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Evaluation of the Extent of Contamination of Groundwater Near a Dumpsite

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Abstract
This research examined the level of contamination of groundwater near a dumpsite at Rumuokania community in Obio/Akpor Local Government Area of Rivers state. The groundwater quality of five boreholes (B_1, B_2, B_3, B_4 and B_5) at different distances (22, 30, 55, 74 and 125 m respectively) away from the dumpsite was assessed. Some physico-chemical and bacteriological parameters of the water samples were analysed and they include Temperature, Taste, Colour, pH, Iron (Fe), Manganese (Mn), Phosphate (PO_4^{-3}), Electrical Conductivity (EC), Turbidity, Salinity, Total alkalinity, Faecal Coliform Bacteria (FCB), Total Coliform Bacteria (TCB) and Total Heterotrophic Bacteria (THB). Results of the analysis indicated that the two Bore-holes nearer to the dumpsite (B_1 and B_2) have high pH values of 5.30 and 5.56, high Turbidity values of 13 and 7 NTU, high Mn values of 0.404 and 0.321mg/l, high TCB values of 36 and 23 and high concentrations of Fe (18.13 and 14.26 mg/l), respectively. The analysis also indicated mild taste and odour forB_1 and B_2 and high Electrical Conductivity (EC) value of 654µs/cmfor $B_{1,}$ indicating possible source of pollution from the dumpsite. These values were above World Health Organization (WHO) and Nigerian Standard for Drinking Water Quality (NSDWQ) standards. However, the concentrations of other measured parameters conformed to the stipulated limits. Furthermore, Water Quality Index (WQI) was used to determine the actual quality of the five Bore-holes. Calculated results indicated that B_1 and B_2closer to the dumpsite had higher WQI values (1485.37 and 1200.45 respectively) indicating possible pollution from dumpsite, while B_3, B_4 and B_5farther away from the dumpsite had lower WQI values (143.12, 122.68 and 116.47 respectively). Thus, the safest distance between a pollution source (dumpsite) and a groundwater source (borehole) in this locality would be far above 125m.

Keywords: *Groundwater, Contamination, Dumpsite, Leachate, Rumuokania.*

1. Introduction

Groundwater pollution is mainly due to the process of industrialization and urbanization that has progressively developed over time without any regard for environmental consequences (Longe and Balogun, 2010). The protection of groundwater is a major environmental issue due to the potential health hazards associated with the use of contaminated water supply. The health hazards can manifest into several water-borne diseases like diarrhoea, typhoid fever, cholera, Hepatitis A, infectious dysentery and many others. Water is essential to life and access to safe drinking water is one of the oldest public health issues and is a prerequisite to poverty reduction and prevention of the spread of water-borne related diseases (Gomez and Naket, 2002; UNICEF, 2005; Cosgrove and Rijsbeman, 2000).

Disposal of solid waste in burrow pits (un-engineered landfills) and open dumps are the common waste management practice in Nigeria. These wastes are usually not segregated thus, they are mixed up with all kinds of waste including domestic, industrial, hazardous and degradable wastes. Un-engineered landfills have been identified as one of the major threats to groundwater resources (Fatta et al., 1999; USEPA, 1984) as waste placed in unlined landfills or open dumps are subjected to either groundwater underflow or infiltration from precipitation thereby producing leachate. Leachate from unlined landfill contains innumerable organic and inorganic compounds which accumulates at the bottom of the landfill and then percolates through the soil to the water aquifer. Thus, areas near landfills may have a greater possibility of groundwater contamination because of the potential pollution source of leachate originating from a nearby dumpsite.

In recent times, the impact of leachate on groundwater and other water resources has attracted a lot of attention because of its overwhelming environmental significance. Abu-Rukah and Al-Kofahi (2001) investigated the effect of leachate on the groundwater from a major landfill in Northern Jordan. Akinbile and Yusoff (2011) investigated the environmental impact of leachate pollution on groundwater supplies in Akure, Nigeria. Furthermore, Okorafor et al. (2012) studied the physic-chemical and bacteriological characteristics of some selected streams and bore holes in Akamkpa and Calabar Municipality in Nigeria. Udeh and Ugbebor (2013) assessed the quality of groundwater near a dumpsite in Rumuowha-Eneka, in Obioakpor LGA, Rivers State. Ugwoha and Emete (2015) investigated the effect of leachate on the quality of groundwater near a dumpsite in Alakahia, Rivers State.The results from these studies revealed possible pollution from nearby dumpsites. The untidy nature of our physical environment along with the proximity of some wells to toilet, rubbish dump and poultry house may be responsible for the presence and some high density of *E. coli* in the drinking water sources.

This research investigated the impact of leachate percolation on groundwater quality in an unlined landfill site at Rumuokania dumpsite in Rivers state. Various physico-chemical parameters including heavy metals and quality indicator microbes were analysed in groundwater samples to understand the possible link of groundwater contamination. The effects of distance of the groundwater sources (bore holes) from the unlined landfill were also studied and some remedial measures were discussed to reduce further contamination of the underlying groundwater.

2. Materials and methods

2.1. Study area

Rumuokania dumpsite is located at Mgbuoba by Shell Location Road, within latitude 4^{o}50'40''N and longitude 6^{o}58'17''E in Obia/Akpor Local Government Area of Rivers State. The dumpsite is surrounded by residential, commercial and industrial set-ups with the nearest building at approximately 15 m. The dumpsite (10 years old burrow pit) has been used for the disposal of all kinds of solid waste, including domestic, commercial and industrial wastes. The disposal of waste in this burrow pit has been stopped for some time now and the area reclaimed. Residential and commercial buildings are now built around the burrow pit and the residents in this area depend on bore holes for their domestic watersources. The map of the study area is shown in Figure 1.

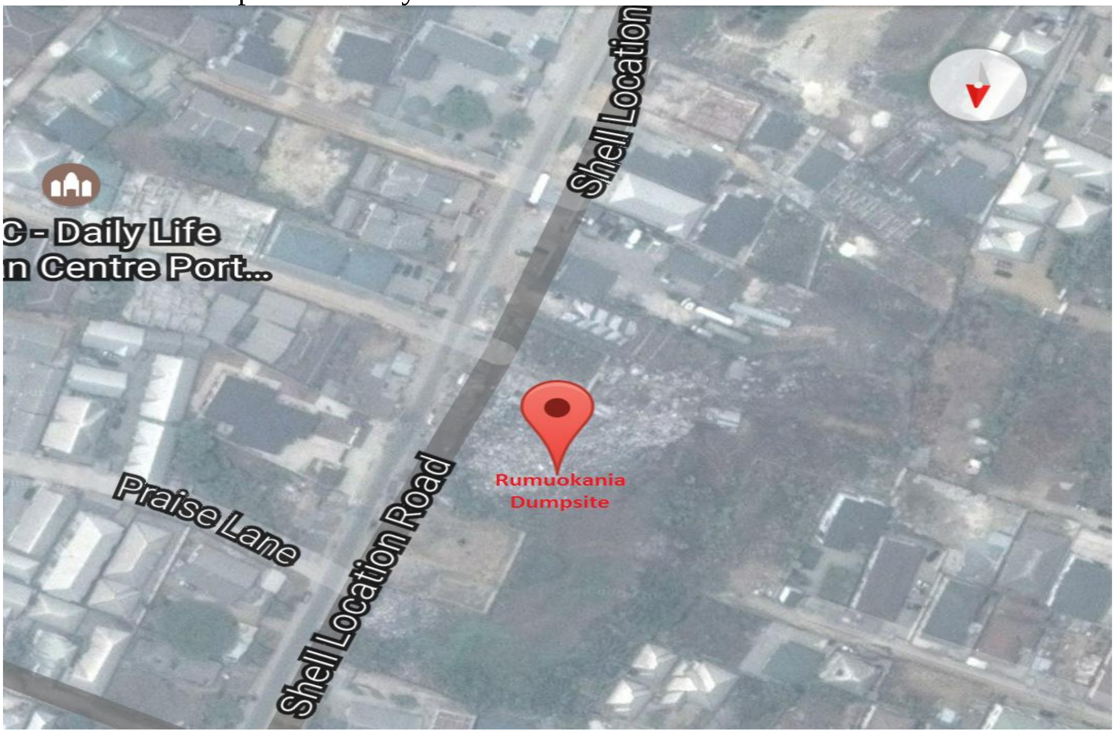

Figure 1: Map of Mgbuoba showing Rumuokania dumpsite.

2.2. Collection of samples

Water samples were collected from five different Boreholes at radial distances of 22m (B1), 30m (B2), 55m (B3), 74m (B4) and 125m (B5) respectively away from the dumpsite. Precautions were taken to prevent accidental contamination of the sample during collection. The water samples were stored in an ice chest container and transported to a laboratory. Some parameters such as pH, temperature and electrical conductivity were measured at the sampling points using the Horiba Water Checker (model U-10) which was calibrated with the standard horiba solution. Other parameters were analysedin the laboratory.

2.3. Laboratory analysis

The water samples were analysed for physical, chemical and bacteriological parameters. The physical parameters include temperature, turbidity, odour and taste, and were determined using the Horiba Water Checker.The chemical parameters include some heavy metals (iron and manganese), alkalinity, total hardness, nitrate, sulphate, phosphate and chloride. The presence of iron (Fe), lead (Pb) and manganese (Mn) in the water samples were determined using the Atomic Absorption Spectrophotometer (AAS) while the total alkalinity was determined using the titration method (APHA, 1985). The phosphate content in the water samples was determined using the Stannous method (APHA, 1998) while the chloride level was determined using the Argentometric titration method (APHA, 1998). The total hardness and calcium ion were determined using the EDTA titration method while the nitrate content was determined using the Brucine method (APHA, 1979). The electrical conductivity was determined at the sampling points using the Horiba Water Meter while the total dissolved solids (TDS) was measured using the Gravimetric Method (APHA, 1998).

The bacteriological parameters include number of Bacteria and Fungi in the water samples. Some of the bacteria enumerated include total heterotrophic bacteria (THB), total coliform bacteria (TCB) and faecal coliform bacteria (FCB). The nutrient agar medium was used for enumeration of total heterotrophic bacteria and was prepared according to manufacturer's specifications. Mac-Conkey broth medium was used for estimation of both total and faecal coliform bacteria in the water samples. Serial dilution procedure as described by Obire and Wemedo (1996) was employed for cultivation and enumeration of bacteria in the different borehole water samples. The ten-fold serial dilution was used to obtain appropriate dilutions of the samples. For total heterotrophic bacteria, aliquots of the required dilutions were plated in duplicates onto the surface of dried sterile nutrient agar medium. In the case of total and faecal coliform bacteria, the most probable number (MPN) technique described by Collins and Lyne (1980) was employed for the estimation of their number in water. Appropriate volumes of undiluted water samples were inoculated into test tube of Mac Conkey broth medium. All incubated media were incubated at 37oC for 24hours except for faecal coliform bacteria the setupof which was incubated at 44.5^{o}C.

2.4. Water quality index

The Water Quality Index (WQI) was used to ascertain the actual quality of each of the groundwater (borehole) around the Rumuokania dumpsite. The WQI was calculated using the weighted Arithmetic Index method, Equation (1). The quality rating scale for each parameter (q_i) and the relative weight (W_i) were calculated using Equations (2) and (3), respectively.

$$\text{Overall WQI} = \frac{\sum \mathbf{qiwi}}{\sum \mathbf{wi}} \qquad (1)$$

$$q_i = \frac{C_i}{S_i} X\ 100 \qquad (2)$$

$$W_i = \frac{1}{S_i} \qquad (3)$$

where q_i = quality rating scale, C_i= concentration of each parameter and S_i = standard for each parameter analysed.

3. Results and discussion

3.1. Physical, chemical & bacteriological parameters of borehole waters

The results of the physical, chemical and bacteriological parameters of the water samples are presented in Table 1. These results were compared with World Health Organization (WHO, 2004) and the Nigeria Standard for Drinking Water Quality (NSDWQ, 2007).The water samples from the boreholes were generally acidic with pH ranging from 5.3 to 5.89 which is below the WHO and NSDWQ guideline for potable water.The groundwater samples from B_1 and B_2 had mild odour and taste but B_1alone was cloudy. The presence of colour was an indication of pollution and confirmed leachate infiltration into borehole B_1 (Udeh and Ugbebor, 2013; Mohamed et al., 2009; Ogedengbe and Akinbile, 2004). However, groundwater samples from B_3, B_4 and B_5 were clear, odourless and tasteless.

The temperature of the water samples ranged from 21.8 to 24.2^{o}C and these were found to be outside the range of WHO standards of 5^{o}C for domestic water hence indicating the presence of foreign bodies.Similar views were reported by (Jaji et al., 2007) in their studies.

The chloride concentration of the groundwater samples ranged from 47.1 to 9.6 mg/l with higher values in B_1 (47.1 mg/l) and B_2(32.3 mg/l), though below the WHO and NSDWQ limits. Manganese (Mn) concentration ranged from 0.404 to 0.170 mg/l with higher values occurring in B_1 (0.404 mg/l) and B_2 (0.321 mg/l). These values are above WHO and NSDWQ limits and can impair the quality of water.

The turbidity values of the groundwater samples were 13, 7, 5, 4 and 4 NTU for B_1, B_2, B_3, B_4 and B_5, respectively. WHO recommended a maximum turbidity value of 5NTU. The high turbidity values in B_1 and B_2 may be due to proximity of the dumpsite indicating higher sediment flow when compared to B_3, B_4 and B_5. Soil particles may have found their way into the boreholes from the unstable side walls thereby increasing the turbidity of the water. A similar observation was made by Akinbile (2006).

The total dissolved solid (TDS) in the groundwater samples range from 472 to 42 mg/l with the highest concentration occurring in B_1 (472mg/l) and B_2 (386mg/l). Also, the electrical conductivity (EC) of the groundwater samples ranged from 654 to 20 μs/cm with higher values in B_1 (654 μs/cm) and B_2 (346 μs/cm) which were the boreholes closer to the dumpsite. Though these values are within WHO and NSDWQ standards, note that value of TDS and EC increased with proximity to dumpsite and EC is a valuable indicator of the amount of material dissolved in water. This indicates a certain level of pollution around the groundwater which may be the effects of leachates from the dumpsite.

Furthermore, the concentration of Iron (Fe) in the groundwater samples ranged from 18.13 to 0.10mg/l with very high concentration occurring in B_1 (18.13mg/l) and B_2 (14.26 mg/l). WHO recommended that a range of 1 to 3 mg/l is permissible,and that higher values would result toobjectionable and sour taste in the mouth. Consumption of water with concentration of Fe above permissible limit may result in the formation of blue baby syndrome in babies and goitre in adults (Ogedengbe and Akinbile, 2004; Shyamala et al., 2008). However, the concentrations of Ca, NO_3, SO_4 and PO_4 in the groundwater samples were low and fond within the specified WHO and NDSWQ standards for drinking water though some of their concentrations increased with proximity to the dumpsite.

The bacteriological characteristics of the boreholewater samples showed the presence of total coliform bacteria (TCB) which were above WHO standards with B_1 (36) and B_2 (23). This high value observed shows the presence of Escherichia Coli and other degrading bacteria which indicates faecal pollution of human wastes from landfill. This confirms bacteriological pollution which might be due to remains of dead animals or the disposal of sewage in the dumpsite and that borehole B_1 and B_2 do not satisfy the WHO requirement for bacteriological characteristics for human consumption. Thus, major treatment of water from these boreholes would be required before domestic consumption.

3.2. WQI of borehole waters

The water quality index (WQI) of the different boreholes was calculated using Equation (1) and summarized in Table 2. Comparing the different overall WQI values of the boreholes to the water quality classification based on the standard WQI values shows that boreholes B_1 and B_2 with overall WQI values of 1485.37 and 1200.45 fell under the "Unsuitable for drinking" category. The quality of water obtainable at these points is highly polluted. This indicates leachate infiltration into the boreholes and could be due to the proximity of the boreholes to the dumpsite. Thus, this might be the reason for the odour and taste observed in the water samples from the boreholes.

Table 1: Measured water parameters from different boreholes at different distances from a dumpsite and the WHO and NSDWQ standards for the parameters.

Water Samples	NSDWQ	WHO	B_1	B_2	B_3	B_4	B_5
pH	6.5 - 8.5	6.5 - 9.5	5.30	5.56	5.84	5.86	5.89
Ca^{2+} (mg/l)	75	75	5.03	3.45	3.8	3.1	2.8
NO_3^- (mg/l)	50	50	2.02	2.07	2.52	1.15	1.67
EC (µs/cm)	500	500	654	346	25	25	20
SO_4^{2-} (mg/l)	100	100	1.0	1.0	1.0	1.0	1.0
Salinity	—	—	0.2	0.2	0.0	0.0	0.0
PO_4^{3-} (mg/l)	0.5	0.5	0.05	0.05	<0.05	<0.05	<0.05
Mg^{2+} (mg/l)	0.20	1.0	0.85	0.87	0.5	0.5	0.5
TH(mg/l)	200	200	24.20	21.32	13.84	6.8	7.6
Alkalinity	250	250	174	143	56	20	14
TDS (mg/l)	500	500	472	386	115	76	42
Cl^- (mg/l)	250	250	47.1	32.3	12.9	10.5	9.6
M (mg/l)	0.2	0.1	0.404	0.321	0.180	0.102	0.170
Fe (mg/l)	0.3	1 – 3	18.13	14.26	0.45	0.34	0.10
Colour	Clear	Clear	Clear	Clear	Clear	Clear	Clear
Odour	odourless	odourless	Mild	Mild	Odourless	Odourless	Odourless
Taste	Tasteless	Tasteless	Mild	Mild	Tasteless	Tasteless	Tasteless
Turbidity (NTU)		5	13	7	5	4	4
Temperature (°C)		5	24.2	22.4	22.5	24.1	21.8
THB (X102CFUML^{-1})		<100	13.4	7.2	4.7	2.5	2.3
TCB (MPN INDEX 100ML^{1})		0-2	36	23	4	1	1
FCB (MPN INDEX 100ML^{1})		0	0	0	0	0	0

TH – Total Hardness, TDS – Total Dissolved Solid, THB - Total Heterotrophic Bacteria, TCB - Total Coliform Bacteria, FCB - Fecal Coliform Bacteria

Table 2: Summary of overall WQI values for allboreholes and water quality classification based on WQI

Borehole	WQI value	Standard WQI value	Water quality
B_1	1485.37	<50	Excellent
B_2	1200.45	50 - 100	Goodwater
B_3	143.12	100-200	Poor water
B_4	122.68	200-300	Very poor water
B_5	116.47	>300	Unsuitable for drinking

Boreholes B_3, B_4 and B_5 had overall WQI values of 143.12, 122.68 and 116.47, respectively. The quality of water at this points fell under the "Poor water" classwhich can only be used for domestic activities such as bathing, cleaning and washing. Generally, the greater the distance between the source of contamination (dumpsite) and a groundwater source (borehole), the more likely natural processes such as oxidation, biological degradation (which sometimes renders contaminants less toxic) and adsorption (binding of contaminants to soil) will reduce the impact of the contamination (USEPA, 1993). This trend of results was also reported in previous studies (Udeh and Ugbebor, 2013;

Ugwoha and Emete, 2015), indicating possible contamination from dumpsiteleachate. Therefore, it could be seen that the effect of dumpsite on a groundwater source pollution declines with distance.

4. Conclusions

The extent of contamination of groundwater near a dumpsite has been examined.It could be inferred from the results obtained that leachates from the Rumuokania dumpsite had steadily polluted the underlying groundwater. The extent of the pollution was more dependent on the proximity to the dumpsite and agrees with previous studies on the effect of dumpsite on groundwater quality (Akinbile, 2011; Udeh and Ugbebor, 2013; Ugwoha and Emete, 2015). It is therefore concluded that the safest distance at which the dumpsite will not contaminate the groundwater in this locality would be greater than 125m. Thus, it is recommended thata routine water quality checkbe carried out on water from boreholes in Rumuokania community to know the extent of contamination, and possibly the necessary treatment that would make the water usable, at any given time.

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