Impact of Domestic and Industrial Waste on Surface and Ground Water Quality Within Slaughter Area, Trans-Amadi Industrial Layout, Port Harcourt, Nigeria

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Abstract

This study aims at evaluating and assessing the impact of domestic and industrial wastes on surface and groundwater quality within the Slaughter area, Trans Amadi industrial layout, Port Harcourt, Nigeria. Standard sampling techniques where adopted. Twenty (20) water samples comprising of ten (10) boreholes and ten (10) surface water samples collected from the study area. Results revealed slightly acidic water for both the surface and borehole water in the area. These parameters were compared with the World Health Organization (WHO) guidelines for drinking water quality. The results from the analyses of the borehole samples yielded parameters that met the requirements by WHO, with exception of Iron (Fe) that had values at some locations above the maximum 0.3 mg/l. This was considered to probably be as a result of corrosion from pipes used in water distribution or dissolution arising from high fabrication activities with in and around the study area. None of the surface water samples met the WHO requirements for drinking water quality. The hydrochemical facies of the water samples were identified by plotting the results of the major cations and anions in milliequivalent per litre in the Piper Trilinear diagram. All the analysed water samples of both the borehole and surface water samples plotted within the Na+ - K+ - Cl- - SO4^2- hydrochemical facies, indicating origin from halite dissolution (Saline). The surface water samples were tested against their suitability for irrigation purposes by plotting electrical conductivity which is a measure of the salinity hazard in the use of water for irrigation against Sodium adsorption ratio (SAR) expressed in milliequivalent per litre, in water classification diagram for irrigation. The result yielded high salinity water (C3) - Medium sodium water (S2) and Very high salinity water (C4) - High sodium water (S3) suggesting that adequate care is required in the use of the surface water for the purposes of irrigation. It is therefore recommended that regular water quality monitoring in the area be carried out for proper environmental protection and sustainability.

Keywords: Waste; Surface water; Groundwater; Water quality; Hydrochemistry

Introduction

In most of the developing countries, municipal solid waste (MSW) disposal has been a chronic problem, particularly in areas with high population density and high production of refuse. Scarcity of land for adequate for landfills often gives rise to indiscriminate dumping of refuse in surface water bodies and improper landfill systems. Landfills or open dumps have been demonstrated by several workers to pose serious threat to groundwater and surface water resources [1,2], especially those constructed and operated without impermeable layers meant to reduce the potential of contamination. The degree of threat is strongly influenced by the composition of the wastes in the landfill, the volume of leachates generated, as well as the Location of the landfill from water bodies such as groundwater and surface water [2]. This in turn has led to pollution of surface and groundwater causing over 20% of the world population (around 1.3 billion people) not to access safe drinking water. Water can be polluted by substances that dissolve in it or by solid particles and insoluble liquid droplets that become suspended in it. The Slaughter area in Port Harcourt, Rivers State, Nigeria (Figure 1), is surrounded by water bodies and is the hub for major commercial and industrial activities. These water bodies have become regions for indiscriminate waste disposals for the commercial activities (Figure 2) as well as effluents from the industries within and around the Slaughter area (Figure 3). There is little or no awareness by the inhabitants in the Slaughter area of the danger that this indiscriminate dumping of refuse would pose to the groundwater resource. This study therefore, examines selected borehole water and some surface water locations for water quality parameters to determine their suitability for drinking and other purposes.

There are high concentrations of commercial/domestic and industrial activities within and around the study area. These gave rise to high generation of both industrial and commercial/domestic waste within the study area. In the light of the above, there is no documented impact assessment of these commercial/domestic and industrial waste in the study area thereby not allowing for proper environmental monitoring. This study is aimed at assessing the borehole and surface water quality parameters of the Slaughter Area of Port Harcourt for drinking and other purposes.

Location of Study Area

The study area lies within Longitudes 70°02'00" and 70°04'10" E; and between Latitudes 40°49'00" and 40°50'00" N of the Equator (Figure 3). Rain falls in the study area almost all the year round and generally very heavy. The average annual rainfall is about 3200 mm. The mean maximum monthly temperatures range from 28°C to 33°C, while the mean minimum monthly temperatures are within the range of 17°C to 24°C. The hottest months are February to May. The relative...
humidity is high throughout the year and decreases slightly during the dry season [3].

The vegetation of the study area comprises of an upland area dominated by rainforest with such economic trees as oil palm and the riverine area which is divided into three main hydro-vegetation zones; the beach ridge zone, the saltwater zone and the freshwater zone. The beach ridge zone consists of fresh water swamp trees, palms and shrubs on the sandy ridges and mangroves in the tidal flats. The saltwater zone consists of the tidal flat vegetated by red stilts rooted mangrove (Fihizophora racemose) and two other species of mangrove. The outliers of raised coastal plain terrace within the tidal flats are vegetated by tall forest tree species and oil palm. The freshwater zone consists of the Upper and Lower Delta flood plains.

Relief in the study area may be grouped into three; the fresh water, the mangrove swamp and the Coastal sand ridges zone. The fresh water zone consists of the flood plain under 20 m above the sea level. It consists of silt and clay and it is more susceptible to perennial inundation by river floods. The southern part is affected by great tidal influence. Most water channels in the fresh water zone are bordered by natural levees, which are of great topographical interest and of great economic importance to the local people for settlements and crop cultivation. The upland is undulating to the hinterland; narrow strip of sandy ridges and beach ridges lies very close to the open sea. The soils of the sandy ridges are mostly sandy loams.

Drainage in the study area is poor because of the low-lying flood plain with much of the surface covered with water. The study area is drained by two main sources; the fresh water system whose waters originate either outside or wholly from the coastal lowlands including the Bonny and Calabar river systems and a host of effluent creeks and streams, and a tidal system.

The study area lies on the Coastal Plain of the Niger Delta. The geology of the study area consists of Recent fluvial deposits transported and redistributed by the Niger River distributaries. The depositional sequences signify a massive continental sand deposit overlaying an alternation of sandstones and clays of marginal marine origin grading into marine clays. The study area consists mainly in the surface, sandy deposits belonging to the Benin Formation of the Niger Delta lithostratigraphic unit. The subsurface geology comprises of the following rock-stratigraphic subdivision; Benin Formation, Agbada Formation, and Akata Formation [4]. These Formations range in age from Eocene to Recent.

Methods of Study

Samples were collected from ten (10) boreholes and ten (10) surface water sampling points in plastic sampling bottles. Sterilized water bottles were used to collect representative water samples to prevent contamination. At each borehole location, the sample bottles were washed and rinsed thoroughly with the sample water before being sampled. The samples were collected close to the well head to maintain the water integrity. The boreholes were allowed to flow for about 3 minutes to ensure stable conditions before samples were collected. The sample was filled to the brim with the sample water, and the lid immediately replaced to minimize oxygen contamination and escape of dissolved gases. Sampling was done using two sets of prelabelled bottles of one litre capacity for ionic and heavy metals analysis respectively. Water samples for the determination of cations were stabilized by adding few drops of dilute HCl to them after collection. To maintain the integrity of the water samples, physico-chemical parameters sensitive to environmental changes such as pH, conductivity and temperature were measured and recorded in-situ using portable digital meters. The co-ordinates of all the sampling locations were recorded using a Garmin 78 model Geographic Positioning System (GPS). The samples were later transported to the laboratory in an ice chest for chemical analysis. Table 1 shows the analytical methods.

Heavy metals were determined using an Atomic Absorption Spectrophotometer (AAS) as described in APHA 3111B and ASTM D3651. This involved direct aspiration of the sample into an air/acetylene or nitrous oxide/acetylene flame generated by a hollow cathode lamp at a specific wavelength peculiar only to the metal under examination. The bottle was filled to the brim with the sample water, and the lid immediately replaced to minimize oxygen contamination and escape of dissolved gases. Sampling was done using two sets of prelabelled bottles of one litre capacity for ionic and heavy metals analysis respectively. Water samples for the determination of cations were stabilized by adding few drops of dilute HCl to them after collection. To maintain the integrity of the water samples, physico-chemical parameters sensitive to environmental changes such as pH, conductivity and temperature were measured and recorded in-situ using portable digital meters. The co-ordinates of all the sampling locations were recorded using a Garmin 78 model Geographic Positioning System (GPS). The samples were later transported to the laboratory in an ice chest for chemical analysis. Table 1 shows the analytical methods.
The milliequivalent per litre of the ions is the milliequivalent of the ion in one litre of a solution.

**Results and Discussion**
### Borehole water samples

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### Surface water samples

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Table 2a: Analytical results for the borehole water samples.

Table 2b: Analytical results for the surface water samples.
Iron in drinking water can produce an unpleasant taste and stain home water. Within humans and all other animals, iron plays a crucial role in the Earth's crust. It occurs in the range of 0.5 – 50 mg/L in natural fresh water. Iron (Fe) is one of the most abundant metals occurring within the high activities of metal fabrications within and around the studied area. Iron (Fe) seen in these boreholes could result from corrosion of steel and cast iron pipes used in water distribution from the boreholes. It could also result from dissolution and infiltration into the aquifers from abandoned mines can deliver toxic levels of iron into rivers and streams. It is not a plant major nutrient and can be toxic to some plant in higher concentrations. The values of iron generated from the samples analyzed ranged from 0 mg/l to 2.8 mg/l with a mean value of 0.1 mg/l in the borehole water samples and 28.446 mg/l to 55.54 mg/l with a mean value of 49.5 mg/l in the surface water; Magnesium ranges in concentrations from 0.35 mg/l to 0.86 mg/l with a mean value of 0.6 mg/l in the borehole samples and 29.10 mg/l to 121.87 mg/l with a mean value of 106.7 mg/l in the surface water samples. Sodium ranges in concentrations from 0.13 mg/l to 5.53 mg/l with a mean value of 0.8 mg/l in borehole water samples and 480.09 mg/l to 531.94 mg/l with a mean value of 503.7 mg/l in the surface water samples. Potassium ranges in concentrations from 2.7 mg/l to 3.6 mg/l with a mean value of 2.9 mg/l in borehole water samples and 94.62 mg/l to 125.01 mg/l with a mean value of 105.9 mg/l in surface water samples. Calcium, magnesium, sodium, and potassium are the dominant constituents present in water in significant concentrations. Calcium, magnesium and potassium are major plant nutrients. Sodium is not a plant major nutrient and can be toxic to some plant in higher concentrations.

Distributions of cations

Calcium ranges in concentrations from 0 mg/l to 0.3 mg/l with a mean value of 0.1 mg/l in the borehole water samples and 28.446 mg/l to 55.54 mg/l with a mean value of 49.5 mg/l in the surface water; Magnesium ranges in concentrations from 0.35 mg/l to 0.86 mg/l with a mean value of 0.6 mg/l in the borehole samples and 29.10 mg/l to 121.87 mg/l with a mean value of 106.7 mg/l in the surface water samples. Sodium ranges in concentrations from 0.13 mg/l to 5.53 mg/l with a mean value of 0.8 mg/l in borehole water samples and 480.09 mg/l to 531.94 mg/l with a mean value of 503.7 mg/l in the surface water samples. Potassium ranges in concentrations from 2.7 mg/l to 3.6 mg/l with a mean value of 2.9 mg/l in borehole water samples and 94.62 mg/l to 125.01 mg/l with a mean value of 105.9 mg/l in surface water samples. Calcium, magnesium, sodium, and potassium are the dominant constituents present in water in significant concentrations. Calcium, magnesium and potassium are major plant nutrients. Sodium is not a plant major nutrient and can be toxic to some plant in higher concentrations.

The values of iron generated from the samples analyzed ranged from 0 mg/l to 2.8 mg/l with a mean value of 0.1 mg/l in the borehole water samples and 0.795 mg/l to 11.375 mg/l with a mean value of 4.3 mg/l in the surface water samples (Tables 2a and 2b). 0.3 mg/l is set by WHO [8] for iron concentration in drinking water. The increase in concentrations of iron (Fe) seen in these boreholes could result from corrosion of steel and cast iron pipes used in water distribution from the boreholes. It could also result from dissolution and infiltration into the aquifers from the high activities of metal fabrications within and around the studied area. Iron (Fe) is one of the most abundant metals occurring within the Earth’s crust. It occurs in the range of 0.5 – 50 mg/L in natural fresh water. Within humans and all other animals, iron plays a crucial role of carrying oxygen within the blood in the form of hemoglobin. Excess iron in drinking water can produce an unpleasant taste and stain home fixtures. Iron is transported into the environment mostly through water and is naturally present in groundwater [9]. However, drainage from abandoned mines can deliver toxic levels of iron into rivers and streams.

The values of zinc generated from the samples analyzed ranged from 0 mg/l to 0.1 mg/l with a mean value of 0.03 mg/l in borehole water samples and 0 mg/l to 0.3 mg/l with a mean value of 0.1 mg/l in the surface water samples (Tables 2a and 2b). Zinc is a bluish – white shiny metal that is typically extracted from ore deep within the earth’s crust. Zinc is the 24th most abundant element in the earth’s crust. In soil, the average zinc concentration is 64 ppm. Zinc is often found in the water supply as a dissolved constituent since zinc compounds are highly soluble in water. One example is rainwater picking up zinc when it gets into contact with galvanized surfaces. Zinc occurs as particulate zinc and dissolved zinc as Zn2+. Zinc is an important dietary element, it gets into contact with galvanized surfaces. Zinc occurs as particulate and is naturally present in groundwater [9]. However, drainage from abandoned mines can impart an unpleasant taste to water. Exposure to large amounts of zinc can cause stomach cramps and anemia, and also can decrease good cholesterol. In marine waters, aquatic species suffer acute effects from zinc at 90 μg/l. Adverse effects of dissolved zinc, include altered behaviour, blood and serum chemistry.
impaired reproduction, and reduced growth occurs in salmon at very low levels (5.6 μg/l in freshwater). In mammals, ingesting large amounts of zinc can cause infertility and underweight of off-springs. Figure 5a is the plot of cations concentrations against borehole sample locations while Figure 5b is the plot of cations concentrations against surface water sample locations.

**Distributions of anions**

The important anions present in water in significant concentrations include Bicarbonates, Chloride, Sulphate, Carbonates and Nitrate. Bicarbonate concentrations in the samples analysed ranges from 3.6 mg/l to 11 mg/l with a mean value of 6.6 mg/l in the borehole water samples and 25.6 mg/l to 36 mg/l with a mean value of 28.1 mg/l in the surface water samples. Chloride concentrations in the samples analysed ranges from 7.2 mg/l to 25.6 mg/l with a mean value of 12.2 mg/l in the borehole sample and 1880 mg/l to 8640 mg/l with a mean value of 6769 mg/l in the surface water samples. Sulphate concentrations in the samples analysed is 0.69 mg/l for the borehole and ranges from 106.6 mg/l to 417 mg/l with a mean value of 301.5 mg/l in the surface water samples; while carbonate concentrations in the water samples analysed ranges from 3.6 mg/l to 11 mg/l with a mean value of 6.6 mg/l in the borehole water samples and from 24.5 mg/l to 36 mg/l with a mean value of 28.6 mg/l in the surface water samples. Sulphate and nitrates are major plant nutrients. High concentration of chloride is toxic to some plants, concentrations of carbonates and bicarbonates in the water give the total alkalinity and pH rating of the water. The concentrations of the anions are plotted in scatter diagrams (Figures 6a and 6b).

**Quality Evaluation for Agricultural Purposes**

The results generated from analysing the borehole and surface water samples are discussed on the bases of the suitability of the water quality for drinking and domestic uses, variations in the hydrochemical facies of the ground water samples and suitability of the surface water for irrigation purposes. The different water quality parameters measured were compared with WHO [8] guidelines for drinking water quality. The result shows that all the parameters analysed for in the borehole water samples met the required concentrations for the WHO [8] guidelines for drinking water quality with exemption to concentrations of Iron (Fe) in all the boreholes apart from boreholes BH6 and BH10. On the other hand, all the parameters analysed for in the surface water, all exceeded the required concentrations for the WHO [8] guidelines for drinking water quality with exemption to pH and concentrations of potassium (K) which were within the required concentration. Concentration of Bicarbonate (HCO3); high concentration of bicarbonate in water can cause precipitation of calcium and magnesium thereby increasing the Sodium concentration in the form of Residual Sodium Carbonate (RSC).

The United States of America, Agriculture Department classification of ground water for irrigation with respect to percent sodium (Table 3). The United States of America, Agriculture department classification of water for irrigation with respect to sodium hazard (Table 4). The United States of America, Agriculture Department (RSC) water classification for irrigation (Tables 5-8). Table 6 is the classification of water for irrigation with respect to sodium hazard. Figure 7 is the Sodium Hazard Classification of the surface water samples in the study area [5]. The water classification diagram for irrigation purposes consists of two major components viz: conductivity (C1 – C4) and Sodium (S1 – S4) components. C1 represents conductivity in low – salinity
Very high salinity water (C4) is not suitable for irrigation under ordinary conditions but may be used in soils with very high permeability and adequate drainage system. Irrigation water must be applied in excess to provide considerable leaching and must be applied only on very high tolerant crops, while High sodium water (S3) may produce harmful degree of exchangeable sodium in most soils and will require special soil management. In all cases, adequate care is required in the use of the surface water for the purposes of irrigation.

**Hydrochemical Facies**

The graphical representations of the groundwater with major cations and anions in the Piper trilinear diagram helps in the understanding of the hydrochemical evolution, groupings and probably areal distribution of the water types [10]. Generally, ground water is classified on the basis of the dominant cations and anions concentrations into four (i – iv) hydrochemical facies by expressing the concentrations of the cations and anions in milliequivalent per liter of the ground water.

These hydrochemical facies classifications of Piper [10] include the following:

1. **Ca\(^{2+}\) - Mg\(^{2+}\) - Cl\(^{-}\) - SO\(_{4}\)\(^{2-}\) facies**: This hydrochemical facies corresponds to the region of permanent hardness water type.
2. **Na\(^{+}\) - K\(^{+}\) - Cl\(^{-}\) - SO\(_{4}\)\(^{2-}\) facies**: This hydrochemical facies corresponds to the region of saline water type.
3. **Na\(^{+}\) - K\(^{+}\) - HCO\(_{3}\)\(^{-}\) facies**: This hydrochemical facies corresponds to the region of alkali carbonates water type.
4. **Ca\(^{2+}\) - Mg\(^{2+}\) - HCO\(_{3}\)\(^{-}\) facies**: This hydrochemical facies corresponds to the region of temporal hardness water type.

The milliequivalent values of the cations and anions are presented in Piper trilinear diagram (Figures 8a and 8b) for the borehole and surface water samples to evaluate the hydrochemical facies of the water; C2, conductivity in medium salinity water; C3, conductivity in high salinity water and C4, conductivity in very high salinity water while S1 represents low sodium water; S2, medium sodium water; S3, high sodium water and S4 very high sodium water. The surface water analysed plotted in C3 - S2 and C4 - S3 sections corresponding to high salinity and medium sodium water; and very high salinity and high sodium water. High salinity water (C3) can only be used for irrigation on selected plants with good salt tolerance, while Medium sodium water (S2) can only be used on coarse-textured or organic soils with good permeability [5].
analysed water samples.

The hydrochemical facies for the borehole and surface water samples analysed in the study area plotted in the (Na⁺ - K⁺ - Cl⁻ - SO₄²⁻) facies; hydrochemical facies (ii) which corresponds to the region of saline water type (Figures 8a and 8b). This suggest that the source of the the borehole and surface water samples are from halite dissolution (Saline) which supported the work of Nwankwoala and Udom [11,12].

Conclusion

The results from the analyses of the borehole samples yielded parameters that met the requirements provided by WHO [8] with exception of Iron (Fe) that ranged between (0 - 2.8) mg/l above the maximum 0.3 mg/l stipulated by WHO [8]. This was considered to probably be as a result of corrosion from pipes used in water distribution or dissolution and infiltration from high fabrication activities within and around the study area. The hydrochemical facies of the water samples were identified by plotting the normalized concentrations of the major cations and anions in millequivalent per litre on the Piper trilinear diagram. All the analysed water samples of both the borehole and surface water samples plotted within the (Na⁺ - K⁺ - Cl⁻ - SO₄²⁻) hydrochemical facie indicating origin from halite dissolution (Saline). The surface water samples were tested against their suitability for irrigation purposes by plotting electrical conductivity which is a measure of the salinity hazard in the use of water for irrigation against Sodium adsorption ratio expressed in millequivalent per litre in water classification diagram for irrigation. The result yielded High salinity water (C3) - Medium sodium water (S2) and Very high salinity water (C4) - High sodium water (S3) suggesting that adequate care is required in the use of the surface water for the purposes of irrigation.

The borehole samples meet the requirements stipulated by the World Health Organization [8] guideline for drinking water quality. The surface water samples did not meet the requirements stipulated by the World Health Organization [8] guideline for drinking water quality. The hydrochemical facies analyses of the borehole and surface water samples plotted within the (Na⁺ - K⁺ - Cl⁻ - SO₄²⁻) which indicates origine from halite dissolution (Saline). The water classification diagram of the surface water samples for irrigation purposes suggests that adequate care is required in the use of the surface water for the purposes of irrigation.

It is therefore recommended from the foregoing that proper landfill system should be provided and maintained for proper environmental sanitation in the study area. This will minimize and completely discourage indiscriminate dumping of refuse into the surface water which contributed to the high values of the analysed parameters in the studied surface water samples, and also reduce the tendency to which the pollutant will percolate into the ground water aquifer. The study area may be developed, using the surface water as a medium for other recreational activities and as channels for water transportation but not for drinking and domestic use.

References