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Evaluation of Concentration of Some Groundwater Parameters around a Major Refuse Dumpsite in Cross River State, Southeastern Nigeria

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ABSTRACT: This study evaluated concentration, possible sources and relationship of groundwater parameters in a major dumpsite in Anantigha Headquarters of Calabar South Local Government Area of Cross River State, Nigeria by collecting samples of borehole water within and around the dumpsite using sterilised containers. Standard methods were used for the analysis. Results obtained show that the mean and standard deviation of the parameters were temperature (26.00 ± 0.10) ^{0}C; pH (3.80 ± 0.36); EC (187.33 ± 41.00)µS/cm; TDS (95.67 ± 20.03) mg/l; NH_4(0.13 ± 0.03)mg/l; Total hardness(19.83 ± 2.56)mg/l; TCC(50.47 ± 31.88)cfu/100ml; FCC(41.00 ± 25.94) cfu/100ml; Fe (0.15 ± 0.03); Zn (0.05 ± 0.03) mg/l and Pb (0.02 ± 0.01) mg/l. The concentration of the various parameters was compared to the World Health Organisation (WHO) and National Sanitation Development Water Quality (NSDWQ) standard. Pearson correlation analysis and principal component analysis were used to examine the relationship and possible sources among the parameters. The findings of the study revealed that electrical conductivity EC, TDS, NH_4, total hardness, Fe, Zn and Pb in borehole BH_2 were within the acceptable limit while Pb concentration of borehole BH_1 and BH_3, temperature, pH, TCC and FCC were above the permissible limit of WHO/NSDWQ. It is recommended that boreholes should be drilled far away from dumpsites to avoid contamination which poses health risks to man.

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The major challenge facing the world today is accessibility to potable water. Due to urbanization and population growth in the city, potable water is becoming scarce and difficult to get. Polluted or contaminated water is not good for consumption as it is associated with water borne diseases which has effect on man's health. Groundwater is a major source of fresh water for man's use, irrigation and industrial purposes in different countries of the world. Water is life and all living things depend on it. An average man (of 53kg – 63 kg) body weight needs about 3 litres of water liquid and food every day to be healthy (Onweluzo and Akazugbe, 2010). Water is used for cooking, washing, sanitation, drinking, growing crops and running factories and industries (Chinyere *et al*, 2018). Generally, water can be obtained from surface water and underground water. Underground water includes well water, borehole water while surface water sources are rivers, lakes, oceans, estuaries, creeks, streams, etc. (McMurry and Fay, 2004). As the population increases, there will be need for land and this will results to contamination of the groundwater due to man's activities. Improper disposal of wastes, poor agricultural practices, septic tanks, pit latrines and graves close to boreholes, poor well construction will lead to borehole contamination or pollution (Lu, 2004; McKinney, 2011). Once water is polluted it becomes expensive and difficult to bring back to its initial stage. The contamination of groundwater (boreholes) triggers the heavy metals though some occur naturally underground. Heavy metals are major pollutants of groundwater and affect the borehole water system. Heavy metals leach to the groundwater when the capacity of the surface soil fails to retain them and through consumption may pass to man and other living organisms. Heavy metals have the ability to exist in particulate, dissolved and colloidal phases when found in water (Adepoju-Bello *et al*, 2009; Edori

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and Nwoke, 2020) and are difficult to be destroyed. According to the World Health Organisation (WHO, 2004), about 80% of all diseases in humans come from water. High mortality and morbidity rates are as a result of water – borne diseases. The quality of water is defined in terms of physical, chemical and biological parameters. Udeme Avenue dumpsite is situated in Anantigha Calabar South Local Government Area of the State. The dumpsite is over 30 years and people build houses and live in it. The only sources of water within the area are boreholes and these boreholes are sunk within the dumpsite. Also there is fish pond within the dumpsite and people feed from it unknowingly. Though studies have been carried out by other researchers on borehole generally within Calabar South, but at the time of their study there were no boreholes in Udeme Avenue. The objective of this paper is to evaluate concentration, sources and relationship of some groundwater parameters around a major refuse dumpsite in Cross River State, Southeastern Nigeria.

MATERIALS AND METHOD

Location, hydrogeology and geology of the study area: Calabar South is situated within latitudes 4^{0}54´N and 4^{0}58´N and longitudes 8^{0}15´E and 8^{0}25´E, and it is one of the eighteen (18) Local Government Areas in Cross River State of Nigeria (Fig.1). The area has two maxima rainfall that peaks in the months of July and September. Climatic data show that Calabar South has a mean yearly rainfall amount of 3000mm and relative humidity of above 85% (NAA weather report, 2006). Geologically, the area is overlain with Tertiary sands of Benin Formation (Coastal Plain Sands). The sands are mostly medium to coarse-grain, pebbly moderately-sorted, with local lenses of fine-grained, poorly cemented sand and silty clay (Fig.2). This formation consists of alternating sequence of loose gravel, sand, silt, clay, lignite and alluvium (Short and Stauble, 1967). The Coastal Plain Sands (Benin Formation) generally constitutes the abundance aquiferous hydrogeologic settings in the area and all the water boreholes are situated in this Formation (Esu and Amah, 1999).

Method: Samples of borehole water were collected from the boreholes within and around the dumpsite in Udeme Avenue Anantigha Calabar South Local Government Area of Cross River State using sterilised plastic containers. The containers for the samples were rinsed with the water to be sampled before samples were collected. The coordinates of each sample point were taken before samples were taken (Table 1). Water samples were collected in a sampling bottle to avoid floating of materials. The stoppers of the sample containers were closed properly to avoid outside contamination. The containers were labelled describing the name of the water body, date, time, sampling-point, and conditions under which samples were collected. The water samples were analysed using Ultra Violet Visible (UV – VIS) Spectrophotometer CE 1011 and physical, chemical, heavy metals and microbiological parameters were determined.

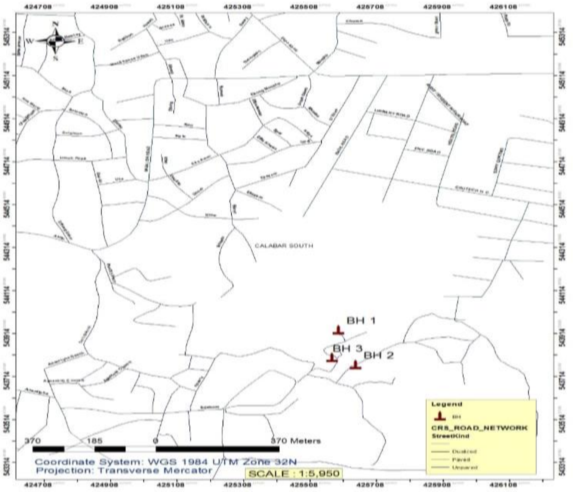

Fig.1 Location map of the study area

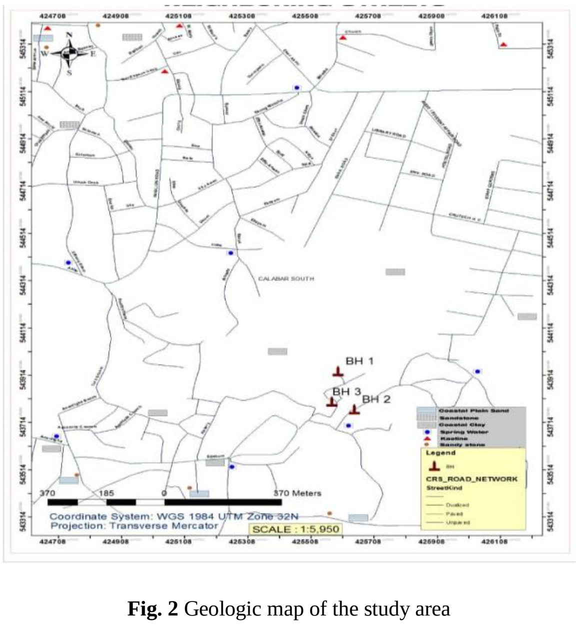

Fig. 2 Geologic map of the study area

RESULTS AND DISCUSSION

The summary of the groundwater water parameters are presented in Table 2. The results were compared with the Nigeria Standard for Drinking Water Quality (NSDWQ, 2015) and World Health Organization (WHO, 2011) standards to ascertain it suitability for use for human consumption. The parameters obtained are as follows: temperature, electrical conductivity, pH, total dissolved solids (TDS), ammonium (NH_4), total hardness, total coliform count (TCC), faecal coliform count (FCC), iron (Fe), zinc (Zn) and lead (Pb). Fig 3 shows the bar chart for distribution of groundwater parameters in the study area.

Temperature and pH: Water samples from all the boreholes were acidic with pH values not within the limit of WHO and NSDWQ standard permissible range. Also the temperature of the water samples in all the boreholes was above the permissible acceptable limit of 25^0C for domestic water which shows the presence of active microorganism in the water (Akinbile *et al*, 2011; Nta *et al*, 2020). The acidity of groundwater is due to the presence of organic acids in the soil as well as those of atmospheric origin infiltrated to the water (Chapman and Kimstach, 1996).

Electrical conductivity (EC): This is the ability of an ion to conduct electric current and this depends on the presence of ions, their total concentration mobility, valence, and relative concentration and on the temperature (Emeka *et al*, 2020). EC depends on the quantity of dissolved solids in water. The result from this study has indicated that the electrical conductivity values of 228, 146 and 188µS/cm for borehole BH_1, BH_2 and BH_3 respectively were below the permissible limit. According to Emeka *et al*, (2020) this shows that the water in the study area was not considerably ionised and has lower level of ionic concentration activities.

Table 1: Midpoint coordinates in the study area

S/N	Location of dumpsite	Label	Latitude	Longitude	Elevation
1	Udene Avenue, Anantigha Calabar South LGA	BH_1	N04^{0}55'14.4''	E008^{0}19'44''	7.0m
2	Udeme Avenue, Anantigha Calabar South LGA	BH_2	N04^{0}55'13.5''	E008^{0}19'45.7''	7.0m
3	Udeme Avenue, Anantigha Calabar South LGA	BH_3	N04^{0}55'10.2''	E008^{0}19'43.4''	6.0m

Table 1 Summary of groundwater parameters in the study area

Parameter	BH_1	BH_2	BH_3	Mean $\pm$ SD	WHO(2011)/ NSDWQ(2015)
Temperature(^{0}C)	26.10	25.90	26.00	26.00 $\pm$ 0.10	25
pH	3.70	3.50	4.20	3.80 $\pm$ 0.36	6.5 - 8.5
EC (µS/cm)	228.00	146.00	188.00	187.33 $\pm$ 41.00	1000
TDS (mg/l)	115.00	75.00	97.00	95.67 $\pm$ 20.03	500
NH4(mg/l)	0.15	0.10	0.13	0.13 $\pm$ 0.03	0.3
Total Hardness(mg/l)	22.50	19.60	19.8	19.83 $\pm$ 2.56	300
Total Coliform count(TCC) cfu/100ml	81.00	53.00	17.40	50.47 $\pm$ 31.88	10
Faecal Coliform count (FCC)cfu/100ml	70.00	20.00	33.00	41.00 $\pm$ 25.94	0
Fe (mg/l)	0.17	0.12	0.15	0.15 $\pm$ 0.03	0.3
Zn(mg/l)	0.08	0.05	0.03	0.05 $\pm$ 0.03	3.0
Pb(mg/l)	0.03	0.01	0.02	0.02 $\pm$ 0.01	0.01

Total dissolved solids (TDS): TDS is the concentration of all dissolved minerals in water. TDS occurs as result of saline water which is discharged from industrial treatment plants leading to soil contamination leaching effect (Boyd, 1999). TDS is a function of temperature and pH. Results of TDS in the study area were 115 mg/l, 75 mg/l and 97 mg/l, which showed that TDS values are within the WHO and NSDWQ permissible range of 500 mg/l.

Ammonium (NH_4): Results of NH_4 in the study area were 0.15, 0.10 and 0.13 mg/l, which showed that NH_4 values are within the WHO and NSDWQ permissible range of 0.30 mg/l.

Total Hardness: Total hardness of water indicates the presence of soluble salts of calcium, magnesium and other heavy metals dissolved in it. Results obtained in this study are within WHO permissive range of 300 mg/l.

Total Coliform Count (TCC): According to Bodoczi (2010), the sanitary quality of water is determined by the presence or absence of pathogenic micro-organisms shown by presence of coliforms. Coliform group of bacteria are a large group of disease causing bacteria that inhabit intestine of man and animals (Sigh *et al.*, 2011).

The result obtained in this study in BH_1, BH_2 and BH_3 were 81.0, 53.0 and 17.4 cfu/100ml respectively exceeded the WHO maximum permissible limit of 10cfu/100ml. This implies that the three boreholes fall within the marginal class and water is at the slight risk of microbial infection and must be treated before consumption (Table 2).

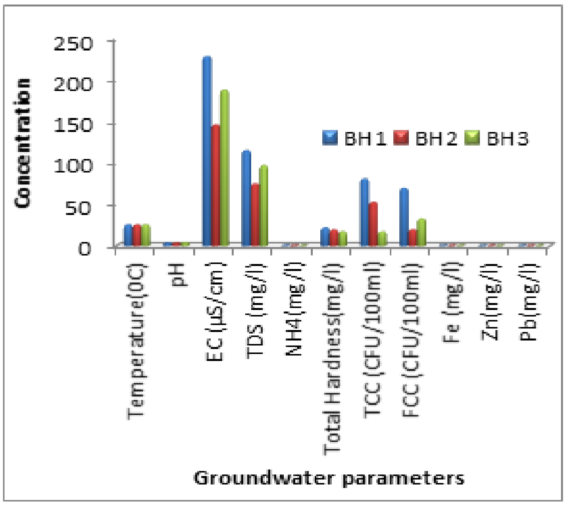

Fig 3. Bar chart showing the concentration of borehole water parameters in the study area

Faecal Coliform Count (FCC): Faecal Coli presence is the most reliable indicators of faecal bacterial contamination of surface and groundwater waters in different countries of the world (WHO, 1989). Faecal coliform bacteria are bacteria found in faeces, they are subset of a larger group of organisms referred to as coliform bacteria which are facultative anaerobes that can survive in the absence of oxygen, gramme negative, non-spore forming, rod-shaped bacteria that ferment lactose, producing gas and acid at about high temperatures of 35^0C.The result obtained in this study in BH_1, BH_2 and BH_3 were 70.0, 20.0 and 33.0cfu/100ml respectively exceeded the WHO maximum permissible limit of 0cfu/100ml. This indicates that the three boreholes fall within the poor class and water is at the risk of infectious disease transmission; not fit for human consumption (Table 2).

Table 2 Classification of water micro-biological limits (DWAF, 1996)

Parameter	Good	Marginal	Poor
TCC	10cfu/100ml	11 – 100 cfu/100ml	>100cfu/100ml
FCC	0cfu/100ml	1 – 10cfu/100nl	>10cfu/100ml

cfu = colony forming units, good = fit for human consumption, poor = poses a health risk

i. Good (negligible risk of microbial infection; fit for human consumption)

ii. Marginal (slight risk of microbial infection; must be treated before consumption)

iii. Poor (risk of infectious disease transmission; not fit for human consumption)

Iron (Fe): Iron is dark-grey in colour in its pure form and occurs in groundwater in form of ferric Hydroxide (Lekan *et al*, 2019). The concentration of iron in the results in this study were 0.17, 0.12 and 0.15mg/l for BH_1, BH_2 and BH_3 respectively and were less than 0.3mg/l which is within the permissible limit of 0.3mg/l as standard by WHO/NSDWQ. Consumption of water containing high concentration of Fe according to Brewer (2009) will cause diabetes, mellitus, liver damage, arteriosclerosis, and other diseases.

Zinc (Zn): Zinc is a soft, lustrous, blue-white metal. It is one of the micronutrient metals .Absorption pathways such as inhalation, dermal contact and ingestion are the ways in which zinc gets into the body (Plum *et al.*, 2010). The concentration of zinc in the results in this study was less than 3.0 mg/l which is within the permissible limit of 3.0 mg/l as standard by WHO/NSDWQ. Abdominal cramps, diarrhoea, pleuritic chest pain, respiratory tract infection and pneumonitis are common with inhalation and ingestion of lethal doses of zinc.

Lead (Pb): Lead is soft, malleable and ductile metal. The concentrations of lead in the results in this study were 0.03, 0.01 and 0.02mg/l for BH_1, BH_2 and BH_3 respectively. The concentration of BH_1 and BH_3 exceeded the permissible limit of 0.01mg/l as standard by WHO/NSDWQ, while BH_2 is within the permissible limit. Exposure to lead causes neurotoxicity, nephrotoxicity, carcinogenicity and endocrine and reproductive failures in adults (Herreros *et al.*, 2008). Moderate exposure to Pb can also significantly reduce human semen quality and causes damage to deoxyribonucleic Acid (DNA) in children and impairment of the reproductive function in adults (Telisman *et al*., 2000).

*Correlation coefficient analysis:*Pearson's correlation coefficient was employed to evaluate the relationship between the concentration of various groundwater (borehole)water parameters in the study area. Rakesh and Raju (2013) found that high correlation coefficient (near +1 or −1) indicates a good relationship between two variables, and its concentration around zero indicates no relationship between them at a significant level of 0.05% level, it can be strongly correlated, if $r > 0.7$, whereas r values between 0.5 and 0.7 shows moderate correlation between two different parameters. As observed in Table 3, the results of coefficients indicated strong positive correlation between the parameters: temperature with EC (r = 1.000); temperature with TDS (r = 0.998); temperature with NH_4(r = 0.993); temperature with TCC (r = 0.971); temperature with FCC (r = 0.964); EC with TDS (r = 0.999); EC with NH_4 (r = 0.995); EC with TCC (r = 0.967); EC with FCC (r = 0.960); TDS with NH_4 (r = 0.998); TDS with TCC (r = 0.955); TDS with FCC(*r* = 0.927); total hardness with TCC (*r* = 0.748); total hardness with FCC (*r* = 0.766) and TCC with FCC (*r* = 1.000). This strong positive correlation indicates that the borehole parameters are closely related suggesting that they likely have common origin or source of contamination which in this case is the dumpsite since they are toxic in nature. There was also moderate positive correlation between the parameters: temperature with total hardness (*r* = 0.567); EC with total hardness (*r* = 0.555); TDS with total hardness (*r* = 0.518). Also there was moderate negative correlation between pH and total hardness (*r* = -0.634 and p > 0.05). This suggests that both parameters are influenced by different anthropogonic activities. The other parameters have weak positive correlation indicating differences in mixed sources of origin, behaviour of those parameters and anthropogenic activities (Sappa *et al*, 2014; Boateng *et al*, 2019).

Table 3 Correlation matrix of the relationship between the various Groundwater (borehole) water parameters concentration in the study area

Parameters		Temp.	pH	EC	TDS	NH_4	Total Hardness	TCC	FCC	Fe	Zn	Pb
Temperature	Pearson Correlation	1										
	Sig. (2-tailed)											
pH	Pearson Correlation	.277	1									
	Sig. (2-tailed)	.821										
EC	Pearson Correlation	1.000**	.291	1								
	Sig. (2-tailed)	.009	.812									
TDS	Pearson Correlation	.998*	.332	.999*	1							
	Sig. (2-tailed)	.037	.784	.028								
NH4	Pearson Correlation	.993	.386	.995	.998*	1						
	Sig. (2-tailed)	.073	.748	.064	.036							
Total Hardness	Pearson Correlation	.567	-.634	.555	.518	.469	1					
	Sig. (2-tailed)	.616	.563	.625	.653	.690						
TCC	Pearson Correlation	.971	.038	.967	.955	.937	.748	1				
	Sig. (2-tailed)	.154	.976	.163	.191	.228	.462					
FCC	Pearson Correlation	.964	.011	.960	.947	.927	.766	1.000*	1			
	Sig. (2-tailed)	.172	.993	.181	.209	.245	.444	.018				
Fe	Pearson Correlation	.993	.386	.995	.998*	1.000**	.469	.937	.927	1		
	Sig. (2-tailed)	.073	.748	.064	.036	.000	.690	.228	.245			
Zn	Pearson Correlation	.596	-.606	.585	.549	.500	.999*	.771	.789	.500	1	
	Sig. (2-tailed)	.593	.585	.602	.630	.667	.023	.439	.421	.667		
Pb	Pearson Correlation	1.000**	.277	1.000**	.998*	.993	.567	.971	.964	.993	.596	1
	Sig. (2-tailed)	.000	.821	.009	.037	.073	.616	.154	.172	.073	.593	

**. Correlation is significant at the 0.01 level (2-tailed), *. Correlation is significant at the 0.05 level (2-tailed),.
c. Listwise N=3

Table 4 The Rotated Component Matrix[a] (Varimax) for groundwater parameters in the study area

Parameters	Component 1	2
Temperature	**.988**	.154
Ph	.422	**-.907**
EC	**.990**	.140
TDS	**.995**	.097
NH4	**.999**	.040
Total Hardness	.433	**.901**
TCC	**.922**	.387
FCC	**.911**	.412
Fe	**.999**	.040
Zn	.465	.885
Pb	**.988**	.154
Eigenvalue	**8.715**	2.285
%Variance	79.224	20.776
Cumulative %	79.224	100.00
Factor1	Temperature – EC – TDS – NH4 – TCC – FCC – Fe – Pb	
Factor 2	pH – Total Hardness – Zn	

Factor analysis: In this study, factor analysis was used to analyse the groundwater (borehole) water samples in the study area to know the likely source of contamination and the results are as shown in Table 4. Factor 1: (Temperature, EC, TDS, NH_4, TCC, FCC, Fe and Pb). This accounted for about 79.22% of the total variance in the data matrix with eigenvalue of 8.72 which is the most significant. The source of these parameters is more likely originating from leachates in the dumpsite. Factor 2: (pH, total hardness and Zn). This accounted for about 20.78% of the total variance of the variables with an eigenvalue of 2.285. The parameters also indicated both positive and negative correlation and most likely to be influenced by anthropogenic and natural activities.

Conclusion: Groundwater water parameters temperature, electrical conductivity, TDS, NH_4, total hardness, Fe, Zn and Pbof a refuse dumpsite in Anantigha, Calabar South Local Government Area of Cross River State, Nigeria was determined. It was revealed that electrical conductivity, TDS, NH_4, total hardness, Fe, Zn and Pb in borehole BH_2 were within the acceptable limit while Pb concentration of borehole BH_1 and BH_3, temperature, pH, TCC and FCC were above the acceptable limit of WHO/NSDWQ.

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