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# Proliferation of Petrol Stations as Indicative of Unsustainable Development in Owerri West County, Nigeria

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***Abstract:*** *Proliferation of petrol stations without adequate corrosion preventive to the underground storage tanks (USTs) and other safety measures threatens total environment in Owerri-West County, Nigeria. This development threatens groundwater resources of the area and calls for serious concerns. In this study, digital mapping of Petrol stations in three roads of Owerri-West was carried out at 15 m and 400 m road buffers using Global Positioning System (GPS) and satellite imagery. The 8 km Nekede-Ihiagwa – Aba Road (1) has 26 petrol stations; the 14 km Owerri-West segment of Port-Harcourt Road (2) has 24 petrol stations and the 6 km Owerri-West segment of Onitsha Road (3) has 20 petrol stations. Out of the 70 petrol stations, 46% was functional, 42% was non functional, 8% was abandoned and 4% was under construction. About 64% of the petrol stations were not properly situated. Age of petrol stations/underground storage tanks (USTs) ranged from 2 to 22 years and number of USTs per station varies between 3 and 12 with average burial depth of 3.6 m (12 ft). All the stations USTs have poor corrosion prevention: bitumen coating and wrapping with black polyethylene, no cathodic protection. Electrical resistivity inversion gave average depth to groundwater (water table) as 24.5 m (80 ft) and lithology consisting of sand and gravel beds, supportive of leakage transport to the water table. Six monitoring wells have been proposed as a way of adaptation to the impending hazards to the near surface aquifer being the only source of domestic water to the highly populated area housing three higher institutions. Monitoring well locations were identified by triangulation based on groundwater flow direction (South-SW), age and cluster of USTs (≥ 15 years).*

***Keywords:*** *Digital Mapping, USTs, Corrosion, Drainage Analysis, Water Table, Monitoring Well, Geo-hazard*

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## I. Introduction

Proliferation of petrol stations without adequate corrosion preventives to the underground storage tanks (USTs) and safety measures threatens total environment in some parts of the world. Sustainability of groundwater is now of great concern in such areas where people depend on shallow groundwater system for their water needs. Hazards due to this behavior on the surface and subsurface particularly to groundwater take a gradual process. As a result, researchers and the authorities often neglect the situation and the future consequences for the ignorant citizens to live with it in less advanced societies. Universal guidelines and regulations for siting and establishing petrol stations exist without special consideration to water table variations. This has to be addressed with regular monitoring and assessment. As latent issues of environmental safety and sustainability, it borders on researchers to create the necessary awareness of the situation and proffer solution accordingly wherever the problem occurs.

Petrol stations suddenly became a booming business since the late 90's in Nigeria. There is indiscriminate sitting and establishment of all manners and standards of petrol stations by individuals predominantly not complying with existing guidelines and regulations. 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 this in parts of Nigeria. Petrol stations are f storage places for 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 situated and handled. Proliferation of petrol stations often is the handiwork of human greed over petroleum products; hoarding, artificial scarcity and profiteering. In the past, there were few petrol stations because investors were not making much profit but due to human factors, fuel hoarding and creation of artificial scarcity, marketers and investors now found petrol station business in Nigeria as gold mine, often without proper safety measures.

Urban growth also has increased the use of automobiles, need for fuel stations and consequently, proliferation of fuel stations most of which lack the minimum requirement for operation. Considering the high risk and dangers associated with petroleum products as highly flammable, its production, transportation, offloading, storage and sale points, should not be taken for granted like other products. According to WHO, 2004, 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 fuel base and station has to be equipped not only with 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.

In Nigeria, the application of the issuance of license to all petrol stations shall be through the DPR in order to save both the people and the environment from pollution. The major concern at fuel 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. The primary objective of this study is to commence monitoring for early detection of leaks from petrol stations within Owerri west, applicable to anywhere in the world where water table is close to surface. Petrol gives off vapours which when mixed with air at ambient temperature can explode and burn if ignited, causing loss of life and damage to the environment. They can contaminate soil, surface water and groundwater, and injurious to aquatic life on exposure. With provision of adequate monitoring to occurrences of hazards, risk can be minimized.

Many of the fuel stations in Owerri-west are constructed without proper development plan, and no cathodic protection to stop corrosion and leakages over an extended period. Often petrol stations cause traffic congestion, air pollution, fire and encroachment on right-of-way of road users, as a result of non-adherence to planning laws. The extent of these problems depends on the criteria or variations such as location and size and set back from the road etc. The underground storage tanks (USTs) 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 (EBRD, 2009). 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 the near surface aquifer being the only source of domestic and drinking water in the area. This fear is not only existing, but a major concern to the communities, institutions, researchers and governments.

## II. Literature Review

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. 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 and *Singh,* 2011). Szabo and Loccisano (2012) described environmental exposure as concentration of a chemical predicted to have adverse effects on 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. Thus, ERA deals with the interaction of agents or hazards, human and ecological resources. Merill et al. (1997) stated that ERA provides a technical basis for evaluating current environmental conditions and forecasting future conditions under selected scenarios. ERA therefore is a welcomed addition to the tools that an environmental planner and a manager can use to facilitate decision making by various stakeholders. This implies that ERA is a process that incorporates technical information and societal options.

According to Phelpstead (2010) there are five steps to environmental risk assessment. The first step in risk assessment process is to identify all the significant hazards. 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. According to him, hazard identification might be done by task analysis, reference to guidance or by inspection of a workplace. When identifying the people at risk, not only those carrying out particular activities, but also those who may be affected by those activities he added. 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, he stated that 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 Phelpstead (2010).

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. Environmental Risk analysis which is the subject of this study is a field of study that attempts to understand events and activities that bring risk to human health or the environment (Sacile, 2007). Increasing the intensity and effectiveness of monitoring is a key process to reduce the risks posed to the environment. According to E. F. O. A., (1999), a more intense and effective approach to oversight aims to deliver pre-emptive, rather than reactive outcome-based supervision. An anticipatory and strategic approach to supervision rests, among other things, on the ability to engage in high- level skeptical conversations on risk appetite framework, and whether an organization's risk culture supports adherence to the approved appetite.

This is in conformity with Joseph, (2005) that safety of people and protection of the environment should at all times be the major concern at fuel stations because they are potentials for accident especially where the general public has unlimited access. 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 Moschini et al. (2005) are uniquely intertwined in the development of death and destruction from disaster. In their conclusion, Moschini et al (2005) reassert that, disaster mitigation is best realized from the potential that people need to unite, to persevere and to understand what affects 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.

In the early works of Beck et al. (1984), it was proven that one of the major contamination sources of the soil, air, ground and surface water related to liquid fuel tank leaking, processed chemical products, toxic chemical products and diluted rejects. As of 1985, fuel 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 tanks, as well as to the creation of a specific agency (Office of Underground Storage Tanks) to monitor these aspects according to the reports of CDEP (2005) and USEPA (2010). Arokoyu et al. (2015) stated that one of the best known classes of groundwater contaminants includes petroleum-based fuels such as diesel. Reports from USEPA (2010) and EBRD, 2009, stated that 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 fuel stations, if released into the environment pollute the soil and water supplies, such that petrol escapes from an underground storage tanks (USTs) or pipelines can travel to great depths and distances (Nicole and Desmon, 2014). Sullivan, (2008) added that the rate of transport will depend on the characteristics of the subsurface lithology and 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.

UST system refers to a storage tank or tanks that have at least 10% of their total combined volume below ground. UST systems that are not regulated by Federal Government usually fall under state/or local jurisdiction. Since each type of UST can be subject to different policies, all regulations regarding 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 after Margane et al. (2012) include:

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

Petrol when released into the environment has several health effects such as its contamination of soil, surface water and groundwater (DEFRA, 2000). 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 according to Abdulrazak and Kobeissi. (2010) and DPR, (2010). Geologic condition such as type and texture of rock and underground karstic nature leads to a high vulnerability of the water resources to pollution as contained in the work of Abdulrazak and Kobeissi. (2010). This implies that groundwater source to a population living in an area where groundwater is near surface such as Owerri-west is at risk of pollution. Ornitz and Champ (2002) stated that 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 in different parts of Nigeria.

As detailed by Tinker and Razor (2008), the quality of groundwater is affected by human activities that include leakage of gasoline from fuel station's underground tanks in addition to the uncontrolled dumping of waste oil and petroleum by-products that also contribute to ground water pollution.

Kang et al. (2012), 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. Greenberg et al. (2007), 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. Beudert et al. (1996), 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. Blamah et al. (2012), 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.

Study conducted by EBEI, (2012), revealed, that the establishment and location of petrol service stations in various parts of Abuja, Nigeria is going on without due regard to planning criteria, safety and without compliance to planning regulation and standards. They maintained that life expectancy of oil tanks is helpful in planning for storage tank replacement. While we've found them lasting longer Stewart, R. (2008), states that a common life expectancy of buried oil tanks is 10-15 years whereas 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 corrosion and leak occurrence. Soil corrosively is a significant factor in petrol station USTs. Soil with pH $\leq$ 5.5 will be highly corrosive to USTs.

Mshelia, (2015) observed a corresponding decrease in the corrosive potential of the soil, and informed that soils are considered "mildly corrosive" if the sulfate and chloride levels are below 200 PPM and 100 PPM, respectively, and soils with pH levels of between 5 and 10, and resistivity greater than 3000 ohm-cm. According to him, an increased moisture content decreases resistivity of soils, in turn increasing their corrosive potential. Mshelia (2015) obtained that when the saturation point of the soil is reached, additional moisture has little or no effect on resistivity. 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.

Afolabi et al. (2011), revealed that the guidelines for sitting petrol stations have not been adhered by most of the petrol stations 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. According to Arokoyu et al. (2015), urban growth has increased use of automobiles, need for fuelling services and consequently, proliferation of filling stations most of which lack the minimum requirements for operation. Revie and Herbert (2008) at 95% confidence level revealed that most petrol filling stations in Nigeria neither conform to the required distance of 400m apart nor conform to the required distance of 15 m from the road.

Absence of cathodic protection of USTs in the study area is significant to the high risk of corrosion and leakage to groundwater contamination being contemplated. Petrol station USTs and metal piping can be cathodically protected in two or three ways (Idowu, 2013). The most common is with magnesium anodes. Another is with impressed current using public power supply. The goal is to extend the life of an underground tank by preventing corrosion and rust. He stated that galvanic protection uses anodes made of high potential magnesium (AZ-63 orH-1), magnesium alloy, and zinc. Idowu (2013) maintained that Zinc anode is recommended is suitable in sandy coastal area like Owerri west, and in other parts of Niger delta where groundwater may be salty. He stated that when a tank is totally protected from corrosion, the entire tank becomes a cathode, and a complement to the faults and pitting of outer tanks, thereby protecting galvanized pipes efficiently.

According to Ekwe et al., 2002, 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, but bitumen coatings of USTs cannot eliminate corrosion. From their analysis, they have pores and flaws that can absorb moisture and stale over time, leaving spots or areas exposed to the soil. They emphasized that bitumen coating needs to be supported with cathodic protection followed by regular checks to verify that the tanks are protected.

This check they said, 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 (Ekwe et al., 2002).

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. In a BBC news of June 5, 2015 some 150 people have died in a fire at a petrol station in Ghana's capital, Accra (Figure 1a). 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". In the Bovas petrol station inferno at Oshogbo, Osun state Nigeria (Figure 1b), it was gathered that some children whose ages were 8 and 12 years sleeping in a mini market attached to the filling station lost their lives as the market 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, reported BBC.

***Figure 1*** *(a): Ghana Petrol Station Inferno (BBC News June 5, 2015);*

*1b: Bovas Filling Station Inferno (This Day News Paper 23 Sept. 2015).*

## III. Materials and Methods

Owerri-west which is located in the rain forest region of Nigeria has a tradition of one year drop after two years rise in rainfall following rainfall intensity analysis conducted by Nwachukwu et al (2018). The wet season runs from mid-March to mid-October, with a break in August, then the long dry Harmattan season.

On getting to the site, the location of all the fuel stations and their boundaries were obtained with the use of GPS. All GPS data were trans-positioned into satellite imagery using 15 m and 400 m buffers to generate digital maps of the current development of petrol stations in Owerri-Wet County (Figures 3a and 3b). These fuel stations include conglomerates which are owned or run by multinational oil producing companies (such as Mobil, Total, AGIP etc.) and Independent Petrol Marketers (IPM) run by private individuals. GPS was used to measure coordinates and elevations, 500 meters radial away from each station. The elevation data was used to obtain contour map of the area. Photographs were taken, and one on one interaction with the operators of each gas station for more information except the abandoned fuel stations. Vertical Electric Sounding (VES) by

Schlumberger configuration was run on each road at petrol station most clustered area. All necessary precautions required in geo-electric measurement were duly considered.

*VES Data Processing:* All field data has been subjected to full computer processing techniques, applying the Advanced Geophysics Incorporation (AGI) 1D inversion method.

Apparent Resistivity (ρa) =

AB/2 = Current Electrode sp
Electrode spread. Thus Appa

Where: K = geometric factor (m) =
R = field resistance = I/V (Ohms). I = current passing through electrodes, and V = voltage

Owerri west is a local government area located between latitude 5o 23' and 5o 34' N and longitude 6o 50' and 7o 35' E, in the rain forest belt of Nigeria. It is about 120 km north of the Atlantic coast of West Africa. 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 roads for this study are: Nekede to Ihiagwa (Road 1), Obinze to Umuguma-Control Junction (Road 2), and Control Junction to Orogwe- Onitcha Road (Road 3

## IV. Results

### *4.1. Preliminary Site Investigation*

It was gathered that during rainy season, there is high rate of risk in the study areas; due to flood and road failure. 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. Petrol stations not properly situated (Figure 2a) are more than the number properly situated (Figure 2b). Some of the stations are non functional to abandoned, while private structural developments often encroach into some existing stations.

*Figure 2a: Station not properly situated*

**Figure 2** (b): Station Properly Situated

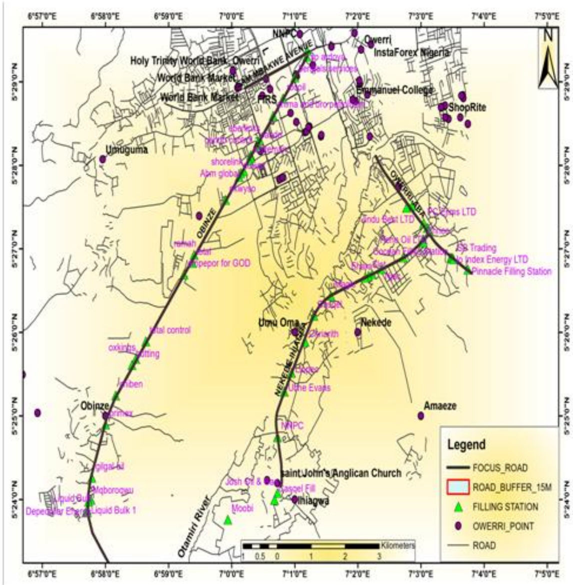


Figure 3a 15 m Buffer Map of the petrol stations

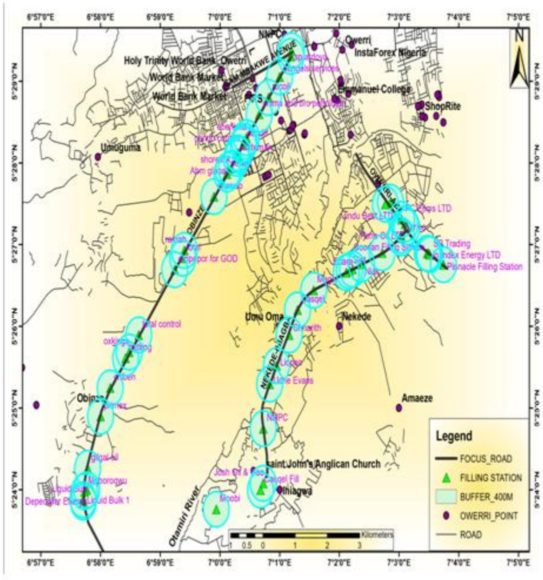


Figure 3b: 400 m Buffer map of the petrol stations

In each of the petrol stations were found a number of pressure release pipes corresponding to the number of USTs in the station. A pressure release pipe of about 6 cm diameter is usually mounted at the rear end of every UST to release pressured gas into the atmosphere, thereby controlling the gas tank pressure with the atmospheric and avoiding explosion. This is why naked light must be avoided in petrol station to avoid ignition of fuel gas coming from the pressure released pipes.

### *4.2. Geophysics Result*

Figure 4, inverted resistivity model of road 1, constrained to 6 geo-electric layers consisting predominantly of sand and gravel beds, show water table at depth of 23 m (Table 1). Figure 5, inverted resistivity model road 2, constrained to 6 geo-electric layers consisting predominantly of sand and gravel beds, indicating water table at depth of 24.5 m (Table 2). Figure 6, inverted Resistivity model road 3, constrained to 7 geo-electric layers consisting predominantly of sand and gravel beds, indicating water table at depth of 26.2 m (Table 3). Average depth to groundwater is 24.5 m and average depth of USTs is 3.6 m, leaving about 21 m interval as highly vulnerable.

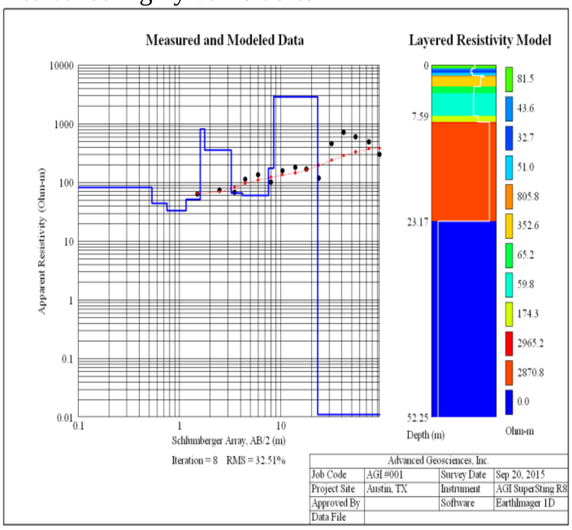


***Figure 4.*** *VES Road 1 (Nekede-Ihiagwa).*

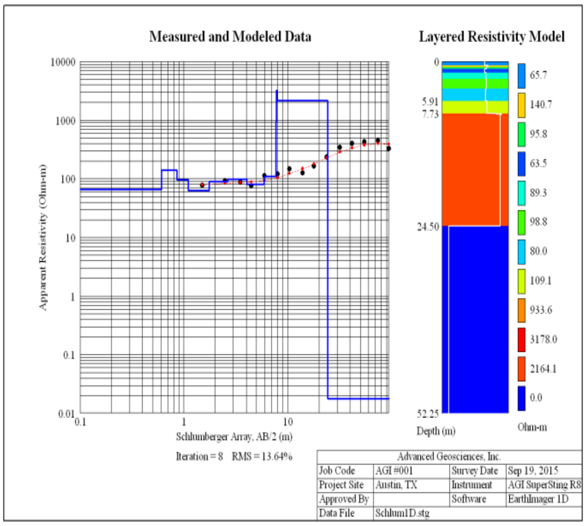


***Figure 5.*** *VES Road 2- PH Road (Obinze to Control)*

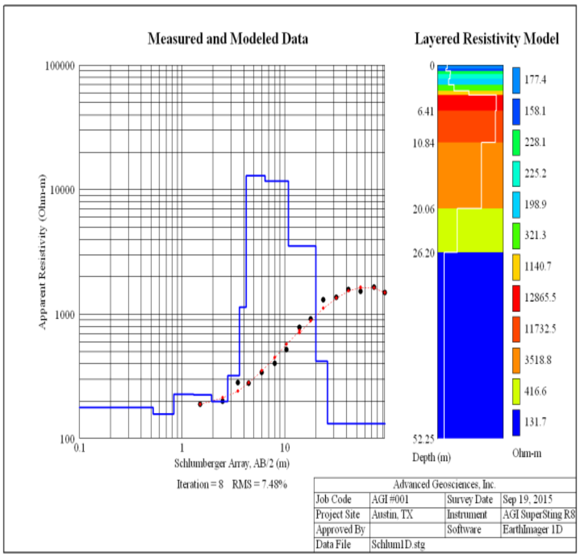


***Figure 6.*** *VES in Road 3- Control-Irete to Orogwe.*

| Layer# | Ohm-m | Depth (m) |
|---|---|---|
| 1 | 158.14 | 0.831 |
| 2 | 321.25 | 3.625 |
| 3 | 12865.5 | 6.414 |
| 4 | 11732.54 | 10.837 |
| 5 | 3518.78 | 20.062 |
| 6 | 416.63 | 26.200 |
| 7 | 131.68 | VES Road 1 |

***Table 2.*** *Inverted Resistivity Model Road 2*

***Table 3.*** *Inverted Resistivity Model Road 3*

| Layer# | Ohm-m | Depth (m) |
|---|---|---|
| 1 | 158.14 | 0.831 |
| 2 | 321.25 | 3.625 |
| 3 | 12865.5 | 6.414 |
| 4 | 11732.54 | 10.837 |
| 5 | 3518.78 | 20.062 |
| 6 | 416.63 | 26.200 |
| 7 | 131.68 | VES Road 3 |

| 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 | VES Road2 |

### *4.3. Result of Gas Station Mapping*

From the map, Road 1 has 4 petrol stations with USTs that are of age ≥ 15 years, representing the reference coordinate of road 1 (Figure 7). At road 2, Mgborogwu petrol station was the only one with USTs above 15 years old and was used as reference coordinate of Road 2 (Figure 8). Road 3 has a total of four petrol stations that are ≥ 15 years, with Okpokija as old as 22 years (Figure 9). The four stations presented the reference coordinate for Road 3.

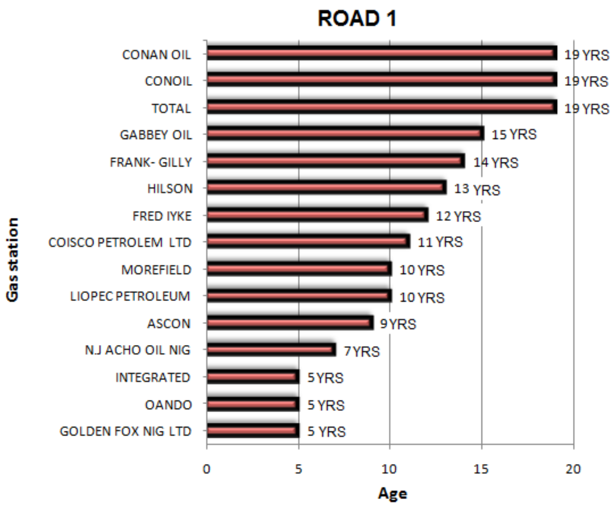


***Figure 7a.*** *Graph of Gas Stations against Age of USTs for Road 1*

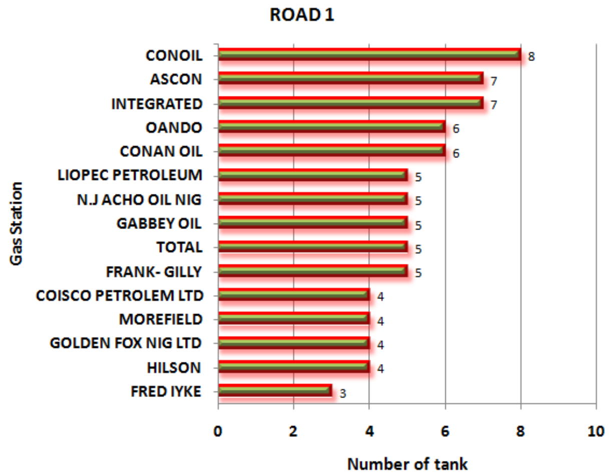


***Figure 7b.*** *Graph of Gas Stations against Number of USTs for Road 1*

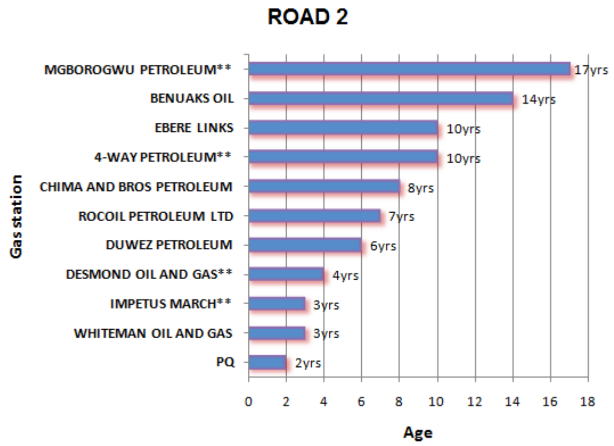


***Figure 8a.*** *Graph of Gas Stations against Age of USTs for Road 2*

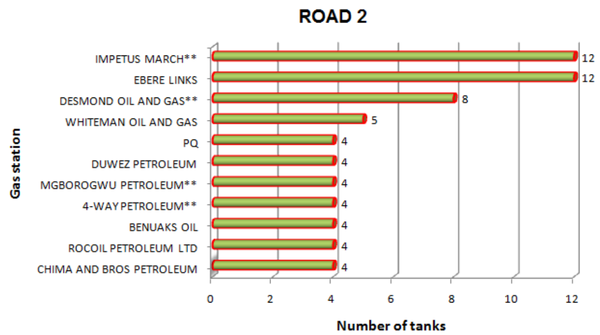


***Figure 8b.*** *Graph of Gas Stations against Number of USTs for Road 2*

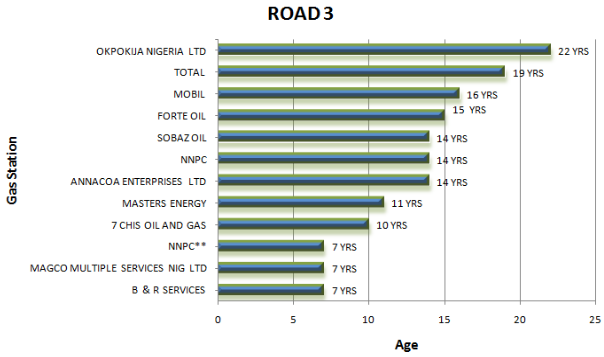


***Figure 9a.*** *Graph of Gas Stations against Age of USTs for Road 3*

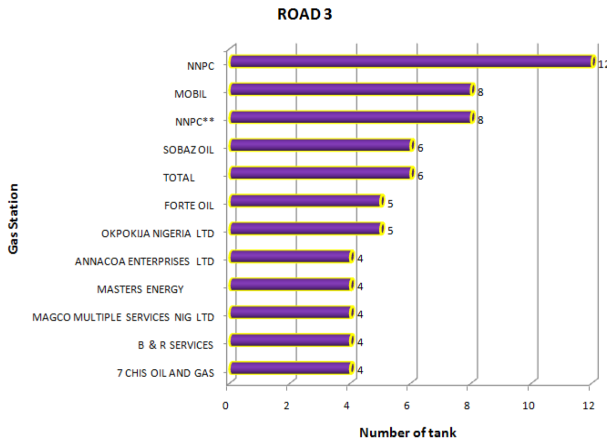


***Figure 9b.*** *Graph of Gas Stations against Number of USTs for Road 3*

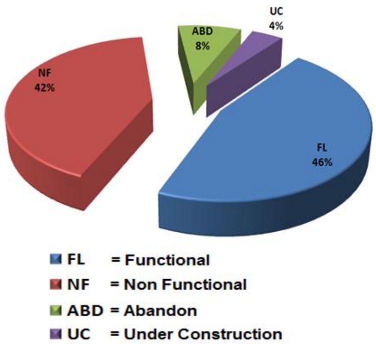


***Figure 10****a: Graph of gas stations against functionality*

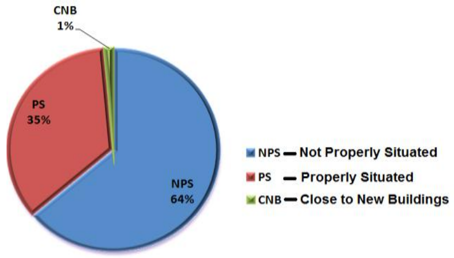


***Figure 10b****:  Situations of gas stations.*

Result of investigation show that the 8 km Aba-Nekede- Ihiagwa Road has 26 petrol stations; the 14 km Port-Harcourt Road has 24 petrol stations while the 6 km Onitsha Road segment 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 (Figure 10a). 64% of the petrol stations is not properly situated, only 35% is properly situated while 1% is encroached by new development of buildings (Figure 10b). The petrol stations have their age range between 2 to 22 years, while buried tanks is 3 to 12 years. 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 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.

### *4.4. Location of Monitoring Wells*

Three monitoring wells have been recommended, and their location selected based on number and age of USTs ≥ 15 years old in each road (Figure 11). 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 three 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 layout of groundwater monitoring wells applicable in Owerri-west is as shown in figures 11a and 11b.

***4.5. Result Analysis***

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. Figure 12 is a typical design of a monitoring well considered very adequate in Owerri west.

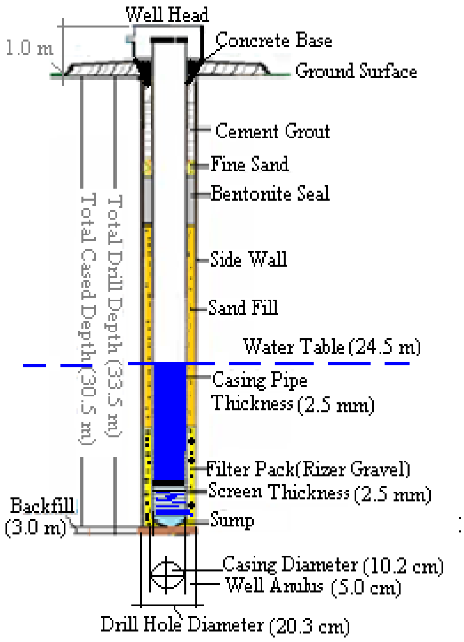


Figure 12; Design of a Monitoring Well considered
adequate in Owerri-West County

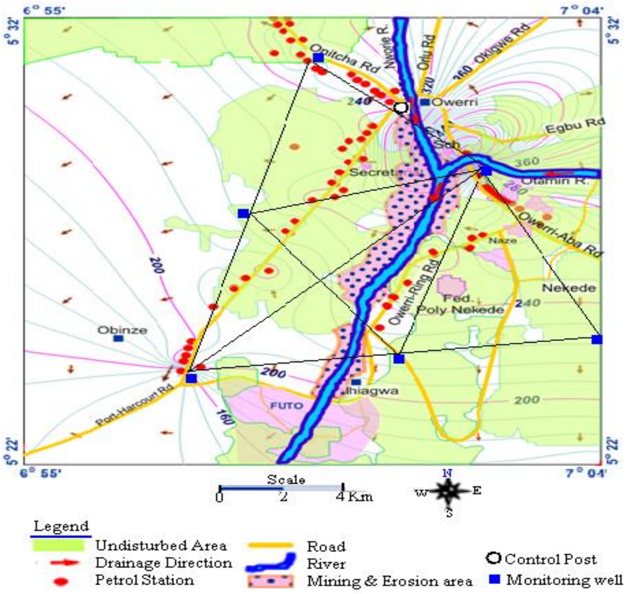


Figure 11a; Drainage analysis and location of Monitoring wells

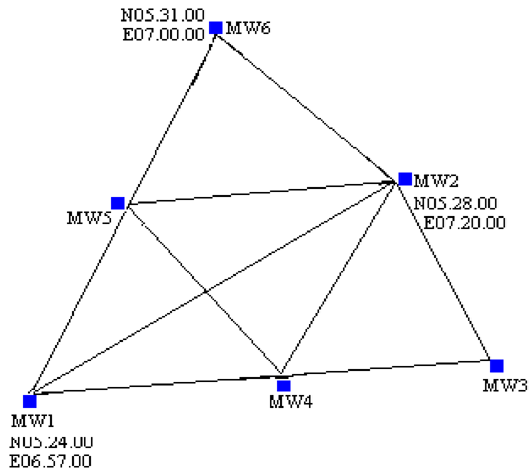


Figure 11b; Layout of the proposed 6 monitoring well

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. This is supported by geophysics result which shows lithology of the area as predominantly sandy with gravel beds, and the findings of Nwachukwu et al. (2010) that horizontal hydraulic conductivity and transmissivity are 12-26.4 m/day and 1370 $m^2$/day respectively.

### *4.6. Result Justification*

Field drainage analysis (Figure 11a) conforms to the direction of groundwater flow as presented by Ibe and Uzoukwu (2001), Ibe et al. (2007) based mainly on topographic analysis. Using numerical analysis by MODFLOW and MODPATH Codes, Nwachukwu,et al, (2010) also confirmed that groundwater and pollutants are flow in the direction predominantly southwest in Owerri-West area. While investigating depth of weathering and soil characteristics Nwachukwu (2003) 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 this area of the Imo River basin, including Owerri-west. Using 21 up-hole positions recorded during a seismic prospecting programme for petroleum exploration in the study area identified two seismic layers as follows: (a) A top intermediate silty sand (Highly weathered) (b) An intermediate sand layer (sub weathered layer) The highly weathered and sub-weathered layers have a total average depth of 21.76m against 24.5 m of water table, and an average velocity of 547.3m/sec. 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.

## V. Conclusion and Recommendations

The findings revealed that the guidelines for sitting petrol stations have not been adhered to by most of the petrol station proprietors, thereby posing serious hazards on residents in close proximity, though some of the stations were located much earlier than the residential houses close to them. The presence of 70 petrol stations and about 600 USTs with poor corrosion preventive measures against 28 km roads in Owerri west is not a sustainable development. This constitutes a major threat to groundwater in the area. Bitumen presently 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 or areas exposed to the soil. Six monitoring well locations have been identified in the SW direction based on groundwater flow direction, cluster and age of USTs.

It is expected of the State legislature therefore to enact law forbidding either government or individuals from converting plots of land to 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. The overall volume of storing tanks and the volume of a single tank at liquid fuel stations must not be larger than $500m^3$ and 100 $m^3$, respectively; the volume of a single tank at a container station must not exceed $30m^3$. Liquid fuel stations have to be equipped with the following items:

Cathodic protection and tools for monitoring protection efficiency, systems for measuring and monitoring the level of petroleum products being stored, and devices preventing emission of vapors 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 neighboring undeveloped plots. 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. Future research may seek funding to enable installation of the monitoring wells as identified.

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