavriels, 1999).

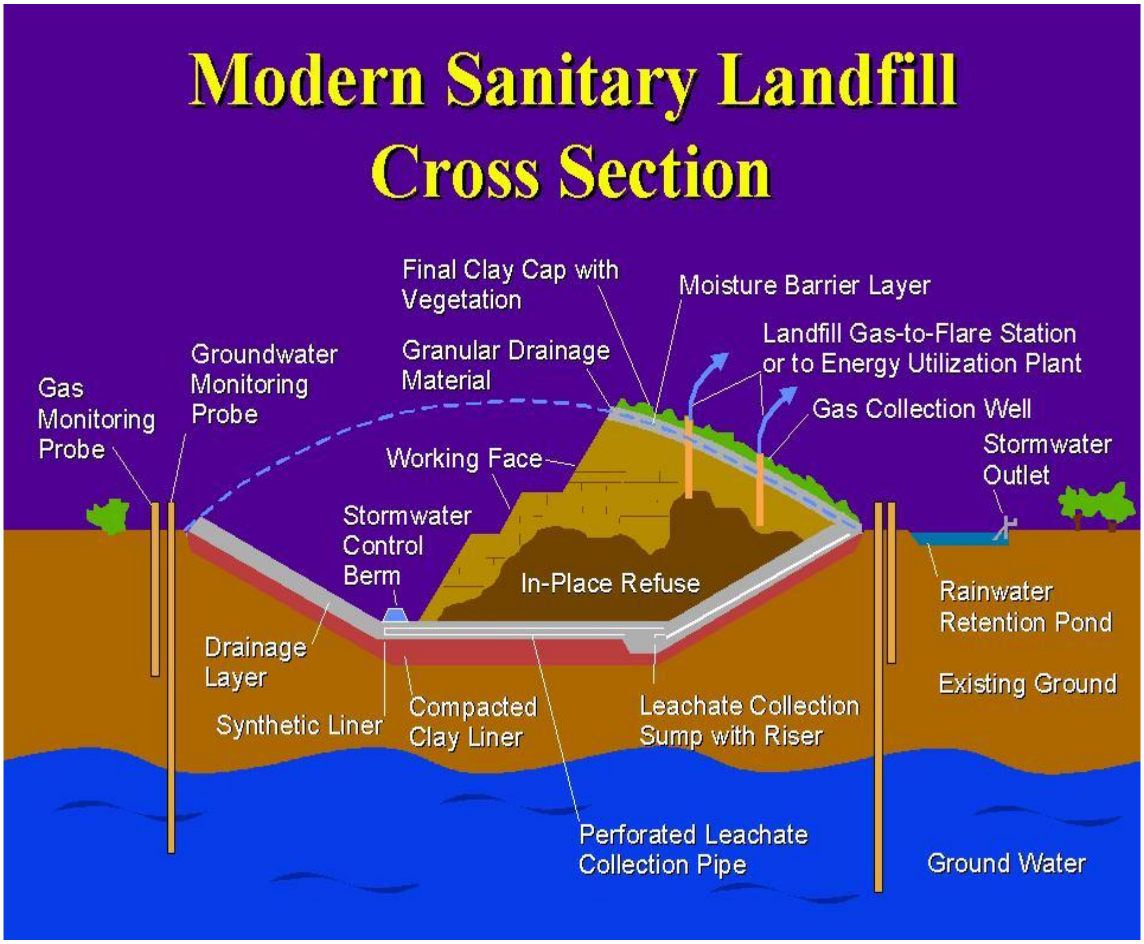

Figure 2.1 Cross-section of a sanitary landfill (www.carbonfund.org)

An operated or semi-controlled dump is often the first stage in a country's effort to upgrade landfills (Koartel & Spillman, 2005). Controlled dumps operate with some form of inspection and recording of incoming wastes, practice extensive compaction of waste and control tipping front and application of soil cover. Operated dumps however implement only limited measures to mitigate other environmental impacts. Operated dumps still practice unmanaged contaminant release and do not take into account environmental cautionary measures such as leachate and landfill gas management (Faullimmel, 2011). This is especially relevant where leachate is produced and is unconstrained by permeable underlying rock or fissured geology. This issue may be less critical in semi-arid and arid climate, where dumps do not generate leachate in measurable quantity (Lars & Gavriels 1999). However, as cities grow and produce waste and their solid waste collection system become more efficient, the environmental impact from open dumps becomes increasingly intolerable. The conversion of open or operated dumps to engineered and sanitary landfills is an essential step to avoid future costs from present mismanagement. The first step and challenge in upgrading open dumps to sanitary landfills involves reducing nuisance such as odour, dust, vermin and birds (Ouedraogo, 2005). The term sanitary landfill is generally used to describe a landfill that engages in waste compaction and apply daily soil cover to reduce nuisance. (Lars & Gavriels, 1999).

Traditional landfills often referred to as “open” or “polluting” dump contains waste under the ground potentially allowing a waste by-product called leachate to enter and contaminate groundwater and other water sources. They also attract rodents, insect and other disease-carrying vermin. Other negative effects of open dump include emission of air pollution, odour and creation of potential fire hazards. In a sanitary landfill these risks are virtually eliminated.

2.4 Landfill and Groundwater Pollution

Taylor and Allen (2006) asserted that for situation assessment, landfills are most identified with the pollution of groundwater by waste-derived liquids. However, any site where waste is concentrated, processed and stored, even for a short period of time, may be a potential point source of groundwater contamination. Such processing facilities are often not well regulated or licensed and frequently occur in urban or semi-urban settings, where local water supply points may be impacted by these activities. Lee and Jones (1991) assert that approximately 75 per cent of the estimated 75,000 sanitary landfills pollute adjacent groundwater with leachate. Leachate derived from waste deposits (landfills, refuse dumps) includes a wide range of contaminations, depending on the types of waste deposited. The likelihood of disposed wastes polluting groundwater is the function of the unsaturated zone and the attenuation capacity of the underlying site, and also on the total and effective precipitation at the site, since the quality and concentration of leachate generated is a function of the access of water to the waste. Naturally, water is never pure in a chemical sense. It contains impurities of various kinds such as gases(H_2S,CO_2,NH_3,H_2),dissolved minerals(Ca, Mg, Na, Salt),suspended matter(clay, silt, sand) and microscopic plants and animals (Park, 1994). These are natural impurities derived from the atmosphere, catchment areas and soil. They are very low in amounts and naturally do not pollute water. However, the quality of natural water is controlled by several factors like geology of the area, with the season of the year and stream natural discharge.

Classical unlined sanitary landfills and open dumps are all known to release large amounts of hazardous and otherwise deleterious chemicals into nearby groundwater, surface water and soil as well to the air, via leachate and landfill gas. However, little quantitative information exists on the total hazard that landfills cause to those who live or otherwise use properties near the landfills.

Groundwater pollution is caused by the presence of undesirable and hazardous material and pathogens beyond certain limits. Much of the pollution is due to anthropogenic activities like discharge of sewage, effluents and waste from domestic and industrial establishment. Also, the situation of groundwater pollution is more pronounced during the rainy season owing to the rate of leachate infiltration, percolation and migration.

Landfills have been identified as one of the major threats to groundwater resources (Fatta *et al.*, 1999). Waste placed in landfills or open dumps are subject to either underflow or infiltration from precipitation. Areas near landfills have great possibility of groundwater contamination because of the potential pollution source of leachate originating from the nearby site. Such contamination of groundwater resource poses a substantial risk to local resource users and to the natural environment (Taylor & Allen, 2006).

2.5 Factors Affecting Groundwater Quality

Hydrochemical evaluation of groundwater system is usually based on availability of a large amount of information concerning groundwater chemistry. The quality of groundwater is as important as its quantity owing to the suitability of water for various purposes. Groundwater chemistry, in turn, depends on a number of factors such as general geology, degree of chemical weathering of various rock types, quality of recharge water and inputs from sources other than rock interaction. Such factors and their interaction result in a complex water quality (Aghazadeh & Mogaddam, 2010). Groundwater quality is determined by natural and anthropogenic factors. Factors affecting groundwater are nature of bedrock geology, depth from surface soil, vegetation, climatic variation, permeability of sediments, and topography, while anthropogenic are nature of human activities, urbanization, industrialization and waste management disposal, amongst others.

Significantly, a number of detailed studies of leachate plumes indicate that they rarely extend more than a few hundred metres from the landfill, before all but a handful of the most persistent contaminants are completely attenuated (Christensen *et al.,* 1994; Robinson *et al* 1999). Concentrations of both reactive and conservative contaminants decrease with the distance along the groundwater flow path therefore, leachate migration is in line with the distance decay principle (Taylor, 1983). It should be noted that the concentration of a pollutant at any point removed from its source may vary throughout the year due to seasonal influences on recharge and release of the contamination, or reaction times governed by variations in factors such as temperature (Taylor & Allen, 2006). Hence, seasonal variation differentiates the concentration of leachate in groundwater. Water is the world's most abundant natural solvent. Therefore, as it moves through the ground it dissolves minerals. These minerals are known as the Total Dissolved Solids (TDS) present in the water. In a shallow aquifer the water has a shorter distance to travel through the ground, and therefore tends to have a lower level of mineralization. Conversely, deeper aquifers tend to be more susceptible to contamination from local land use activities, and can be vulnerable to nitrate and microbial contamination (McLeod *et al.,* 2005).

The amount of water that moves through the unsaturated zone is an important determinant of the extent of groundwater mineralization. Groundwater moves slowly through sediments with a low permeability, such as clay and silt. This slow movement allows more time for minerals to dissolve. Sediments with high permeability such as sand and gravel, on the other hand, allow groundwater to move through them more quickly. This results in a variation in the level of dissolved minerals.

Climatic variations such as rainfall and evaporation can also affect groundwater quality. In semi-arid regions where discharging groundwater evaporates, precipitation infiltrating through the soil can re-dissolve salts and carry them back to the groundwater. In area with higher precipitation and lower evaporation, precipitation reaching the groundwater is less mineralized.

According to Taylor and Allen (2006), waste deposited in landfills or in refuse dumps immediately becomes part of the prevailing hydrological system. Fluid derived from rainfall, snowmelt and groundwater, together with liquids generated by the waste itself through processes of hydrolysis and solubilisation, brought about by a whole series of complex biochemical reactions during degradation of organic wastes, percolate through the deposit and mobilize other components within the wastes. The resulting leachate subsequently migrates either through direct infiltration on site or by infiltration of leachate-laden runoff offsite. The leachate composition and its pollution intensity depend on many aspects such as landfill age, waste ingredient and hydraulic conditions of landfill (Bidhendi *et al.*, 2010).The rate and characteristics of leachate production depends on a number of factors such as solid waste composition, cover design, compaction, interaction of leachate with environment and landfill design operation, particle size, degree of compaction, hydrology and hydrogeology of site, age of landfill, moisture and temperature condition, and available oxygen(Longe & Balogun, 2010; Papadopoulou *et al.*, 2007).The composition and volume of disposed wastes vary nationally and regionally in relation to the local activities, and the quality and type of products that communities consume. Lower income areas waste is typically rich in food-related waste, mostly organic substances. Decomposition of organic matter can alter the physico-chemical quality of groundwater and promote the mobility of dangerous chemical, involving metals and solvents. The generation of waste is the function of increased income and degree of industrialization, and leachate from waste disposed from highly industrialized areas may contain a wide variety of anthropogenic contaminants.

With Lagos being the commercial and industrial hub of Nigeria, the concentration of industrial activity, increase in product consumption due to rapid annual growth severely brings about high rate of degradable waste generation for leachate formation.

Solid wastes could be defined as non-liquid and non-gaseous products of human activities, regarded as being useless; taking the form of refuse, garbage or sludge (Leton & Omotosho, 2004). Adedibu (1985) grouped solid wastes into eight classes, namely domestic, municipal, industrial, agricultural, pesticides, residential and hazardous wastes. However, solid waste can be classified as biodegradable or non-biodegradable, soluble or insoluble, organic or inorganic, liquid or solid, toxic or nontoxic (Kostova, 2006). Irrespective of the classification of solid wastes, most of the urban wastes are degradable which aid the rate of leachate formation and migration compared to non-biodegradable wastes that can last for many years without any sign of decomposition. Therefore, there is possibility of leachate generation, plume extension and migration at the base of urban landfill owing to the composition of discarded materials and frequent surface water ingression from urban precipitation.

2.5.1 Landfill Lifespan: Contamination of groundwater is directly associated with the lifespan of the landfill. Pollutants generated over years are quite different in terms of physicochemical and heavy metal concentration due to time and age of the landfills, as well as nature of the decomposed waste. According to Kostova, 2006, concentration (mg/L) of leachate constituent are in phases namely transition (0-5 years), acid-formation (5-10 years), methane fermentation (10-20 years) and final maturity (>20 years). Groundwater may not be contaminated at the inception of waste deposition in the landfill. More than 3400 Municipal Solid Waste Landfills were closed or abandoned throughout the United State between 1988 and 1993 as a result of ageing. There is need for monitoring these abandoned landfills to determine the risk of soil and groundwater contamination and to generate information on leachate migration (U.S. EPA, 2003).The age of a landfill also significantly affects the quantity of leachate formed. The ageing of a landfill is accompanied by increased quantity of leachate. Leachate generated in the initial period of waste deposition (up to 5 years) in landfills, have pH-value range of 3.7 to 6.5 indicating the presence of carboxylic acids and bicarbonate ions. With time, pH of leachate becomes neutral or weakly alkaline ranging between 7.0 and 7.6. Landfills exploited for long period of time give rise to alkaline leachate with pH range of 8.0 to 8.55 (Slomczynska & Slomczynski, 2004; Longe & Balogun, 2010).

2.5.2 Leachate Migration: In unsealed landfill above an aquifer like Solous, water percolating through landfills often accumulates within or below the landfill (Freeze and Cherry, 1979). According to Taylor and Allen (2006), this is due to the production of leachate by degradation processes operating within the waste, in addition to the rainwater percolating. The increased hydraulic head developed increases downward and outward flow of leachate from the landfill or dump. Downward flow threatens underlying groundwater resources. Observation of poor water quality in adjacent wells or boreholes are indicators that leachate is being produced and is moving. The direction of groundwater flow may not conform to surface water flow direction. However, groundwater moves slowly and continuously through the open spaces in the soil and rock. If a landfill contaminates groundwater, a plume of contamination will occur. Wells in that plume will be contaminated, but other wells, even those close to the landfill, may be unaffected if they are not in the plume. Also, the behaviour of the leachate pollution plume generated in the groundwater zone is governed by the variability in leachate concentrations and groundwater flow directions (Christensen *et al*., 1995).

However Lee and Kitanidis, (1993) stated that leachate migration from disposal sites can be influenced by site design, waste type, hydrogeology, geochemistry and climatological conditions. A rigorous analysis which takes all these factors into consideration is a formidable task.

2.6 Characteristics of Leachate in Groundwater Quality

Longe and Omole (2008) state that the greatest contamination threat to groundwater comes from the leachate generated from the material which often contains toxic substances especially when wastes of industrial origins are land filled. However, it has been widely reported that leachates from landfills for non-hazardous waste could as well contain complex organic compound, chlorinated hydrocarbons and metals at concentrations which pose a threat to both surface and groundwater.

The produced leachate is normally composed of organic and inorganic compositions. In addition, as time elapses, the produced leachate permeates into ground systems leading to change of physical and chemical properties of groundwater (Vasanthi *et al*., 2008). Longe and Enekwechi, (2007) and Lee *et al*. (1986) stated that heavy metals such as cadmium, arsenic, chromium have been reported at excessive level in groundwater due to landfill operation. Longe and Enekwechi. (2007) report that the volume of leachate depends principally on the area of the landfill, the meteorological and hydrogeological factors and effectiveness of capping. The volume of leachate generated is therefore expected to be very high in humid regions with high rainfall, or high runoff and shallow water table (Chapman, 1992). The geology and hydrogeology of any potential landfill site thus has major bearing on the level of natural protection for groundwater from contamination by landfill leachate. From previous studies, most landfill leachate has high levels of Biochemical oxygen demand (BOD), Chemical oxygen demand (COD), ammonia, chloride, sodium, potassium, hardness and boron. With respect to time and age, the condition within a landfill often varies over time, from aerobic to anaerobic thus allowing different chemical reactions to take place (Taylor & Allen, 2006).

2.7 Water Quality Standards in Nigeria

The Nigerian Standard for Drinking Water Quality (NSDWQ) was approved by the Council of the Standards Organization of Nigeria in 2007 specifying upper and lower limits of contaminants known to pose a risk to the wellbeing of individuals (NIS, 2007). Table 2.1 provides a comparison of the World Health Organization’s standard of water quality with that of the Nigerian Standard for Drinking Water Quality. From Table 2.1, minor differences exist between World Health Organization (WHO) and Nigerian Standard for Drinking Water Quality (NSDWQ), in the standards of measuring the minimum and maximum concentration of water quality.

Table 2.1 Water quality variables and their standard limits

	Parameter	**Units**	**WHO**	**NSDWQ**
1	Temperature	^0C	25	NS
2	pH	NS	6.5-8.5	6.5-8.5
3	Electrical Conductivity(EC)	(µScm^{-1})	1000	1000
4	Total Suspended Solid(TSS)	Mg/L	3.0mg/l	NS
5	Total Hardness(TH)	Mg/L	100mg/l	150mg/l
6	Chloride(Cl^-)	Mg/L	250mg/l	250mg/l
7	Nitrate($N0_3^-$)	Mg/L	10mg/l	50mg/l
8	Dissolved Oxygen(O_2)	Mg/L	2.0mg/l	NS
9	Iron(Fe)	Mg/L	0.03mg/l	0.3mg/l
10	Lead(Pb)	Mg/L	0.01	0.01mg/l
11	Total Acidity	Mg/L	NS	NS
12	Total Alkalinity	Mg/L	200mg/l	NS
13	Sodium(Na)	Mg/l	200mg/l	NS
14	Phosphate($P0_4^-$)	Mg/L	5mg/l	NS
15	Sulphate($S0^3$)	Mg/L	250mg/l	100mg/l
16	Copper(Cu)	Mg/L	0.5mg/l	1mg/l
17	Calcium(Ca)	Mg/L	200mg/l	NS

Source Nigerian Industrial Standard (2007)

2.8 Evaluation of Water Quality

Several methods for evaluating water quality exist. However these methods cannot clearly express the water pollutant categories. Yeh *et al.*, (2008) attempted to develop a cost-effective programme for monitoring the quality of groundwater by sampling existing wells in order to obtain useful information. Water Quality Index method (WQI) provides the mechanism for presenting a cumulatively derived numerical expression defining a certain level of water quality. One of the major advantages of WQI is that, it incorporates data from multiple water quality parameters into a mathematical equation that rates the health of water quality with a number (Yogedra & Puttaiah, 2008).

Water Quality Index was first developed by Horton (1965) in the United States of America using ten (10) of the most commonly measured water quality variables such as dissolved oxygen, pH, coliforms, specific conductance, alkalinity and chloride. Horton's method of water quality assessment is now widely used across Africa, Asia and Europe.

Water Quality Index (WQI) method uses a rating system to determine the influence of individual quality parameters on the overall quality of water. A general WQI approach is based on the under listed factors (Fernandez *et al.*, 2012; Dunnette, 1979):

1. Parameter selection
2. Determination of a Quality Function Curve
3. Sub-indices aggregation with mathematical expression

Several water quality indices have been formulated by different international organizations. Studies have shown the Water Quality Index to be one of the most effective tools to communicate information on the overall quality status of water to the users and policy makers within each community (Subba Rao, 1997; Tiwari & Mishra, 1985; Krishna *et al.*, 1991; Pathak

& Bhatt, 1991; Dhamija & Jain 1995; Singha, 1995; Singh, 1992; Saxena & Kaur, 2003; Jinwal *et al*., 2008)

2.9 Review of implications of the physico-chemical parameters on health

The presence of chemicals in groundwater and drinking water is an important factor in determining the risk posed by landfills sites. However, it does not tell us the effect, if any, the consumption of contaminated water has on human health. There are studies of negative health implications of drinking contaminated water resulting in reduced capacity and/or life expectancy (Twadddle, 1996).Open dumps generate various environmental and health hazards. The decomposition of materials produces methane, which can cause fire and explosions and produce strong leachate, which pollute surface and groundwater (Oyelola *et al.*, 2009). In the same vein, the ensuing smoke that fills the air from the uncontrolled burning of solid waste during the dry season constitutes serious environmental pollution, adversely affecting solid waste workers and scavengers. Toxic and hazardous waste when burning with other waste like asbestos fibre may introduce potential carcinogenic fibres to the smoke plume. Elliot and Taylor (1996) and Oyelola *et al.*, (2009) stated that a lag period of ten years is generally assumed for cancers to develop as a result of cancer-inducing agent exposure, and 5 years for lymphatic and hematopoietic cancers. Incessant outbreak of fire in open dumps especially during the dry season immensely contributes to air pollution. There is also the practice of reducing the quantity of waste in the dump site through burning. Dump managers in some cities intentionally set ablaze waste to extend the life span of the dumpsite. Landfill fires may be caused deliberately through arson, or accidentally through spontaneous combustion, the deposition of hot wastes or even the rays of the sun. These fires, however, cause or have the potential to cause major environmental upheavals. Emissions from these fires are also known to cause respiration problems in humans and animals. Lead has been implicated in various disease such as anemia, brain damage, anorexia, mental deficiency, vomiting and even death in humans (Maddock & Taylor, 1977; Bulut & Baysal, 2006; Ogundiran & Afolabi, 2008).Cadmium also has been reported to cause agonistic and antagonistic effects on hormones and enzymes leading to a lot of malformations like kidney and liver damage, bone loss or decrease in bone strength and lung cancer (Lewis, 1991; Donalson, 1980; Ogundiran & Afolabi, 2008). High nitrate concentration has detrimental effects on infants less than three to six months of age. (Longe & Balogun, 2010). Nitrate reduces to nitrite which can oxidize haemoglobin (Hb) to methaemoglobin (metHb), thereby inhibiting the transportation of oxygen around the body (Chapman, 1992; Lee & Jones-Lee, 1993; Al Sabahi *et al*., 2009; Longe & Balogun, 2010).

The potential health implications from groundwater contamination are thus very vast, as outlined in Table 2.2. The following presents a brief overview of some of the most common accepted side-effects that usually occur from certain contaminants.

2.9.1 Dissolved Oxygen: This is a measure of the amount of oxygen in water. Oxygen is measured in its dissolved form as dissolved oxygen (DO). If more oxygen is consumed than is produced, dissolved oxygen levels decline and some sensitive animals may move away, weaken, or die (U.S. EPA, 2012). One of the adverse effects of pollution of a water body is a decrease in dissolved oxygen (DO). Decrease in dissolved oxygen is a positive indicator of water pollution. The primary reason for depletion of DO is the proliferation of oxygen-demanding aerobic bacteria. The quality of water or wastewater is commonly expressed by an estimate of dissolved oxygen (DO). Two other parameters of interest are the ***biochemical oxygen demand (BOD)***, which is a measure of the amount of oxygen consumed in the biological processes that break down organic matter in water, and the ***chemical oxygen demand (COD)***, which is a measure of the oxygen required to oxidize all compounds, both organic and inorganic, in water. The greater the BOD (or COD), the greater is the degree of pollution (Narayanan, 2009).

2.9.2 Chloride: Chloride is found in many chemical and other substances in the body. It is an important part of the salt found in many foods and used in cooking. It is also an essential part of the digestive (stomach) juices. It is found in table salt or sea salt as sodium chloride. Too much chloride from salted foods can increase blood pressure, even in young children (Calabrese & Tuthill, 1985) and cause a buildup of fluid in people with congestive heart failure, cirrhosis, or kidney disease (www.health.nytimes.com). Although excessive intake of drinking-water containing sodium chloride at concentrations above 2.5 g/litre has been reported to produce hypertension (Fadeeva, 1971), this effect is believed to be related to the sodium ion concentration.

2.9.3 Nitrates: This is the end product of the biochemical oxidation of ammonia and nitrogen from organic matter. It is a measure of the original quantity of organic matter with which water is associated. The excessive concentration of nitrate in polluted water is very dangerous, as it may cause methemoglobinemia-***the blue baby disease*** (cyanosis) in infants and stomach disorder in adults (Kumar *et al.,* 2006).Evidence indicates correlation between nitrate intake and stomach cancer incidence. Nitrate reduces to nitrite which can oxidize hemoglobin (Hb) to methaemoglobin (metHb), thereby inhibiting the transportation of oxygen around the body (Chapman, 1992; Lee & Jones-Lee, 1993; Al Sabahi *et al.,* 2009; Longe & Balogun, 2010)

2.9.4 Total Hardness: Water can be classified on the basis of hardness into soft (0 – 75mg/l), moderately hard (75 – 150mg/l) and hard (151 – 300mg/l) (Sawyer 1960). Water hardness relates to the amount of calcium and magnesium compounds present in water. That is, it has high concentration of Ca^{2+} and Mg^{2+} ions, which react with soap to form scum. If bicarbonates and carbonates of calcium and magnesium are present, it is called temporary or carbonate hardness. This can be largely removed by boiling, or addition of lime. But if sulphates, chlorides, and nitrates of calcium and magnesium are present which cannot be removed by previous processes (liming and boiling), is known as permanent or non-carbonate hardness. Underground waters are generally harder than surface waters (Ayoade, 2003).

2.9.5 Heavy metals are elements having atomic weights between 63.546 and 200.590 (Kennish, 1992), and a specific gravity greater than 4.0 (Connell et al., 1984). They exist in water in colloidal, particulate and dissolved phases with their occurrence in water bodies being either of natural or anthropogenic origin (Adepoju-Bello *et al*, 2009). They include aluminum, arsenic, beryllium, bismuth, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, strontium, thallium, tin, titanium, zinc, etc. (Garg, 2009). A heavy metal is a member of a loosely-defined subset of elements that exhibit metallic properties (Duffus, 2002). Some heavy metals are dangerous to health and environment (e.g. mercury, cadmium, lead, Chromium). Some may cause corrosion (e.g. zinc, lead). Some of these elements are actually necessary for humans in minute amount(cobalt, copper, chromium, manganese and nickel) while others are carcinogenic or toxic, affecting, among others, the central nervous system (manganese, mercury, lead, arsenic),the kidneys or liver(mercury, lead, cadmium, copper) or skin, bones, or teeth (nickel, cadmium, copper, chromium) (Zevenhoven and Kilpinen, 2001). Unlike organic pollutants, heavy metals do not decay and thus pose a different kind of challenge for remediation (Baby *et al.*, 2010). One of the largest problems associated with the persistence of heavy metals is the potential for bioaccumulation and biomagnifications causing heavier exposure for some organisms than is present in the environment alone (Beetseh and Abrahams, 2013).

2.9.6 Iron: Iron is a lustrous, ductile, malleable, silver-gray metal. Its presence in human tissue for extended periods may cause conjunctivitis, choroditis and retinitis. A common problem for human is iron deficiency, which may lead to anemia. A man needs an average daily intake of 7mg of iron and a woman 11mg. Presence of Iron in water can lead to change of colour of groundwater (Rowe *et al.*, 1995)

2.9.7 Copper: Copper is a reddish metal with a face-centered cubic crystalline structure Lenntech, 2012. It can be found in many kinds of food, in drinking water and in air. Long-term exposure to copper can cause irritation of the nose, mouth and eyes and it causes headaches, stomachaches, dizziness, vomiting and diarrhea. According to the Agency for Toxic Substances and Disease Registry (2004), intentionally high uptakes of copper may cause liver and kidney damage even death.

2.9.8 Turbidity: The American Public Health Association (APHA, 1989) defines turbidity as "the optical property of a water sample that causes light to be scattered and absorbed rather than transmitted in straight lines through the sample". In simple terms, turbidity answers the question, "How cloudy is the water?" The ability of light to pass through water is directly proportional to the volume of suspended particles within the water body. The higher the volume of suspended particles, the cloudier the water becomes. Turbidity is measured using an electronic turbidity meter. The results are reported in Nephelometric Turbidity Units (NTU) or by filtering a water sample and comparing the filter's colour (how light or dark it is) to a standard turbidity chart. APHA specifies drinking water turbidity shall not exceed 0.5 NTUs, but WHO specifies 5 NTUs (mg/l). Thus, turbidity conditions may increase the possibility for waterborne disease. If turbidity is largely due to organic particles, dissolved oxygen depletion may occur in the water body (Postolache *et al.,* 2012). Higher turbidity levels are often associated with higher levels of disease-causing microorganisms such as viruses, parasites and some bacteria. These organisms can cause symptoms such as nausea, cramps, diarrhea, and associated headaches (U.S. EPA, 2013).

2.9.9 Electrical Conductivity (EC*)*: Conductivity indicates the presence of ion within the water, usually due to saline water. It is more-or-less a function of the concentration of dissolved ions. The electrical conductivity of water estimates the total amount of solids dissolved in water-TDS. It is measured in ppm (part per million) or in mg/l. The electrical conductivity of the water depends on the water temperature; the higher the temperature, the higher the electrical conductivity would be. If the conductivity of a stream suddenly increases, it indicates that there is a source of dissolved ions in the vicinity. Therefore, conductivity measurements can be used as a quick way to locate potential water quality problems (NGRDC, 2000). The electrical conductivity of water increases by 2-3% for an increase of 1 degree Celsius of water temperature (Smart, Growing Intelligently, 2012). Its maximum value permissible according to WHO, 2004 is 1000 µScm$^{-1.}$ Many EC meters are nowadays automatically standardized to 25^{o}C.

2.9.10 pH: It is the concentration of hydrogen ion in the water. The pH value of water denotes the reciprocal of log of hydrogen ion concentration, and is determined with the aid of a potentiometer or pH meter. The water will be acidic if its pH is less than 7, and will be alkaline if its pH value is more than 7. Pure water has a pH value of 7. pH has synergistic effects; in stagnant water, pH is affected by its age and the chemicals discharged by communities and industries. pH is an indicator of the existence of biological life as most of them thrive in a quite narrow and critical pH range (Sisodia and Chaturbhuj, 2006). The pH of water affects the solubility of many toxic and nutritive chemicals. As acidity increases, most metals become more water soluble and toxic (Ali, 2010). Toxicity of cyanides and sulfides also increases with a decrease in pH (increase in acidity). Ammonia, however, becomes more toxic with only a slight increase in pH (NGRDC, 2000). The excess of the examined parameter leads to various health problems presented in a Table 2.2.

2.9.11 Total Acidity arises from the presence of weak or strong acids and/or certain inorganic salts. The presence of dissolved carbon dioxide is usually the main acidity factor in unpolluted surface waters. There is no particular implication apart from palatability consideration in excessively acid waters (U.S. EPA, 2001). The acidity of water will affect its corrosiveness and also the speciation of some of its other constituents.

2.9.12 Total Alkalinity: The alkalinity of a natural body of water is generally due to the presence of bicarbonates formed in reactions in the soil through which water percolates. It is a measure of the capacity of water to neutralize acids and it reflects its so-called buffer capacity (U.S. EPA, 2012). Alkalinity in natural waters may be attributable to bicarbonate and hydroxides. Alkalinity is involved in the consequential effects of eutrophication of water (U.S. EPA, 2001).

2.9.13 Phosphate: Phosphorus occurs widely in nature, in plant, in micro-organisms, in animal waste and so on. The significance of phosphorus is principally in regard to the phenomenon of eutrophication of lakes and, to a lesser extent, rivers. Phosphorus gaining access to such water bodies, along with nitrogen as nitrate, promote the growth of algae and other plants leading to blooms, littoral slimes, diurnal dissolved oxygen variation of great magnitude and other related problems. Phosphorus exists in orthophosphate, polyphosphate, organic phosphate and so on (U.S. EPA, 2001). High phosphate levels in drinking water may cause digestive problems in humans and animals.

2.9.14 Calcium: This element is the most important and abundant in human body and adequate intake is essential for normal growth and health. There is some evidence to show that the incidence of heart disease is reduced in areas served by public water supply with a high degree of hardness, the primary constituent of which is calcium, so that the presence of the element in a water supply is beneficial to health (U.S. EPA, 2001).

2.9.15 Sodium: It is abundant in rocks and soils. It is always present in natural water. It is used medicinally as a laxative (U.S. EPA, 2001).

Table 2.2 Major parameters and related health risks

No	Variable	Health Risk
1	Temperature	NS
2	pH	Gastrointestinal discomfort
3	Electrical Conductivity	NS
4	Total Suspended Solid	NS
5	Iron	Conjunctivitis, chloroiditis, retinitis.
6	Sodium	Hypertension
7	DO	NS
8	Calcium	NS
9	Sulphate	Intestinal discomfort, diarrhea and dehydration.
10	Nitrate	Cyanosis (blue baby diseases) and asphyxia.
11	Chloride	Increased blood pressure, building up of fluid in people with congestive heart failure, cirrhosis, or kidney disease.
12	Lead	Carcinogenic
13	Copper	Gastrointestinal disorder.

Source: Nigerian Industrial Standard (2007)

NS – Not specified

CHAPTER THREE

RESEARCH METHODS

3.1 Study Area

According to the National Population Commission (2006), Lagos State which covers an area of 3,577 km^2 accounts for about 9,013,534 (6.43%) with 3.2% annual growth rate, of Nigeria's total population of over 140 million (Figure 3.1). Alimosho Local Government Area is the largest local government in Lagos state with coordinates 6^{0}36'38'N/3^{0}17'45'E. It has a total population of about 1,362,077, and land area of 185 km^2 with average density of 713 persons per square kilometer approximately.

The study area Igando, as illustrated in Figure 3.2, is bounded in the North and West by River Owo and IfakoIjaiye, Agege respectively, and the East by Ikeja Local Government Area while it is bounded in the South by Oshodi/Isolo, Amuwo-odofin and Ojo local Government Areas of Lagos State (Akoteyon *et al.,* 2011).

Lagos State climate is generally classified under tropical region with alternate dry and wet seasons. The dry season usually lasts from November to March and the rainy season starts in April and lasts through till October. Annual precipitation is put at about 1, 700 m^3 and serves as a major source of groundwater recharge (Jeje, 1983). The hydrology is dominated by River Owo and its tributaries (River Abesan, River Oponu and River Illo). They drain into the Ologe lagoon (Odumosu 1999). It has a temperature range of 28 ^{0}C to 33 ^{0}C. It is characterized by swamp forest and coastal plains especially in the riverine and coastal parts. The subsurface geology reveals two basic lithologies; clay and sand deposits. These deposits may be inter-bedded in places with sandy clay or clayey sand and occasionally with vegetable remains and peat (Ayolabi & Peters, 2005).

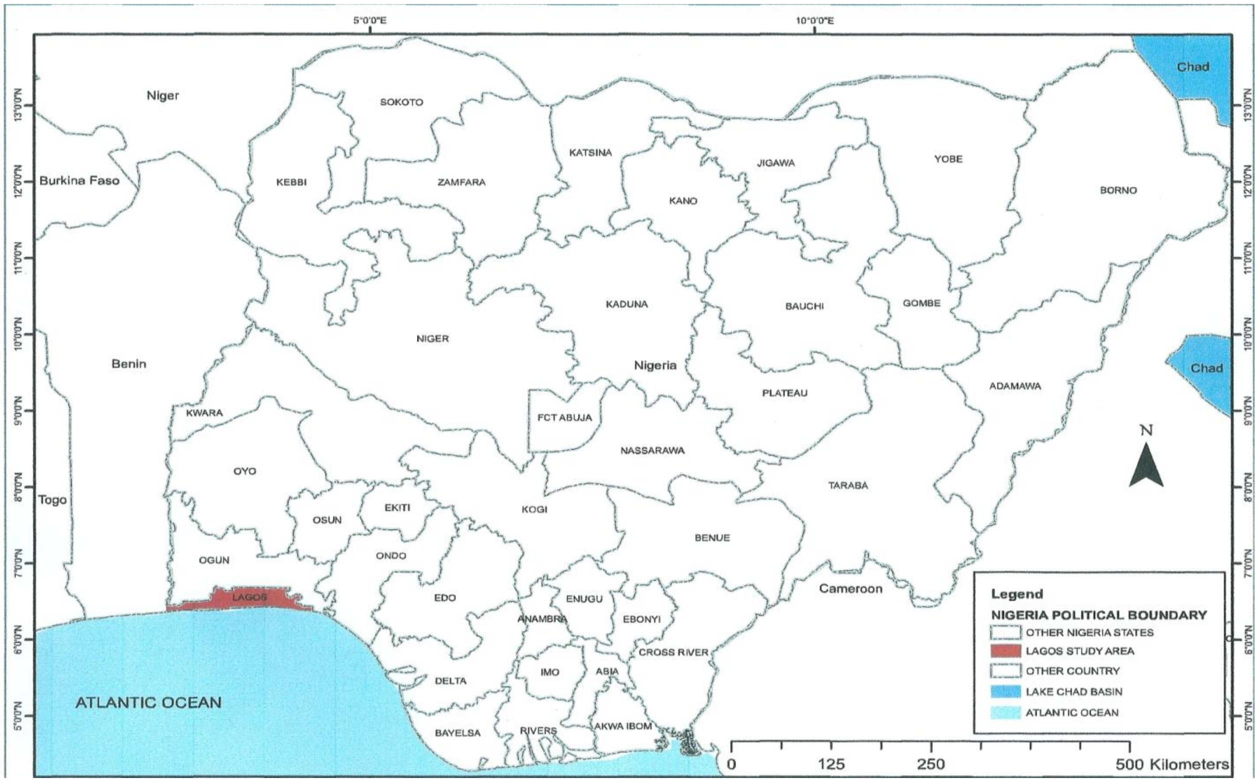

Figure 3.1 Nigeria map showing Lagos as a study area

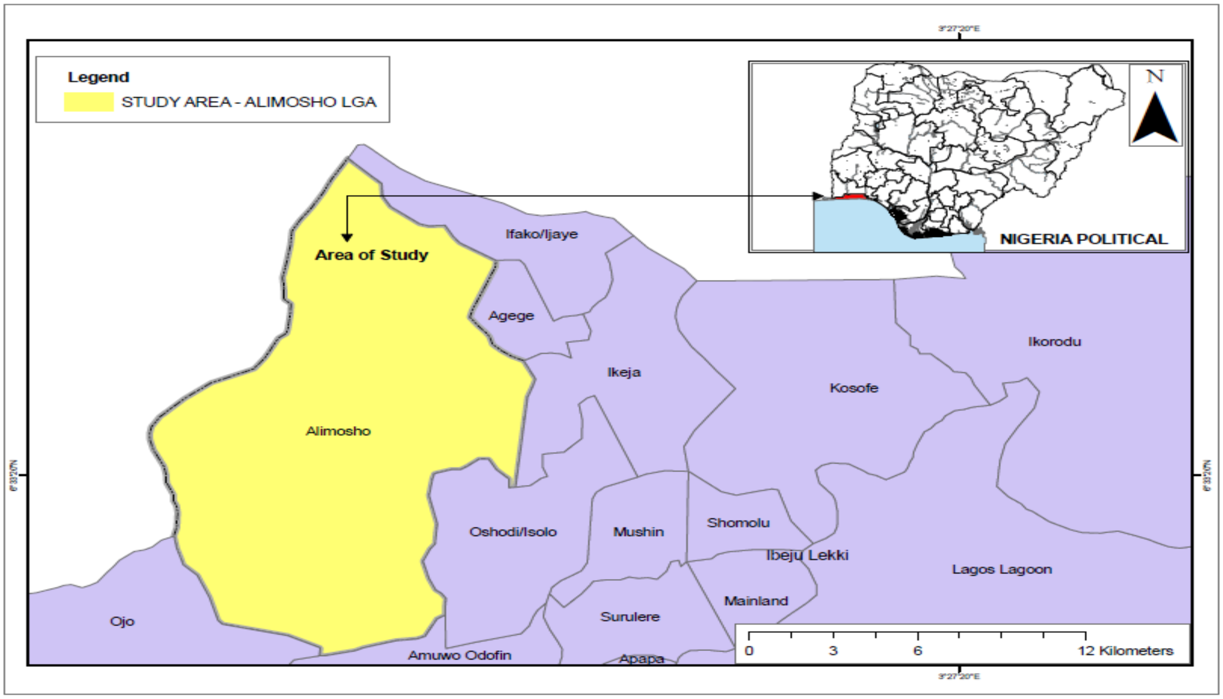

Figure 3.2 Lagos map showing Alimosho Local Government Area

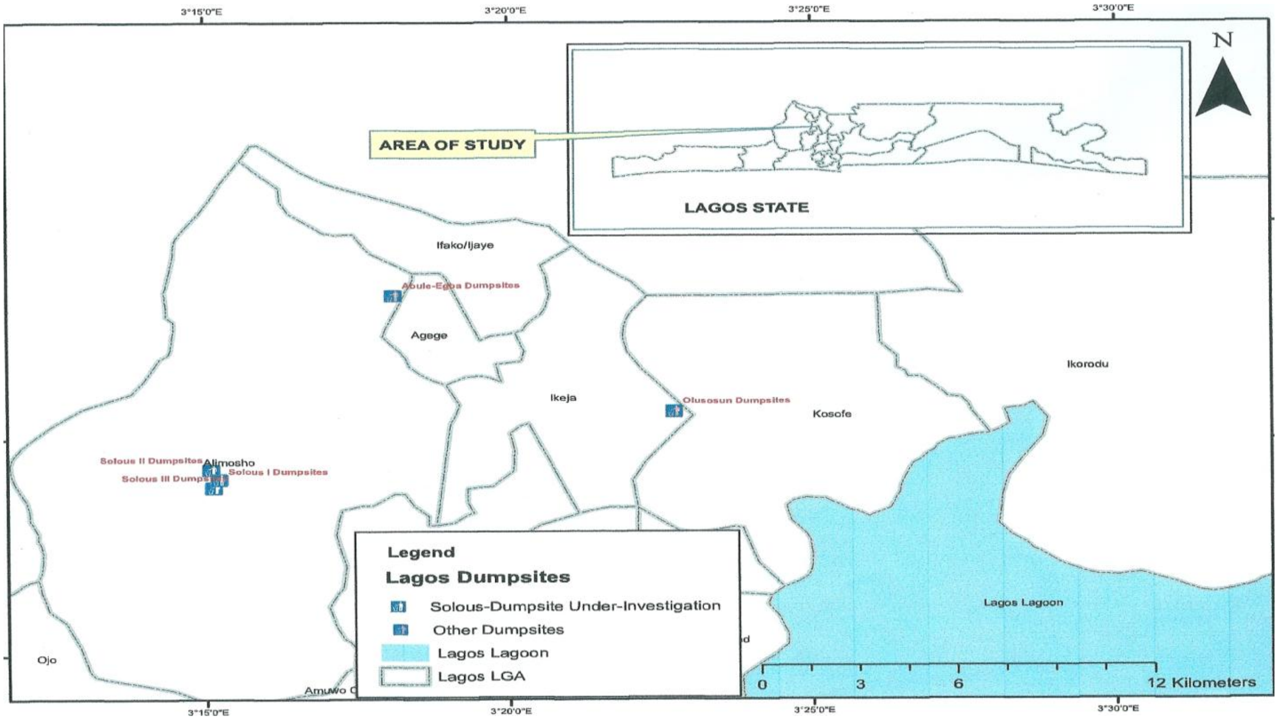

Figure 3.3 spatial distributions of major dumpsites in Lagos State

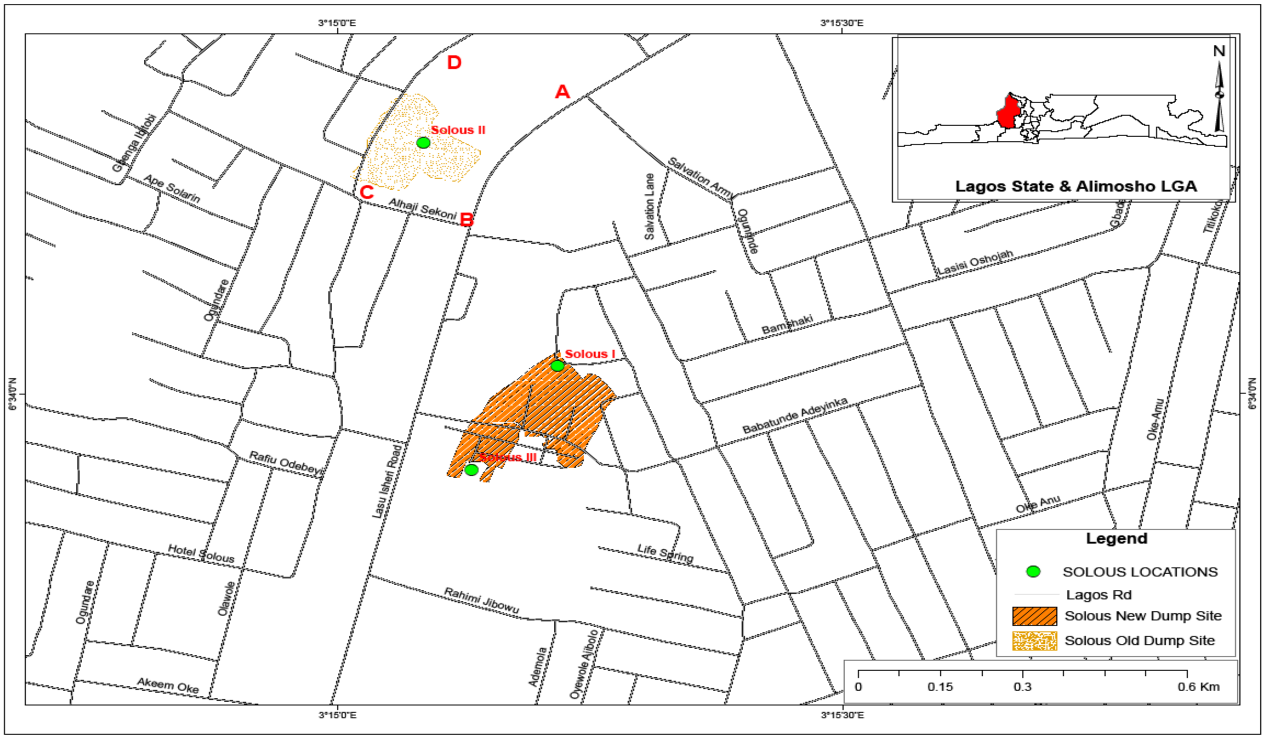

Figure 3.4 Solous dumpsites

Alimosho is mostly residential and as at a 2008 household survey, generate 773.37 tonnes of waste annually. Major land use for the area is residential and agricultural with little commercial activity.

The Solous landfill is situated at Igando in Alimosho Local Government Area of Lagos State, Nigeria (Figure 3.3 and 3.4). It commenced operation in the year 1996 with a projected lifespan of between 5 and 6 years (LAWMA, 2010). As a result of urban pull, this dumpsite is now surrounded by residential, commercial and industrial activities. The study area comprises both of closed and existing dumpsite and is an authorized dumpsite for Lagos State Waste Management Authority (LAWMA) known as **Solous** landfill. Solous landfill is sub-divided into three (3) sections namely **Solous I, II and III**. All 3 landfills are currently operational, despite since passing their expiration date, and form the basis of this study. The existing landfill covered about 10.8 hectares of land and receives an average waste of about 2,250 m^2 per day. According to Longe and Balogun, (2010), soil stratigraphy of Solous landfill consists of intercalated with lateritic clay that is capable of protecting underlying confined aquifer from leachate contamination.

Figure 3.5 Study area showing the dumpsite

3.2 Types and Sources of Data

The study used both the primary and secondary data. Primary data were collected through direct field survey. The data were collected from water and soil samples around the second largest landfill called Solous situated in Igando, within Alimosho Local Government Area of Lagos State.

Groundwater samples were collected from eighteen wells in locations surrounding the dumpsites. Water samples were designated a W_1, W_2, W_3… W_{18} and were immediately taken to the Lagos

State Environmental Protection Agency (LASEPA) for chemical, physical and heavy metals analyses. Analyses were carried out by LASEPA officials with author in attendance and results were obtained for interpretation. Soil textural/ grain size analysis was carried out at the Department of Agronomy, University of Ibadan.

Secondary data comprised information from journals, articles, textbook and other publications. World Health Organization(WHO, 2004), Nigerian Standard for Drinking Water Quality (NSDWQ, 2007) standard limits and Lagos State maps were also part of secondary data utilized.

3.3 Sample and Sampling Techniques

Systematic random sampling of soil and water samples with direct field survey methods were used for the gathering of data around the landfills in the last week of the month of July, 2012. The whole area of the dumpsite with a buffer zone of about 800metres to the focal point of the landfills was sampled. Eighteen (18) groundwater and soil sample points were cardinally selected for the study (Figure 3.6). The selected landfill site (Solous) is located in Igando and consists of 3 separate landfills, located spatially and adjacent to one another. Within the geographical extent of about eight hundred metres (800 m) from the landfill, about thirty (30) wells and bore holes were identified. Eighteen (18) of the wells were sampled based on the proposed distance in line with the spatial quadrat of the active landfills.

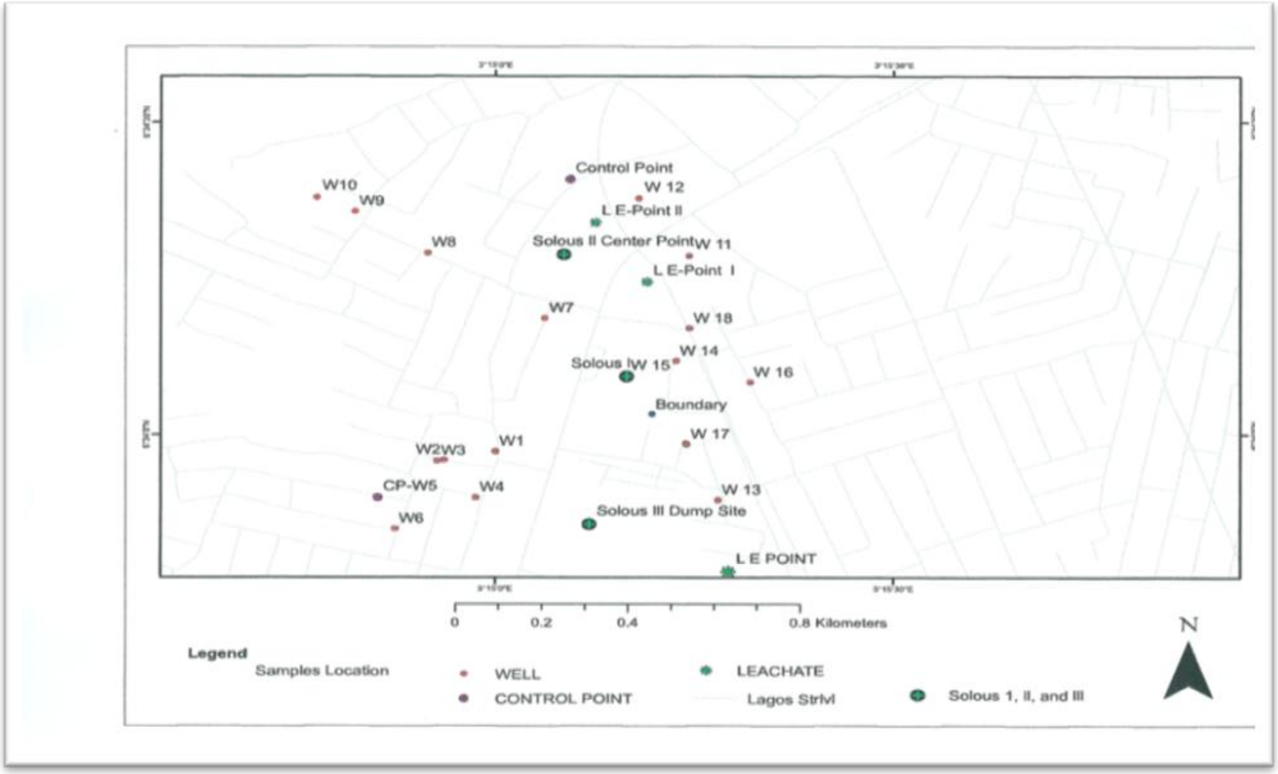

Figure 3.6 Overlay map showing approximate sample locations

Soil samples were collected with the aid of a soil auger and the range of sampling were within two metres to the wells sampled. Geographic coordinates (x,y,z) of all sampling points were identified through hand-held Global Positioning System (GPS channel 76CSx Garmin model), that measures in 2-3 m level of accuracy. Digital camera (Sony 14.1 megapixel model) was used at vantage point to take the aerial view of the dumpsites. The satellite image area of the study area were scanned and overlaid with sampling points with the aid of Arcview 3.0 and Sofer software.

Table 3.1 illustrates the location of the eighteen (18) sampled wells with respect to their distance in metres to the nearest landfill in Solous dumpsites. The distance between the sampling points ranged from 71 m to 655 m. Also, geographical elevation of the study area ranged from 24 m –

35 m above the sea level. This is because Lagos is almost entirely located below the mean sea level.

Table 3.1 Site description of the sampled locations

	Easting	**Northing**	**Elevation**		**Location**
Code	**X**	**Y**	**Z**	**Distance**	**Street Name**
W_1	3.25000000000	6.56622000000	27	293 m to Solous III	43 Atoke Street
W_2	3.24893000000	6.56599000000	27	386 m to Solous III	7 OkisesanIsola Avenue
W_3	3.24878000000	6.56597000000	24	400 m to Solous III	8 Itako Avenue
W_4	3.24959000000	6.56499000000	29	274 m to Solous III	15 SegunAlaka Street
W_5	3.24755000000	6.56500000000	27	481 m to Solous III	21 Miracle Centre
W_6	3.24790000000	6.56416000000	26	450 m to Solous I	18 OtunbaOladokun Street
W_7	3.24886000000	6.56173000000	30	445 m to Solous III	Ayeni Street-Off Governor Street
W_8	3.25434000000	6.56181000000	34	382 m to Solous III	41 Oyewole Ajiboro Street
W_9	3.25529000000	6.56177000000	35	462 m to Solous III	53 Prince Olofin Street
W_{10}-Control Point	3.25758000000	6.56246000000	35	**655 m to Solous II**	4 Obolo Close
W_{11}	3.25196000000	6.57138000000	31	71 m to Solous II	1 John Kay Crescent
W_{12}	3.25300000000	6.57296000000	34	224 m to Solous II	8 AbayomiAkele Street
W_{13}	3.25466000000	6.56492000000	23	264 m to Solous III	8 Adebayo Odueko Street
W_{14}	3.25377000000	6.56863000000	26	122 m to Solous I	9 Oluwakemi Street
W_{15}	3.25370000000	6.56788000000	23	169 m to Solous I	Oba Gbadamosi Street
W_{16}	3.25533000000	6.56806000000	26	181 m to Solous I	16 Olorunsogo Street
W_{17}	3.25400000000	6.56641000000	24	166 m to Solous II	17 Anifowose Close
W_{18}	3.25406000000	6.56950000000	26	218 m to Solous I	6 Samson Dada Street

Source: Fieldwork survey 2012

3.4 Parameters Examined

This study examined twelve (12) parameters of physical and chemical (including heavy metals) namely; Temperature (^{0}C), pH, Nitrate ($N0^-{}_3$), Chloride (Cl^-), Total Hardness (TH), Total Suspended Solid (TSS), Dissolved Oxygen (DO), Electrical conductivity (EC), Iron (Fe), Chromium (Cr^{3+}), Cadmium (Cd), and Lead (Pb). The criteria behind the selection of these parameters are based on the parameters being the common pollutant elements in groundwater around the dumpsites. According to National Population Commission (2006), the inhabitants of Lagos State were estimated at 9,013,534 people. Furthermore, the 2010 household survey puts Igando within Alimosho, which is the largest Local Government Area in Lagos State to be 1,319,571 people with population density of 712.5 per square kilometer on185.2 km^2 area of land.

Figure 3.7 (a & b): Soil sampling

Figure 3.8 Water samples taken to LASEPA for analyses

3.5 Data Collection methods

Eighteen (18) water samples were collected for water quality analysis and thirty-six (36) soil samples for textural analysis of the soil. The soil samples were collected from the topsoil and subsoil layer and are illustrated in Figure 3.7a and 3.7b. The water samples were collected in well-labeled 5-litre plastic bottles after severe stirring of the water in the well and composite mixture. The samples were labeled W_1 – W_{18}. Water samples were immediately transported to Lagos State Environmental Protection Agency (LASEPA) laboratory, Alausa, Ikeja for laboratory analysis in accordance with APHA, 2005 recommendations (Fig. 3.8). Information on landfills and Solous in particular was obtained from the Lagos State Waste Management Authority (LAWMA) Ijora, Lagos. Soil samples were analyzed for textural grain size of silt, clay and loamy composition of the topsoil and subsoil layers, at the Agronomy Department, University of Ibadan, Nigeria.

3.6 Analytical Techniques and Laboratory Analysis

The adopted methods of analyses for the examination of all parameters in potable and waste water were in accordance with APHA, 2005 standard recommendation. All samples were analyzed for selected physical, chemical and heavy metals parameters.

3.6.1 Onsite analysis

Temperature, hydrogen ion (pH) concentration, conductivity, and dissolved oxygen were subjected to in-situ measurement. Dissolved Oxygen was measured with the aid of a Dissolved Oxygen (D.O) meter (Orion 3 star model). Hydrogen ion (pH) concentration was determined using the pH 211 microprocessor meter model. Both instruments have an in-built thermometer which was used to measure temperature.

Also, Electrical Conductivity was measured with the aid of a conductivity/EC meter.

3.6.2 Offsite analysis

Examined parameters including pH, Electrical conductivity (μScm^{-1}), Temperature (^{o}C),Total Suspended Solid (TSS),Total hardness (TH),Nitrate (NO^{-}_{3}) Dissolved Oxygen(DO) Phosphate($P0_4$), Sulphate ($S0_3$), Calcium (Ca), Sodium (Na), Chloride (Cl^{-}), Iron(Fe), copper (Cu) and Lead (Pb) were analyzed at the Lagos State Environmental Protection Agency (LASEPA). Sampled water was analyzed for potability at potable water laboratory. Atomic Absorption spectrophotometer was used to determine the concentration of each heavy metal under specific wavelengths.

The samples (100 ml each) were digested with 5ml of nitric acid (HNO_3) to liberate organic molecule from the samples, and heated at the temperature range of 45 ^{0}C to 65 ^{0}C before being taken to sensitive laboratory. Chemical parameters were detected through different titrations applicable to each variable.

Soil samples for A and B horizons were analyzed for textural composition of sand, clay and silt at the laboratory of the Department of Agronomy, University of Ibadan. Method of analysis included the dispersion of the soil and separation of soil particles into size groups. Soil was pre-treated to remove organic matter and salts to allow it disperse completely. The soil triangle was then used to convert particle sizes into the recognized texture classification of sand silt and clay percentages.

3.7 Data Analysis

The obtained data were subjected to descriptive statistical analysis such as mean, standard deviation, coefficient of variation, graph, table, range as well as inferential statistics like correlation and regression. Correlation analysis was used to verify the relationship between examined parameters with the aid of IBM-SPSS 20. All examined parameters in each well in relation to distance from the landfill and varying levels of concentration in mg/L were illustrated in graphical format.

The mean and coefficient of variance was used to show the degree of variation in the examined variables. Correlated parameters were subjected to regression analysis model and their scatter diagram plotted to show the actual degree of association between examined parameters.

Results from water analysis were compared with those obtained by Longe & Balogun (2008) and Afolayan (2011) to illustrate temporal variation of water quality parameters. Results were also compared with World Health Organization (WHO 2004) and Nigerian Standard for Drinking Water Quality (NSDWQ 2007).

The quality of water in surrounding areas of the Solous dumpsites were analysed using the Contamination Index method and contamination levels of the area was mapped.

According to Backman *et al*., (1998), contamination index (Cd) may be considered as such if the measured concentration of parameters and the upper permissible levels of a contaminant is taken into account. Contamination index is defined as Eq. 1 and 2:

$$\mathbf{Cd} = \sum_{i-1}^{n} Cfi \qquad \mathbf{(1)}$$

$$\mathbf{Cfi} = \frac{CA_{i-1}}{CN} \qquad \mathbf{(2)}$$

where,

Cd= contamination index;

Cfi=contamination factor of the i-th component,

CAi = analytical value of the i-th component and

CNi=upper permissible concentration of the i-th component according to WHO standards.

Contamination index (Cd) is calculated individually for each water sample, as a sum of the contaminant factors of single component that exceed the maximum contaminant levels (Ramos *et al*., 2004). Therefore, Contamination Index summarizes the effects of several quality parameters that may be harmful to humans and the environment. The value scale for contamination index consists of 3 ranges; Cd< 1 (low contamination), 1 < Cd < 3 (medium contamination) and Cd > 3 (high contamination) (Edet *et al.*, 2002)

Also the spatial distribution of land use and degree of each parameters concentration in relation to sampling point was overlaid in maps.

CHAPTER FOUR

DATA PRESENTATION AND ANALYSIS

4.1 Data Presentation

Water and soil samples were evaluated to understand the effects of dumpsite location on the quality of water in surrounding areas. The data is presented in the form of table, figures and text for effective data and results presentation.

4.2 Physical Parameters

Analysis of the physical properties of sampled groundwater (Table 4.1) shows that in all sample locations, appearance, odour and turbidity were found to be within the WHO standard limit. Temperature ranged between 25.4°C - 26.6°C below the standard limit of 35°C - 40°C, indicating the presence of foreign bodies such as active micro-organisms (Akinbile and Yusoff, 2011; Jaji *et al*., 2007). Algae was also observed growing in and around most of the well sampled. The complete data set is provided in Appendix A.

Table 4.1 Physical variables in Solous

PHYSICAL	**Appearance**	**Temperature**	**Odour**	**Turbidity**
W.H.O STANDARD	Colourless	35 - 40^{0}C	Odourless	5 NTU (mg/l)
W1	Colourless	26.2	Odourless	Clear*
W2	Colourless	26.5	Odourless	Clear*
W3	Colourless	26.3	Odourless	Clear*
W4	Colourless	26.1	Odourless	Clear*
W5	Colourless	26.1	Odourless	Clear*
W6	Colourless	26.0	Odourless	Clear*
W7	Colourless	26.1	Odourless	Clear*
W8	Colourless	25.8	Odourless	Clear*
W9	Colourless	25.8	Odourless	Clear*
W10	Colourless	26.5	Odourless	Clear*
W11	Colourless	26.3	Odourless	Clear*
W12	Colourless	26.1	Odourless	Clear*
W13	Colourless	26.6	Odourless	Clear*
W14	Colourless	26	Odourless	Clear*
W15	Colourless	25.8	Odourless	Clear*
W16	Colourless	25.8	Odourless	Clear*
W17	Colourless	25.4	Odourless	Clear*
W18	Colourless	25.6	Odourless	Clear*

* 1 NTU – 5 NTU

4.3 Chemical Parameters

The mean concentrations of chemical parameters, inclusive of heavy metals, of groundwater samples are shown in Tables 4.2 and 4.3 compared with WHO and NSDWQ standards. Table 4.4 shows the descriptive statistics of heavy metals in the ground water samples.

Table 4.2 Chemical variables in Solous

	pH	**Total Acidity**	**Total Alkalinity**	**Total Hardness**	**Choride**	**Nitrates**	**Phosphate**	**Sulphates**	**Dissolved Oxygen**	**Compliance (%)**
W.H.O STANDARD	6.5 - 8.5	NS	200	100	250	10	5	250	2	
NSDWQ	6.5 - 8.5	NS	NS	NS	250	50	NS	100	NS	
W1	6.3	38	25	32	11	3.4	0	4.0	**5.53**	88.89
W2	6.4	35	35	34	12	6.3	0	1.0	**5.26**	88.89
W3	5.3	42	20	30	13	5.0	1.85	2.0	**5.54**	88.89
W4	6.0	54	15	20	12	6.3	1.86	2.0	**5.71**	88.89
W5	6.0	43	15	36	34	5.3	2.12	4.0	**5.68**	88.89
W6	5.9	66	20	32	12	5.8	0	15.0	**4.36**	88.89
W7	4.1	115	15	16	121	5	1.91	3.0	**5.0**	88.89
W8	4.9	67	15	12	4	3.5	0	2.0	**5.71**	88.89
W9	7.6	270	**570**	86	ND	6.9	0.77	29	**3.15**	77.78
W10	6.4	37	15	28	13	4.4	1.16	2	**5.28**	88.89
W11	5.3	40	40	56	27	5.4	1.33	1	**4.78**	88.89
W12	6	71	55	18	102	6.3	0.43	10	**4.72**	88.89
W13	8.1	ND	**1605**	62	ND	1.4	0.85	0	1.88	88.89
W14	6.7	21	55	72	14	6.3	0	2.0	**5.47**	88.89
W15	7.1	11	10	4	28	**11.9**	0	4.0	**4.85**	77.78
W16	6.1	34	20	8		4.4	2	0.0	**5.34**	88.89
W17	7.4	126	196	94		**20.9**	0.91	4.0	**4.54**	88.89
W18	5.3	58	10	4		3.6	1.14	2	**5.2**	
Compliance (%)	100	88.89	100	100	88.89	100	100	5.56		

Table 4.3 Heavy metal concentration in Solous

Parameters (mg/l)	**Magnesium**	**Zinc**	**Copper**	**Manganese**	**Iron**	**Lead**	**Chromium**	**Compliance (%)**
W.H.O STANDARD	150	1.5	0.5	0.5	0.03	0.015	0.1	
NSDWQ	0.2	3	1	0.2	0.3	0.01	0.05	
W1	0.12	0	0.00	0	0.03	0	0	100
W2	0.09	0	0.00	0.0041	**0.04**	**0.018**	0	71.43
W3	0.03	0	0.00	0.0107	0.02	**0.016**	0	85.71
W4	0.05	0	0.00	0	0.02	0.005	0	100
W5	0.09	0	0.01	0	0.03	0.011	0	100
W6	0.12	0	0.01	0	**0.04**	0.002	0	85.71
W7	0.16	0	0.03	0	0.00	0.004	0	100
W8	0	0	0.03	0	0.01	0	0	100
W9	1.43	0	0.05	0	**0.06**	0.012	0	85.71
W10	0.04	0.16	0.03	0	**0.05**	**0.380**	0	71.43
W11	0.29	0	0.06	0	0.03	0	0	100
W12	0.06	0	0.04	0	0	0	0	100
W13	0.47	0	0.08	0	**0.44**	0.009	0.00	85.71
W14	0.07	0	0.06	0	0.01	0.001	0	100
W15	0.12	0	0.08	0	0.01	0	0	100
W16	0.10	0	0.09	0	0.02	0	0	100
W17	0.27	0	0.06	0	0.01	0.010	0	100
W18	0.00	0	0.10	0	0	0	0	100
Compliance (%)	100	100	100	100	72.22	88.24	100	

*ND – Not Detected *NS – Not Supplied

Table 4.4 Descriptive Statistics of variables in Solous

Parameters (mg/l)	Range	Mean	Std. Deviation
Magnesium	1.43	0.1950	0.32960
Zinc	0.16	0.0089	0.03771
Copper	0.10	0.0406	0.03351
Manganese	0.01	0.0008	0.00265
Iron	0.44	0.0456	0.09995
Lead	0.38	0.0260	0.08855
Chromium	0.00	0.0000	0.00000
Nitrates	19.50	6.23	4.23568
pH	4.00	6.16	0.99655
Dissolved Oxygen	3.83	4.89	0.97832
Chlorides	121.00	22.39	34.12286

Chemical parameters of whose samples showed a 100% compliance with WHO standards include: Total Hardness, Chlorides, Phosphates, Sulphates, Magnesium, Zinc, Manganese and Chromium.

4.3.1 Total Alkalinity: Concentrations in W_9 (570mg/l) and W_{13} (1605mg/l) exceeded WHO standards of water quality. A percentage compliance of 88.89% was recorded for samples taken. Alkalinity refers to the capability of water to neutralize acid and its importance is underscored by its ability to control pH changes. High alkalinity, while not detrimental to humans may cause drinking water to have a flat, unpleasant taste (Adams, 2001).

4.3.2 Nitrates: Concentrations in all samples except W_{15} and W_{17} were found to exceed WHO standard limit. However both samples remained within the NSDWQ limit of 50mg/l. A percentage compliance of 88.89% was recorded for samples taken. High nitrate levels in the bloodstream reduce the ability of the red blood cells to transport oxygen (WRIG 2013). Ingestion of nitrates in drinking water has been known to cause methemoglobinamia in infants less than six months (Johnson *et al*., 1987).

4.3.3 Dissolved Oxygen: All samples exceeded the standard limit except W_{13}. Dissolved Oxygen is essential to the survival of aquatic life (Lenntech, 2012).

4.3.4 Copper: Of the 18 groundwater samples, all were within stated WHO limits except W_{18}. However, it remained within the NSDWQ standards and does not present any health concerns. High intake of Copper can cause liver and kidney damage which may eventually lead to death. It also causes stomach ached, dizziness, vomiting and diarrhea.

4.3.5 Iron: Concentrations in W_2, W_6, W_9, W_{10} and W_{13} were found to exceed WHO standards. W_{13} also exceeded upper limit standards of the NSDWQ which is even higher (0.3) than the WHO standard. Average concentration of Iron was recorded at 0.456mg/l (Table 4.4).

Iron concentrations however do not pose potential health risk as they fall well within the recommended daily dietary allowance (7mg – 18mg). Water with high iron concentrations may be discoloured and stain washed clothing (Adams, 2001).

4.3.6 Lead: Lead was observed to be above standard limits in W_2, W_3 and W_{10}. Percentage compliance across all samples was 88.24%. Lead has many toxic effects on human health with children being the most vulnerable population (Payne, 2008). Excessive exposure to Lead is associated with various neurodevelopmental problems and a 4.1-fold increased risk of attention-deficit hyperactivity disorder in children (Brodkin *et al*., 2007; Sanborn *et al*., 2002). The concentrations of Lead in the samples were insufficient to pose any serious health risk to individuals.

4.4 Comparison of Current Results with Previous Studies

Table 4.5 illustrates temporal variation of the common water quality parameters by Balogun and Longe in 2008, and Afolayan in 2011. Obvious observations about the recorded data are the fluctuation of the minimum, maximum and average mean value. As at 2008, Solous 1 was open but was closed in 2011. It was later re-opened in 2012. Intermittent opening and closing of the landfill has been the major reason for the fluctuation of water quality parameters across authors (Balogun and Longe, 2008; Afolayan, 2011).

While the mean concentration of hydrogen ion (pH) increased from 6.13mg/l in 2008 to 7.22mg/l in 2011, there was a reduction (17.21%) in 2012 to 6.16mg/l. Mean concentration of dissolved oxygen increased from 3.19mg/l in 2008 to 3.87mg/l in 2011. A further increase (21.02%) was recorded in 2012 (Figure 4.1). Nitrates both increased by 48.31% respectively. Of the heavy metals, Iron increased (75%) from 0.01mg/l to 0.04mg/l between 2011 and 2012, while recording a significant drop from 0.08mg/l to 0.01mg/l in the three year period between 2008 and 2011. From the above analysis, heavy metals have a tendency to be significantly depleted over a 3-year period.

Table 4.5 Descriptive statistics of water quality parameters in previous studies

Variable	**Max**	**Min**	**Mean**	**Range**
pH	7.07	5.30	6.13	1.77
	7.74	6.85	7.22	0.89
	8.10	4.10	6.16	4.00
DO	3.94	2.9	3.19	1.03
	4.34	3.41	3.87	0.93
	5.71	1.88	4.89	3.83
NO3	60.50	17.40	38.50	43.10
	9.5	0	3.22	9.5
	20.90	1.40	6.23	19.50
Cl	13.43	2.84	7.80	27.31
	24	5	10.8	19
	121.00	0	22.39	121.00
Fe	0.15	0.02	0.08	0.13
	0.02	0	0.01	0.02
	0.44	0	0.04	0.46
Zn	0.23	0.00	0.08	0.23
	0.16	0	0.09	0.16

Source: Balogun and Longe (2008), Afolayan(2011) and study results

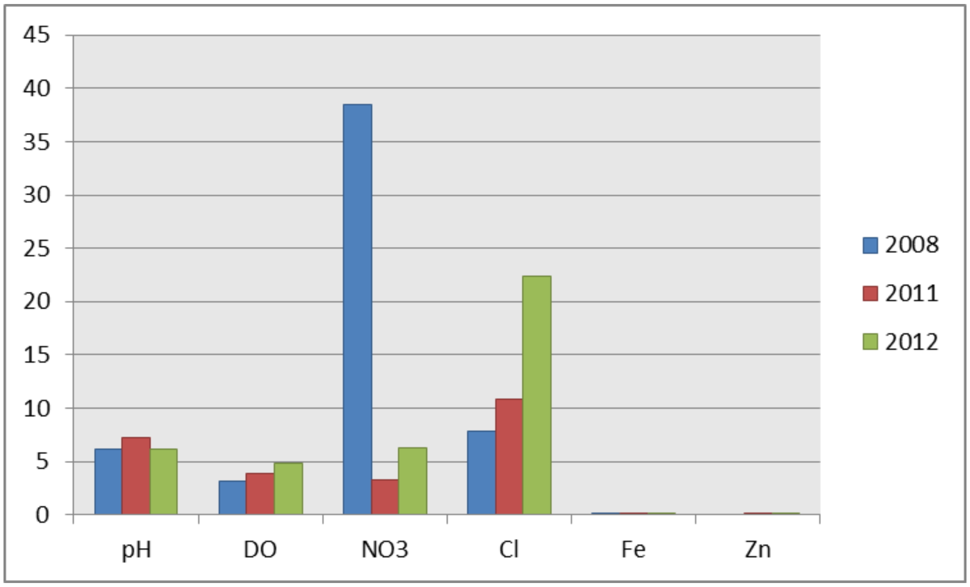

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Figure 4.1 Temporal variation of examined paramters

*All paramters are measured in mg/l except pH

Variation in physicochemical and heavy metal parameters is the function of waste management strategies and seasons (Afolayan *et al.*, 2012). Concentrations of heavy metals in landfills are usually higher in its early stages due to higher metal solubility and low pH caused by the production of organic acids. With increase in age of the landfill, pH level decrease accompanied by decreasing lower metal solubility levels. This in turn leads to a rapid decrease in the concentration of heavy metals (Kulikowska & Klimiuk, 2008). Lower levels of parameters in current study can also be attributed to the time of the year within which the sampling was done (in the rainy season) due to a rise in the water table and dilution of concentration of parameters tested (Kola-Ogunsanya, 2012).

4.5 Hypothesis Testing

H_o: There is no significant relationship between the location of the dumpsite and groundwater quality.

H_1: There is a significant relationship between distance from dumpsite and ground water quality.

4.5.1 Relationship between Chemical Parameters

Correlation is the mutual relationship between two variables. Direct relationships exist when increase or decrease in one parameter results in an increase or decrease in the value of another parameter (Patil & Patil, 2011).

The results of the correlation matrix shown in Table 4.6 shows that only a few significant correlations exist in the data. There is a significant relationship between (SO_4^{2-}) and Total Acidity ($r=0.816$, $p< 0.01$). This agrees with the findings of Toivonen and Osborne, Dockery *et al*. (1996). The negative but significant relationship that exist between Dissolved Oxygen and Total Alkalinity ($r=0.900$, $p <0.01$) is also evidenced in the study carried out by Bhatnagar and Devi in 2012.

The result of the F-statistics (Table 4.7) shows no significant relationship between distance from the dumpsite and all the examined parameters.

Table 4.6 Relationship between water chemical parameters

S/no	Variable	Total Acidity	Total Alkalinity	Total Hardness	Cl^{-+}	No_3^-	Po_4^{3-}	SO_4^{2-}	DO	Distance
1	Total Acidity									
2	Total Alkalinity	0.061								
3	Total Hardness	0.438	0.453							
4	Cl^-	0.106	-0.263	-0.397						
5	No_3^-	0.284	-0.17	0.416	0.135					
6	Po_4^{3-}	0.059	-0.044	-0.12	0.276	-0.113				
7	SO_4^{2-}	0.816**	0.119	0.358	-0.045	0.117	-0.219			
8	DO	-0.292	-0.900**	-0.501*	0.131	0.005	0.142	-0.411		
9	Distance	-0.033	0.151	0.057	0.101	0.258	-0.01	-0.105	-0.236	

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table 4.7 Analysis of variance for water chemical parameters

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	108365.419	8	13545.677	0.859	0.591[b]
Residual	94572.314	6	15762.052		
Total	202937.733	14			

a. Dependent Variable: Distance

b. Predictors: (Constant), DO, Po_4^{3-}, No_3^-, Cl^-, Total Acidity, Total Hardness, SO_4^{2-}, Total Alkalinity

4.5.2 Relationship between Chemical Parameters and Distance

The relationship between heavy metal parameters is shown in Table 4.8. Concentrations of Fe, Mg, Cu, Zn, Pb, Cr, and Mn detected in compliance with WHO standards were 72%, 100%, 94%, 100%, 88%, 100% and 100% respectively (Table 4.3). There is a positive association between (Pb) and (Zn) (r=0.998), (Cr) and (Fe) (r=0.986) Distance and (Cu) (r=0.927).

The result of the F-statistics (Table 4.9) also shows a significant relationship between distance from the dumpsite and examined parameters.

Table 4.8 Relationship between Heavy Metals and Distance

S/no	Variable	Fe	Mg	Cu	Zn	Pb	Cr	Mn	Distance
1	Fe	1							
2	Mg	0.298	1						
3	Cu	0.21	0.193	1					
4	Zn	0.002	-0.117	-0.073	1				
5	Pb	0.018	-0.096	-0.101	0.998**	1			
6	Cr	0.986**	0.21	0.27	-0.059	-0.048	1		
7	Mn	-0.061	-0.147	-0.402	-0.078	-0.035	-0.078	1	
8	Distance	0.057	0.021	0.927**	-0.016	-0.043	0.138	-0.350	1

**. Correlation is significant at the 0.01 level (2-tailed).

Table 4.9 Characteristics of regression analysis of heavy metal parameters

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	363,575.296	7	51,939.328	16.620	0.000^{b}
Residual	31,251.204	10	3,125.120		
Total	394,826.500	17			

a. Dependent Variable: Distance

b. Predictors: (Constant), Mn, Pb, Fe, Mg, Cu, Cr, Zn

The relationship between chemical parameters is further described in the scatter diagrams in Fig. 4.2 (lead and zinc) and 4.3 (distance and copper). While no relationship exists between lead and zinc, it was discovered that copper levels significantly increased with increasing distance. All parameters are stated in mg/l except distance (m).

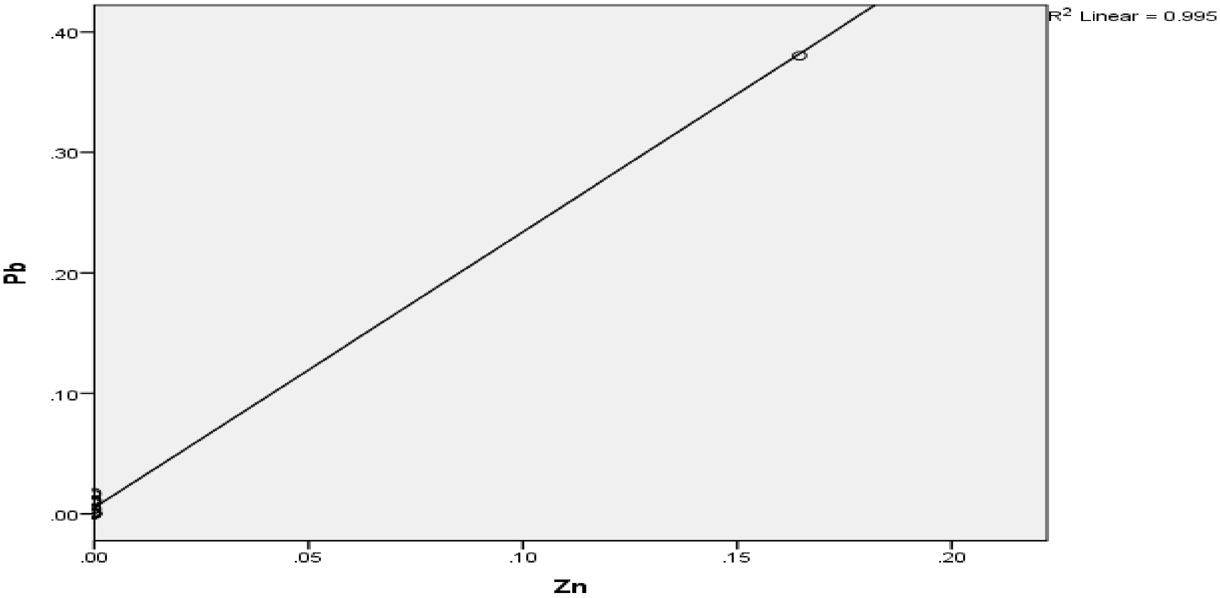

Fig 4.2 Scatter diagram showing relationship between Lead and Zinc

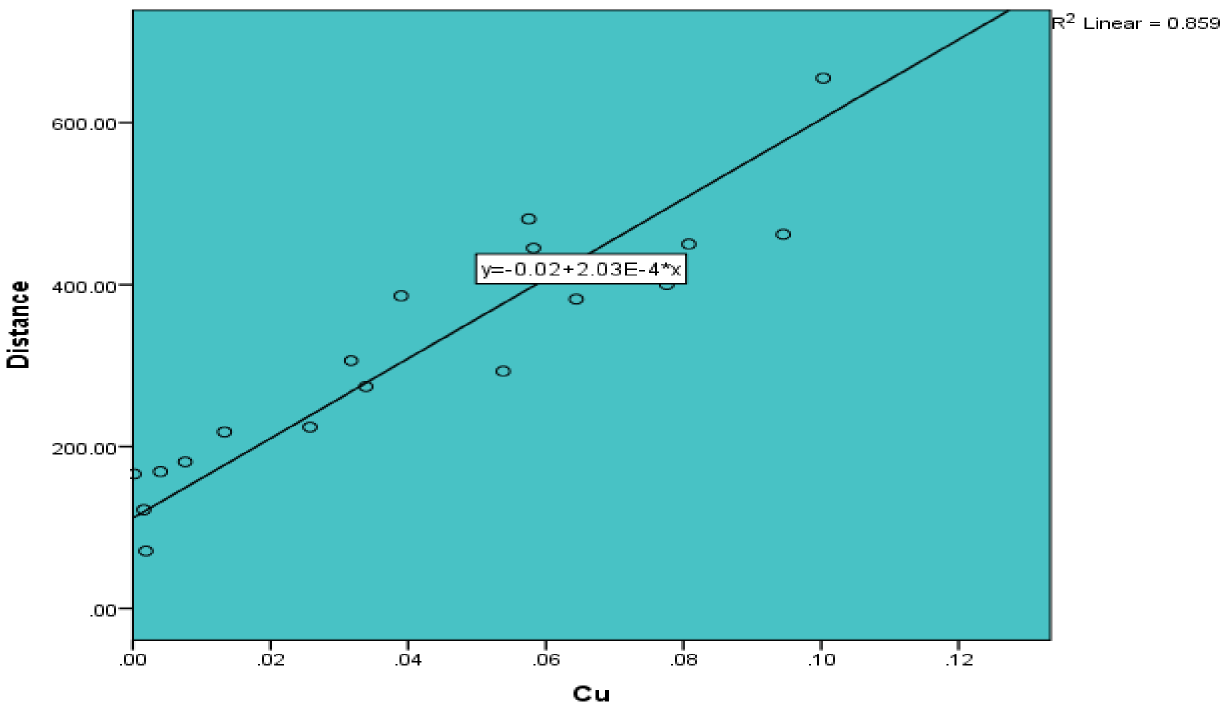

Fig 4.3 Scatter diagram showing relationship between Distance and Copper

Table 4.10a-c shows that, the stated hypotheses of the variation in the concentration of the examined parameters in water samples of the study area in relation to the distance of each sampling point from the landfill. Sampling point W_{15} has high concentration of Nitrate ($N0^{-3}$), higher than the WHO standard limits at the distance of 169m to the landfill center. Concentration of lead (Pb) was higher than the WHO standard in W_2 and W_3 within the range of 400m to the center. Movement of copper, conductivity, alkalinity was high about 400m away from the center of the landfill. Therefore, spatial variation occurs within the examined variable. Concentrations of lead, copper and iron were higher further away from the landfill sites. Only nitrates adhered to the distance decay principle of reducing concentrations with increasing distance. All wells within the range of 200m to the center of the landfills were not seriously affected. All wells over 400m from the center of the landfills were also not affected.

Table 4.10a: Parameter concentration with distance from Solous 1

S/No.	**Code**	**Location**	**Distance (m)**	**High Variable**
1	W_{14}	1	122	
2	W_{15}	1	169	Nitrate
3	W_{16}	1	181	
4	W_{18}	1	218	
5	W_{6}	1	450	

Table 4.10b: Parameter concentration with distance from Solous 2

S/No	**Code**	**Location**	**Distance(m)**	**High Variable**	
1	W_{11}		71		
2	W_{12}	2	224		
3	W_{10}		655		
4	W_{11}		71		

Table 4.10c: Parameter concentration with distance from Solous 3

S/No	**Code**	**Location**	**Distance (m)**	**High Variable**
1	W_{13}	3	264	Total Alkalinity, Iron
2	W_{4}	3	274	
3	W_{1}	3	293	
4	W_{8}		382	
5	W_{2}	3	386	Lead
6	W_{3}	3	400	Lead
7	W_{7}	3	445	
8	W_{9}		462	
9	W_{5}	3	481	

4.5.3 Relationship between sampled water and water quality standards

H_0: There is no significant difference in the quality of a water sample in the area compared with the water quality standard of the World Health organization.

H_1: There is a significant difference in the quality of a water sample in the area compared with the water quality standard of the World Health organization.

The physical parameters of the sampled points (appearance, temperature, odour and turbidity) were in compliance with WHO standards.

Total Acidicty, Total Hardness, Chloride, Phospate, Sulphates, Calcium, Magnesium, Sodium, Pottasium, Zinc, Manganese and Chromium were in 100% compliant with WHO standards. W_9 and W_{13} were above standards of alkalinity. Dissolved Oxygen was higher in 17 of the 18 sample points. Iron and Lead also exhibited 72% and 88% compliance respectively (Table 4.3). The results also show a reduction in most examined parameters over time.

The present results are drastically low compared to the findings of Balogun and Longe (2008); Afolayan (2011) and Afolayan *et al*., (2011).

4.6 Determination of contamination using Contamination Index

The degree of contamination of groundwater samples is shown in Table 4.11. The computed Contamination Index table shows W_9 has the highest degree of contaminant parameters (Total Alkalinity, Dissolved Oxygen and Iron). Dissolved Oxygen was the most prominent contamination parameter discovered in all samples except W_{13}. W_2 had the highest Contamination Index (99.8%) while W_{16} had the lowest (2.2). There is high degree of contamination in W_2, W_3, W_5, W_6, W_9, W_{10}, W_{13}, W_{17} and W_{18}. Samples W_1, W_4, W_7, W_8, W_{11}, W_{12}, W_{14}, W_{15}, and W_{16} recorded medium contamination while there was no area of low contamination recorded. Dissolved oxygen, iron and lead were the most common contaminants. Figure 4.4 shows areas with corresponding degrees of contamination. Water sampled in the areas around Solous 2 and 3 dumpsites showed higher contamination than the areas sampled around Solous 1.

Table 4.11 Contamination Index Table for constituents in groundwater samples

Code	Total Alkalinity	NO3	DO	Fe	Pb	Contamination factor(Cf)	Contamination parameters	Contamination index(Cd)	Level of contamination
W2	35	6.3	**5.26**	**0.036**	**0.02**	2.13,32.15,65.49	DO, Fe and Pb	99.8	High contamination
W3	20	5	**5.54**	0.023	**0.02**	2.27,65.6	DO,Pb	67.9	High contamination
W5	15	5.3	**5.68**	**0.032**	0.01	2.34,32.25	DO and Fe	34.6	High contamination
W6	20	5.8	**4.36**	**0.041**	0.00	1.68,31.98	DO and Fe	33.7	High contamination
W9	**570**	6.9	**3.15**	**0.059**	0.01	7.22,2.85,1.08,31.35	Total Alkalinity, DO, and Fe	42.5	High contamination
W10	15	4.4	**5.28**	**0.046**	**0.38**	2.14,31.81,41.32	DO, Fe and Pb	75.3	High contamination
W13	**1605**	1.4	1.88	**0.437**	0.01	8.02,18.78	Total Alkalinity and Fe	26.8	High contamination
W17	196	**20.9**	**4.54**	0.008	0.01	3.43,1.99,1.77	Nitrate and DO	7.2	High contamination
W18	10	3.6	**5.20**	0.000	0.00	2.1	DO	2.1	High contamination
W1	25	3.4	**5.53**	0.026	0.00	2.27	DO	2.3	Medium contamination
W4	15	6.3	**5.71**	0.022	0.00	2.36	DO	2.4	Medium contamination
W7	15	5	**5.00**	0.002	0.00	.71,2	Conductivity and DO	2.7	Medium contamination
W8	15	3.5	**5.71**	0.009	0.00	2.36	DO	2.4	Medium contamination
W11	40	5.4	**4.78**	0.028	0.00	1.89	DO	1.9	Medium contamination
W12	55	6.3	**4.72**	0.000	0.00	1.86	DO	1.9	Medium contamination
W14	55	6.3	**5.47**	0.013	0.00	2.235	DO	2.2	Medium contamination
W15	10	**11.9**	**4.85**	0.006	0.00	1.09,1.925	Nitrate and DO	3	Medium contamination
W16	20	4.4	**5.34**	0.020	0.00	2.17	DO	2.2	Medium contamination

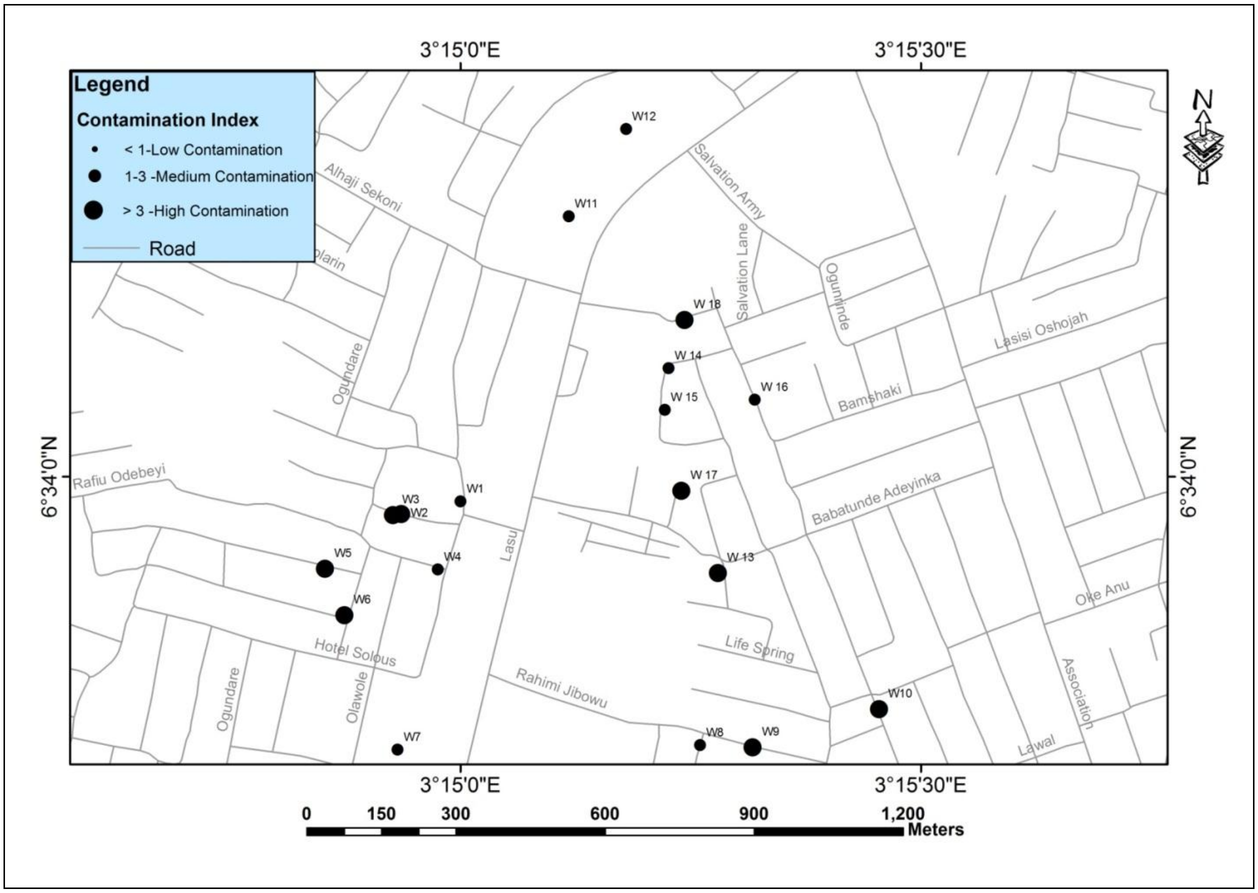

Figure 4.4 Spatial variation of contamination index across the study area

4.7 Influence of soil physical properties

Table 4.12 illustrates the soil samples of each sampling point from A (0 – 30cm) and B (30 – 60cm) horizons. It also corresponds with the number of water sampling points. The composition of sand (67.11%) ranked the highest, with clay (21.18%) content higher than silt (11.71%). Excess sand over clay and silt is attributed to the coastal location of the state (Lagos) under study. Coarse textured soils generally have moderate to high sensitivities because they are more permeable and tend to have lower sorption potentials, find textured soils, on the other hand have very slow permeabilities and high sorption potentials (Huddleston, 1996).

While the high concentration of clay obstructs the free migration of leachate, excess sand allows the free movement of pollutants together with the groundwater, hence proximity of well to the dumpsite may not be the sole determinant of groundwater pollution. The clay content found within the soil samples explains the slow movement of contaminants from the dumpsite to surrounding wells due to leaching. However, the high composition of sand within the study area suggests an increase in parameters over time with significant health implications for the people who depend on surrounding wells for domestic use.

Table 4.12 Soil structure of the study area

S/N	**Sample**	**Clay**	**Silt**	**Sand**
1	W_1A	14.8	34	51.2
	W_1B	12.8	4	83.2
2	W_2A	40.8	14	45.2
	W_2B	12.8	12	75.2
3	W_3A	32.8	8	59.2
	W_3B	44.8	12	43.2
4	W_4A	6.8	4	89.2
	W_4B	12.8	18	69.2
5	W_5A	8.8	10	81.2
	W_5B	26.8	14	59.2
6	W_6A	6.8	14	79.2
	W_6B	16.8	14	69.2
7	W_7A	16.8	14	69.2
	W_7B	12.8	20	67.2
8	W_8A	8.8	8	51.2
	W_8B	10.8	10	79.2
9	W_9A	10.8	16	73.2
	W_9B	30.8	10	59.2
10	$W_{10}A$	16.8	8	75.2
	$W_{10}B$	44.8	8	51.2
11	$W_{11}A$	26.8	6	67.2
	$W_{11}B$	32.8	8	59.2
12	$W_{12}A$	34.8	6	59.2
	$W_{12}B$	24.8	14	61.2
13	$W_{13}A$	12.8	14	73.2
	$W_{13}B$	34.8	6	40.8
14	$W_{14}A$	8.8	8	83.2
	$W_{14}B$	12.8	0	87.2
15	$W_{15}A$	10.8	20	69.2
	$W_{15}B$	26.8	20	53.2
16	$W_{16}A$	10.8	10	79.2
	$W_{16}B$	20.8	8	71.2
17	$W_{17}A$	34.8	2	63.2
	$W_{17}B$	40.8	8	51.2
18	$W_{18}A$	8.8	22	69.2
	$W_{18}B$	20.8	12	67.2
	Total	**752.8**	**416**	**2384.8**
	Ave. Total	**21.01**	**12.06**	**66.24**
	Percentage	**21.18%**	**11.71%**	**67.11%**

CHAPTER FIVE

SUMMARY, RECOMMENDATION AND CONCLUSION

5.1 Summary of Findings

In Africa, the most congested city is Lagos which has been ranked as the most urbanized and industrialized city in Nigeria. Waste generation has been attributed to the level and degree of national development. However, with the stated urban characteristics, old and rudimentary system of waste management is still the dominant method throughout the Nigerian States without future implication on groundwater quality. The Solous landfills in Igando, Alimisho Local Government Area has three major landfills without any plan for the inhabitants with respect to groundwater consumption to avoid water borne diseases on human health. Ideally, there is need for better way of waste disposal without interference with any environmental resources. Landfilling has been regarded as the easiest way of disposing waste and refuse within the city of Lagos over years. Among the three major existing landfills (Olusosun, Abule-egba and Solous) in Lagos State, Solous is the second largest after Olusosun.

This research examined the quality of groundwater around the three dumpsites in Solous in order to compare the concentration of the examined variable with the WHO (2004) and NSDWQ (2007) standard limits.

Seventeen (17) parameters were examined in relation to eighteen water samples collected. It was discovered that nitrate ($N0^-_3$), electrical conductivity (EC), total alkalinity (TA), iron (Fe), lead (Pb) and copper (Cu) were above the WHO standard limit in some samples. Concentration of heavy metals and chemical parameters such as iron, lead and copper were more available in groundwater around Solous 2 and 3 while, nitrate was the only chemical parameter with high concentration around Solous 1. Results also indicated that groundwater within the range of Solous 1 landfill had less concentration of heavy metals than the other landfills.

The results also showed no signification variation in water quality with increasing distance from the dumpsite. Findings also indicated that the ground water around Solous 1 was of better quality for domestic use than groundwater around Solous 2 and 3 due to temporal reduction of contaminant concentration over time.

Results were compared with studies carried out by previous researchers to observe temporal variation of water quality parameters. The analysis indicated a significant depletion of heavy metals over time.

It is obvious that time, role of waste management strategy, soil stratigraphy, groundwater flow direction, landfill life span, distance from the leachate, Piezometric level, season, underlying geology, all play vital roles in groundwater quality around dumpsites in relation to waste decomposition, leachate formation and migration as well as groundwater contamination.

5.2 Recommendations

Toward the control of groundwater vulnerability to pollution through landfills, there is need for adequate and proper planning, design and construction, and strategic management disposal of waste. Ordinary landfills or dumpsites need to be outlawed and provision of modern sanitary landfills should be provided to ameliorate and alleviate the incessant groundwater contamination. Government is to locate new landfills away from the general population to avoid contamination of their water supply. Lagos State as the most populous city in Africa should seek for national and international assistance in the area of modern technology for the implementation of better sustainable environmental sanitation practice.

In the case of closed landfills, the surface must be capped with materials that inhibit high rate of infiltration, specifically clay or peat material, because high rate of infiltration aggravates waste decomposition and enhance leachate migration. Construction of barriers such as trenches, cut-off-walls or defence well may be appropriate especially where leachate has threatened or polluted the aquifer.

Detailed analysis of hydrogeology and groundwater flow direction in the area is highly required to safeguard the exploration and exploitation of groundwater. Government agencies such as Lagos State Environmental Protection Agency (LASEPA) and Lagos State Waste Management Authority (LAWMA) should engage in more research to monitor contaminant levels and plan mitigation strategies.

Modern waste management and treatment policy should be put in place for the landfill and waste disposal must be controlled by pre-treatment before disposal or after disposal. In an ideal sanitary landfill, there is compartmentalization of treatment plants for waste and leachate for recycling and other uses. There is also a need for public awareness about the specific purpose of which the groundwater in the study area can be used for and incase of domestic use, necessary purification methods should be applied for health safety.

To forestall the continuous contamination of groundwater through the disposal of docmestic and industrial waste, the government would need to consider other sanitary methods of waste disposal such as recycling. To reduce the incidence of water borne diseases, appropriate water resource management strategies need to be applied. Potable water from government/public water works should always circulate to the affected and likely to be affected areas as and when due.

5.3 Conclusion

Groundwater is a universally valuable renewable resource for human life and economic development. Growth and development on the earth surface has rendered surface water of certain areas of the world useless despite its availability in large quantity. The study observes indiscernible migration of decomposed waste into leachate from the base of the landfill to be the point source of groundwater pollution. This obviously limits groundwater functions for various purposes (such as domestic, industrial and agriculture). Implication of the groundwater pollution could also be attributed to different health related problems.

Although both surface and groundwater may be available in large quantity in Igando owing to the geographical location but purpose and accessibility to it is limited in terms of quality.

Concentrations of some variables were not detected. This indicates the impact of time in parameter reduction. Concentration of the examined parameters were analysed, discussed and explained with relevant statistical tools. Hydrogen ion (pH) has the highest degree of correlation with other examined variables, that is, concentration of hydrogen ion in water directly influenced some parameters. Of more important is their reduction in relation to time.

However**,** not all contaminant parameters obeyed the distance decay principle with the exception of Nitrate with an average distance of 167 metres reduced with distance. Also, the present results are drastically low compared to the findings of Balogun and Longe (2008); Afolayan (2011). Of the soil samples taken, the composition of sand ranked the highest, with clay content higher than silt showing that the study location is predominantly sandy.

Moreover, pH is the only parameter with the highest rate of interaction through analysed correlation coefficient because it synergistically influenced both chemical, and heavy toxic metals especially anions and cations than any other water quality variable. Also those well within the range of 200m to the landfills center were not seriously affected.

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APPENDIX

A: ANALYSIS OF GROUNDWATER SAMPLES – COMPLETE DATA OF LABORATORY RESULTS

PHYSICAL PROPERTIES							
	Appearance	**Temperature**	**pH**	**Odour**	**Turbidity**	**Conductivity**	**Total Suspended Solid**
W.H.O STANDARD	Colourless	35 - 40^{0}C	6.5 - 8.5	Odourless	5 NTU (mg/l)	1.0 mscm	30mg/l
W1	Colourless	26.2	6.3	Odourless	Clear	0.23	0
W2	Colourless	26.5	6.4	Odourless	Clear	0.42	2
W3	Colourless	26.3	5.3	Odourless	Clear	0.28	1
W4	Colourless	26.1	6	Odourless	Clear	0.26	0
W5	Colourless	26.1	6	Odourless	Clear	0.59	0
W6	Colourless	26	5.9	Odourless	Clear	0.4	4
W7	Colourless	26.1	4.1	Odourless	Clear	1.29	0
W8	Colourless	25.8	4.9	Odourless	Clear	0.12	0
W9	Colourless	25.8	7.6	Odourless	Clear	9.22	5
W10	Colourless	26.5	6.4	Odourless	Clear	0.42	2
W11	Colourless	26.3	5.3	Odourless	Clear	0.28	1
W12	Colourless	26.1	6	Odourless	Clear	0.26	0
W13	Colourless	26.6	8.1	Odourless	Clear	ND	8
W14	Colourless	26	6.7	Odourless	Clear	0.54	0
W15	Colourless	25.8	7.1	Odourless	Clear	0.79	2
W16	Colourless	25.8	6.1	Odourless	Clear	0.31	0
W17	Colourless	25.4	7.4	Odourless	Clear	4.43	2
W18	Colourless	25.6	5.3	Odourless	Clear	0.2	3

MICROBIOLOGY			
	Total Plate Count	**Total Coliform Count**	**Confirmatory Feacal Coliform Test**
W.H.O STANDARD	100 cfu/ml	NIL	NEGATIVE
W1	30	540	NEGATIVE
W2	40	>2400	POSITIVE
W3	80	920	NEGATIVE
W4	20	49	NEGATIVE
W5	30	0	NIL
W6	100	23	NEGATIVE
W7	10	0	NEGATIVE
W8	30	>2400	POSITIVE
W9	80	>2400	NEGATIVE
W10	10	0	NIL
W11	80	79	NEGATIVE
W12	100	23	NEGATIVE
W13	40	>2400	POSITIVE
W14	50	49	NEGATIVE
W15	40	>2400	POSITIVE
W16	10	23	NEGATIVE
W17	50	>2400	POSITIVE
W18	100	0	NEGATIVE

CHEMICAL PROPERTIES								
	Total Acidity	**Total Alkalinity**	**Total Hardness**	**Chloride**	**Nitrates**	**Phosphate**	**Sulphates**	**Dissolved Oxygen**
W.H.O STANDARD	NS	200 mg/l	100 mg/l	250 mg/l	10 mg/l	5 mg/l	250 mg/l	2.0 mg/l (min)
W1	38	25	32	11	3.4	0	4	5.53
W2	35	35	34	12	6.3	0	1	5.26
W3	42	20	30	13	5	1.85	2	5.54
W4	54	15	20	12	6.3	1.86	2	5.71
W5	43	15	36	34	5.3	2.12	4	5.68
W6	66	20	32	12	5.8	0	15	4.36
W7	115	15	16	121	5	1.91	3	5
W8	67	15	12	4	3.5	0	2	5.71
W9	270	570	86	ND	6.9	0.77	29	3.15
W10	37	15	28	13	4.4	1.16	2	5.28
W11	40	40	56	27	5.4	1.33	1	4.78
W12	71	55	18	102	6.3	0.43	10	4.72
W13	ND	1605	62	ND	1.4	0.85	0	1.88
W14	21	55	72	14	6.3	0	2	5.47
W15	11	10	4	28	11.9	0	4	4.85
W16	34	20	8		4.4	2	0	5.34
W17	126	196	94		20.9	0.91	4	4.54
W18	58	10	4		3.6	1.14	2	5.2

TRACE/TOXIC HEAVY METAL												
	Calcium	**Magnesium**	**Sodium**	**Potassium**	**Zinc**	**Copper**	**Manganese**	**Iron**	**Cadmium**	**Silver**	**Lead**	**Chromium**
WHO STD	200 mg/l	150 mg/l	200 mg/l	<20 mg/l	1.5 mg/l	0.5 mg/l	0.5 mg/l	0.03 mg/l	0.002 mg/l	NS	0.015 mg/l	0.10 mg/l
W1	0.7916	0.1205	0.3166	0.0798	0	0.0019	0	0.0264	0	0	0	0
W2	1.1915	0.0894	0.3788	0.0588	0	0.0016	0.0041	0.0356	0	0	0.0176	0
W3	0.3258	0.0314	0.4822	0	0	0.0002	0.0107	0.0229	0	0	0.0160	0
W4	0.4805	0.0476	0.2738	0.022	0	0.0040	0	0.0224	0	0	0.0047	0
W5	0.4639	0.0870	0	0.4037	0	0.0076	0	0.0324	0	0	0.0108	0
W6	0.4571	0.1195	0.2435	0.2503	0	0.0133	0	0.0406	0	0	0.0015	0
W7	0.0747	0.1583	0.4951	0.6508	0	0.0257	0	0.0019	0	0	0.0036	0
W8	0.0237	0	0.0787	0	0	0.03388	0	0.0091	0	0	0	0
W9	0.514	1.4337	0.6958	0.0480	0	0.0538	0	0.0593	0	0	0.0117	0
W10	0.2336	0.0406	0.2965	0.052	0.1645	0.0317	0	0.0458	0	0	0.3802	0
W11	2.0495	0.2893	0.5112	0.3105	0	0.0644	0	0.0279	0	0	0	0
W12	0.1151	0.0637	0.3153	0.5062	0	0.0390	0	0	0	0	0	0
W13	0.9129	0.4738	0.7856	1.3497	0	0.0776	0	0.4365	0	0	0.0089	0.0048
W14	0.9118	0.0706	0.3192	0.0345	0	0.0582	0	0.0131	0	0	0.0008	0
W15	0.9602	0.1181	0.5040	0.1962	0	0.0808	0	0.0061	0	0	0	0
W16	0.0644	0.1016	0.2434	0.071	0	0.0945	0	0.0203	0	0	0	0
W17	0.7184	0.2671	0.3639	0.5962	0	0.0575	0	0.0082	0	0	0.0104	0
W18	0.0342	0.0009	0.2854	0	0	0.1003	0	0	0	0	0	0