# Effects of urbanization on groundwater quality: A case study of Port-Harcourt, Rivers State



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# EFFECTS OF URBANIZATION ON GROUNDWATER QUALITY: A CASE STUDY OF PORT-HARCOURT, SOUTHERN NIGERIA

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***Abstract***
*The impact of anthropogenic activities on groundwater quality along coastal aquifer in Port-Harcourt, due to growing rate of urbanization is of a great concern. Groundwater samples were collected from different parts of Port-Harcourt metropolis and analyzed for relevant physico-chemical and bacteriological parameters using standard field and laboratory techniques. The effect of urbanization on the groundwater quality is shown through the observed low pH (average 4.9), high nitrate, iron, manganese and copper in some locations in the area. The bacteriological investigation also indicates the high concentration of total coliform, which can be attributed to groundwater contamination via animal faeces. Water in the area is predominantly soft to moderately hard and is dominated by Calcium-Chloride water type indicating a marine source. The huge human activities in the area have degraded the groundwater resources and significant actions such as upgrading the sewage waste disposal system and strict sanitary system is recommended for the area.*

***Key words:*** Groundwater Quality, Urbanization, Port-Harcourt,

## Introduction

Groundwater is the main resource of drinking water in many parts of the world. Contamination resulting from industry, urbanization and agriculture poses a threat to the groundwater quality (Amadi, 2009). The task of balancing groundwater protection and economic activities is challenging. Therefore, understanding the effects of different water management strategies and the role of climate change is essential for the sustainable use of coastal groundwater resources (Prasad and Narayana, 2004).

According to Olobaniyi and Owoyemi (2006), the coastal regions of the world are the most densely populated areas in the world. More than one third of the world's populations are living within 100 km of the coastline (Hughes, et al., 1998). At the same time, the coastal regions provide about one third of the world's ecosystem services and natural capital (Aris, et al., 2007). Such growth is accompanied by increasing demand for water supply leading to the over-exploitation of the aquifer system and excessive drainage for land reclamation purposes. Contamination of the groundwater by natural means (seawater intrusion) and through anthropogenic means (human activities) cannot be ruled out in the area.

The study is aimed at evaluating the quality of groundwater from the coastal plain-sand aquifer Port-Harcourt area with the view of determining its suitability for domestic, irrigational and industrial purposes. The heavy industrial and human activities in the area lead to the present study. The aquifer system in the area is largely unconfined, highly porous and permeable and the possibility of anthropogenic interference cannot be completely ignored, hence the need for this study.

## Description of the Study Area

Port-Harcourt, the 'garden-city and treasure base of the nation' is situated about 60 km from the open sea lies between longitude 6°55'E to 7°10'E of the Greenwich meridian and latitude 4°38'N to 4°54'N (Fig. 1) of the Equator, covering a total distance of about 804 km$^2$ (Akpokodje 2001). In terms of drainage, the area is situated on the top of Bonny River and is entirely lowland with an average elevation of about 15 m above sea level (Nwankwoala, 2005). The topography is under the influence of tides which results in flooding especially during rainy season (Nwankwoala and Mmom, 2007). Climatically, the city is situated within the sub-equatorial region with the tropical monsoon climate characterized by high temperatures, low pressure and high relative humidity all the year round. The mean annual temperature, rainfall and relative humidity are 30°C, 2,300 mm and 90% respectively (Ashton-Jones, 1998). The soil in the area is mainly silty-clay with interaction of sand and gravel while the vegetation is a combination of mangrove swamp forest and rainforest (Teme, 2002).

## General Geology of the Area

Port-Harcourt falls within the Niger Delta Basin of Southern Nigeria which is defined geologically by three sub-surface sedimentary facies: Akata, Agbada and Benin formations (Whiteman, 1982). The Benin Formation (Oligocene to Recent) is the aquiferous formation in the study area with an average thickness of about 2100 m at the centre of the basin and consists of coarse to medium grained sandstone, gravels and clay with an average thickness of about 2100 m at the centre of the basin and consists of coarse to medium grained sandstone, gravels and clay (Etu-Efeotor and Akpokodje, 1990). The Agbada Formation consists of alternating deltaic (fluvial, coastal, fluviomarine) and shale, while Akata Formation is the basal sedimentary unit of the entire Niger Delta, consisting of low density, high pressure shallow marine to deep water shale (Schield, 1978).

## Methodology

Groundwater samples (Fig. 1) were collected from 40 boreholes between June and September 2008. Groundwater samples were collected in pairs in polyethylene bottles. Temperature, electrical conductivity (EC), pH and turbidity were measured in the field using standard portable meters equipped with sensors and electrodes as recommended by American Public Health Association (APHA, 1995). All meters were calibrated and tested daily before the measurements. Two drops of $HNO_3^-$ were added to the polyethylene bottles for the determination of cations and trace elements while the remaining pair in which no acid was added was used for anion determination. All the samples were immediately stored at 4°C until the laboratory analyses. The cations were determined by the atomic absorption spectroscopy (AAS) while the anions analyses were carried out on a Dionex DX-120 ion chromatograph. The trace elements were determined using an ICP-MS (Perkin-Elmer ELAN 6100). The accuracy of the analyses was performed using the ionic balance error (Schroll, 1976) and it was below 5% for all samples indicating very high precision (APHA, 1995).

During the sampling exercise, the co-ordinate of the sampled boreholes were taken with the aid of global positioning system. The data obtained were used to generate the digital terrain model (DTM) and the contour map of the area as contained in figures 2 and 3 respectively.

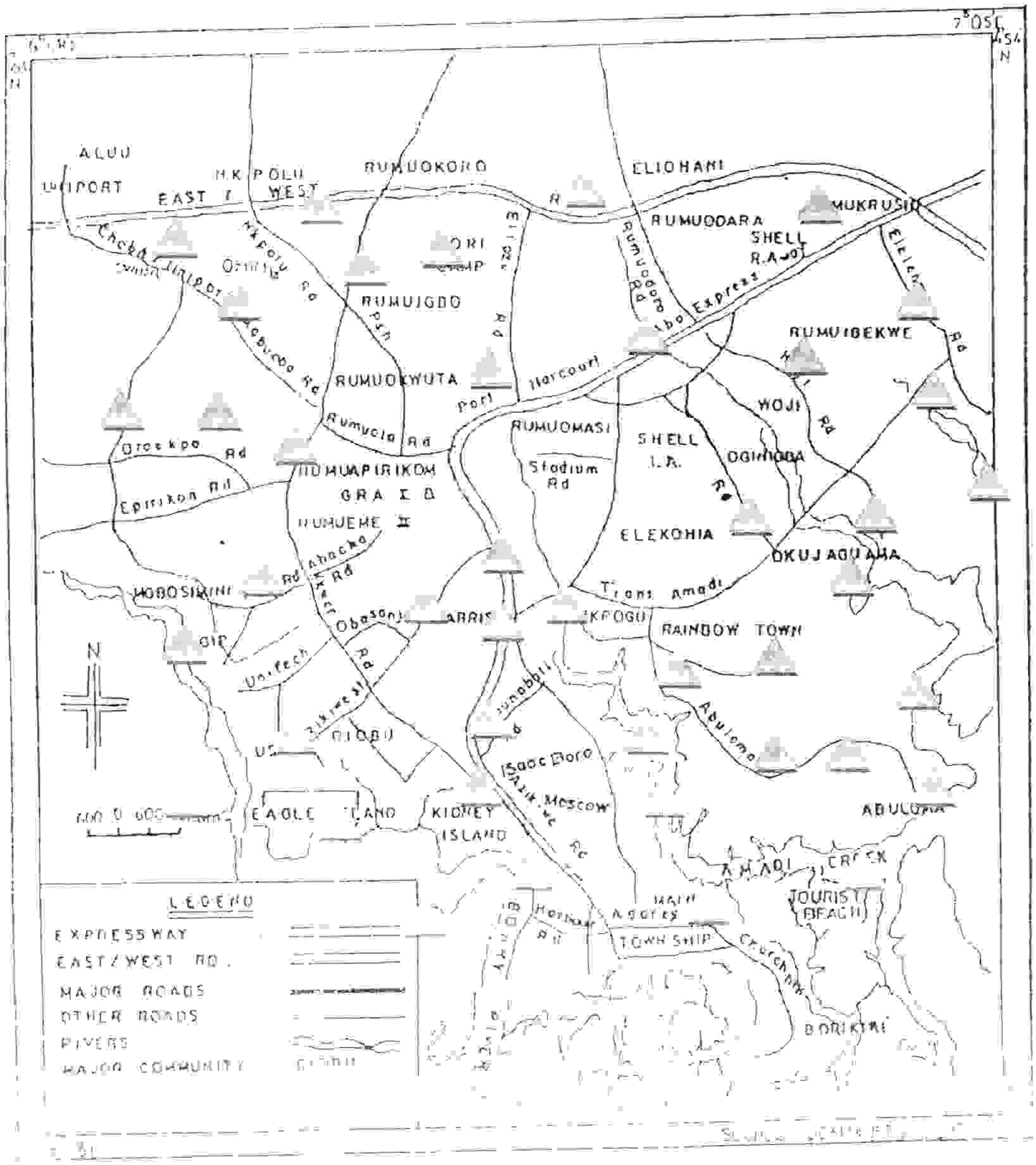


Fig 1: Map of Port-Harcourt township showing the sampling locations (After Akpoghomeh, 2001)

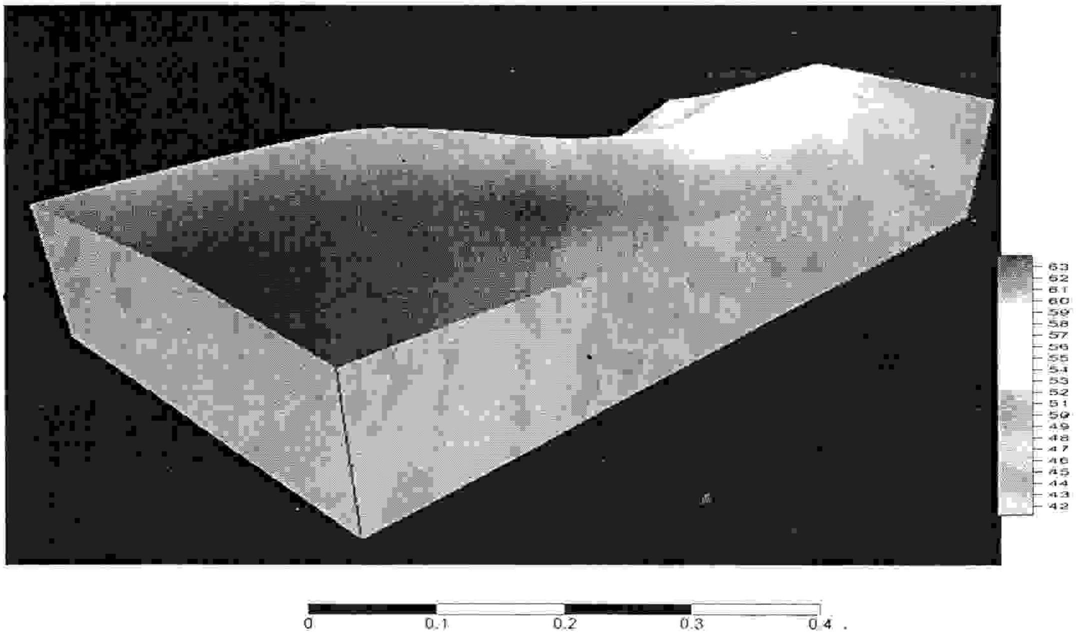


Fig. 2: Digital Terrain Model (DTM) of the area


Fig. 3: Contour map of the area showing the major towns

## Results and Discussion

The statistical summary of the physio-chemical and bacteriological analyses are contained in Table 1

## Physical Parameters

Temperature alters the saturation value of solid and gasses in water. From the analyzed samples the ambient temperature was recorded at 29°C. Water for drinking purposes has a better fresh taste at lower temperature of about 15°C but higher temperature do not imply impurities (Olasehinde, 1999). The pH of the water varied from a minimum of 4.02 to a maximum of 6.92. The pH is slightly low when compared with the recommended range of 6.5 to 8.5 by World Health Organization (WHO, 2006) and Nigerian Standard for Drinking Water Quality (NSDWQ, 2007). The water is said to be slightly acidic and this could be attributed gas flaring and breakdown of vegetation and subsequent infiltration of acid-rain into shallow water-table. The conductivity values ranges from 106$\mu$s/cm to 142$\mu$s/cm with an average conductivity value of 128$\mu$s/cm. The concentration of biochemical oxygen demand (BOD) and chemical oxygen demand (COD) are within the water quality index for a good drinking water as recommended by WHO (2006) and NSDWQ (2007).

### Chemical Parameters

#### Anions

The concentration of the major anions ($Cl^-$, $SO_4^{2-}$, $HCO_3^-$) analyzed have very low concentrations (Table 1) compared with the WHO and NSDWQ standards $NO_3^-$, whose concentration in some location is above the maximum permissible limits of 45 mg/l by WHO (2006) and NSDWQ (2007). Nitrate contamination of ground water depends upon climate, fertilizer or manure management, rock-type and animal wastes. A climate with rainfall exceeding evapo-transpiration often leads to the movement of rainwater to groundwater. In Port-Harcourt, water received though precipitation is more than that lost through evapo-transpiration from soils and plants.

**Table 1: Summary of the Physio-chemical Parameters Analyzed.**

| Parameters | Minimum | Maximum | Mean |
|---|---|---|---|
| pH | 4.02 | 6.92 | 5.10 |
| Temp. (°C) | 27.0 | 30.0 | 29.0 |
| Cond. ($\mu$s/cm) | 106.0 | 142.0 | 128.0 |
| $Na^+$ (mg/l) | 0.40 | 13.73 | 7.22 |
| $K^+$ (mg/l) | 21.17 | 62.22 | 44.31 |
| $Cu^{2+}$ (mg/l) | 2.36 | 3.67 | 2.97 |
| Pb (mg/l) | <0.01 | <0.01 | <0.01 |
| $Ca^{2+}$ (mg/l) | 66.13 | 98.11 | 79.86 |
| $Mg^{2+}$ (mg/l) | 0.32 | 8.72 | 5.8 |
| $Fe^{2+}$ (mg/l) | 0.04 | 0.86 | 0.43 |
| Mn (mg/l) | 0.03 | 2.7 | 0.73 |
| Zn (mg/l) | 0.01 | 0.64 | 0.17 |
| As (mg/l) | <0.01 | <0.01 | <0.01 |
| $Cl^-$ (mg/l) | 1.09 | 3.60 | 1.93 |
| $HCO_3^-$ (mg/l) | 0.0 | 0.0 | 0.0 |
| $SO_4^{2-}$ (mg/l) | 0.96 | 1.78 | 1.31 |
| $NO_3^-$ (mg/l) | 24.8 | 132.6 | 52.4 |
| COD (mg/l) | 11.55 | 12.98 | 12.11 |
| BOD (mg/l) | 9.00 | 10.23 | 9.71 |
| Total Coliform (cfu/100ml) | 5.0 | 65.0 | 38.0 |
| E. Coli (cfu/ml) | 0.0 | 12.0 | 4.0 |

BOD- Biochemical Oxygen Demand, COD Carbon Oxygen Demand

Nitrates are highly soluble salts and when water moves on the surface of a soil, it dissolves some nitrates that are present in the surface layers of soils and seeps into the soil and recharges the groundwater. Also animal wastes, which are rich in nitrates, can find their way into the groundwater via infiltration. High concentration of nitrate in water causes blue baby syndrome in infants.

#### Cations

The cations ($Na^+$, $K^+$, $Ca^{2+}$ and $Mg^{2+}$) have their concentrations (Table 1) within permissible limits of WHO (2006) and NSDWQ (2007) standards.

#### Trace Elements

The concentrations of Pb, Fe, As and Zn are falls within the WHO and NSDWQ maximum allowable limits (Table 1) while Mn and Cu in some locations have values higher the maximum permissible limit of 0.2 mg/L and 1.0 mg/L respectively by WHO (2006) and NSDWQ (2007) standards for a safe drinking water. High concentration of Mn and Cu in the body causes neurological and gastrointestinal disorders respectively. The concentrations of the anions/cations and trace elements are illustrated using bar charts in Figures 4 and 5 respectively while the relationship between the concentration of BOD and COD was shown in figure 6 via a pie chart.

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**Bacteriological Analysis**

The concentration of total coliform ranges from 5.0 cfu/100ml to 48.0 cfu/100ml and a mean value of 38.0 cfu/100ml as against 10.0 cfu/10ml maximum permissible limit by WHO (2006) and NSDWQ (2007). The concentration of E.coli. varies from 0.0 cfu/ml to 12 cfu/ml with an average value of 4.0 cfu/ml as against the WHO (2006) and NSDWQ (2007) maximum allowable value of cfu/ml for a safe drinking water. Faecal indicator bacteria are universally present in high numbers in the faeces of humans and warm-blooded animals and causes urinary tract infection like meningitis, diarrhea, cholera, typhoid as well as morbidity and mortality among children (Amadi, 2009). It also causes acute renal failure, hemolytic anemia in adults and other water borne diseases (Okuofu, et al., 1990).

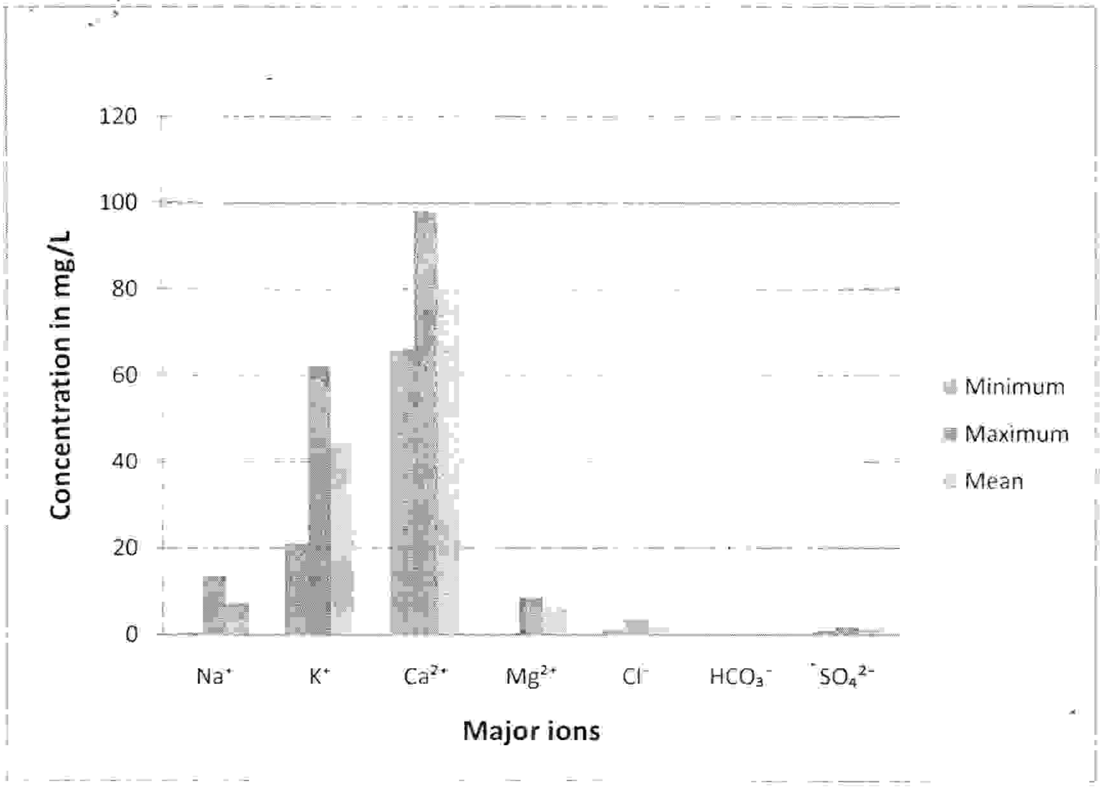


Fig.4: Concentration of Major Cations and Anions in the groundwater in the area

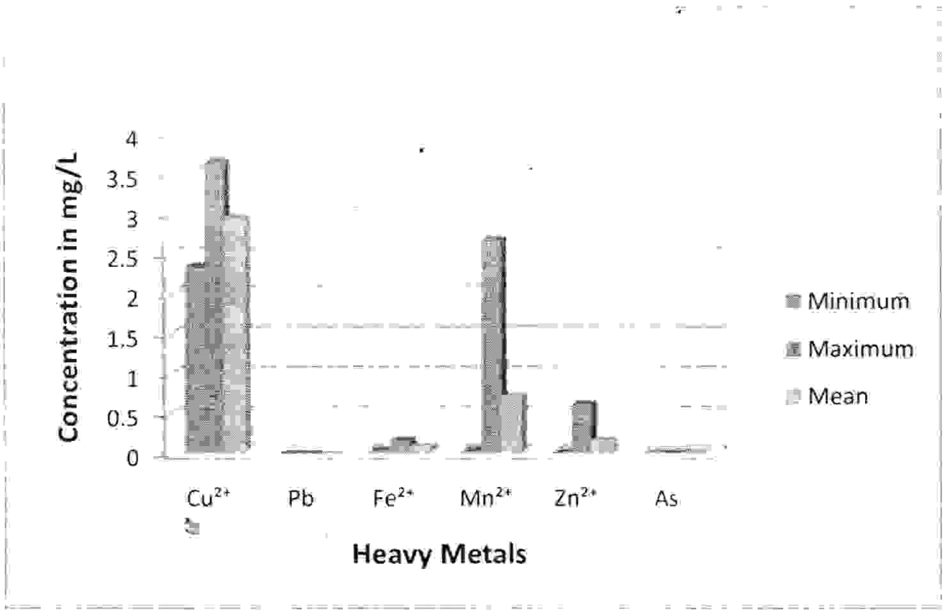


Fig.5: Concentration of Trace Elements in the groundwater in the Area

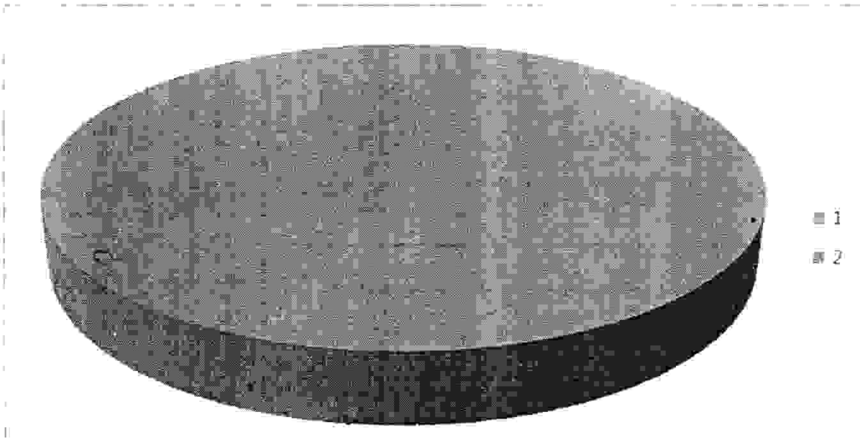


Fig.6: Mean Concentration of BOD and COD in the groundwater in the Area.

**Tri-linear Triangle**

Piper (1944) outline certain fundamental principles in a graphic procedure which appears to be an effective tool in separating analytical data for critical study with respect to sources of the dissolved constituents in water. The cations are grouped into three major divisions: sodium ($Na^{+}$) plus potassium ($K^{+}$), calcium ($Ca^{2+}$) and magnesium ($Mg^{2+}$). The anions are similarly grouped into three categories: bicarbonate ($HCO_3^-$) plus carbonate ($CO_3^-$), sulphate ($SO_4^{2-}$) and chloride ($Cl^-$). Each sample will be represented by a point in each trilinear diagram (Fig. 7). The diamond field is designed to show both anion and cation groups. For each sample, a line is projected from its point in the cation and anion trilinear diagrams into the upper region where the lines intersect (Fig. 7). The water in the area is calcium-chloride type, which may be attributed to a marine source.

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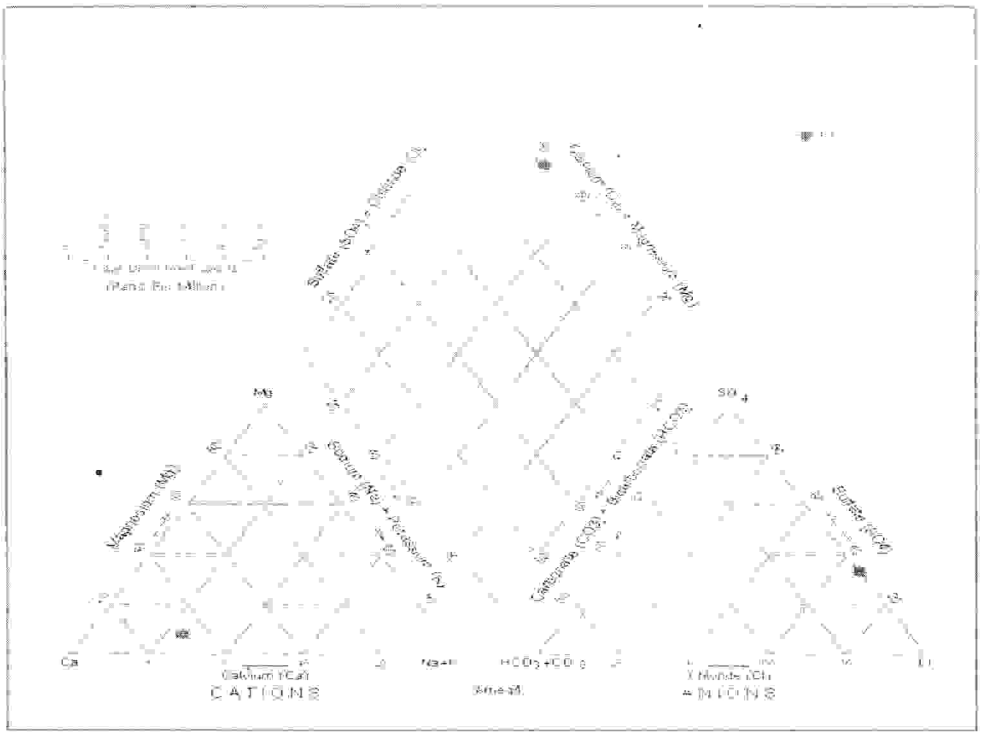

Fig.7: Piper diagram of groundwater samples in the Area

## Conclusion

Groundwater samples from Port-Harcourt area were analyzed for different physico-chemical parameters. Majority of the results falls within the permissible limits of WHO except pH with low values signifying slightly acidic condition which can be linked to gas flaring forming acid-rain and subsequent infiltration into the shallow aquifer in the area. The high Fe, Mn and Cu concentration in some locations within the vicinity of dumpsites can be attributed to the infiltration of leachate from nearby dumpsite into the aquifer system. Also, the high $NO_3^-$ concentration may be attributed to fertilizer application during farming as well as human and animal waste. The upsurge in human population in the area coupled with poor sanitary system accounted for the presence of total coliform in the groundwater, which signifies faecal contamination. The water in the area is Calcium-Chloride type, indicating possible marine origin.

## Recommendation

The Federal Government should enforce without any further delay, zero gas flaring policy in the country and offenders prosecuted. This will reduce the problem of acid-rain in the area. The use of existing dumpsites within the metropolis should be discontinued. The aquifer system in the area is characterized by high porosity, high permeability and shallow water-table. It is therefore necessary that future dumpsites in the area irrespective of location should be designed in such a manner as to incorporate multiple barrier system, consisting of impervious material which will impedes the migration of plumes/leachate into the groundwater system (Fig.8a and 8b). This will ensure a good protection for the groundwater system in the area.

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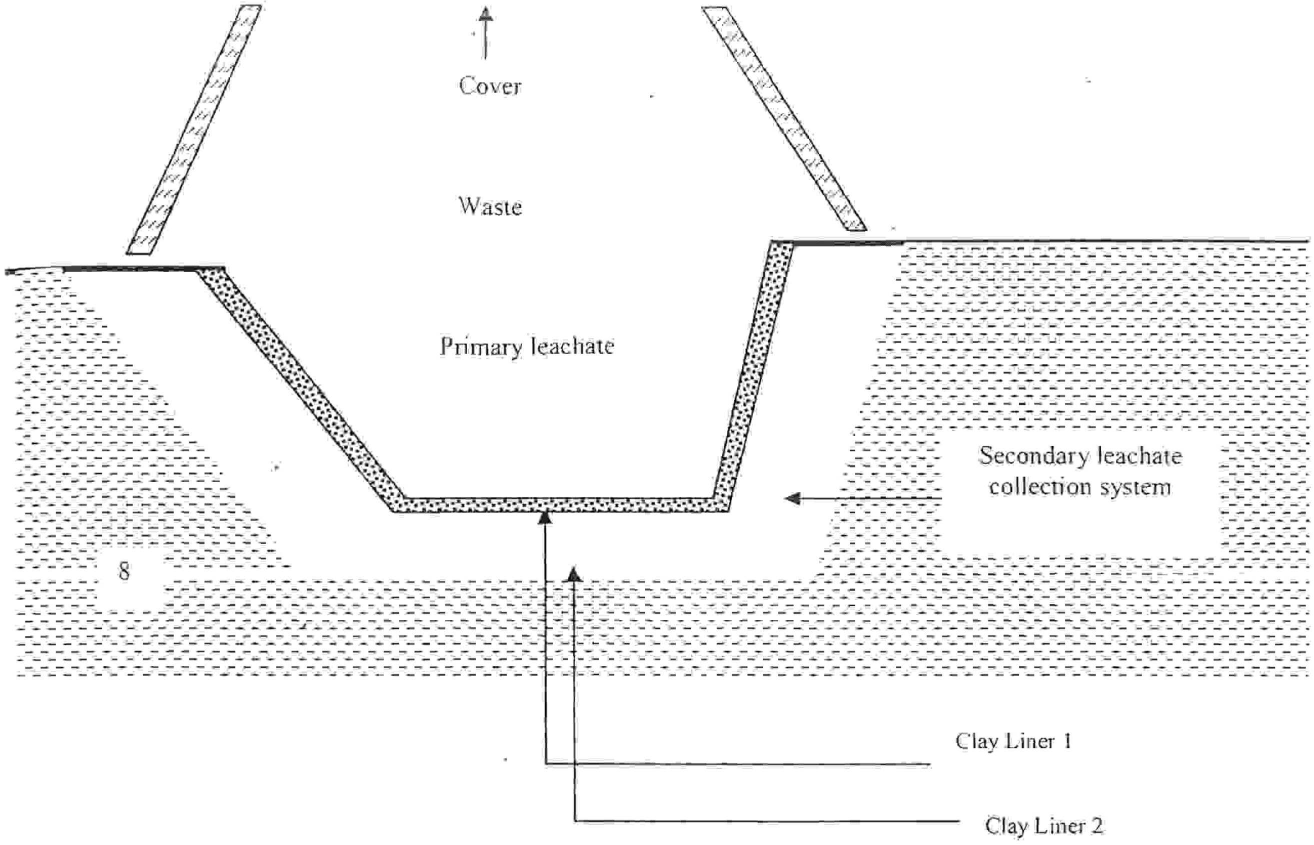


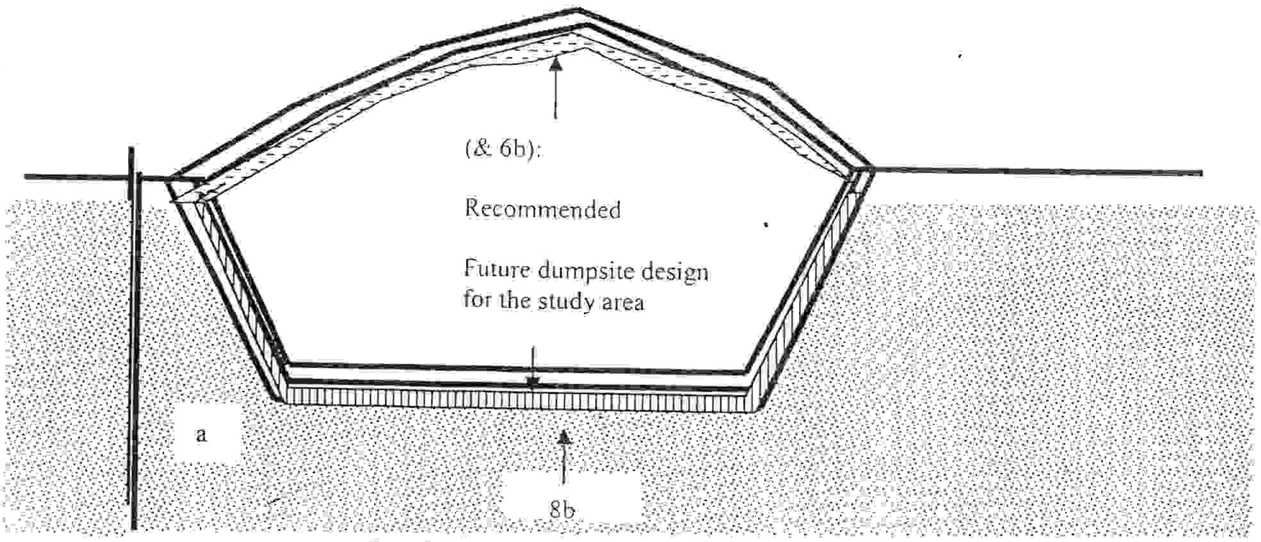

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