

**PROLIFERATION OF PETROL STATIONS: RISKS, IDENTIFICATION
AND DESIGN OF GROUNDWATER QUALITY MONITORING WELLS
IN OWERRI WEST, IMO STATE, NIGERIA**

BY

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**A THESIS SUBMITTED TO THE
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**IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR
THE AWARD OF MASTERS OF SCIENCE {M.Sc.} DEGREE IN
ENVIRONMENTAL TECHNOLOGY**

NOVEMBER, 2017

CERTIFICATION

I, hereby certify that this thesis is the result of my research for M.Sc. degree in Environmental Technology, in the Department of Environmental Technology, Federal University of Technology Owerri, Nigeria. This thesis has neither in whole nor in part been presented elsewhere for the award of another degree.

 DR. M.A NWACHUKWU SUPERVISOR SIGNATURE	14/02/2018 DATE
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 DR. P.N. OKEKE HEAD OF DEPARTMENT SIGNATURE	14/02/18 DATE
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EXTERNAL EXAMINER	 SIGNATURE	13/04/18 DATE
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DEDICATION

This thesis is dedicated to God Almighty whom all glory must be given for providing me with wisdom to carry out this research work successfully and for sparing my life throughout the duration of my study at Federal University of Technology, Owerri.

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ABBREVIATIONS

BAT-Best Available Technique

CNS- Central Nervous System

EDB- Ethylene dibromide

EGAS -Environmental Guidelines and Standards

ERA- Environmental Risk Assessment

GIS- Geographic Information System

GPS- Global Positioning System

IPM- Independent Petroleum Marketers

MTBE- Methyl tert-butyl ether

UST- Underground Storage Tank

VES- Vertical Electrical Sounding

ABSTRACT

Petrol stations located along three roads: Nekede-Ihiagwa – Aba Road (1), Owerri-West segment of Port-Harcourt Road (2) and Owerri-West segment of Onitsha Road (3) were specifically investigated and mapped using Global Positioning System (GPS). Results show that the number of petrol stations is more than necessary. The 8 km Road (1) has 26 petrol stations; the 14 km Road (2) has 24 petrol stations while the 6 km Road (3) has 20 petrol stations. Out of a total of 70 petrol stations, 46% were functional, 42% were non functional, 8% were abandoned and 4% were under construction at time of this investigation. Petrol stations that were not properly situated were 64% while 1% is encroached by new developing structures. The petrol stations have their age range between 2 to 22 years, number of underground storage tanks (USTs) from 3 to 12 and average depth of USTs as 3.6 m (12 ft.). All the stations have similar size USTs and same corrosion prevention treatment of only bitumen coating and wrapping with black polyethylene. No cathodic protection. Electrical resistivity inversion gave average depth to groundwater as 24.5 m (80 ft) and lithology consisting predominantly of sand and gravel beds which implies that leakage from USTs would easily migrate to the water table. Drainage analysis confirmed surface drainage towards South-SW, corresponding to groundwater flow direction. USTs between ages of 15 to 22 years are at greater risk of corrosion and leakage, whereas approximately one million people in the area depend on groundwater for drinking and other domestic uses. Six monitoring well locations have been identified based on groundwater flow direction (South-SW), cluster of petrol stations, and age (≥ 15 years) of USTs.

Keywords: Corrosion; Drainage analysis; Fuel Station USTs;

Mapping; Monitoring wells; Risk; Water table; Water quality;

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of Study

Petrol stations suddenly became a booming business since the late 90's. There is indiscriminate siting and establishment of all manners and standards of petrol stations by individuals predominantly not complying with existing guidelines and regulations (Genovese, 2004).

Proliferation of petrol stations all over the world is perceived to have serious environmental consequences that call for regular monitoring and risk assessment. Unfortunately such monitoring and risk assessment needed for assurance of environmental safety is not carried out in some affected areas. Petrol stations are fuel storage places accommodating petroleum products such as petrol, gasoline, kerosene and often cooking gas, available in urban and rural area settings. These products have the potential to cause accident; fire disaster, air pollution, soil contamination and groundwater pollution, thus threatening human life and property if not properly handled (Hanekom, 2001).

Proliferation of petrol stations in Nigeria is the handiwork of human greed over petroleum products; hoarding, artificial scarcity and profiteering in the presence of political and economic instability since late 90's. Petrol stations are classified as objects of high potential environmental impact, and that is why very

strict environmental regulations together with relevant recommendations regulate their construction and operation. In the past, there were few petrol stations because investors were not making much profit but due to human factors, petrol hoarding and creation of artificial scarcity, marketers, and investors found petrol stations business as gold mines without proper safety measures. (Afolabi *et al.*, 2011).

Urban growth also has increased the use of automobiles, need for petrol stations and consequently, proliferation of petrol stations most of which lack the minimum requirement for operation. Considering the high risk and dangers associated in petroleum products as highly flammable, its production, transportation, offloading, storage and sale points, they should not be taken for granted like other products (Kasupda, 2009)

According to WHO (2004) report, more than 2.3 million lives and properties worth more than 4.5 billion are lost to fire outbreaks associated with petroleum product mishandling. A petrol station can be operated only upon obtaining the so-called administrative decision. By virtue of the decree of the government, every liquid petrol base and station has to be equipped not only with installations, devices and systems preventing penetration of petroleum products into the soil, surface water and groundwater, but also with measuring systems that permit monitoring and adequate warning of potential hazards.

Location of petrol station generally despite its importance to the economy, is expected to be guided by defined environmental rules and regulations. The standard for environmental protection equally is determined by such factors as legislation and economic priorities of the individual state. In Finland for example, the environmental protection Act 86/2000(12) states that, within industrial operation, where contamination of the environment is possible, Best Available Technique (BAT) should be applied in granting environmental permit after evaluating the circumstances for which the permit is being sought. Petrol Station's activities therefore, fall within the circumstance or risk operation category because they are hazardous workplace so required to be licensed properly. While in Nigeria, the Department of Petroleum Resources (DPR) Environmental Guidelines and Standards (EGAS) of 1991, serve the petroleum industry as a comprehensive working document with serious consideration for the preservation and protection of the Niger Delta and by extension of the Nigerian Environment (Nerry *et al.*, 1997). Its operation falls under the petroleum regulation Act CAP 150 of 1967 which stipulated that application of the issuance of license to all petrol stations shall be through the DPR in order to aid save both the people and the environment from pollution. It was in line with this principle that in 2002, World Summit on Sustainable Development (WSSD) refocused its plan on promoting health through

sustainable development and sustainable management of ecosystem and biodiversity so as to guarantee effective environmental sustainability for all.

The major concern at petrol stations are the location of the station, the possibility of leakage due to corrosion of the buried storage tanks, the safety of the people and protection of the environment since petrol and other motor fuels are potentially hazardous. At ambient temperature, petrol gives off vapours which when mixed with air in appropriate proportion, can burn with explosive force if ignited. All petroleum products are potential pollutants which, if released, can cause damage to the environment. They can contaminate soil, surface water and groundwater. They are injurious to aquatic life and can give health related effects on human if incorrectly handled. With availability of adequate monitoring to occurrences of these hazards, risk can be minimized (EBEI, 2012).

Safety practice in petrol Station is of utmost importance which helps to prevent unforeseen hazards that could affect human health and the environment. Many of the fuel stations are constructed without proper development plan, and cathodic protection to check corrosion and leakages. There are problems of spillage and leakages that contaminate soil, groundwater and surface water. Often petrol stations cause traffic congestion, air pollution, fire and encroachment on right-of-way of the road networks, as a result of non-adherence to planning laws. The

extent of these problems depends on the criteria or variations such as location size and set back from the road etc. The underground storage tanks (UST) in these stations are subject to leak proof test because they are not adequately protected against corrosion. The corrosion control measures applicable are not likely to sustain the tanks beyond 15-20 years. The fear is that corrosion control measures can fail and many of these fuel station's USTs may have leakage at the same time thereby contaminating ground water in the area. This fear is not only existing, but a major concern to environmentalists, researchers and governments (www.epa.gov)

1.2 Statement of Problem

In locating petrol stations, it is important to take some precautionary measures like locating them at a required distance from buildings; places of public assembly such as markets, hospitals and schools and areas of high traffic congestions and residential buildings. This should be in accordance with the guidelines provided by the Department of Petroleum Resources and Fire service safety rules that the distance between two nearest petrol stations should be 400m and between a petrol station to the nearest residential building should not be less than 50m to prevent possible hazards.

Unfortunately in Owerri West in the recent years, these guidelines have not been followed. As a result, there have been cluster of petrol stations that are

located close to residential areas. This might constitute serious hazards to residence in close proximity to such petrol stations.

Fuel stations in Owerri west are constructed without proper development planning resulting to cluster and environmental risks. Spillages from handling and leakages from storage may arise to contaminate soil, groundwater and surface water. Cluster of petrol stations may cause traffic congestion, air pollution, fire and encroachment on right-of-way of the road networks, due to non-adherence to planning laws. The extent of these problems depends on the criteria or variation such as location, size and set back from the road etc. Also the underground Storage Tanks (USTs) in these petrol stations are subject to leak because they are not fully protected against corrosion. The corrosion control measures applicable are not likely to sustain the tanks for a long time. The fear is that corrosion control measures can fail and many of these petrol station's USTs may have leakage at the same time thereby contaminating ground water in the area.

It is therefore against this background that the study examined the spatial pattern of location of these petrol stations and the possible hazards associated with their locations in Owerri West. This is necessary because the entire population of Owerri west depends on groundwater for both drinking and other domestic uses, and any incident of leakage of USTs in petrol stations will result to serious health issues and affecting sustainability of water supply in the area.

1.3 Aims and Objectives of the Study

1.3.1 Aims

The aim of this study is to identify environmental risks associated with multiple petrol stations and sites for installation of monitoring wells in Owerri West.

1.3.2 Objectives

1. To determine the location(s) where monitoring wells could be installed for regular monitoring of water quality in the area and produce a suitable design of groundwater monitoring well based on the result of investigation.
2. To confirm direction of groundwater/contaminant migration in Owerri-west through surface drainage analysis.
3. To determine average depth to water table and ascertain nearness of UST to groundwater and the vulnerability of contamination when leakage occurs.

1.4 Justification of the Study

Water table aquifer within FUTO, Ihiagwa, Obinze, Eziobodo, Avu, Irete, Orogwe and Nekede is said to be contaminated, yet it is the primary source of water in the area. There is an understanding that Fawason Nail Factory (closed) and several Waste Dumps (active and abandoned), multiple petrol stations (old and new, functional and non functional) are the principal sources of the contaminants. Shallow wells within FUTO and The Federal Polytechnic Nekede, and the neighborhood communities with depths ranging from 36-60m are most likely producing water of poor quality causing high disease burden. This is true, since the contaminants sources are predominantly north, FUTO and the neighborhood communities are south, and groundwater flow is southward. Unfortunately, the numerous shallow wells serving FUTO, Poly Nekede and the communities are never tested for quality assurance from year to year as no regulatory body is following this problem. Three standard wells in FUTO and one in Ihiagwa with depths 110-130m are non functional due to neglect, maintenance problem, near surface availability of water, and the concern for water but not the quality. It is then justified that placing a set of monitoring wells in the direction of groundwater flow will enable understanding of water quality, fate and transport of contaminants in the area. Data obtained will be used to design in-situ treatment model for sustainable management and conservation of groundwater in Owerri west.

1.5 Scope of study

This study is limited to risk assessment specifically fire and groundwater pollution due to multiple petrol stations in Owerri West area of Imo State. The research covers all steps involved in mapping and identification of suitable sites for installation of groundwater quality monitoring wells in the area.

CHAPTER 2

2.0 Literature Review

2.1 The Concept of Environment

There are different types of environment, for convenience, environment can only be divided into three broad categories namely; Land or Terrestrial environment, Air or Atmospheric environment and Water or Aquatic environment (Pfeffer *et al.*, (2005). The terrestrial environment is one of the broad divisions of the biophysical environment and characterized by the dominance of land, farms and vegetative features as a result of the influence of climatic, edaphic and biotic factors. The terrestrial environment is usually divided into biomes or vegetative regions with distinctive peculiarities of plant and animal forms. The vegetative region could be natural or man-made through such processes like reforestation. The air environment includes the air boreal environment which encompasses the tree tops, ropes wires that are located at high altitudes above the ground (Dike, 2007). The term aquatic habitat covers a whole spectrum from the world's oceans to the estuaries around their fringes, from major lakes to small ponds and to the marshes and swamps that are often found associated with them (Barnes *et al.*, 1991). It is simply an ecological concept located in a body of water (Alexander, 1999). Alexander, (1999) opened that it is simply an ecological concept located in a body of water, there could be fluctuations in the environment and most organisms that

live in it are those that have the facilities to swim and breathe in the dissolved oxygen. Leakage of petroleum product to a water body would prevent aquatic organisms from normal access to oxygen, resulting to their sudden death.

2.2 Environmental Risks

2.2.1 Risk

Risk is broadly defined as the likelihood that a harmful consequence will occur as a result of an action or condition. It involves the combined evaluation of hazard and exposure.

2.2.2 Environmental Risk Assessment (ERA)

Environmental Risk Assessment (ERA) is a process of predicting whether there may be a risk of adverse effect on the environment caused by a chemical substance (Lacey *et al.*, 2011). Szabo *et al.*, (2012) described environmental exposure as concentration of a chemical predicted, and compared to predicted no-effect concentrations for different environmental components. ERA can also reveal if measures are needed to limit the potential environmental consequences of a substance, e.g., in a certain application and it can point if further testing and knowledge about a substance is needed. ERA deals with the interaction of agents or hazards, human and ecological resources. It describes human populations, ecological resources and agents, analyses agents and exposure potential, characterizes the potential for adverse effects, defines uncertainties, generates

options to deal with the risks, and communicates information about the risks to human and ecosystem. Gilbert *et al.*, (1997) stated that ERA provides a technical basis for evaluating current environmental conditions and forecasting future conditions under selected scenarios. ERA is a welcomed addition to the tools that an environmental planner and a manager can use to facilitate the decision making by various stakeholders. ERA is a process that incorporates technical information and societal options.

2.2.3: Steps to Risk Assessment

According to Phelpstead (2010), there are five steps to environmental risk assessment (Figure 2.1). The first step in risk assessment process is to identify all the significant hazards associated with the work. Hazards are the things with the potential to cause harm. It is important to identify both the safety hazards that might give rise to immediate physical injury and health hazards that might cause diseases or ill-health. The hazard identification might be done by task analysis, reference to guidance or by inspection of the workplace (Phelpstead, 2010). When identifying the people at risk, think not only of those carrying out particular activities, but also of those who may be affected by those activities. In the case of petrol stations, not only the station and the operators are at risk, the entire surrounding environment shares the risk. Having identified a particular hazard and the people who might be harmed by it, the next step in the risk assessment process is to answer a simple

question: Is the level of risk generated by the hazard acceptable or does it need to be reduced? When hazards are identified through the risk assessment process, it is necessary to decide on the precautions needed to control those hazards to an acceptable level. This is the most important part of risk assessment- identifying the further action that is needed and taking that action. The significant findings of a risk assessment should be recorded to provide a statement of the hazards in the workplace, the extent of the risks that they present and the action taken to control those risks (Phelpstead, 2010).

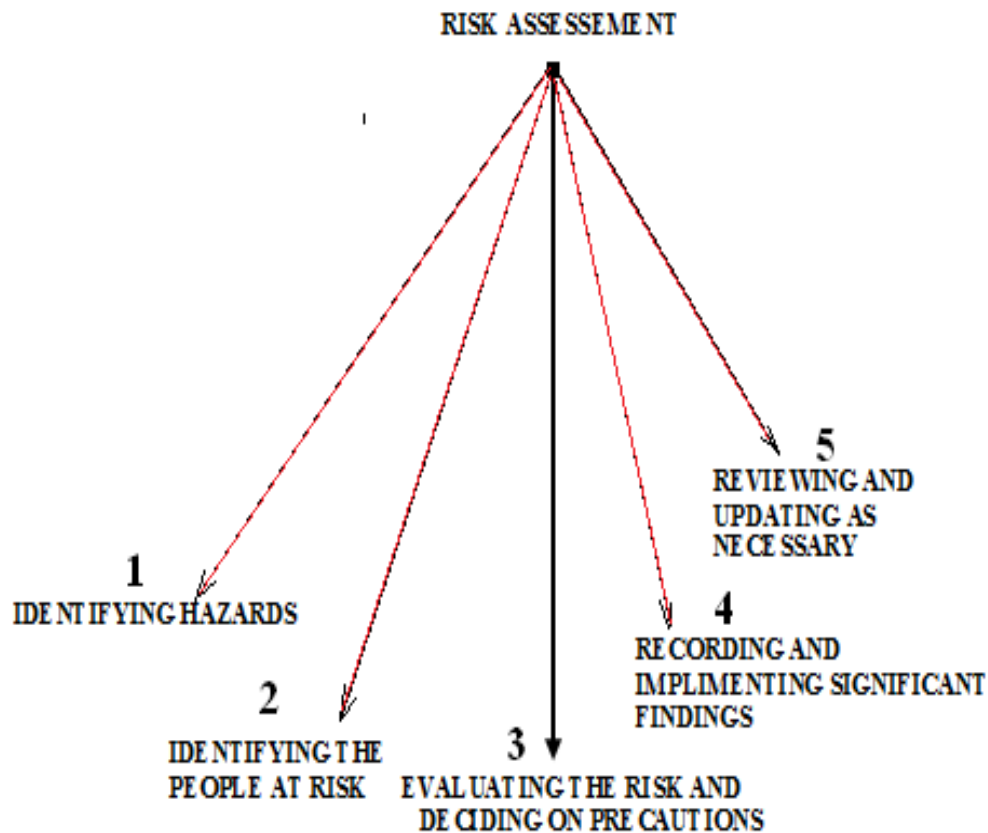


Figure 2.1: Steps to risk assessment. Source; (Phelpstead, 2010)

2.2.4 Cultural Aspect of Environmental Risk Assessment

Increasing the intensity and effectiveness of monitoring is a key process to reduce the risks posed to the environment. According to Richard (1999), a more intense and effective approach to oversight aims to deliver pre-emptive, rather reactive, outcome-based supervision. An anticipatory and strategic approach to supervision rests, among other things, on the ability to engage in high-level sceptical conversations on risk appetite framework, and whether an organization's risk culture supports adherence to the approved appetite. . Richard (1997) discovered weakness in risk culture as often considered as a root cause of the global workplace crises, headlines risk and compliance events. A sound risk culture consistently supports appropriate awareness, behaviours and judgment about risk taking within a strong risk governance framework. A second risk culture bolsters effective risk management, promotes sound risk-taking, and ensures that emerging risk or risk-taking activities beyond an organization's risk appetite are recognized, assessed, escalated and addressed in a timely manner.

2.3 Environmental Health and Safety (EHS)

Environmental health and safety are separate practice areas; however, they are often linked. The reason for this is typically to do with organizational management structures; however, there are strong links among disciplines (IFC, 2007) . One of the strongest links between these is that a single risk may have impact in

all three areas, albeit over differing timescales. For example, For example, the release of petroleum product by leakage of UST in a petrol station or a toxic chemical to soil and groundwater may have immediate short-term safety consequences, more protracted health impacts, and much long-term environmental impact. Over time, a form of risk analysis called “environmental risk analysis” has developed (Helsinki, (2000). Environmental Risk analysis is a field of study that attempts to understand events and activities that bring risk to human health or the environment (Antunes et al 2015).

2.4 Fuel Stations Hazard Mitigation

Hazards as viewed by Burton *et al.*, (1978) are those elements of the entire physical environment that are harmful to man and are caused by forces extraneous to him. Hazards also are threat to future source of danger and have the potential to cause harm to people (death, injury, disease and stress); harm to human activities (economic and educational activities); harm to property (property damage and economic loss) and environmental harm(loss of fauna and flora, pollution and loss of amenities). This is in conformity with EFOA, (1995) that safety of people and protection of the environment should at all time be the major concern at petrol stations because they are potentials for accident especially where the general public has unlimited access. The necessity therefore, for well designed, construction and operation of such facilities should be of paramount importance. Noting that, petrol

and other fuel are potentially hazardous at ambient temperature and they give off vapours which when mixed with air in a proportion and ignited, can cause injury to aquatic life, harmful effects to human's health and environmental damage if incorrectly handled. It is generally important in the planning process for the development particularly in the urban centres, to give much consideration to measures that reduce hazards. Planners should at all times assess possible hazards in planning and promote ways of avoiding or mitigating damage that might cause hazards, risk and vulnerability.

These hazards as ascertained by Joseph, (2005) are uniquely intertwined in the development of death and destruction from disaster. It is therefore appropriate to reassert that, disaster mitigation is best realized from the potential that people need to unite, to persevere and to understand what affect them and to take common actions towards sustainable development programs particularly in cities where the large population dwells, and where most economic activities are taking place. This is affirmed by Blaike *et al.*, (1994) that vulnerability to hazard and risk from social perspective is more pronounced on urban poor who most at all times find it hard to reconstruct their livelihood after a disaster than the rich. This is because a time dimension is relevant since reconstruction in poor areas can take long time, which affects the economy and the livelihood of the area drastically. Also the poorer

population groups do not always have a choice of location, as such may be forced to live in risky areas including in and around petrol stations.

2.5 Risk of Groundwater Contamination by Petroleum Products

It was widely proven that one of the major contamination sources of the soil, air, underground and surface water has been related to liquid petrol tank leaking, processed chemical products, toxic chemical products and diluted rejects (Moschini *et al.*, 2005). As of 1985, petrol underground storage tanks became a priority in the United States, leading to the regulation, by the Environmental Protection Agency (EPA) of prevention, detection and fixing of leaking in the tanks, as well as to the creation of a specific agency (Office of Underground Storage Tanks) to monitor these aspects (EPA, 2010). One of the best known classes of groundwater contaminants includes petroleum-based fuels such as diesel.

2.6 Causes of Accidental Release of Fuel from Petrol Station

According to Connecticut Department of Environmental Protection (2005) and EBRD (2009), there are several hazardous substances used and generated by fuel stations for example, accidental release of fuel from fuel stations may occur due to:

- Leaks from storage tanks and connecting pipe work arising from damage, aging and improper installation.
- Small spills during unloading or vehicle filling which are not cleaned up

- Failure or absence of oil/water separator or drainage system.
- Failure to drain tanks and pipe work adequately prior to maintenance and repair work.
- A major spill such as tank failure or over filling.
- Atmospheric discharge of petrol vapour from pressure release pipes.

Fuel leakage from petrol stations, if released into the environment, petrol and diesel pollute the soil and water supplies. Whenever petrol escapes from an underground Storage Tank (UST) or pipelines, it can travel significant distances. Therefore, there is need for consistent and accurate monitoring of fuel delivered, stored and dispensed at any fuel station in order to detect leaks from each underground tank and connected pipe. (Nicole and Desmon , 2014).

Table 2.1: Main hazardous substances used and generated by petrol stations.

	Waste generated by petrol stations	Hazardous components
1	Antifreeze	Methanol, ethylene, glycol
2	Battery acid	Sulphuric acid
3	lubricant, degreaser	Petroleum solvents, alcohols, glycolether, volatile organic compounds
4	Engine and radiator flushes	Chlorinated hydrocarbons, toluene, phenols
5	hydraulic(brake fluid)	dichloroperchloroethylene
6	Used and or waste oil; motor oil, grease, lubes etc	Hydrocarbons, fluorocarbons
7	Gasoline(gasoline, diesel, petrol, kerosine)	Hydrocarbons
8	Fuel	Hydrocarbons, methyl tert buthyl

		ether, heavy metals etc
9	Transmission fluid(automatic)	Hydrocarbons
10	Car wash detergent	Phenol, heavy metals
11	Car wax or polish	Petroleum distillate, xylene
12	Equipment from the replacement and decommissioning of tanks and pipeworks	Hydrocarbons, fluorocarbons
13	Oily sludge from oil tank cleaning and oil/water separator	Hydrocarbons, fluorocarbons, heavy metals

Source: Connecticut Department of Environmental Protection (2005) and EBRD (2009)

It is noticed here that using decommissioned oils or petrol tanks for irrigation water storage generates potential contamination risks to the soil and groundwater. As shown in (Table 2.1) related to the automotive diesel limits specifications, the guidelines do not specify the limits related to hazardous elements to public health e.g, ethylbenzene, etc.

2.7 Oil Spill from Fuel Stations

When an oil spill occurs, it causes a multiple of problems for the environment. An oil spill happens when liquid petroleum is released into the environment by vehicles, vessels or pipelines (PLs). It happens on a large scale and is mostly seen in water bodies and soil. It happens due to human negligence and is a major form of pollution. Proliferation of fuel stations causes spillage on the environment during tanker operations, dispensing of fuels, oils, and through water. An oil spill and their effects can also be experienced with refined petroleum or even waste oil from large scale industries. What is common in all these is that the damage caused

by them is permanent and takes a longer time to clean up. As oil spills, it floats on water and prevents sunlight to pass through it. The shiny substance that is seen sometimes on top layer of water is nothing but oil which makes it difficult for plant and sea animals to survive. In contaminated soil, it also destroys farm products.

(www.conserve.energy.future)

2.7.1 Types of Oil Spill

- ***Class A Oil-Light, Volatile Oil***

Class A oil is light and fluid spreads quickly when spilled and has strong odour.

Class A oil is the most toxic but persistent of oils. If the oil soaks into the soil, the effects will be long lasting. In water, class A oil disperses readily but affect aquatic life in the upper water column. Class A oils include high-quality light crude oils as well as refined products such as gasoline and jet fuels. Toxic components of gasoline include benzene, a known carcinogen and hexane, which can damage nervous systems in human and animals. (www.ehow.com)

- ***Class B Oil- Non-Sticky Oils***

Class B oils are known as ‘non-sticky oils’. They are less toxic than Class A oils but more likely to adhere to surfaces. According to the U.S. fish and wild life services, they can cause long-term contamination. Lower- quality light crude oils fall into Class B. Class B oils leave a film on surface, but the film will dilute and

disperse if flushed vigorously with water. Class B oils are lightly flammable and will burn longer than class A oils. (www.ehow.com)

- ***Class C oil- Heavy, Sticky Oils***

Class C oils are heavy and sticky. While they do not spread as quickly or penetrate sand and soil as easily as lighter oils, Class C oils adhere to surfaces. Class C oil does not easily dilute and disperse, making it especially detrimental to wildlife, such as fur-bearing marine mammals and waterfowls. Because it produces such a sticky film, a class C oil spill can severely contaminate intertidal zones, leading to expensive long term clean-ups. Class C oils include most types of crude oil and bunker B and bunker C fuel oils. Such oils are prone to forming lumps of oil or emulsions. (www.ehow.com)

- ***Class D Oil- Non-Fluid Oil***

Class D oil is solid and has the least toxicity. The biggest environmental concern posed by class D oil occurs if the oil is heated and hardens on a surface, making clean-up nearly impossible. The U.S. Environmental Protection Agency (EPA) points out that as the volatile component of some oils evaporate; they may leave behind class D residues. (www.ehow.com)

- ***Non- Petroleum Oil***

Synthetic oils and oils derived from plant or animal fats are regulated by the EPA because they cause contamination if released into the environment. Non-petroleum oils are slow to breakdown and easily penetrate soil, causing long-lasting damage to an affected area. Examples of non-petroleum oil products include cooking fats and synthetic oil. (www.ehow.com)

2.8 Leakage from Petrol Station

Fuel leakage from fuel stations, if released into the environment, petrol and diesel pollute the soil and water supplies. Whenever petrol escapes from an underground Storage Tank (UST) or pipelines, it can travel significant distances. Petrol vapours can find their way into basements of buildings and public drains with serious consequences should the vapours come into contact with an ignition source Goldberg (1992).

The level of risk associated with leakage means early detection of leak is essential. Immediate corrective action must be taken when leaks are detected (Cutter *et al.* 2000). Therefore, there is need for consistent and accurate monitoring of fuel delivered, stored and dispensed at any fuel station in order to detect leaks from each underground tank and connected pipe. (www.opea.org.uk).

2.9 Health Effects of Petroleum Products

2.9.1 Ethylbenzene

Ethylbenzene can quickly contaminate groundwater because it doesn't bind to soil. This means that it can seep into groundwater when spilled, or when it is injected into water supplies like other hydraulic fracking chemicals. Ethylbenzene enters the body rapidly, through vapors, or through contaminated food and water (Institute of Petroleum 2002). When someone drinks water contaminated with ethylbenzene, it enters the body through the digestive tract quickly. People that are exposed to toluene are at risk of serious health complications. Damage to the central nervous systems (CNS) is the most common side effect of both short and long term exposure. (Hessel, 1997)

2.9.2 Toluene

Toluene exposure has been linked to: Central nervous system (CNS) dysfunction, Narcosis, CNS depression, Upper respiratory tract irritation, Cardiac Arrhythmia. According to the Environmental Protection Agency (EPA), people that ingest toluene are also at risk of constriction and necrosis of myocardial fibers, swollen liver, congestion and hemorrhage of the lungs, and tubular kidney necrosis. Symptoms of exposure include: Fatigue, Headaches, Nausea, Sore throat, Eye irritation. When a pregnant woman is exposed to toluene, her baby is at risk of

suffering birth defects, including attention deficits, craniofacial and limb anomalies and CNS dysfunction. Pregnant women also carry an increased risk of sudden abortion when exposed to toluene.

2.9.3 Diesel

According to Chilcott of the Health Protection Agency (2006), diesel is dangerous for the environment. It is flammable, its vapour / air mixtures may be explosive, Can cause: eyes irritations, chemical pneumonitis following aspiration or inhalation of aerosol (or aspiration of liquid) during manual siphoning, skin irritation following skin exposure and possibly cancer. The oral toxicity of diesel is relatively low, with two studies reporting LD50 values of 7.5 g/kg (Beck, Hepler & Hansen (1984).) and 16 ml/kg in the rat. There are several symptoms that can point to toxic exposure to diesel fuel. Diesel fuel toxicity has serious consequences when there is long term exposure. Repeated skin contact to diesel fuels can lead to severe irritation and may increase the risk of skin cancer. Long-term exposure can lead to lung cancer, kidney damage, and can affect the blood's ability to clot.

2.9.4 Atmosphere

Volatile Organic Compounds (VOC) is air pollutants which can have detrimental effect on human health by contributing to the respiratory issues, and VOCs are mutagenic or toxic to reproduction and harmful to the unborn. They have harmful

environmental effects (crops, vegetation and materials damage, and reduced visibility) when they chemically interact with oxides or nitrogen and sunlight to form ground-level ozone. Some airborne organic compounds such as benzene, which increases the risk of cancer, have been recorded at fuel stations at levels above the average levels for urban areas where traffic is the primary source of emission (Marta Doval, 1995)

2.9.5 Hydrogen Sulphide

Hydrogen sulphide gas is found in petroleum and natural gas. Oil or natural gas is considered sour if it has a high percentage of hydrogen sulphide. Natural gas can contain up to 28% hydrogen sulphide gas, consequently, it may be an air pollutant near petroleum refineries and in oil and gas extraction areas. The principal source of anthropogenic H₂S is a by-product in the purification of natural gas and refinement of crude oil. (www.ncbi.nlm.nih.gov).

Common symptoms of exposure to long-term, low levels of H₂S include; headache, skin complications, respiratory and mucous membrane irritation, respiratory soft tissue damage and degeneration, confusion, impairment of verbal recall, memory loss and prolonged reaction time. Exposure to high concentration can cause unconsciousness, known as ‘‘KNOCKDOWN’’ and can be lethal.

(www.ncbi.nlm.nih.gov). Exposure to H₂S is one of the leading causes of sudden

death in the workplace. At concentrations greater than 500ppm, inhalation of H₂S can lead to immediate collapse and unconsciousness. A single breath at 1,000ppm results to immediate loss of consciousness, cardiac arrest and death unless the unconscious victim is successfully revived. Almost all organ systems are affected by H₂S, but the most susceptible are those with exposed mucous membrane (e.g. Nose, eyes and throat) and those with high oxygen demand (e.g. lungs, brain). Neurotoxicity of the central nervous system (causing nausea, dizziness, confusion, headaches and sleeping problems) and pulmonary edema (build-up of fluid in the lungs) are other well documented effects of H₂S poisoning. Cardiovascular and gastrointestinal toxicity are also associated with H₂S exposure.

(www.ncbi.nlm.nih.gov).

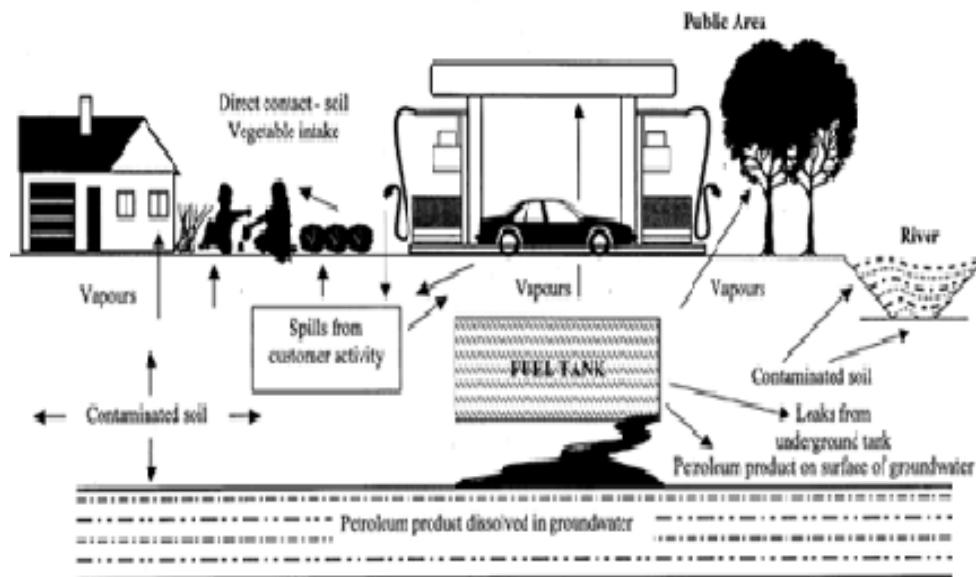


Figure 2.2: Contamination of groundwater and surface water due to gas station hazards

2.10 Underground Storage Tank (UST)

UST system refers to a storage tank or tanks that have at least 10% of their total combined volume below ground. This includes the tank of any connected piping, additional equipment, and containment system. USTs are commonly used to hold materials such as petroleum products; water, natural gas or sewage. UST systems require constant monitoring and upkeep and are subjected to several types of regulations. Federal regulations apply to USTs holding substances such as petroleum and other hazardous substances. UST systems that are not regulated by FG usually fall under state/or local jurisdiction. Since each type of UST can be subject to different policies, all regulations regarding a UST system should be checked to make sure compliance with all policies, laws and regulations have been met. Some of the regulations applying to USTs include (Sullivan, 2008):

- Corrosion protection
- Spill protection
- Overfill protection
- Record-keeping
- Financial responsibility for spills
- Corrective actions.



Figure 2.3: A typical UST installation

2.10.1 Environmental Effects of Underground Storage Tank (UST)

A well maintained UST system is not a health or environmental hazard. However, if the system is in poor condition or improperly monitored, the substance contained in the system may leak into and contaminate the surrounding soil, groundwater and community water supplies. Petroleum products, one of the most popular set of substances stored in USTs can make water unsafe to drink and have other health long-term health effects if it is released into the environment as well as remaining in the soil and water systems for extended periods. (SEEG, 2003)

Leakage of flammable products can also cause potential fire and explosion hazards. Hazardous substances can escape into the environment through:

- Spills
- Overfill
- Tank explosion. (www.epa.gov)

2.10.2 *Corrosion of underground Storage Tank*

According to EBEL (2012), corrosion in soil is a natural process which means electrochemical oxidation of metal in reaction with an oxidant such as oxygen.

Rusting, the formation of Iron Oxides is a well-known example of electrochemical corrosion. This type of damage typically produces oxides or salts of the original metal and results in distinctive orange colouration.

- Corrosion is a natural process which converts refined metal to their more stable oxide. It is the gradual destruction of materials (usually metals) by chemical reaction with their environment. In most common use of the word, this means electrochemical oxidation of metal in reaction with an oxidant such as oxygen (Afolabi et al 2011) Rusting, the formation of Iron Oxides is a well-known example of electrochemical corrosion. This type of damage typically produces oxides or salts of the original metal and results in distinctive orange coloration as shown in (Fig. 2.3).

Soil corrosivity is a significant factor in petrol station USTs. Soil with $\text{pH} \leq 5.5$ will be highly corrosive to USTs. The factors that contribute to the corrosive potential of soil are aeration, moisture content, temperature, pH, and resistivity. Sandy and Loamy soils have excellent to good corrosion resistance. Soils with very high resistivity have no corrosion potential. As soil temperature tends to 0°C and continues to decrease there is a rapid increase in resistivity with a corresponding decrease in the corrosive potential of the soil. Generally soils are considered “mildly corrosive” if the sulfate and chloride levels are below 200 PPM and 100 PPM, respectively, for soils with pH levels of between 5 and 10, and resistivity greater than 3000 ohm-cm (Arbabi, 2015). According to him, an increased moisture content decreases resistivity of soils, in turn increasing their corrosive potential. Arbabi obtained that when the saturation point of the soil is reached, additional moisture has little or no effect on resistivity.



Figure 2.4; Fuel leakage from a corroded UST; Source: DEFRA 2000

Petrol station USTs and metal piping can be cathodically protected in two ways. The most common is with magnesium anodes (Figure 2.5a). Another is with impressed current (Figure 2.5b) using public power supply. The goal is to extend the life of an underground tank by preventing corrosion and rust. Galvanic Protection (Figure 2.5c) uses anodes made of high potential magnesium (AZ-63 or H-1), magnesium alloy, and zinc. Zinc anode is recommended in the sandy coastal area of Owerri west, and in parts of Niger delta where groundwater may be salty. When a tank is totally protected from corrosion, the entire tank becomes a cathode. The duration of protection measured is dependent on the resistivity of the environment in which the tank is installed. If the tank is installed in non-corrosive dry sandy soil (High resistivity), it may be relatively free of corrosion and the

anode will last a lifetime. However, if the tank is installed in wet, clayey or chemically contaminated environment (Low resistivity), the anode gets consumed in less time. The anodes have limitations: zinc can be used on land and in seawater, magnesium in freshwater, and aluminium in seawater. Galvanic anode systems have some limitations and drawbacks; for example, they cannot be used where there are stray currents or interference, they do not allow adjustment of the injected current, and the anodes must be replenished after consumption. In impressed current, cathodic protection buried metal structures receive the protection current from an external source or current rectifier installed on the surface and using a set disperser current in the electrolyte consisting of a bed of inert anode: $2\text{OH} - 2\text{e}^- = 2\text{H}_2\text{O} + \frac{1}{2}\text{O}_2$ and electrolytic reaction cathode: $2\text{H}_2\text{O} + 2\text{e}^- = 2\text{OH}$.

The corrosion of buried pipes and tanks in gas service stations can be eliminated by proper application of cathodic protection. Cathodic protection acts as a complement to the faults and pitting of outer tanks and also protects galvanized pipes efficiently. (Revie and Herbert, 2008)

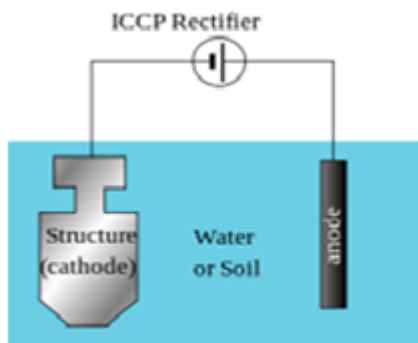


Figure 2.5(a)

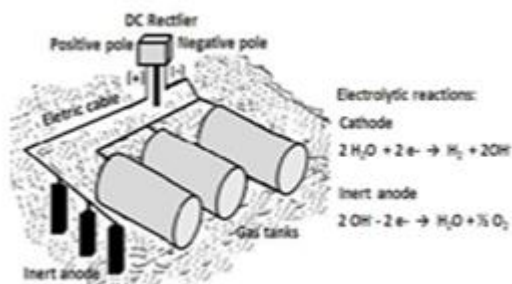


Figure 2.5(b):

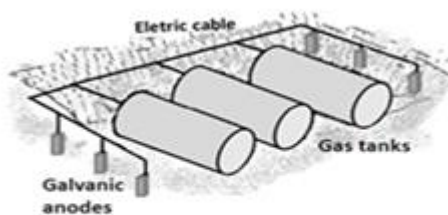


Figure 2.5(c):

Figure 2.5(a): Protection system with magnesium Anode

Figure 2.5(b): Impressed current cathodic protection of buried tanks at a gas station

Figure 2.5(c): Protection system with galvanic anodes (zinc) for buried tanks at a gas station
 Revie and Herbert (2008),

2.10.3 Corrosion Prevention by use of Bitumen Coating

The abundance reserves of natural bitumen and distillation from crude oil make bitumen coating and wrapping of USTs with black polyethylene cost effective in Nigeria. Bitumen coatings of USTs cannot eliminate corrosion. They have pores and flaws, which can absorb moisture and stale over time, leaving spots or areas exposed to the soil. Bitumen coating needs to be supplemented by cathodic protection followed by regular checks to verify that the tanks are protected against corrosion. This check should be done by measuring the potential of the tanks in the

ground. Since the tanks are kept within minimum levels of potential, external corrosion will be eliminated even when the coating is deteriorated (Idowu, 2013)

2.10.4. Leaking of Underground Storage Tanks

Leaking USTs are one of the most serious threats to the quality of our nation's groundwater. 50% of the nation's population and 100% in virtually all rural areas, rely on groundwater for drinking water. About 680,000 federally regulated USTs are a major threat to groundwater quality. USTs hold toxic materials such as gasoline and waste oil, which contain dangerous substances that can cause cancer and harm developing children. Chemicals in USTs can quickly move through soil and pollute groundwater. There is no safe level of exposure to many of these toxic substances. One drop of fuel can contaminate about 300 cubic meters of fuel.

Crude oil and petroleum products storing tanks, as well as pipelines, are made subject to leak proof tests according to the following pattern: up to 30 years of service, ground tanks and pipelines are to be tested every 10 years up to 20 years of service and thereafter every 5 years. Crude oil and petroleum products storing tanks in which the tightness of the inter-wall space is monitored continuously need not be subjected to leak proof test.

The overall volume of storing tanks and the volume of a single tank at liquid fuel stations must not be larger than 500 m³. and 100m³, respectively; the volume of a

single tank at a container station must not exceed 30m³. Liquid fuel stations have to be sewerred and equipped with the following items: specialises devices that prevent penetration of petroleum products into the soil, surface water and groundwater; systems for measuring and monitoring the level of crude oil products being stored, and devices preventing emission of vapours of petroleum products into the atmosphere. The distance of liquid fuel dispenser (with the exception of the petrol station pavilion) must not be less than 10m from the forest boundary, and 5m from the boundary of neighbouring undeveloped. (www.louisssiana.gov).

2.10.5 *Life Expectancy of Underground Storage Tanks*

The life expectancy of oil tanks is helpful in planning for storage tank replacement. While we've found them lasting longer, Encyclopedia of Building & Environmental Inspection (EBEI) states that a common life expectancy of buried oil tanks is 10-15 years (EBEI, 2012). At about 20 years, the risk of leaks from buried steel oil tanks becomes significant. Leaks can occur earlier if a tank was damaged at installation or was not properly piped. Even if you think the tank is good, young, and not leaking, buried oil tanks should be tested for water in the tank bottom. Water should be pumped out since it corrodes the tank and leads to leaks. Oil tank leaks can also be due to damage at time of installation, improper installation, acidic soils, or piping defects. A 1986 Maryland study found a 40% leak rate in petroleum product storage tanks (oil, gas, kerosene, waste oil) of which

oil piping caused 82% of all leaks, and location (urban vs rural) and soil conditions were important factors in leak occurrence (Ogunkoya, 2016).

2.10.6 *Leak Prevention from Underground Storage Tank*

The most common releases from USTs are during filling, either from fill hose disconnection or from overfills. Prior to delivery, an accurate assessment of delivery volume should be made. Verification of tank volume meters with sticking of the tank (and conversion to volume using appropriate tank chart) should be conducted. Delivery volume should be such as to not fill the tank above 90% of capacity. Overfill alarms (audible, strobe, or both), which operate based on floats within the tank, are usually set at 85% to warn delivery person to cease filling, with another high level alarm at 90%. These alarms should be adjacent to the fill connection area to ensure they are seen and heard (www.yale.edu/ehs)



Figure 2.6: Audible and strobe overfill alarm

2.11. Contamination of Groundwater and Surface Water

Surface water and groundwater resources are endangered by several pollution sources. Apart from the widespread of microbiological pollution from wastewater, the contamination risk related to hydrocarbons from petrol stations is most severe. Petro when released into the environment has several health effects such as its contamination of soil, surface water and groundwater (Margane et al, 2012). The extremely high number and dense spacing of fuel stations is in complete disregard to an area's richness in surface water and groundwater resources and their importance for water supply. The geological underground karstic nature leads to a high vulnerability of the water resources to pollution. Because flow velocity of groundwater in the unsaturated zone is fast, there is an imminent danger of a quick transfer of any contaminant, a fact that would dramatically affect the groundwater source to the population living in an area. Uwakwe, (2010), stated that hydrocarbon pollution of the subsurface, especially in unsaturated soils, has become a big problem with the development of petrochemical industry and installation of numerous fuel stations and underground pipes.

2.11.1. Effects of Human Activities on Groundwater

As detailed by Abulrazak et al (2010), the quality of groundwater is affected by human activities that include leakage of gasoline from petrol station's underground tanks in addition to the uncontrolled dumping of waste oil and petroleum by-

products that also contribute to ground water pollution. Pollution of soils with hydrocarbon derivatives is often observed in soils around petrol stations (areas where petroleum and mineral gas are obtained, processed and distributed).

Gong et al, (1996) informed that oil spillage occurs through tanker accidents, during refueling and distribution resulting in the release of crude and refined oil into the soil environment. Organic pollutants differ in charge and solubility. Non-polar compounds such as hydrocarbons are poorly soluble in water and absorb readily into hydrophobic soil particles and soil organic matter. Petroleum and its products are of major concern in pollution studies due to their structural complexity, slow biodegradability, bio-magnification potential and above all, serious health hazards associated with their release into the environment.

Kang et al, (2012) maintained that the use of petroleum products lead to contamination of soil and changes in soil properties with petroleum derived substances which can lead to water and oxygen deficit as well as shortage of available forms of nitrogen and phosphorus. Greenberg et al, (2007) noted that contamination of the soil environment can also limit its protective function, unfavorably affect its chemical characteristics, reduce fertility of animals and negatively influence plant production. This threatens human health and that of the organisms that are dependent on the soil. Crude oil in soil makes soil condition unsatisfactory for plant growth due to its reduction in the level of plant nutrient or

a rise in toxic levels of certain elements such as Iron and Zinc. Beudert *et al.*, (1996) also confirmed that soil contamination with petroleum has serious hazard and causes organic pollution of underground water, which limits its use, causes economic loss, environmental problems and decreases the agricultural productivity of the soil. A well maintained UST system will not cause a health or environmental hazard.

2.12 Fire Risk at Fuel Station (Petrol Vapour)

Petrol gives off highly flammable vapour even at very low temperatures. Because of the flammability of petrol vapours, fuel stations carry a risk of fire explosion not common to other types of retail outlets. Ignition of petrol vapours can happen if vapour comes into contact with a heat source capable of igniting it. An ignition spark might come from an electrical switch, a cigarette or a static electrical discharge. Petrol vapour is heavier than air and tends to sink to the lowest possible level of its surroundings and may gather in tanks, cavities, drains, pits or other low points and travel across the ground due to gravity (downhill) or may be carried in the direction of the wind (www.hsa.ie), www.aepa.org.uk

Igniting cigarette lighter, use of cell phones, cars with electrical faults, car engine steaming while pumping fuel, etc are frequent causes of fire in petrol stations. Some 150 people have died in a fire at a petrol station in Ghana's capital, Accra as shown in Fig 2.7a below. It is thought that people were in the petrol station

sheltering from the downpours when the fire broke out. Flood helped cause the fire. The waters "caused the diesel and petrol to flow away from the gas station, and fire from a nearby house led to the explosion" (BBC News June 5, 2015).



Figure 2.7a

Figure 2.7a: Ghana Petrol Station Inferno (BBC News June 5, 2015)

In the Bovas petrol station inferno at Oshogbo, Osun state Nigeria (Plate 2.7b), it was gathered that some children whose ages were 8 and 12 years sleeping in a mini supermarket attached to the filling station lost their lives as the supermarket joined the station into flames around 12pm on Wednesday, 23rd September, 2015. This petrol station was not well equipped as there were no adequate fire extinguishers located in the station. (This Day News Paper 23 Sept. 2015)



Figure 2.5b

Figure 2.5b: Bovas Filling Station Inferno (This Day News Paper 23 Sept. 2015)

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Area of Study

For the purpose of this study analysis, three study areas were selected which represent different human environments in which many petrol stations are constructed and other human activities take place.

Owerri west is a local government area in Imo state Nigeria, located between latitude of 5.231' and 5.34' west and longitude 6°.50' and 7.0 East at the rain forest belt of West Africa, about 120 km north of the Atlantic coast as shown in Figure 3.1. Owerri West has a total population of about one million people based on Nigerian census (2006), and covers an area of 15 square kilometres. The three sampled locations in Owerri west are: Mechanic village to Nekede Junction along Aba road/ Nekede- Ihiagwa Road (Road 1), Obinze to Umuguma-control Junction (Road 2), and Control Junction (Irete) to Orogwe- Onitcha Road (Road 3). These areas have multiple petrol stations constructed at close proximity to each other and residential buildings.

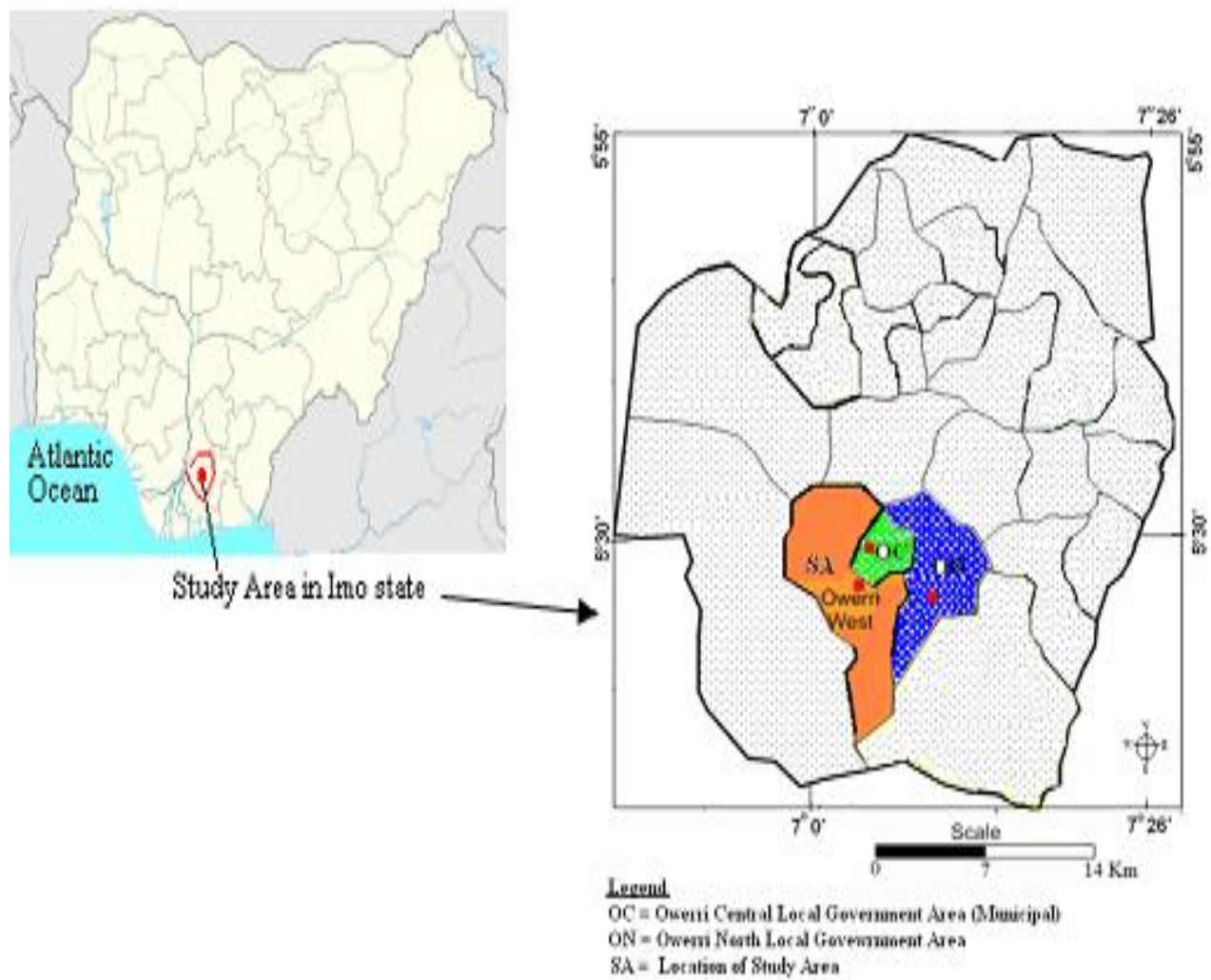


Fig. 3.1 Map of Nigeria Showing Imo State and Owerri West (Study Area)

3.1.1 Climate of the Study Area

Owerri West is located at the subequatorial zone. There are four distinct seasons:

- 1) The long wet season from mid-march to July characterized by high rainfall and high humidity.
- 2) Short dry season which is the August break.

- 3) The short wet season which follows after the August break and lasts from September to October.
- 4) The long dry season or harmattan season from November to mid-March.

3.1.2 Vegetation and Soils

The vegetation is distinct with occasional grasses and canopy trees except within the margin of the sample areas and the adjoining outskirts of the environment. The soils are predominantly tertiary sands and clay which are highly leached, slightly acidic and suited only to a limited range crops.

3.2 Field Sampling

3.2.1 Field Mapping

The field work was done with the aid of environmentalists, geologist and geophysicist from Geoprobe Consult Ltd who was hired. The field work lasted two days for investigations on the three roads. On getting to the site, the list of all the fuel stations and their boundaries were obtained with the use of Global Positioning System (GPS). GPS was used to measure coordinates and elevations, 500 metres radial away from each station. The elevations were used to obtain contour map of the area. Photographs were taken and we had one on one interaction with the managers/supervisors of each petrol station for more information though there was no information from all the abandoned petrol stations due to no presence of human being.

3.2.2 Determination of Water Table

3.2.2.1 Electrical Resistivity Survey

OHMEGA-500 Electrical Resistivity Equipment was used to conduct a Vertical Electric Sounding (VES). Schlumberger configuration was used for a total spread (L) of 320 m. VES station was located 50m away from high tension electric wire with the traverse running normal. A distance of 95 m ($L/2$) was covered on the right of traverse, and another 95 m ($L/2$) was run on the left, in each traverse. All necessary precautions required in geo-electric measurement were duly considered. The survey lasted approximately 1hr 30 min in each location under favourable weather condition. Transmitter electrodes (A, B) were used to inject current into the ground. The current flow between A and B is measured with the potential electrodes (M, N) as shown in Fig 3.2

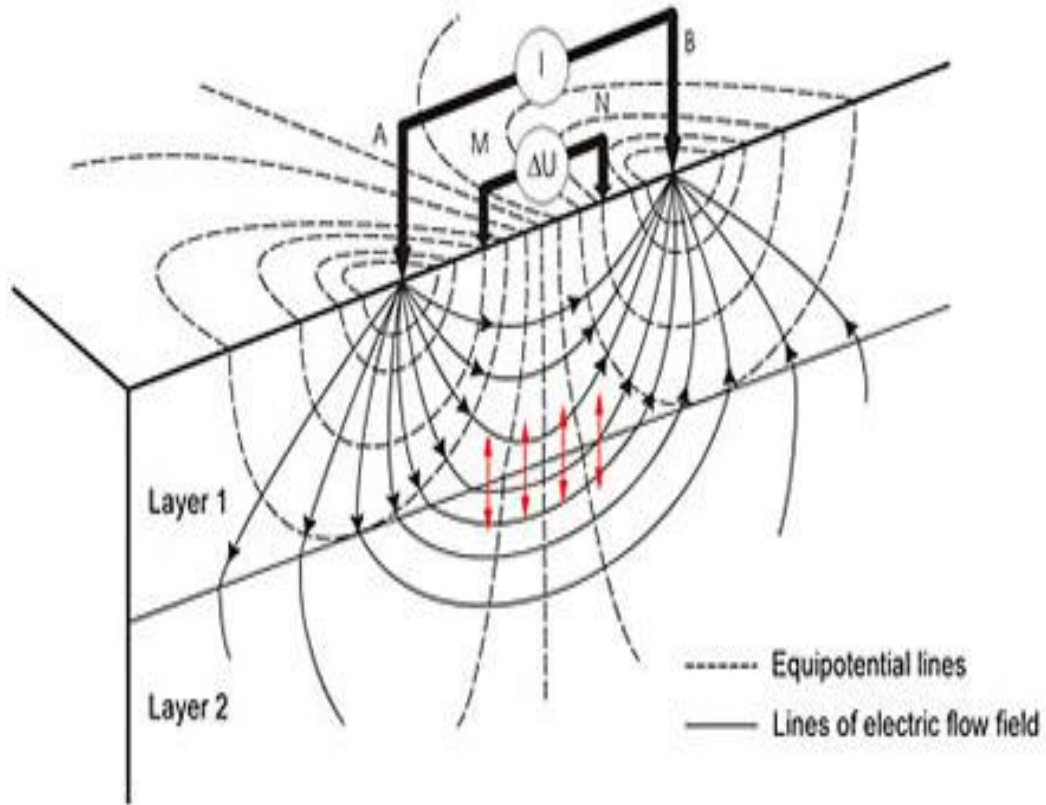


Fig. 3.2 Point –Measurement Electric Flow

Several 4-point-measurements are taken where the receiver electrodes M , N remain in place and the transmitter electrodes are symmetrically extended outwards. Thus the current penetrates successively deeper into the ground. When the current flow sinks to a layer with different electrical conductivity the current flow field is deformed, this can be measured at the receiver electrodes M , N . From this data a layer model based on the electrical conductivity of the different subsurface materials is calculated as shown in Plate 3.1.



Plate 3.1: VES Field survey

Data Processing: All field data would be subjected to full computer processing techniques, applying the Schlumberger computer automatic analysis package, and the Advanced Geophysics Incorporation (AGI) 1D resistivity analytical software.

Apparent Resistivity (ρ_a) $\pi \frac{(AB/2)^2 - (MN/2)^2}{MN} \text{*(Ohm-m)}$

MN

AB/2 = Current Electrode spread, MN/2 = Potential Electrode spread

Thus Apparent Resistivity Equation (1) can be expressed as follows:

$$\rho a = K \times R \text{ } (\Omega\text{-m}), \text{ (1)}$$

Where: K = geometric factor; $\pi \frac{(AB/2)^2 - (MN/2)^2}{MN}$ (m)

R = field resistance = I/V (Ohms).

I = current passed to the earth through electrodes, and V = voltage

3.3 Location of Monitoring Wells

Monitoring Wells and their locations were selected based on age and number of USTs ≥ 15 years old in each road. The SW direction of groundwater flow was a major determinant in positioning the monitoring wells. A reference coordinate representing a point of concentration of older petrol stations (15 years+) in each road was also established. The reference coordinates were connected in a triangle. A similar Triangle projected SW mapped out the most vulnerable area to USTs leakage and groundwater contamination by triangulation. Based on the reference coordinates, triangular loops were constructed. Meeting points of the triangular loops represent sites of monitoring wells.

3.4 Preliminary Field Investigation

3.4.1 Field Survey

This was obtained physically upon sighting the petrol stations and also through questionnaire/interview with the supervisors/managers of each station visited. As at August, 2015, there were 70 petrol stations in the study area.

The functional petrol stations were those actively in service dispensing petroleum products to customers; the non-functional were those which previously were actively in service, but as at the time of the survey, were closed down/not in operation; Non compliance petrol stations are those that were functional but did not comply to the field survey questionnaire (refused to disclose information); Under construction petrol stations are those that are yet to be completed; Abandoned petrol stations are those abandoned that are not functional/may not function again; Those under seal are the petrol stations sealed by the government. These fuel stations include conglomerates which are owned or run by multinational oil producing companies (such as Mobil, Total, Oando) and Independent Petrol Marketers (IPM) run by private individuals. All the petrol stations are listed below.

3.4.2 Depth and Number of Underground Storage Tanks (USTs)

Depths of the USTs were obtained through interviews with managers/supervisors of each fuel station. The numbers of tanks were also obtained, though many did not comply in releasing information about their stations.

3.4.3 Fire Safety

During the field survey, fire extinguishers were inspected in all the fuel stations. The date of expiration was check with due date of servicing. Number of fire extinguishers at each station was also checked.

3.4.4 Corrosion Safety

An interview was carried out in all the petrol stations on their corrosion safety. This was done to ascertain the measures taken to protect underground storage tanks and their prevention from rusting which and cause leakage.

3.4.5 Department of Petroleum Resources (DPR) Inspection

DPR is charged with the responsibility of regulating the oil and gas industry and there are so many laws guiding the entire industry. Interviews were made too on DPR inspection of these petrol stations. Many complied while others did not respond well with the interview. Records were also checked for confirmation of DPR visit.

3.4.6 Proximity of One Petrol station to another, residential homes and other facilities

Many of the petrol stations inspected were at close proximities to one another and also close to residential homes and places of public assembly. The findings

revealed that many of these petrol stations were constructed much earlier before the buildings

CHAPTER FOUR

4.0 RESULTS

4.1 Field Survey

The survey showed that during rainy season, there is high rate of risk in the study areas; due to flood and road failure, many vehicles usually get stuck on the road. There is traffic obstruction, congestion and noise hazards with oil spillages which put residents and commuters at high risk of environmental pollution. Many of the trucks carrying fuel brake down during this period and cause oil leakages that got washed by rain into the Otamiri River thereby contaminating both surface and groundwater water in the area. Many of the stations are not properly situated, and many are not functional to abandoned, while private structural developments encroach into some existing stations.

4.2 Field Mapping (Gas Station)

As at August, 2015, there were 70 petrol stations in the study area as shown in the Geographic Information System (GIS) Map (Fig 4.1). The GIS map also indicated drainage direction, river, undisturbed area etc.

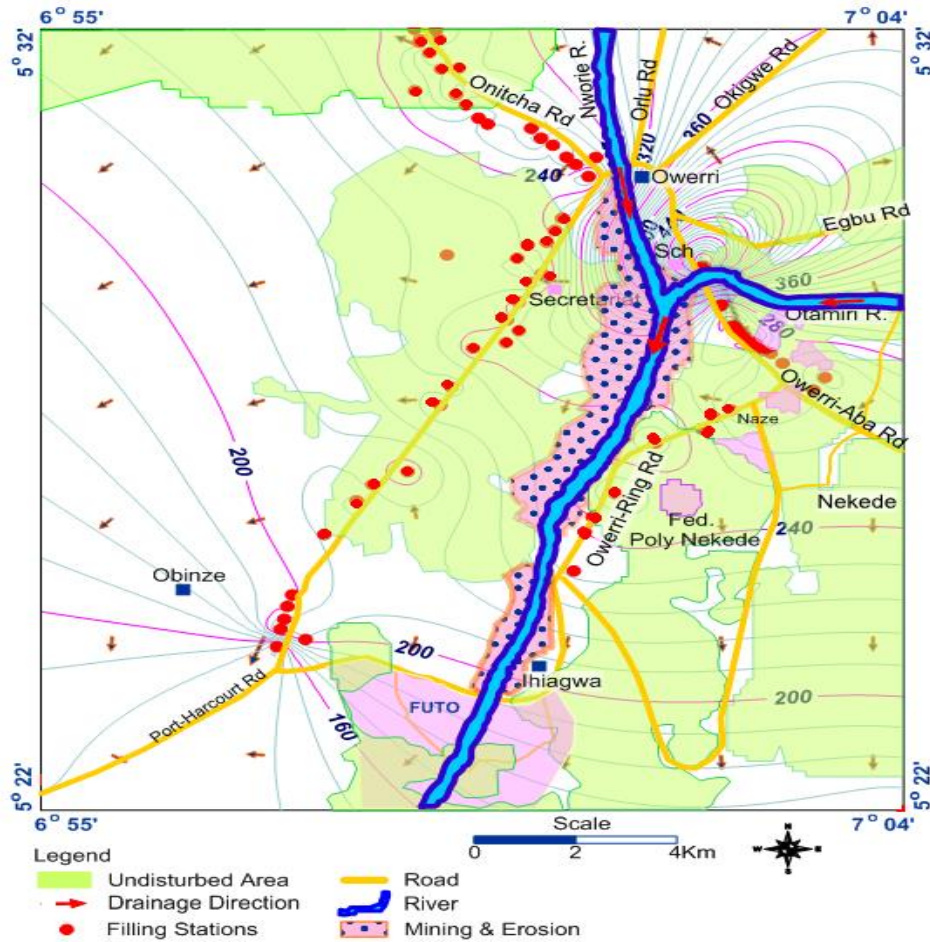


Figure 4.1: GIS Project Map showing location of petrol stations along the three investigated roads

Functional petrol stations were 46%, 42% were non-functional, 8% were abandoned, and 4% were under construction. Also, 64% were not properly situated, 35% were properly situated as shown in (fig 4.2).

The functional petrol stations were those actively in service dispensing petroleum products to customers; the non-functional were those which previously were actively in service, but as at the time of the survey, were closed down/not in operation; Non compliance petrol stations are those that were functional but did

not comply to the field survey questionnaire (refused to disclose information); Under construction fuel stations are those that are yet to be completed; Abandoned petrol stations are those abandoned that are not functional/may not function again; Those under seal are the petrol stations sealed by the government.

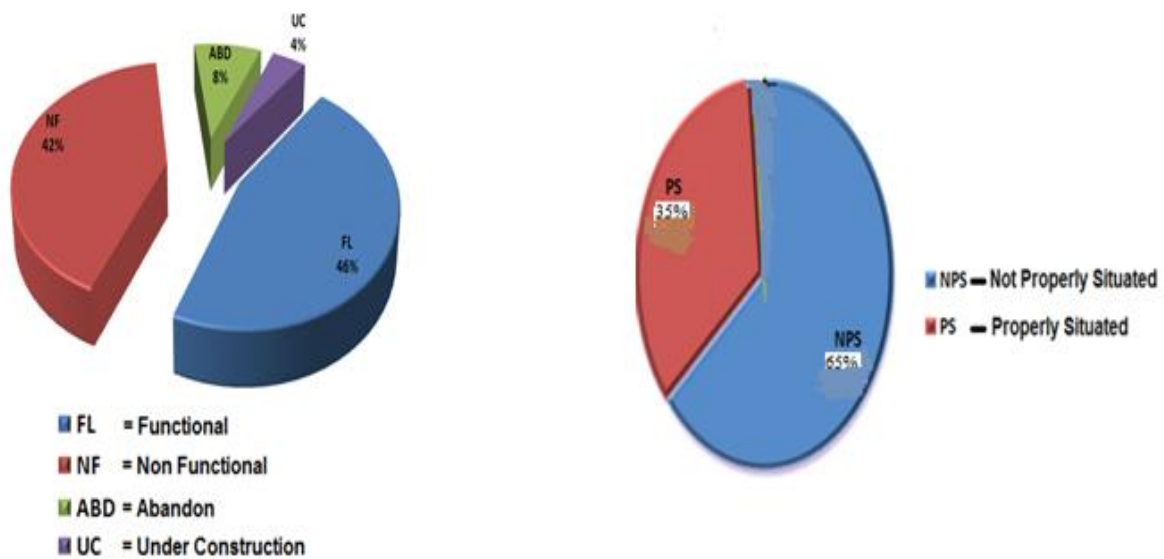


Figure 4.2 Graph of Total Petrol Stations against Functionality and Location of all Road

Petrol stations in three roads: Owerri-west segment of Port-Harcourt Road (14 Km), Owerri-west segment of Onitsha Road (6 Km) and the Nekede/Ihiagwa-Aba Road (8 Km) were specifically investigated. Results of investigation show that the 8 km Nekede/Ihiagwa-Aba Road has 26 petrol stations; the 14 km Port-Harcourt Road has 24 petrol stations while the 6 km Onitsha Road has 20 petrol stations.

Out of a total of 70 petrol stations, 46% is functional, 42% is non functional, 8% is abandoned and 4% is under construction. 64% of the petrol stations are not properly situated; only 35% is properly situated while 1% is encroached by new development of buildings. The petrol stations have their age range between 2 to 22 years, and buried tanks between 3 to 12 as shown in (fig. 4.3, 4.4 & 4.5). All the stations have same corrosion prevention treatment of only bitumen coating and wrapping with black polyethylene, no cathodic protection.

Petrol stations of ages from 10 to 22 years are perceived to be at risk of contaminating groundwater. Whereby, electrical resistivity inversion gave average depth to groundwater as 24.5 m (80 ft) and average depth of buried tanks was obtained as 3.6 m (12 ft.). Drainage analysis across the area confirmed direction of surface drainage to the south-south-west direction. This conforms to the direction of groundwater flow stated by Nwachukwu et al., 2010.

Further analysis of this result considered locations of older stations and the possibility of corrosion and leakage of storage tanks. It is concluded that petrol stations between ages of 15 to 22 years are at greater risk of corrosion and leakage, and that any leakage from depth of 3.6 m would easily migrate to the water table at 24.5 m, and transported south-southwest of the area. Geophysics result also show the subsurface geology of the area to consist predominantly of sand and gravel

beds characterized by horizontal hydraulic conductivity 12-26.4 m/day and transmissivity up to 1370 m²/day (Ekwe et al. 2006).

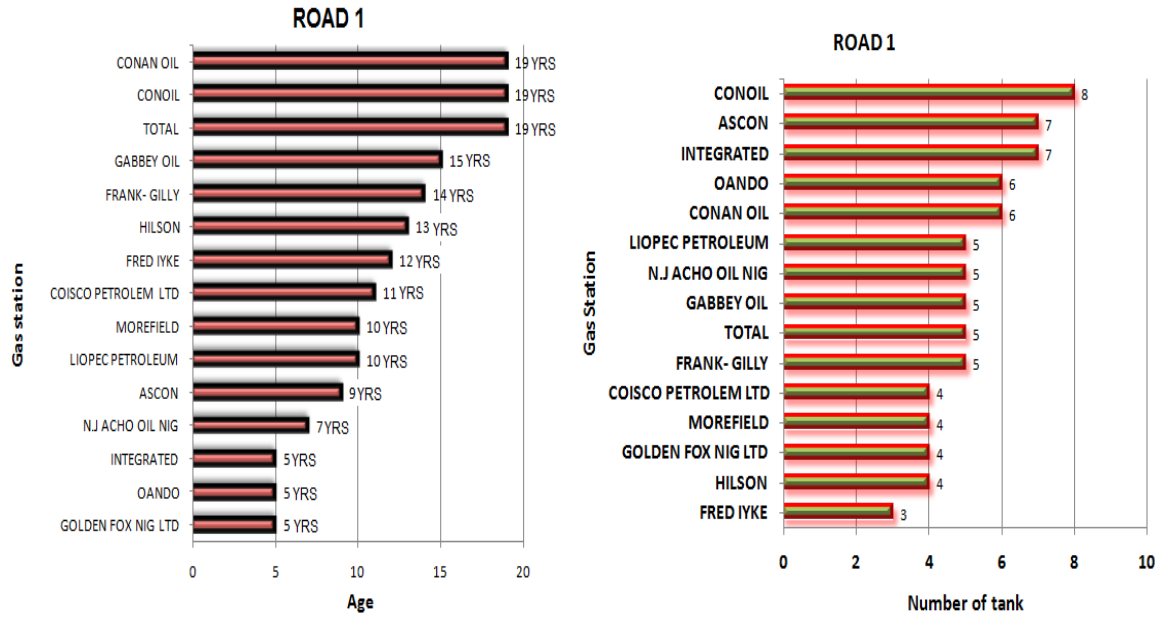


Fig. 4.3; Graph of Gas Stations against Age and Number of USTs for Road 1

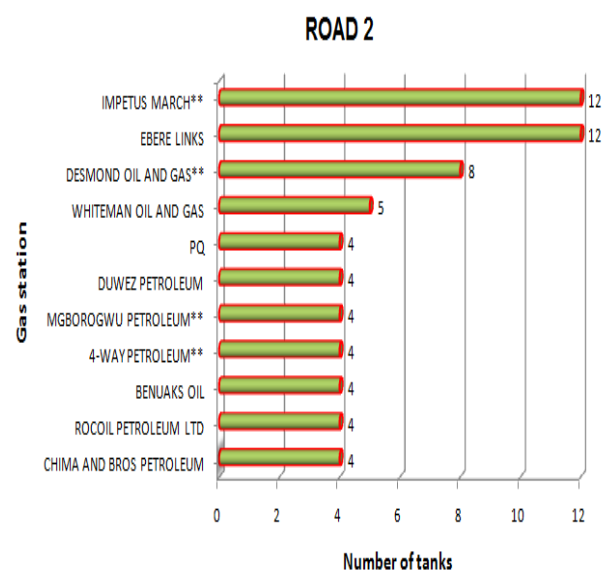
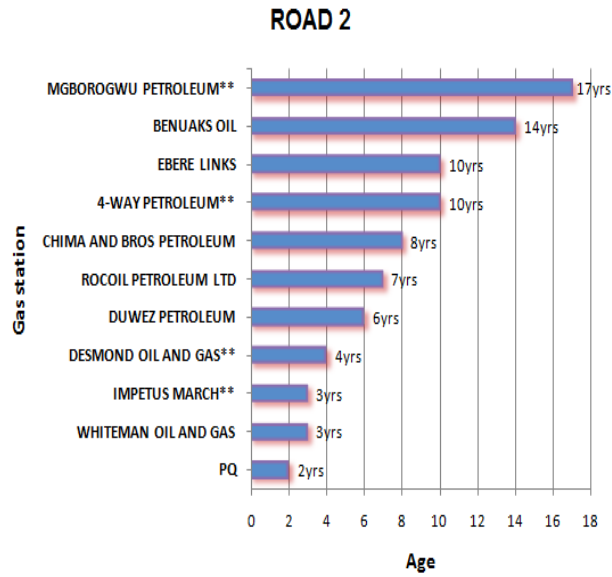


Fig.4.4; Graph of Gas Stations against Age and Number of USTs for Road 2

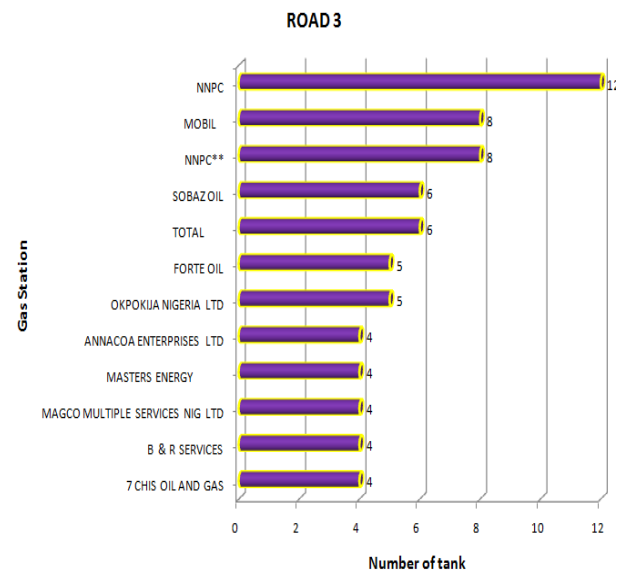
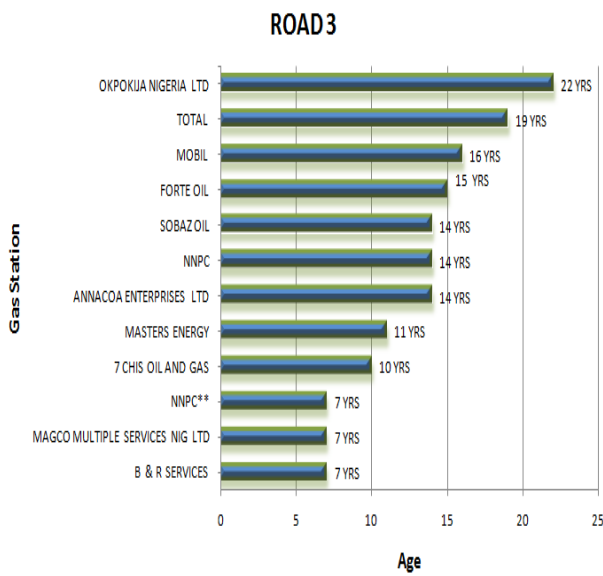


Fig 4.5; Graph of Gas Stations against Age and Number of USTs for Road 3

4.3 Lists and locations of all the sampled fuel stations in study area

Table 4.1: Road 1- Nekede-Ihiagwa Road

S/N	Name of Station	Side of the Road	Name of Area	Location/proximity to buildings/residents
1	FRANK- GILLY	Right	Nekede	Not properly situated, close to shops/residential buildings
2	TOTAL	Right	Nekede	Not properly situated, close to shops/residential buildings
3	FRED IYKE	Right	Nekede	Not properly situated, close to shops/residential buildings
4	CONOIL	Right	Nekede	Not properly situated, close to next station
5	HILSON	Right	Nekede	Not properly situated, close to next station
6	GOLDEN FOX NIG LTD	Right	Nekede	Not properly situated, close to next station
7	CHYBYKE	Right	Nekede	Not properly situated, close to next station
8	GABBEY OIL	Right	Nekede	Not properly situated, close to next station
9	ASCON	Right	Nekede	Not properly situated, close to next station
10	MOREFIELD	Right	Nekede	Not properly situated, close to next station
11	CONAN OIL	Right	Nekede	Not properly situated, close to next station
12	THE BUNCHES PETROLEUM	Right	Nekede	Distanced, properly situated
13	OANDO	Right	Nekede	Distanced, properly situated
14	ABANDONED	Left	Nekede	Distanced, properly situated
15	INTEGRATED	Right	Nekede	Distanced, properly situated
16	PC EJIMS LTD	Left	Nekede	Distanced, properly situated

17	MASTER ENERGY	Left	Nekede	Not properly situated, close to residential buildings/shops
18	N.J ACHO OIL NIG	Right	Ihiagwa	Not properly situated, close to residential buildings/shops
19	SLOTTS NIG LTD	Left	Ihiagwa	Not properly situated, close to residential buildings/shops
20	GRACELAND PETROLEUM	Left	Ihiagwa	Not properly situated, close to residential buildings/shops
21	COISCO PETROLEM LTD	Left	Ihiagwa	Not properly situated, close to residential buildings/shops
22	CHARIANTH LTD	Right	Ihiagwa	Not properly situated, close to residential buildings/shops
23	LIOPEC PETROLEUM	Left	Ihiagwa	Not properly situated, close to residential buildings/shops
24	DEPFAN INTER LINKS	Right	Ihiagwa	Not properly situated, close to residential buildings/shops
25	MUODU LAMACO PET	Left	Ihiagwa	Not properly situated, close to residential buildings/shops
26	NNPC	Left	Ihiagwa	Not properly situated, close to residential buildings/shops

Table 4.2. Road 2- Obinze to Control

S/N	Name of Station	Side of the Road	Name of Area	Location/proximity to buildings/residents
1	IMPETUS MARCH**	Left	Obinze	Not properly situated, close to residential buildings/shops
2	MGBOROGWU PETROLEUM**	Right	Obinze	Not properly situated, close to residential buildings/shops
3	UNDER CONSTRUCTION	Right	Obinze	Distanced, properly situated
4	UNDER CONSTRUCTION	Left	Obinze	Distanced, properly situated
5	UNDER CONSTRUCTION	Left	Obinze	Distanced, properly situated
6	VERDITH RESOURCES	Right	Obinze	Distanced, properly situated

7	CHIBEN OIL COY LTD	Left	Avu	Distanced, properly situated
8	OXX KINGS PETROLEUM	Left	Avu	Distanced, properly situated
9	UNDER CONSTRUNCTION	Left	Avu	Distanced, properly situated
10	UNDER CONSTRUNCTION	Left	Avu	Distanced, properly situated
11	UNDER CONSTRUNCTION	Left	Avu	Distanced, properly situated
12	DUWEZ PETROLEUM	Left	Avu	Distanced, properly situated
13	UNDER CONSTRUNCTION	Left	Avu	Distanced, properly situated
14	WHITEMAN OIL AND GAS	Right	Umuguma`	Not properly situated, close to residential buildings/shops
15	DESMOND OIL AND GAS**	Left	Umuguma	Not properly situated, close to residential buildings/shops
16	PQ	Right	Umuguma	Not properly situated, close to residential buildings/shops
17	OANDO	Right	Umuguma	Not properly situated, close to residential buildings/shops
18	EBERE LINKS	Left	Umuguma	Not properly situated, close to new residential buildings/shops
19	CHIMA AND BROS PETROLEUM	Left	Umuguma	Express/ close proximity to new residential buildings/shops
20	UNDER CONSTRUNCTION UNDER CONSTRUNCTION	Left	Umuguma	Not properly situated, close to residential buildings/shops and others
21	ROCOIL PETROLEUM LTD	Left	Umuguma/Control	Not properly situated, close to residential buildings/shops
22	BENUAKS OIL	Left	Umuguma/Control	Not properly situated, close to residential buildings/shops
23	4-WAY PETROLEUM**	Left	Umuguma/Control	Not properly situated, close to residential buildings/shops
24	FORTE OIL**	Left	Umuguma/Control	Not properly situated, close to residential buildings/shops

Table 4.3 Road 3- Onitcha Road (Control to Orogwe)

S/N	Name of Station	Side of the Road	Name of Area	Location/proximity to buildings/residents
1	NNPC**	Left	Control Junctioncs	Not properly situated, close to buildings/junction, others
2	NNPC	Right	Onitcha Road/Irete	Distanced, properly situated
3	FLEDWIN PETROLEUM	Left	Onitcha Road/Irete	Distanced, properly situated
4	MOBIL	Right	Onitcha Road/Irete	Distanced, properly situated
5	TOTAL			
6	INDEX	Right	Onitcha Road/Irete	Distanced, properly situated
7	MASTERS ENERGY			
8	NNPC	Right	Onitcha Road/Irete	Distanced, properly situated
9	UJUAKU INDUSTRIAL LTD	Right	Onitcha Road/Irete	Distanced, properly situated
10	ANNACOA ENTERPRISES LTD	Right	Onitcha Road/Irete	Not properly situated, close to buildings/junction, others
11	UNDER CONSTRUCTION	Right	Onitcha Road/Orogwe	Not properly situated, close to buildings/junction, others
12	FORTE OIL	Right	Onitcha Road/Orogwe	Not properly situated, close to buildings/junction, others
14	OKPOKIJA NIGERIA LTD	Right	Onitcha Road/Orogwe	Not properly situated, close to buildings/junction, others
15	7 CHIS OIL AND GAS	Right	Onitcha Road/Orogwe	Not properly situated, close to buildings/junction, others
16	B & R SERVICES	Right	Onitcha Road/Orogwe	Not properly situated, close to buildings/junction, others
17	MGBOROGWU PETROLEUM	Right	Onitcha Road/Orogwe	Not properly situated, close to buildings/junction, others
18	ROYAL LONAG VENTURES LTD	Right	Onitcha Road/Orogwe	Not properly situated, close to buildings/junction, others
19	UNDER CONSTRUCTION	Left	Onitcha Road/Orogwe	Not properly situated, close to buildings/junction, others
20	SOBAZ OIL	Left	Onitcha Road/Orogwe	Not properly situated, close to buildings/junction, others

4.4 Water Table Determination

4.4.1 Electrical Resistivity Survey

Inverted Resistivity model constrained to 6 geo-electric layers consisted predominantly of sand and gravel beds, indicating water table at depth of 23 m in road 1, 24.5 m in road 2 and 26.2 m in road 3 constrained to 7 layers as shown in fig 4.3, 4.4 and 4.5. This gave 24.5 m as average depth to water table across the area.

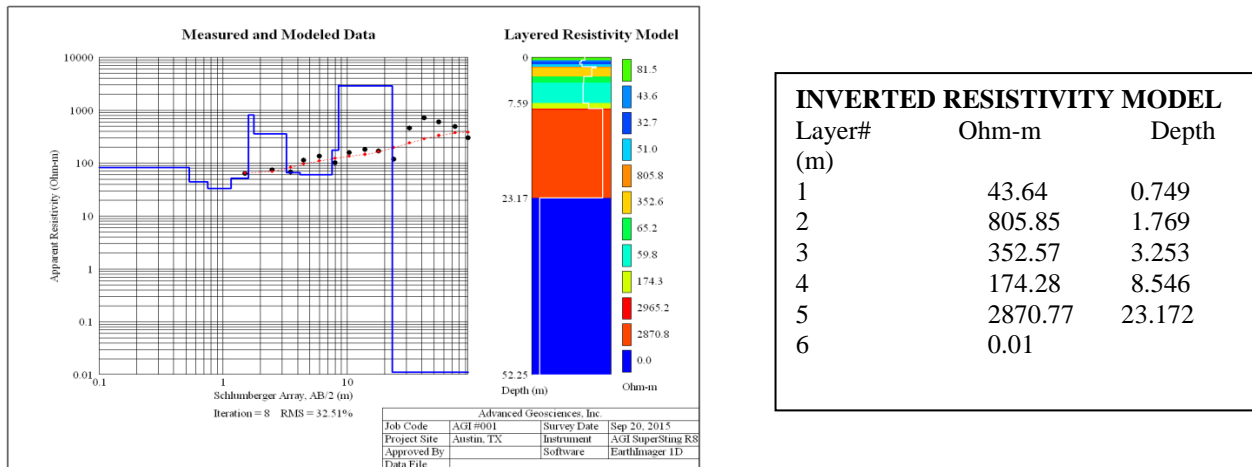
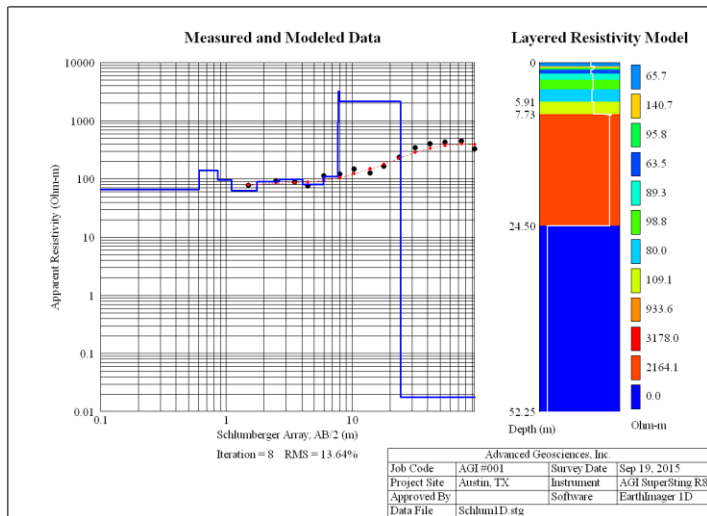
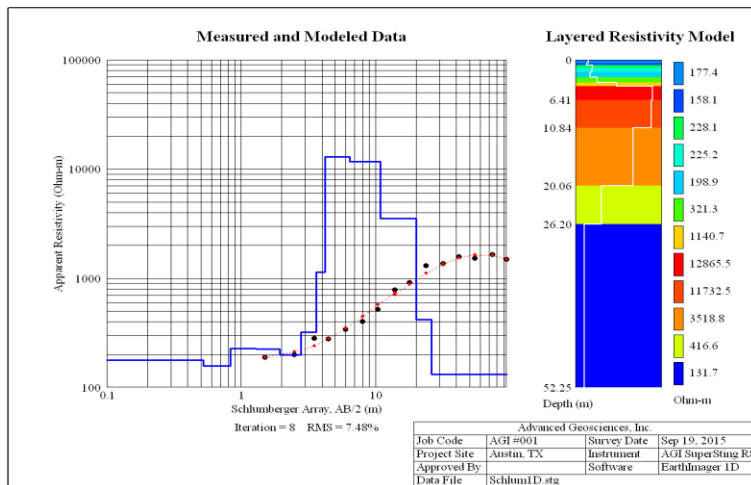


Fig. 4.6: VES for Road 1



INVERTED RESISTIVITY MODEL		
Layer#	Ohm-m	Depth (m)
1	140.74	0.853
2	89.27	2.651
3	98.81	4.055
4	3177.99	7.882
5	2164.08	24.502
6	0.02	

Figure 4.7: VES for Road 2



INVERTED RESISTIVITY MODEL		
Layer#	Ohm-m	Depth (m)
2	158.14	0.831
6	321.25	3.625
8	12865.5	6.414
9	11732.54	10.837
10	3518.78	20.062
11	416.63	26.200
12	131.68	

Figure 4.8: VES for Road 3

4.5 Fuel Stations at close Proximity to Public Place

The result also revealed that, some of the petrol stations were operating at close proximities to markets, Banks, motor parks or other public areas as shown in Plate 4.1 and 4.2. However, based on their dates of location and history as obtained, it was obvious that it was the presence of some of these petrol stations that attracted the locations of most of those markets, commercial shops, motor parks, Banks and

other commercial activities because of the strategic locations of the petrol stations sites for business. The clustering of those markets, motor packs and commercial shops around the petrol stations without observing the 90m proximity (DPR, 2011) had made the petrol stations to be found not right in the midst of those structures. From the result therefore, only 30% were located in close conformity with the guidelines while 70% of the sampled petrol stations did not adhered to the 400m distance between them as required by DPR as shown in Table 4.1

Table 4.4 Proximities between sampled fuel stations to the nearest one to them and residential buildings along the study area

Location	Distance in meter			Total	DPR Requirement
	≤100	101-399	400		
Nekede-Ihiagwa Road	20	6	0	26	400metres
Ph Road	19	5	0	24	
Onitcha Road	10	10	0	20	
Total	49	21	0	70	

Not complied=70% Complied with little distance=30%

It is common to see some of these petrol stations located at close proximity only to be separated by a wall or narrow path in the township. The non- conformance to DPR specification includes those at close proximity to residential buildings/ public

places. Results showed that residential houses were located at unfriendly distances to petrol stations (< 50m) while few were sited at a convenient distance to those petrol stations (50m >). This gross violation of the DPR proximities requirement guideline by the petrol stations and residents in terms of location sites increase the residents' vulnerability to the petrol related hazards. However, the study revealed that some of these affected petrol stations were located much earlier than some of the residential houses, however, over the years and at present could do nothing to stop the encroachment or stiff competitions over land close to major roads for location of shops, residential houses or the petrol stations even though such situation clearly undermined the guidelines and subject the environment to serious effects because of the economic viability of those choice plots of land.

Generally, as stipulated in the DPR Procedure Guide (2010) under the Petroleum Act CAP 150 of 1967 and captioned "Specific Directives," the implications for flouting the DPR guidelines by petrol station ranges from classifying that petrol station as illegal to revocation of license depending on the gravity of the offence. This is because as the petrol stations operate under such condition, both human health and the environment are threatened. However, the study gathered that DPR has done very little over the years to discourage the situation. It claimed that most of the petrol stations affected were either given EIA waivers or clearance by the state government compelling DPR to licensed them. Whereas, the encroached

residential building continues because of lack of government political law to enforce the urban planning Law, as such, the use of land in the town is left in the hands of the landowners" discretion.

For instance, Frank Dilly and Total Petroleum Nigeria Limited (Plate 4.1 &4.2) are located at less than 43m away from Weatheral roundabout , New Market/ Motor park, and other shops and human activities were built in 2001 and 1996 respectively (years after the markets were located). This might have contributed to the environmental problems such as indiscriminate/perennial waste disposal, noise and flooding the immediate neighbourhoods are facing.

As a matter of importance and rule, petrol stations are expected to be sited away from places where people normally gathered for any form of activities (Wikipedia, 2010). However, this was not given due consideration in Owerri West, Imo State.



Plate 4.1 Frank Gilly Petrol Station at close proximity to public place



Plate 4.2 Total Petrol Station at close proximity to public place



Plate 4.3: Morefield fuel station located at close proximity to residential buildings

4.6 Fire Safety

The petrol stations inspected maintained proper enforcement of Fire safety with fire extinguishers placed at each fuel dispenser, offices and other areas within the station. Each Petrol station had more than 5 fire extinguishers that were serviced. There were fire point assembly, smoke detector/fire alarm and exit routes for emergency, this is conformity to the DPR specifications.

4.7 Locations for Installation of Monitoring Wells

Six monitoring wells have been recommended, and their locations selected based on age and number of USTs ≥ 15 years old in each road (Fig. 4.6). The SW direction of groundwater flow was also a major determinant in positioning the monitoring wells. A reference coordinate representing a point of concentration of older petrol stations (15 years+) in each road was established. The six reference coordinates were connected in a triangle. Projecting a similar triangle SW successfully mapped out the most vulnerable area to USTs leakage and groundwater contamination by triangulation. The six monitoring wells were thus located on the bases of age of stations, groundwater flow direction, and cluster of USTs. It is on these bases that the reference coordinates were assigned and constructed to the triangular loops. Meeting points of the triangular loops represents sites of monitoring wells. Monitoring well could be placed at offset of 500 m to the reference coordinate in the direction of groundwater flow (S-SW), and a typical design of groundwater monitoring well applicable in Owerri-west.

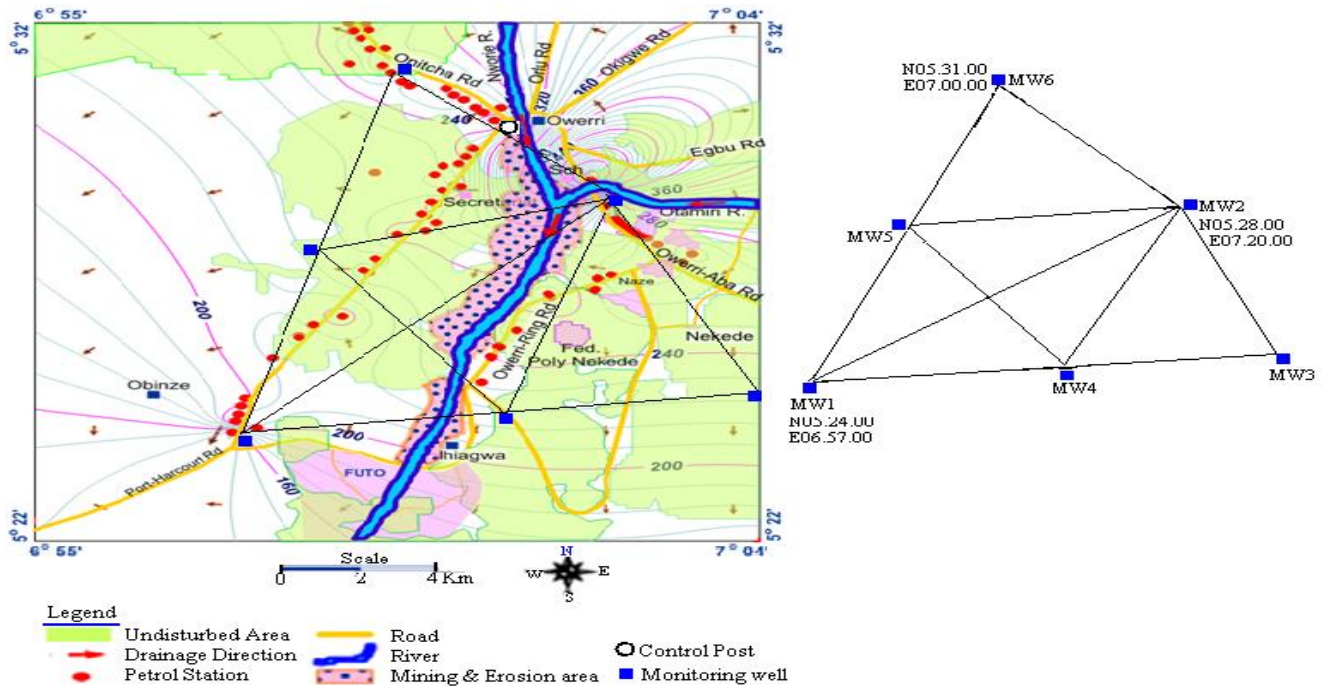


Figure 4.9: Project Map showing location of petrol stations against selected location of six monitoring wells and areas most vulnerable to UST leakage and groundwater contamination.

Petrol stations USTs of ages from 10 to 22 years are perceived to be at risk of corrosion to contaminating groundwater. Whereby, electrical resistivity inversion gave average depth to groundwater as 24.5 m (80 ft) and average depth of buried tanks was obtained as 3.6 m (12 ft.). Drainage analysis across the area confirmed direction of surface drainage to the South-South-West direction. Unfortunately, the entire population of Owerri west depends on shallow water wells for their water supply, produced from water table aquifer. If leakage occurs from any of these petrol station tanks, the several shallow private domestic wells serving the three

major tertiary institutions and the communities in the area will be easily contaminated and condemned.

Considering the population of Federal University of Technology Owerri and Federal Polytechnic Nekede, both located in this area and the attendant population density, any leakage of petroleum product to the groundwater will represent a disaster to the area with serious physical and health consequences to the people. This result suggests that six monitoring wells at 500 m offset from each of the three roads reference coordinate be installed in the direction south-west. Fig. 4.7 is a typical design of a monitoring well considered very adequate in Owerri west.

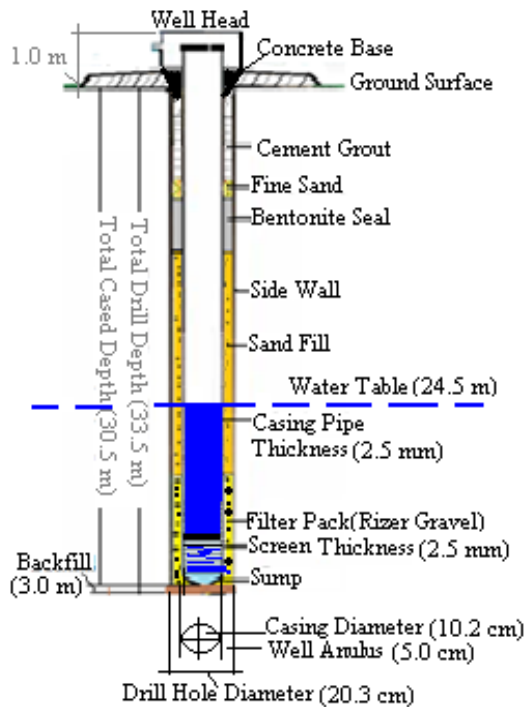


Figure 4.10, Design of Groundwater Monitoring Well for Owerri-West

Conformity of Drainage Analysis

Drainage Analysis conforms to the direction of groundwater flow stated by Nwachukwu et al., 2010. Previous work by Ibe and Uzoukwu (2001) found groundwater flow across the study area to the SW, based mainly on topographic analysis. Ibe et al. (2007) also reported that pollutants are transported southwards by surface water flow in the study area of Owerri-west. According to them, the pollutants could easily migrate to the water table and immediately contaminate groundwater. Results of this study emphasize moderate to high vulnerability of soil and water resources in the southern flank of the Imo River basin, comprising Owerri-West. The result which is consistent with velocity values of unconsolidated sediments suggests that any spill of petroleum products to the subsurface will

easily migrate to the water table. Considering the population of Federal University of Technology Owerri and Federal Polytechnic Nekede, both located in this area and the attendant population density, any leakage of petroleum product to the groundwater will represent a disaster to the area with serious hardship to the people

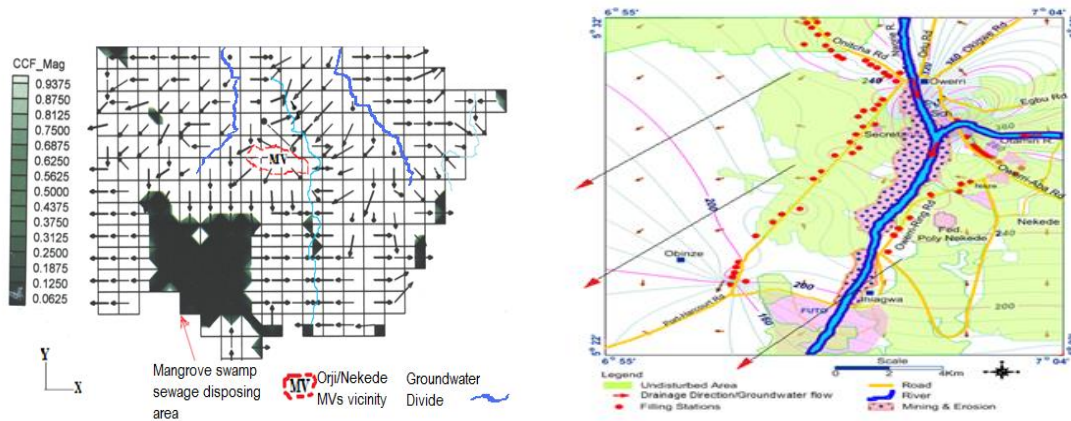


Figure 4.11: (a) Groundwater flow pattern based on MODFLOW code (Nwachukwu et al. 2010)

Figure 4.11(b) Drainage analysis of study area tending to groundwater flow direction

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The findings revealed that the guidelines for sitting petrol stations have not been adhered by most of the petrol stations proprietors, thereby posing serious hazards on residents in close proximity to them even though some of these petrol stations were located much earlier than the residential houses close to them. The presence of 70 petrol stations against a total of 7 km roads in Owerri west constitute a major threat to groundwater in the area. It is expected of the State legislature therefore to enact law forbidding either government or individuals from converting plots of land for petrol stations within unauthorized locations of a city. Any attempt by either of the two sides to convert the use of any land within residential area should be resisted by the people and the court.

Leaking USTs are one of the most serious threats to the quality of groundwater. 100% of people in Owerri-west virtually rely on groundwater for drinking water and for other domestic purposes.

5.2 RECOMMENDATION

The overall volume of storage tanks and the volume of a single tank at liquid fuel stations must not be larger than 500 m³ and 100 m³, respectively; the volume of a single tank at a container station must not exceed 30 m³. Liquid fuel stations have to be sewerred and equipped with the following items: specialized devices that prevent penetration of petroleum products into the soil, surface water and groundwater; systems for measuring and monitoring the level of crude oil products being stored, and devices preventing emission of vapours of petroleum products into the atmosphere. The distance of liquid fuel dispenser (with the exception of the petrol station pavilion) must not be less than 10m from the forest boundary, and 5m from the boundary of neighbouring undeveloped plots. This procedure for monitoring leakage from petrol stations is adaptable elsewhere where proliferation of petrol stations is identified without lasting corrosion prevention devices.

Bitumen Coatings used to coat the external cells of tanks at an economic scale cannot eliminate corrosion. They have pores and flaws, which can absorb moisture and stale over time, leaving spots on areas exposed to the soil. The current cathodic protection penetrates the exposed areas precisely, totally eliminating corrosion in any season and at any point of the tank where these flaws and pores appear. In such cases conventional coatings alone cannot ensure the protection of buried tanks but need to be supplemented by cathodic protection.

After installing the cathodic protection system, it is necessary to verify that the tanks are protected against corrosion. This check should be done by measuring the potential of the tanks in the ground. Since the tanks are kept within minimum levels of potential, external corrosion will be eliminated, whatever the state of the coating used. There should be no crowd in petrol stations including human and automobiles. Gas stations must place warning signs that cell phones should be turned off for safety while pumping gas. There should be no smoking or use of lighter or naked light inside and around petrol stations. Fire extinguishers must be serviced/refilled every 6 months and all staff must be trained on how and when to use them. There should be enforcement on the use of Personal Protective Equipments (PPE) on all petrol station workers. Three monitoring well locations have been identified in the SW direction based on groundwater flow direction, concentration and age of USTs. Future research may seek funding to install the monitoring wells as identified for environmental safety.

In location or construction of petrol stations, the guidelines for the location and operation of petroleum stations in Nigeria as provided by Petroleum Regulation Act CAP 150 of 1967, which stipulated that application for the issuance of license to all petrol stations categories, shall be through DPR. DPR is vested with the responsibility to determine whether or not an application is suitable for

“Approval to construct” (ATC). Some of these requirements expected of petrol stations before being suitable for licensing to operate which relate to this study are:

(i). Environmental Impact Assessment (EIA) Report carried out on the proposed petrol station by DPR accredited consultants must be presented. (ii). The total number of petrol stations within 2km stretch should be 4 on both sides of the road, including the one under construction for a single carriage (iii). The distance between existing petrol stations on approved sites and the proposed one should be 400m apart (iv). The distance between one petrol station to the nearest residential building should be 50m apart. (v), the distance between one petrol station and the nearest place of public assembly should be 90m apart.

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APPENDICES

Appendix 1: Field survey for Road 1

NAME OF STATION	ELEVATION (FT)	NORTHING (N)	EASTING (E)	FUNCTIONALITY	YEAR OF ESTABLISHMENT	DEPTH AND NO OF UST	FIRE SAFETY	CORROSION SAFETY(CP OR OTHERS)	DPR INSPECTION
FRANK- GILLY	594	05°28.304	07°02.171	FL	2001/14 YRS		3 YES	BITUMEN+ BLACK POLYTHELENE	YES
TOTAL	232	05°28.280	07°01.221	FL	1996/15 YRS		5 YES	BITUMEN+ BLACK POLYTHELENE	YES
FRED WYKE	261	05°28.246	07°01.233	N F	2003/12 YRS		3 NOT SIGHTED	BITUMEN+ BLACK POLYTHELENE	YES
CONOIL	234	05°28.256	07°01.232	N F	1996/15 YRS		8 YES	BITUMEN+ BLACK POLYTHELENE	YES
HILSON	224	05°27.991	07°01.356	N F	2002/13 YRS		4 YES	BITUMEN+ BLACK POLYTHELENE	YES
GOLDEN FOX NIG LTD	244	05°27.982	07°01.364	N F	2010/5 YRS		4 NOT SIGHTED	BITUMEN+ BLACK POLYTHELENE	YES
CHYBYKE	254	05°27.951	07°01.390	U S			-	-	-
GABBEY OIL	267	05°27.908	07°01.420	N F	2000/15 YRS		5 YES	BITUMEN+ BLACK POLYTHELENE	YES
ASCON	251	05°27.859	07°01.473	N F	2006/9 YRS		7 YES	BITUMEN+ BLACK POLYTHELENE	YES
MOREFIELD	220	05°27.776	07°01.548	N F	2000/10 YRS		4 YES	BITUMEN+ BLACK POLYTHELENE	YES
CONAN OIL	238	05°27.729	07°01.569	N F	1996/15 YRS		6 YES	BITUMEN+ BLACK POLYTHELENE	YES
THE BUNCHES PETROLEUM	262	05°27.732	07°01.594	U S					
QANDO	275	05°27.654	07°01.667	FL	2010/5 YRS		6 YES	BITUMEN+ BLACK POLYTHELENE	YES
ABANDONED	272	05°27.579	07°01.746	N F					
INTEGRATED	273	05°27.620	07°01.742	FL	2010/5 YRS		7 YES	BITUMEN+ BLACK POLYTHELENE	YES
PC EJIMS LTD	248	05°27.298	07°03.298	N F					
MASTER ENERGY	267	05°27.216	07°03.245	NC					
N.J ACHO OIL NIG	272	05°26.772	07°01.376	FL	2008/7 YRS		5 YES	BITUMEN+ BLACK POLYTHELENE	YES
SLOTTS NIG LTD	250	05°26.772	07°01.166	NC					
GRACELAND PETROLEUM	245	05°26.622	07°01.030	NC					
COSCO PETROLEUM LTD	225	05°26.433	07°01.561	FL	2004/11 YRS		4 YES	BITUMEN+ BLACK POLYTHELENE	YES
CHARIANTH LTD	218	05°26.504	07°01.143	NC					
UOPEC PETROLEUM	257	05°25.517	07°00.962	FL	2005/10 YRS		5 YES	BITUMEN+ BLACK POLYTHELENE	YES
DEPFAN INTER LINKS	239	05°25.456	07°00.917	NC					
MILODU LAMACO PET	240	05°25.426	07°00.902	NC					
NNPC	234	05°24.745	07°00.721	N F					

Appendix 2: Field survey for Road 2

NAME OF STATION	ELEVATION	NORTHING (N)	EASTING (E)	FUNCTIONALITY	YEAR OF ESTABLISHMENT	DEPTH AND NO OF UST	FIRE SAFETY	CORROSION SAFETY(CP OR OTHERS)	DPR INSPECTION
IMPETUS MARCH**	133	05°23.745	06°57.678	FL	2012/3 YRS		12 YES	BITUMEN+ BLACK POLYTH YES	
MGBOROGWU PETROLEUM**	231	05°23.976	06°57.715	FL	1998/17 YRS		4 YES	BITUMEN+ BLACK POLYTH YES	
UNDER CONSTRUCTION	204	05°24.215	06°57.768	NF					
UNDER CONSTRUCTION	200	05°24.277	06°57.784	NF					
KINGS PETROLEUM	198	05°24.429	06°57.834	NF					
VERDITH RESOURCES	206	05°23.841	06°57.971	ABD					
CHIBEN OIL COY LTD	209	05°25.228	06°58.163	NF					
OXX KINGS PETROLEUM	219	05°25.671	06°58.495	NF					
UNDER CONSTRUCTION	205	05°25.886	06°58.656	NF					
UNDER CONSTRUCTION	194	05°26.056	06°59.018	NF					
UNDER CONSTRUCTION	227	05°28.917	06°59.422	ABD					
DUWEZ PETROLEUM	242	05°27.854	07°00.119	FL	2009/6 YRS		4 YES	BITUMEN+ BLACK POLYTH YES	
UNDER CONSTRUCTION	251	05°27.916	07°00.158	NF					
WHITEMAN OIL AND GAS	246	05°27.858	07°00.142	FL	2012/3 YRS		5 YES	BITUMEN+ BLACK POLYTH YES	
DESMOND OIL AND GAS**	232	05°26.900	07°00.131	FL	2011/4 YRS		8 YES	BITUMEN+ BLACK POLYTH YES	
PQ	238	05°27.923	07°00.159	FL	2013/2 YRS		4 YES	BITUMEN+ BLACK POLYTH YES	
QANDU	224	05°28.8/4	07°00.140	NF					
FRFRF I INKS	246	05°28.778	07°00.425	FI	2005/10 YRS		12 YES	BITUMEN+ BLACK POLYTH YES	
CHIMA AND BROS PETROLEUM	224	05°28.589	07°00.667	FL	2007/8 YRS		4 YES	BITUMEN+ BLACK POLYTH YES	
UNDER CONSTRUCTION	226	05°28.624	07°00.694	UC					
ROCOIL PETROLEUM LTD	235	05°28.842	07°00.853	FL	2008/7 YRS		4 YES	BITUMEN+ BLACK POLYTH YES	
BENUAKS OIL	234	05°29.068	07°01.018	FL	2001/14 YRS		4 YES	BITUMEN+ BLACK POLYTH YES	
4-WAY PETROLEUM**	245	05°29.179	07°01.105	FL	2005/10 YRS		4 YES	BITUMEN+ BLACK POLYTH YES	
FORTIE OIL**	253	05°29.293	07°01.185	NF					

Appendix 3: Field work for Road 3

NAME OF STATION	ELEVATION (FT)	NORTHING (N)	EASTING (E)	FUNCTIONALITY	YEAR OF ESTABLISHMENT	DEPTH AND NO OF UST	FIRE SAFETY	CORROSION SAFETY(CP OR OTHERS)	DPR INSPECTION
NNPC**	216	05°29.393	07°01.202	FL	2008/7YRS		8 YES	BITUMEN+BLACK POLYTHELENE	YES
NNPC	257	05°29.555	07°01.061	FL	2001/14 YRS		12 YES	BITUMEN+BLACK POLYTHELENE	YES
FLEDWIN PETROLEUM	259	05°29.658	07°00.699	NF	-	-	-	-	-
MOBIL at close proximity	254	05°29.751	07°00.882	NF	1999/15 YRS		8 NOT SIGHTED	BITUMEN+BLACK POLYTHELENE	YES
TOTAL at close proximity	244	05°29.769	07°00.869	FL	1996/19 YRS		6 YES	BITUMEN+BLACK POLYTHELENE	YES
INDEX at close proximity	275	05°30.077	07°00.608	NF					
MASTERS ENERGY at close proximity	256	05°30.093	07°00.591		2006/11 YRS		4 YES	BITUMEN+BLACK POLYTHELENE	YES
NNPC	256	05°30.644	06°59.839	ABANDONED					
UJWAKU INDUSTRIAL LTD	245	05°30.723	06°59.745	NF					
ANNACOA ENTERPRISES LTD	257	05°30.745	06°59.731	FL	2001/14 YRS		4 YES	BITUMEN+BLACK POLYTHELENE	YES
UNDER CONSTRUCTION	276	05°31.033	06°59.513	NF					
FORTE OIL	262	05°31.371	06°59.360	FL	2000/15 YRS		5 YES	BITUMEN+BLACK POLYTHELENE	YES
MAGCO MULTIPLE SERVICES NIG LTD	254	05°31.754	06°59.148	FL	2008/7 YRS		4 YES	BITUMEN+BLACK POLYTHELENE	YES
OKPOKJIA NIGERIA LTD	246	05°31.895	06°59.088	FL	1993/22 YRS		5 YES	BITUMEN+BLACK POLYTHELENE	YES
7 CHIS OIL AND GAS	274	05°31.680	06°59.156	FL	2005/10 YRS		4 YES	BITUMEN+BLACK POLYTHELENE	YES
B & R SERVICES	258	05°31.764	06°59.342	NF	2008/7 YRS		4 NOT SIGHTED	BITUMEN+BLACK POLYTHELENE	YES
MGBOROGWU PETROLEUM	246	05°31.085	06°59.093	NC					
ROYAL LONAG VENTURES LTD	270	05°31.385	06°59.543	NC					
UNDER CONSTRUCTION	245	05°31.724	06°59.138	NF					
SOBAZ OIL	256	05°31.881	06°59.308	FL	2001/14 YRS		6 YES	BITUMEN+BLACK POLYTHELENE	YES

Appendix 4: Lists and locations of all the sampled fuel stations in study area ROAD 1- Nekede/Ihiagwa-Road

S/N	Name of Station	Side of the Road	Name of Area	Location/proximity to buildings/residents
1	FRANK- GILLY	Right	Nekede	Not properly situated, close to shops/residential buildings/next station
2	TOTAL*	Right	Nekede	Not properly situated, close to shops/residential buildings/next station
3	FRED IYKE	Right	Nekede	Not properly situated, close to shops/residential buildings/next station
4	CONOIL*	Right	Nekede	Not properly situated, close to next station
5	HILSON	Right	Nekede	Not properly situated, close to next station
6	GOLDEN FOX NIG LTD	Right	Nekede	Not properly situated, close to next station

7	CHYBYKE	Right	Nekede	Not properly situated, close to next station
8	GABBEY OIL *	Right	Nekede	Not properly situated, close to next station
9	ASCON	Right	Nekede	Not properly situated, close to next station
10	MOREFIELD	Right	Nekede	Not properly situated, close to next station
11	CONAN OIL *	Right	Nekede	Not properly situated, close to next station
12	THE BUNCHES PETROLEUM	Right	Nekede	Distanced, properly situated
13	OANDO	Right	Nekede	Distanced, properly situated
14	ABANDONED	Left	Nekede	Distanced, properly situated
15	INTEGRATED	Right	Nekede	Distanced, properly situated
16	PC EJIMS LTD	Left	Nekede	Distanced, properly situated
17	MASTER ENERGY	Left	Nekede	Not properly situated, close to residential buildings/shops
18	N.J ACHO OIL NIG	Right	Ihiagwa	Not properly situated, close to residential buildings/shops
19	SLOTTS NIG LTD	Left	Ihiagwa	Not properly situated, close to residential buildings/shops
20	GRACELAND PETROLEUM	Left	Ihiagwa	Not properly situated, close to residential buildings/shops
21	COISCO PETROLEM LTD	Left	Ihiagwa	Not properly situated, close to residential buildings/shops
22	CHARIANTH LTD	Right	Ihiagwa	Not properly situated, close to residential buildings/shops
23	LIOPEC PETROLEUM	Left	Ihiagwa	Not properly situated, close to residential buildings/shops
24	DEPFAN INTER LINKS	Right	Ihiagwa	Not properly situated, close to residential buildings/shops
25	MUODU LAMACO PET	Left	Ihiagwa	Not properly situated, close to residential buildings/shops
26	NNPC	Left	Ihiagwa	Not properly situated, close to residential buildings/shops

**Appendix 5: Lists and locations of all the sampled fuel stations in study area
Road 2- Obinze to Control**

S/N	Name of Station	Side of the Road	Name of Area	Location/proximity to buildings/residents
1	IMPETUS MARCH**	Left	Obinze	Not properly situated, close to residential buildings/shops
2	MGBOROGWU PETROLEUM**	Right	Obinze	Not properly situated, close to residential buildings/shops
3	UNDER CONSTRUCTION	Right	Obinze	Distanced, properly situated
4	UNDER CONSTRUCTION	Left	Obinze	Distanced, properly situated
5	UNDER CONSTRUCTION	Left	Obinze	Distanced, properly situated
6	VERDITH RESOURCES	Right	Obinze	Distanced, properly situated
7	CHIBEN OIL COY LTD	Left	Avu	Distanced, properly situated
8	OXX KINGS PETROLEUM	Left	Avu	Distanced, properly situated
9	UNDER CONSTRUCTION	Left	Avu	Distanced, properly situated
10	UNDER CONSTRUCTION	Left	Avu	Distanced, properly situated
11	UNDER CONSTRUCTION	Left	Avu	Distanced, properly situated
12	DUWEZ PETROLEUM	Left	Avu	Distanced, properly situated
13	UNDER CONSTRUCTION	Left	Avu	Distanced, properly situated
14	WHITEMAN OIL AND GAS	Right	Umuguma`	Not properly situated, close to residential buildings/shops
15	DESMOND OIL AND GAS**	Left	Umuguma	Not properly situated, close to residential buildings/shops
16	PQ	Right	Umuguma	Not properly situated, close to residential buildings/shops
17	OANDO	Right	Umuguma	Not properly situated, close to residential buildings/shops

18	EBERE LINKS	Left	Umuguma	Not properly situated, close to new residential buildings/shops
19	CHIMA AND BROS PETROLEUM	Left	Umuguma	Express/ close proximity to new residential buildings/shops
20	UNDER CONSTRUCTION UNDER CONSTRUCTION	Left	Umuguma	Not properly situated, close to residential buildings/shops and others
21	ROCOIL PETROLEUM LTD	Left	Umuguma/Control	Not properly situated, close to residential buildings/shops
22	BENUAKS OIL	Left	Umuguma/Control	Not properly situated, close to residential buildings/shops
23	4-WAY PETROLEUM**	Left	Umuguma/Control	Not properly situated, close to residential buildings/shops
24	FORTE OIL**	Left	Umuguma/Control	Not properly situated, close to residential buildings/shops

**Appendix 6: Lists and locations of all the sampled fuel stations in study area
Road 3- Onitcha Road (Control to Orogwe)**

S/N	Name of Station	Side of the Road	Name of Area	Location/proximity to buildings/residents
1	NNPC**	Left	Control Junctions	Not properly situated, close to buildings/junction, others
2	NNPC	Right	Onitcha Road/Irete	Distanced, properly situated
3	FLEDWIN PETROLEUM	Left	Onitcha Road/Irete	Distanced, properly situated
4	MOBIL	Right	Onitcha Road/Irete	Distanced, properly situated
5	TOTAL			
6	INDEX	Right	Onitcha Road/Irete	Distanced, properly situated
7	MASTERS ENERGY			
8	NNPC	Right	Onitcha Road/Irete	Distanced, properly situated
9	UJUAKU INDUSTRIAL LTD	Right	Onitcha Road/Irete	Distanced, properly situated
10	ANNACOA ENTERPRISES LTD	Right	Onitcha Road/Irete	Not properly situated, close to buildings/junction, others

11	UNDER CONSTRUCTION	Right	Onitcha Road/Orogwe	Not properly situated, close to buildings/junction, others
12	FORTE OIL	Right	Onitcha Road/Orogwe	Not properly situated, close to buildings/junction, others
14	OKPOKIJA NIGERIA LTD	Right	Onitcha Road/Orogwe	Not properly situated, close to buildings/junction, others
15	7 CHIS OIL AND GAS	Right	Onitcha Road/Orogwe	Not properly situated, close to buildings/junction, others
16	B & R SERVICES	Right	Onitcha Road/Orogwe	Not properly situated, close to buildings/junction, others
17	MGBOROGWU PETROLEUM	Right	Onitcha Road/Orogwe	Not properly situated, close to buildings/junction, others
18	ROYAL LONAG VENTURES LTD	Right	Onitcha Road/Orogwe	Not properly situated, close to buildings/junction, others
19	UNDER CONSTRUCTION	Left	Onitcha Road/Orogwe	Not properly situated, close to buildings/junction, others
20	SOBAZ OIL	Left	Onitcha Road/Orogwe	Not properly situated, close to buildings/junction, others

Appendix 7: Measured Data VES-1-Nekede Road

; Data#	V (mV)	I (mA)	MN (m)	AB/2 (m)	Ohm-m
1	1010.000	100	1.000	1.500	63.46
2	386.000	100	1.000	2.500	72.76
3	180.000	100	1.000	3.500	67.86
4	180.000	100	1.000	4.500	113.10
5	120.000	100	1.000	6.000	134.77
6	50.000	100	1.000	8.000	100.14
7	45.000	100	1.000	10.500	155.51
8	28.927	100	1.000	14.000	177.89
9	215.714	100	7.000	14.000	177.89
10	120.000	100	7.000	18.000	167.90
11	46.000	100	7.000	24.000	116.38
12	100.000	100	7.000	32.000	454.07
13	90.000	100	7.000	42.000	707.57
14	43.767	100	7.000	55.000	591.79
15	186.440	100	28.000	55.000	591.79
16	79.000	100	28.000	75.000	481.21
17	30.000	100	28.000	95.000	297.18

Appendix 8: Measured Data VES 2-PH Road

; Data#	V (mV)	I (mA)	MN (m)	AB/2 (m)	Ohm-m
1	1220.000	100	1.000	1.500	76.65
2	490.000	100	1.000	2.500	92.36
3	500.000	100	2.000	3.500	88.36
4	120.000	100	1.000	4.500	75.40
5	100.000	100	1.000	6.000	112.31
6	60.000	100	1.000	8.000	120.17
7	42.000	100	1.000	10.500	145.14
8	20.141	100	1.000	14.000	123.86
9	150.193	100	7.000	14.000	123.86
10	116.000	100	7.000	18.000	162.30
11	93.000	100	7.000	24.000	235.30
12	74.000	100	7.000	32.000	336.01
13	50.000	100	7.000	42.000	393.09
14	31.400	100	7.000	55.000	424.57
15	133.758	100	28.000	55.000	424.57
16	72.000	100	28.000	75.000	438.58
17	33.000	100	28.000	95.000	326.90

Appendix 9: Measured Data VES 3-Onitcha Road

; Data#	V (mV)	I (mA)	MN (m)	AB/2 (m)	Ohm-m
1	3000.000	100	1.000	1.500	188.50
2	1050.000	100	1.000	2.500	197.92
3	1580.000	100	2.000	3.500	279.21
4	440.000	100	1.000	4.500	276.46
5	300.000	100	1.000	6.000	336.94
6	200.000	100	1.000	8.000	400.55
7	150.000	100	1.000	10.500	518.36
8	126.113	100	1.000	14.000	775.55
9	940.442	100	7.000	14.000	775.55
10	650.000	100	7.000	18.000	909.43
11	510.000	100	7.000	24.000	1290.35
12	300.000	100	7.000	32.000	1362.22
13	200.000	100	7.000	42.000	1572.37
14	111.841	100	7.000	55.000	1512.22
15	476.421	100	28.000	55.000	1512.22
16	270.000	100	28.000	75.000	1644.66
17	150.000	100	28.000	95.000	1485.92



Integrated petrol station: properly situated

