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ASSESSMENT OF THE IMPACT OF SOLID WASTE DUMPS ON GROUND WATER QUALITY, CALABAR MUNICIPALITY, NIGERIA

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Abstract: -

Solid waste dump where leachate generated is allowed to escape to the surrounding and underlying water body is a major threat to borehole water. This study was designed to assess the impact of solid waste dumps on ground water quality and the current status of the quality of borehole water in Calabar municipality. Randomly selected boreholes around Lemna road where the final dump site of solid waste in Calabar is located, Etta Agbor area where there are no major dumpsites but a few sporadic dumps and Satellite town where there are relatively no dumpsites were thoroughly examined. Physicochemical properties of water quality were determined following standard analytical procedure and metal content by atomic absorption Spectrophotometry using Shimadzu atomic absorption spectrophotometer (model AA6800, Japan). Metal content and other physicochemical parameters generally displayed the trend Lemna road > Etta Agbor road > Satellite town. The differences were found to be statistically significant (ANOVA, $p < 0.05$), suggesting that solid waste dumpsites have reasonable influence on the quality of ground water in Calabar municipality. A significant ($p < 0.01$) positive correlation was observed between each of the metals and between the metals and most of the physicochemical parameters, suggesting that a similar source is responsible for their presence at the concentration determined. When compared with WHO drinking water standards, borehole water in the study area especially Lemna road was seriously implicated. The study thus concludes that solid waste dumps in Calabar municipality have significant influence on the quality of ground water and that continuous use of borehole water from the study area for drinking or other domestic purposes without any form of physical or chemical treatment could pose serious toxicological risk. It was therefore recommended that ground water in Calabar municipality should be put under surveillance in other to protect it from further degradation and safeguard public health.

Keywords: - *Solid waste, dumpsite, ground water, quality, toxicological risk*

1.0 INTRODUCTION

Solid waste management has remained an undisputable environmental problem in the developing countries of the world and stands out amongst the arrays of global environmental hazards besieging metropolitan cities. The problem has become increasingly complex due to the increase in human population, industrial and technological revolutions, in addition to the fact that the processes that control the fate of wastes in the receiving media are complex. The indiscriminate handling and disposal of waste, leads to environmental degradation, destruction of the ecosystem and poses great risks to public health. Solid waste is any non-fluidic/non-flowing substance which has been identified to be of no use or has no immediate economic demand at a particular point or source either as a raw material, end product, expired products, containers or after use remnants and which must be disposed of [1,2]. Solid waste is generated from various human activities such as domestic, hospital, industrial and agricultural activities. According to Udiba [3], it may be categorized according to its origin (domestic, industrial, commercial, construction or institutional); according to its contents (organic material, glass, metal, plastic paper etc); or according to hazard potential (toxic, non-toxin, flammable, radioactive, infectious etc). Landfills and open dumping remains the major method of disposing solid waste in Nigerian cities. Solid waste disposed in landfills is usually subjected to series of complex biochemical and physical processes, which lead to the production of both leachate and gaseous emissions. Municipal waste dumping sites which are designated places where waste from various sources are deposited are not properly designed nor constructed; consequently, wastes dumped over the year's biodegenerate and generate leachates that ultimately become point source of pollution into soil and groundwater. When precipitation occurs, the percolating water (Leachates) dissolves many organic and inorganic salts which may be transported to nearby aquifers resulting in the alteration of the water quality. The rate of production and characteristic of leachate produced depends on a number of factors which include but not limited to solid waste composition, particle size, degree of compaction, hydrology of site, age of landfill, moisture, temperature condition, and availability of oxygen [4, 5]. The implication of the dumpsite on groundwater hydrology is that leachates from dumpsite infiltrates into the ground and also move in the direction of groundwater flow thereby contaminating the groundwater along its path [6]. Contamination of ground water with chemical substances automatically limits the quality of the water. Once groundwater is contaminated, it remains extremely difficult to rectify. Scientists had believed that Groundwater is naturally very clean because the soil layers above the water table act as natural filters that prevent pollutants from infiltrating down to it. But recent findings revealed that those soil layers often do not adequately protect aquifers from contamination as leachates move down the soil strata and penetrate even at great depth [5, 7, 8]. Leachate migration from dump sites or landfills and the subsequent release of pollutants to ground water aquiver pose a high risk if not adequately managed. Groundwater protection is therefore a major environmental issue.

Groundwater is a globally important and valuable renewable resource for human life and economic development. The provision of quality water for human consumption is essential for sustainable development. Safe drinking water is a basic need not only for human development but also for his health and well-being. It is an internationally accepted human right [9]. It has been observed that bad quality water consumption leads to several health challenging issues such as typhoid, liver and kidney diseases [8]. Although environmentally related health problems affect people of all ages and from all sectors, children are more vulnerable than adults. Among children below five years, environmental related illnesses are responsible for more than 4.7 million deaths annually [9]. Physicochemical properties of water are relevant parameters that directly or indirectly determine its suitability as a source of water for human consumption or for other usages like agricultural and industrial purposes. Water for human consumption must be free from microorganisms and chemical substances in concentration large enough to cause environmental imbalance and disease. At present, private borehole operators in Calabar municipality sell untreated water to members of the teaming population in the area and so there is no quality standard that has been established in this area [7]. Boreholes which are located near waste dumps, latrines or soak away pit are likely to be contaminated by materials from these places [5].

There has been a fairly efficient "waste management" in Calabar since the year 2000 though with decreasing vigor in recent years. Waste management in this contest has essentially been waste collection and relocation. Lemna road is the final dumpsite for waste collected in the city. Today, there is an increase in human activities in the city due to population increase. Since increase in human activities will lead to increase in the volume of waste generated which will result to being dumped, then more waste will be dumped into the environment leading to increased groundwater and general environmental pollution [10]. Of great concern also is the fact that sporadic dumps are gradually resurfacing in most part of the city. It is no longer an uncommon sight to find solid waste hipped even at the waste collection centers for weeks without being attended to. As the population of the area has been on the increase because of the peaceful atmosphere of the area, industrialization, tourism activities, and better health care to reside and work [7], so also the need for portable water for drinking and domestic activities. Though there is availability of pipe borne water in most areas of Calabar municipality, ground water (Bore hole) remains the major source of portable water for a greater proportion of the populace. There is therefore much pressure on water leading to increase in the construction of boreholes. It is pertinent to note that quality considerations are important whatever the utilization of water: industrial, agricultural and domestic usages all have their criteria of adequacy [11]. It is in view of the above that this study was designed to assess the possible impact of solid waste dumps on ground water quality and ascertain the current water quality status of boreholes water in the vicinity of the final refuse dump at Lemna road as well as other parts of the ancient city in order to safeguard public health.

2. Materials and Methods

2.1. Study Area

Calabar Municipality lies geographically along longitudes 08^0 18'E and 08^0 26'E Greenwich meridian and latitudes 04^0 55'N and 04^0 58'N of the eqsuator. In the North, Calabar Municipality is bounded by Odukpani and Akamkpa Local

Government Areas, at the East by the Great Kwa River. At the South it is bounded by the Calabar River and Calabar South Local Government Area. It has an area of 331.551 square kilometers. Calabar Municipality is characterized by a double maxima rainfall regime which occurs in June and September. It has an annual rainfall of 3000mm and a harmattan wind blowing over the area in December and January respectively.

The annual temperature is 28^0 C with a high evapotranspiration and an average humidity of 90%. The vegetation of the study area is characterized by mangrove swamp and rainforest, but due to human activities like cutting down of trees, for roads, building of houses, schools and market it has resulted in the depletion of the rainforest. The soil is composed of coastal plain sand which belongs to tertiary deposits. The alluvial deposits are used for construction with light brown and grey colour. According to Cross River Basin Authority [12] Cross River State Hydrological Province are grouped into four units namely: basement and intrusive rocks, sandstone, shale and alluvial deposits. The lithology is characterized by an underlying aquifer. The surface and ground water bodies are recharged by high precipitation. The aquifer is confined with few aquicludes made up of silt, clay and sandstone.

Figure 1: Map of Calabar Municipality showing sample locations

2.2 Sample collection and preservation

The procedure for sample collection and analysis was adopted from America Public Health Association [13]**. F**ive boreholes around the final dump site at Lemna road were randomly sampled. This area is inhabited by people who belong to the lower class of the socio-economic strata. Five boreholes were randomly selected long Etta Agbor area where there are no major dumpsites but a few sporadic dumps and inhabited by people who belong mostly to the middle class of the socio-economic strata. Lastly, five boreholes were also selected randomly at Satellite town where there are no dumpsites at all and inhabited by people who belong to the upper class of the socio-economic strata. Grabs sample of water was collected monthly for three months (June, July, and August 2015) from each of the selected boreholes into pre-washed 2-litre polypropylene container preserved in coolers stocked with ice block and transported to Institute of oceanography university of Calabar for analysis.

2.3 Analysis of physicochemical parameters

Electrical conductivity, total dissolved solid and temperature were determined on site using HACH conductivity/TDS meter (model 44600, USA), pH was determined on site electronically using Zeal-tech digital pH meter (model 03112, India). Total suspended solid was determined at Institute of Oceanography, University of Calabar. In the determination of total suspended solid, a glass fibre filter paper 5.5mm diameter was dried to a constant weight in an oven at 105^0C. It was then cooled to room temperature in a desiccators and the weight noted. A gooch funnel about the same size of the glass fibre was prepared. Rubber adapter and a filtering flask were fixed and connected to vacuum pump. The glass fibre was carefully placed in the funnel. A 100ml of a well shaken sample was quickly filtered. The glass fibre was removed carefully, dried to a constant weight at 105^0C and suspended solid calculated according to Ademoroti [14]. The Modified Winkler- Azide Method was used to analyze water samples for dissolved oxygen (DO) [13].

3.6 Sample Preparation for Metal Analysis

The samples were digested according to standard methods for the examination of water and waste water, America Public Health Association [13]. Each sample was thoroughly mixed, 20ml was transferred into a conical flask, 10ml concentrated nitric acid added to it and brought to slow boiling before evaporating on a hot plate to lowest volume. (5-10ml) concentrated HNO_3 acid was added as necessary until digestion was completed, as shown by a light colour clear solution.

Metal concentration in the digest was determined by Atomic Absorption Spectrophonometry using Shimadzu Atomic Absorption Spectrophotometer (model AA-6800, Japan) equipped with Zeaman background correction and graphite furnace at Institute of Oceanography, University of Calabar. The calibration curve was prepared by running different concentrations of standard solutions. The instrument was set to zero by running the respective reagent blank. Average value of three replicate was taken for each determination and was subjected to statistical analysis.

3.8 Analytical Quality Assurance

In order to check the reliability of the analytical methods employed for metal determination, one blank and combine standards were run with every batch of the samples to detect background contamination and monitor consistency between batches. The result of the analysis was validated by digesting and analyzing Standard Reference Material, coded IAEA-336 following the same procedure. The analyzed values and the certified reference values of the elements determined were compared to ascertain the reliability of the analytical method employed. Reagents used, viz. HNO_3 (Riedel-deHaën, Germany), HCl (Sigma-Aldrich, Germany) were of analytical grade.

3.9 Data Analysis

Data collected was subjected to statistical test of significance using the analysis of variance (ANOVA) test to assess significant differences in physic-chemical parameters and heavy metals across sampling stations. Pearson product moment correlation coefficient was used to assess association between the physico-chemical parameters and heavy metals. Statistical analysis was done using SPSS software for windows (SPSS 17.00).

4.1 PRESENTATION OF RESULTS

4.1.1 Analytical quality assurance

To evaluate the accuracy and precision of the analytical procedure employed, Standard reference material of coded IAEA - 336 was analyzed in like manner to our samples. The analyzed values were all within the range of the certified reference values for the elements determined, suggesting the reliability of the method employed (Table 1).

TABLE 1 Results of analysis of reference material (Lichen IAEA -336) compared to the certified reference value (mg/kg).

Element (mg/kg)	Pb	Cd	Cu	Zn	Cr
A Value	5.25	0.140	4.00	55.78	1.20
R value	4.2-5.5	0.1-2.34	3.1- 4.1	56-70	1.00-2..00

A Value = Analyzed value **R Value = Reference value.**

4.1.2 Physicochemical Parameters of Water Quality

Average monthly values obtained from the measurement of physicochemical parameters of water quality of the randomly selected borehole across the sampling areas (Lemna road, Etta Agbor road and Satellite town) are presented in Table 2 and the spatial distribution of the mean values of the parameters presented in Figure 2 and Figure 3.

Table 2: Average monthly values of physicochemical parameters of borehole water from Satellite town, Etta Agbor Road and Lemna road, Calabar

Physicochemical parameter	Sampling Month	Satellite town	Etta Agbor Road	Lemna Road
Temperature	June	26.88	26.80	26.88
	July	27.28	27.00	26.38
	August	27.69	27.18	26.08
	Mean ± SD	27.28±0.40	26.99±0.19	26.45±0.40
pH	June	6.56	6.34	5.58
	July	6.54	6.42	5.30
	August	6.75	6.74	5.62
	Mean ± SD	6.61±0.11	6.50±0.21	5.50±0.17
Electrical conductivity	June	172.90	250.33	562.85
	July	141.71	228.98	584.77
	August	194.51	303.10	547.23
	Mean ± SD	169.71±26.54	260.80±36.15	564.95±18.86
Dissolved Oxygen	June	9.62	5.66	4.22
	July	11.26	6.34	5.12
	August	14.16	8.32	5.68
	Mean ± SD	11.68±2.30	6.77±1.38	5.01±0.74
Total Dissolved Solid	June	34.88	66.40	99.70
	July	39.54	80.90	234.50
	August	47.32	95.60	211.70
	Mean ± SD	40.58 ±6.28	80.97±14.60	181.97±7.15
Total Suspended Solids	June	0.02	0.16	0.4
	July	0.04	0.28	0.62
	August	0.00	0.34	0.84
	Mean ± SD	0.02±0.02	0.26±0.09	0.62±0.22

Results obtained from the measurement of physicochemical parameters of water quality of the randomly selected borehole across Lemna road, Etta Agbor Road and Satellite town (Table 2) indicates that the average monthly temperature values ranged from 26.08 to 27.69^oC. The lowest temperature (26.08^oC) was recorded at Lemna road in the month of August and the highest temperature (27.69^oC) at Satellite town also in the month of August. The mean temperatures across the sampling areas throughout the period of study were 27.28±0.40 for Satellite town, 26.99±0.19 for Etta Agbor road and 26.45±0.40 for Lemna road. Borehole water temperature in the study followed the order- Satellite town > Etta

Agbor > Lemna road (Figure 2). Statistical analysis shows that the differences in temperature across the sampling stations were statistically significant (ANOVA, $p < 0.05$), water temperature of boreholes at Satellite town being significantly higher than Etta Agbor and Lemna road. The difference in water temperature between Satellite town and Etta Agbor was however not statistically significant at 95% confidence level.

Table 2 shows that average monthly pH ranged from a minimum value of 5.30 at Lemna road in the month of July to a maximum of 6.75 at Satellite town in the month of August. The mean pH values across the sampling stations in the study were 6.61±0.11 for Satellite town, 6.50±0.21 for Etta Agbor road and 5.50±0.17 for Lemna road. pH followed the trend Satellite town > Etta Agbor > Lemna road (Figure 3). The difference in pH values across the sampling stations were found to be statistically significant (ANOVA, $p < 0.05$), Limna road being significantly lower Satellite town and Etta Agbor road. The difference in pH between Etta Agbor and Satellite town was however not statistically significant (ANOVA, $p > 0.05$).

Average monthly values of Electrical Conductivity (EC) measured in the study ranged from a minimum of 141.71 at Satellite town in the month of July to a maximum of 584.77 at Lemna road in the month of July. The mean values of EC across the sampling stations in the study were 169.71±26.54 for Satellite town, 260.80±36.15 for Etta Agbor road and 564.95±18.86 for Lemna road (Table 2). Electrical conductivity therefore followed the trend Lemna road > Etta Agbor > Satellite town (Figure 2). The difference in EC across the sampling stations was found to be statistically significant (ANOVA, $p < 0.05$), Limna road being significantly higher than Satellite town and Etta Agbor road. Etta Agbor was also found significantly higher than Satellite town.

Table 2 also indicates that Dissolved Oxygen (DO) ranged from 4.22 mg/l to 14.16 mg/l. The lowest value of DO (4.22 mg/l) was recorded at Lemna road in the month of June and the highest DO value (14.16 mg/l) at Satellite town in the month of August. The mean values of DO across the sampling areas throughout the period of study were 11.68±2.30 mg/l for Satellite town, 6.77±1.38 mg/l for Etta Agbor road and 5.01±0.74 mg/l for Lemna road. Dissolved oxygen in the study followed the order- Satellite town > Etta Agbor > Lemna road (Figure 3). Statistical analysis shows that the differences in DO across the sampling stations were statistically significant (ANOVA, $p < 0.05$), dissolved oxygen value of boreholes in Satellite town being significantly higher than Etta Agbor and Lemna road. The DO value of boreholes water around Etta Agbor was also statistically higher than Lemna road at 95% confidence level.

Total Dissolved Solid (TDS) ranged from a minimum value of 34.88 mg/l at at Satellite town in the month of June to a maximum of 234.50 mg/l at Lemna road in the month of July. The mean TDS values across the sampling stations in the study were 40.58±6.28 for Satellite town, 80.97±14.60 for Etta Agbor road and 181.97±7.15 for Lemna road (Table 2). TDS therefore followed the trend Satellite town < Etta Agbor < Lemna road (Figure 3). The difference in TDS across the sampling stations was found to be statistically significant (ANOVA, $p < 0.05$), Limna road being significantly higher Satellite town and Etta Agbor road. The TDS value of boreholes water around Etta Agbor was also statistically lower than Lemna road at 95% confidence level.

Total Suspended Solids (TSS) of borehole water measured in the study ranged from a minimum of 0.00 mg/l at Satellite town in the month of August to a maximum of 0.84 mg/l at Lemna road also in the month of August (Table 2). The mean values of TSS across the sampling stations in the study were 0.02±0.02 for Satellite town, 0.26±0.09 for Etta Agbor road and 0.62±0.22 for Lemna road. Total suspended solid therefore followed the trend Lemna road > Etta Agbor > Satellite town (Figure 2). The difference in TSS across the sampling stations was found to be statistically significant (ANOVA, $p < 0.05$), Limna road being significantly higher than Satellite town and Etta Agbor road. Etta Agbor was also found significantly higher than Satellite town.

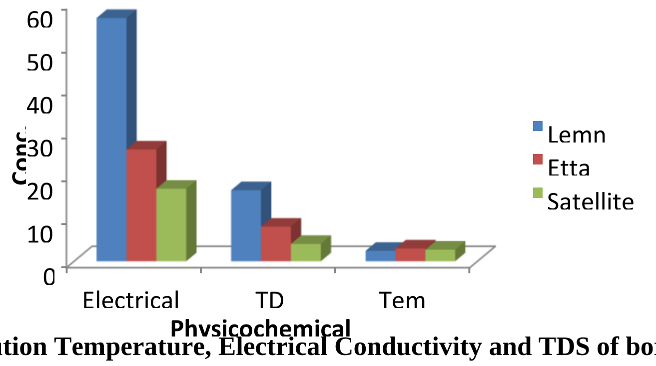

Figure 2: Spatial distribution Temperature, Electrical Conductivity and TDS of borehole water across sampling stations

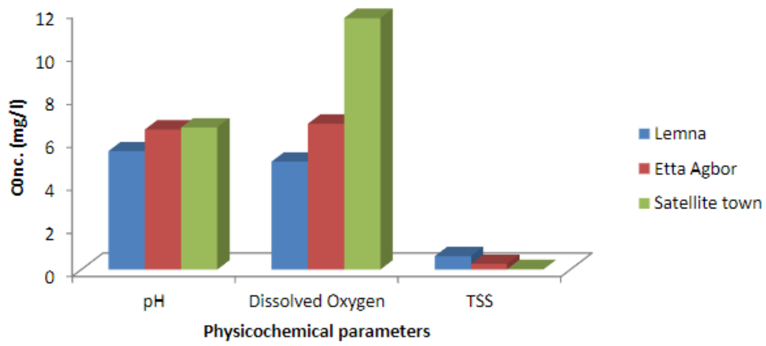

Figure 3: Spatial distribution of pH, Dissolved Oxygen and TSS of borehole water across sampling station

4.1.3 Metal content of borehole water

Results obtained from the determination of metal content of water across the sampling areas are presented in Table 3. The spatial distributions of the mean values of the metals are presented in Figure 4 and Figure 5.

Table 3: Average Metal Contents of borehole water from Satellite town, Etta Agbor road and Lemna road, Calabar

Physicochemical parameter	Sampling Month	Satellite town	Etta Agbor Road	Lemna Road
Lead	June	0.008	0.040	0.074
	July	0.002	0.036	0.052
	August	0.004	0.048	0.088
	Mean ± SD	0.005±0.00	0.0410.01±	0.07±0.02
Cadmium	June	0.008	0.022	0.030
	July	0.004	0.014	0.016
	August	0.010	0.024	0.036
	Mean ± SD	0.007±0.00	0.02±0.01	0.03±0.01
Copper	June	0.918	1.682	2.949
	July	0.508	1.478	2.946
	August	0.542	1.690	3.146
	Mean ± SD	0.66±0.23	1.62±0.12	3.01±0.11
Zinc	June	1.038	2.030	4.092
	July	0.698	1.798	3.922
	August	1.180	2.164	4.234
	Mean ± SD	0.97±0.24	2.00±0.18	4.08±0.15

Results obtained from the determination of metal content of water samples from randomly selected borehole across the study area indicates that lead (Pb) ranged from 0.002 to 0.88 mg/l. The lowest concentration (0.002 mg/l) was recorded at Satellite town in the month of July and the highest concentration (0.88 mg/l) at Lemna road in the month of August. The mean Pb concentrations across the sampling areas throughout the period of study were 0.005±0.00 mg/l for Satellite town, 0.041±0.01 mg/l for Etta Agbor road and 0.07±0.02 mg/l for Lemna road (Table 3). Lead content of borehole water in the study followed the order- Satellite town < Etta Agbor < Lemna road (Figure 4). Statistical analysis shows that the differences in Pb concentration across the sampling stations was statistically significant (ANOVA, $p < 0.05$), Pb concentration of boreholes water at Lemna road being significantly higher than Etta Agbor and Satellite town. Lead concentration of boreholes along Etta Agbor road was also found to be significantly higher than Satellite town at 95% confidence level.

Table 3 shows that Cadmium (Cd) concentration ranged from a minimum of 0.004 mg/l at Satellite town in July to maximum concentration of 0.036 mg/l at Lemna road in August. The mean Cd concentration across the sampling stations in the study was 0.007±0.00 mg/l for Satellite town, 0.02±0.01 mg/l for Etta Agbor road and 0.03±0.01 mg/l for Lemna road. Cadmium concentration therefore followed the trend Lemna road > Etta Agbor > Satellite town (Figure 4). The difference in Cd concentrations across the sampling stations was found to be statistically significant (ANOVA, $p < 0.05$), Satellite town being significantly lower Etta Agbor road and Lemna road. The difference in cadmium concentration between Lemna road and Etta Agbor was however not statistically significant (ANOVA, $p > 0.05$).

Average monthly Copper (Cu) content measured in the study ranged from a minimum of 0.508 mg/l at Satellite town in the month of July to a maximum of 3.146mg/l at Lemna road in the month of August (Table 3). The mean concentrations across the sampling stations were 0.66±0.23 mg/l for Satellite town, 1.62±0.12 mg/l for Etta Agbor road and 3.01±0.11 mg/l for Lemna road. Copper concentration also followed the trend Lemna road > Etta Agbor > Satellite town (Figure 5). The difference in Cu concentrations across the sampling stations was found to be statistically significant (ANOVA, $p < 0.05$), Limna road being significantly higher than Satellite town and Etta Agbor road. Etta Agbor was also found significantly higher than Satellite town.

Average monthly Zinc (Zn) concentration determined in the study ranged from a minimum of 0.698 mg/l at Satellite town in the month of July to a maximum of 4.234 mg/l at Lemna road in the month of June. The mean concentration across sampling stations was 0.97±0.24 mg/l for Satellite town, 2.00±0.18 mg/l for Etta Agbor road and 4.08±0.15 mg/l for Lemna road (Table 3). Zinc concentration also followed the trend Lemna road > Etta Agbor > Satellite town (Figure 5). The difference in Zn concentrations across the sampling stations were found to be statistically significant (ANOVA,

$p < 0.05$), Limna road being significantly higher than Satellite town and Etta Agbor road. Etta Agbor was also found significantly higher than Satellite town

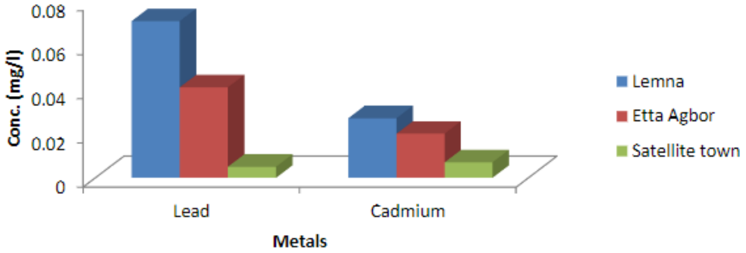

Figure 4: Spatial distribution of Lead and Cadmium concentration of borehole water across sampling stations

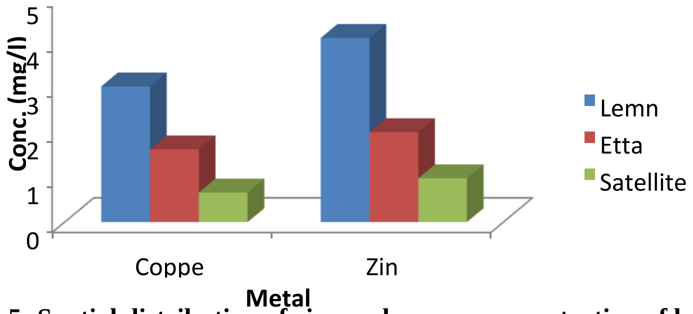

Figure 5: Spatial distribution of zinc and copper concentration of borehole water across sampling stations

Table 4: WHO, NSDWQ and EU Standards

	Tempt.	pH	EC (µs/cm)	DO	TDS	TSS	Lead	Cadmium	Copper	Zinc
WHO Std	25	6.5-8.5	250	NS	500	NG	0.01	0.005	1	5
NSDWQ	-	6.6-8.5	1000	NS	500	NG	0.01	0.003	1	3
EU std	25	6.5-8.5	250	NS	-	NG	0.01	0.005	2	5

EU = European Union. NSDWQ = Nigerian Standards for Drinking Water Quality WHO = world Health Organization.

Table 6 shows the European Union (EU), Nigerian Standards for Drinking Water Quality (NSDWQ) and World Health Organization (WHO) drinking water standards.

Table 5: Correlation between physicochemical parameters of water quality

		Tempt	pH	EC	DO	TDS	TSS	Lead	Cadmium	Copper	Zinc
Tempt	Pearson Correlation	1									
	Sig. (2-tailed)										
pH	Pearson Correlation	.775**	1								
	Sig. (2-tailed)	.000									
EC	Pearson Correlation	-.697**	-.898**	1							
	Sig. (2-tailed)	.000	.000								
DO	Pearson Correlation	.711**	.700**	-.675**	1						
	Sig. (2-tailed)	.000	.000	.000							
TDS	Pearson Correlation	-.783**	-.746**	.825**	-.577**	1					
	Sig. (2-tailed)	.000	.000	.000	.000						
TSS	Pearson Correlation	-.745**	-.719**	.819**	-.627**	.907**	1				
	Sig. (2-tailed)	.000	.000	.000	.000	.000					
Lead	Pearson Correlation	-.710**	-.719**	.831**	-.780**	.822**	.825**	1			
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000				
Cadmium	Pearson Correlation	-.574**	-.477**	.607**	-.578**	.623**	.608**	.828**	1		
	Sig. (2-tailed)	.000	.001	.000	.000	.000	.000	.000			
Copper	Pearson Correlation	-.671**	-.748**	.854**	-.752**	.785**	.835**	.838**	.592**	1	
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000		
Zinc	Pearson Correlation	-.730**	-.859	.928**	-.716**	.809**	.770**	.871**	.720**	.797**	1
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000	
	N	45	45	45	45	45	45	45	45	45	45

Table 7.0 indicates that all the parameters investigated in this study displayed a highly significant correlation with each other. The correlations were significant at 99% percent confidence level

4.2.0 Discussion of Results

4.2.1 Physicochemical Parameters of Water Quality

Inadequate control of refuse dumpsites where leachate generated is allowed to escape to the surrounding and underlying water body is a major threat to borehole water. The chemical composition of the leachate according to Eni [5], depends in the nature of the refuse, the leachate rate, and the age of the dumpsite. In the present study, the mean temperatures of borehole water (27.28±0.40 for Satellite town, 26.99±0.19 for Etta Agbor road and 26.45±0.40 for Lemna road) observed were found to be above the World Health Organization (WHO) and European Union (EU) drinking water standards of 25°C for domestic water supply. Water temperature above 40 ^{O}C depicts polluted water [15]. The temperature of borehole water recorded in this study though slightly above the permissible limits, the water cannot be termed polluted with respect to temperature alone. The distribution pattern of the temperatures across the study areas (Satellite town > Etta Agbor > Lemna road) does not show a clear influence of refuse dump site or population density on ground water temperature as the differences in temperature between Etta Agbor and Lemna road was not statistically significant at 95%n confidence level. This observation is in agreement with the findings of Digha and Ekanem [7] who in their study of the effects of population density on water quality in Calabar municipality concluded that the distribution pattern of the physic-chemical parameters does not show a clear relationship between population density and water chemistry. A wider temperature range (25 - 29.5 ^{o}C) has previously been reported for boreholes located close to Lemna landfill in Calabar Metropolis [5]. Higher temperatures ranging from 28.5 – 30.0 ^{o}C was reported for Akim town, Essien Town, Ediba and Ikot Effanga Mkpa all in Calabar Municipality [7]. Mean temperatures of 24.45±0.04 ºC, 27.98±0.50 ºC and 27.25±0.08 ºC were reported for Okoro Agbor, Orok Orok and Mount Zoin areas of Calabar [8]. A mean value of 29.08±0.22 ºC was reported for ground water in Dareta Village, Zamfara State [16]. Water temperature controls the rate of chemical reactions. A 10 ^{0C} rise in temperature doubles the rate of most chemical reactions. Increase in temperature leads to increase in solubility of substances. At high temperatures total dissolved solids is increased as more solute goes into solution. It also affects how much oxygen the water can hold. Cold water holds more oxygen thus enhancing the biological characteristics of surface water. Extreme changes in temperature can place stress on the organisms within an ecosystem. Therefore, temperature is important to aquatic plants and animals and the overall health of the water [17].

The pH of water is a very important parameter in the determination of water quality since it affects other chemical reactions such as solubility and metal toxicity [16]. It is most important in determining the corrosive nature of water. The lower the pH value, the higher the corrosive nature of the water. The pH values of borehole water recorded in the study were found to be slightly acidic. The mean pH recorded at Etta Agbor and Satellite town were however within the acceptable pH range of 6.5 - 8.5 assigned by World Health Organization [18], United State Environmental protection Agency [19] and the Nigerian Standards for Drinking water Quality [20], making it suitable for portability with respect to pH. The mean pH value of borehole water at Lemna road was outside the acceptable range of pH range and therefore not suitable for drinking without any form of treatment. The low pH observed at Limna road may suggest a downward transfer of leachate into groundwater. Topography, type of waste and the hydrology of the study area are possible factors that could aide leachate migration into groundwater. The pattern of pH displayed in the study (Satellite town > Etta Agbor > Lemna road) suggest that the solid waste dumpsite may have reasonable influence on the pH of borehole water in Calabar Municipality as indicated by the statistically significant differences in pH values across the study area, bearing in mind however that much more information is needed to ascertain the exact relationship between them. pH values ranging from 5.5 - 8.7 have previously been reported for boreholes in some parts of Calabar municipality [5]. A similar pH range of 6.0 – 6.3 was reported for Akim town, Essien Town, Ediba and Ikot Effanga Mkpa all in Calabar Municipality [7]. Mean values of 4.97±0.01, 5.33±0.03 and 5.42±0.02 were reported for Okoro Agbor, Orok Orok and Mount Zoin areas of Calabar [8]. In other parts of the country, a pH range of 5.68-5.72 was reported for groundwater Supplies in Akure, Nigeria [21] and 6.61- 694 for wells in Kubwa, Bwari Area Council, FCT, Nigeria [22]. A mean pH value of 6.13 was recorded by Longe in lagos 2010) [4] and 6.34±0.26 for ground water in Dareta village Zamfara State [16]. Electrical conductivity (EC) of water is a measure of the ability of the given water to conduct electricity due to the presence of ionic solutes [23]. The magnitude of the conductivity therefore is a useful indication of the total concentration of the ionic solute. The mean values of electrical conductivity of borehole water obtained in the study (169.71±26.54 for Satellite town, 260.80±36.15 for Etta Agbor road and 564.95±18.86 for Lemna road) reveals that the levels of dissolved ionic substances in boreholes around Satellite town were within the World Health Organization (WHO), European Union (EU) standards of 250 µs/cm and the Nigerian Standard for Drinking Water Quality (NSDWQ) guidelines for potable water of 1000 µs/cm (table 4). The EC for Boreholes around Etta Agbor and Lemna road were within the Nigerian Standards for Drinking Water Quality guidelines but above WHO and the EU standards. The pattern of EC displayed in the study (Lemna road > Etta Agbor > Satellite town) indicates that EC values were higher at the Lemna road where the final dumpsites for waste generated in Calabar is located followed by Etta Agbor road where there only few sporadic dumps and least at Satellite town where there are no dumpsites at all. The statistically significant differences in EC values express across the areas suggest that the solid waste dumpsite may have some significant influence on the electrical conductivity of borehole water in the study area. Digha and Ekanem [7] have previously reported lower electrical conductivity values ranging from 95.2 – 296 µs/cm for Akim town, Essien Town, Ediba and Ikot Effanga Mkpa all in Calabar Municipality. Mean values of 46.5±0.01 µs/cm, 97±0.24 µs/cm and 53.23±0.02 µs/cm were reported for Okoro Agbor, Orok Orok and Mount Zoin areas of Calabar [8]. A mean value of 0.41µs/cm was reported for ground water in Kubwa, Bwari Area Council, Fct, Nigeria [22] and 597.60±229.32 µs/cm for samaru, Zaria, Nigeria [24]. Mean values of 901.40±50.26µs/cm and 884.45±61.28 µs/cm were reported for groundwater in West Thrace, Turkey [25]. Oxygen molecules are dissolved in water and measured as dissolved oxygen (DO). The presence of dissolved oxygen water is good because the survival of most organisms in it depends on sufficient level of the dissolved oxygen. DO is therefore a good indicator of water quality [17] as its evaluation is crucial to the survival of organisms and ultimately in establishing the degree of freshness of the water [26, 27, 28]. The mean values of Dissolved Oxygen (DO) of borehole water obtained in the study (11.68±2.30 mg/l for Satellite town, 6.77±1.38 mg/l for Etta Agbor road and 5.01±0.74 mg/l for Lemna road) displayed the pattern State housing > Etta Agbor > Lemna road. The high DO obtained could be attributed to shallow nature of most of the borehole which could have made aeration easy. The study was carried out between June and August which corresponds to the peak of the wet season in the study area, the water table rises significantly during this period. The lower DO values observed at Lemna road may be explained on the account of closeness to the final solid waste dumpsite, which inferred the presence of oxygen demanding pollutants that use up the oxygen in water. This observation is in agreement with observations made by Igbinosa and Okoh [29]. The high DO observed at Satellite town maybe be due to near absence of oxygen demanding pollutant in the water. Solid waste dumpsite may therefore exert some level of influence on the dissolved oxygen component of ground water. World Health Organization, European Union and The Nigerian Standards for Drinking Water Quality do not have a specified standard for Dissolved oxygen for portable water. Do values ranging from 3.50 – 18.60 mg/l have previously been reported for boreholes in Calabar municipality [5].

Total dissolved solid (TDS) is a measure of total inorganic salts and other substances that are dissolved in water. The amount of TDS in a given water sample indicates the general nature of salinity of that water. The water that contains more than 500mg/l TDS is not considered suitable for drinking water supply. In the present investigation The mean values of TDS of borehole water (40.58±6.28 mg/l for Satellite town, 80.97±14.60 for Etta Agbor road and 181.97±7.15 for Lemna road) shows that total dissolved solutes across the three sampling stations were within the World Health Organization (WHO) and the Nigerian Standard for Drinking Water Quality (NSDWQ) guidelines limits of 500 mg/l (table 6). Statistical analysis indicates that the pattern of TDS displayed in the study (Lemna road > Etta Agbor > Satellite town) suggest refuse dumps may have influence on the TDS level of boreholes in the study area. The difference in TDS across the sampling stations was found to be statistically significant (ANOVA, $p < 0.05$), Limna road being significantly higher Satellite town and Etta Agbor road. The total dissolved solid value of boreholes water around Etta Agbor was also statistically lower than Lemna road at 95% confidence level. The high TDS observed in the study suggest a downward transfer of leachate into groundwater. Lower TDS values ranging from 3.40 – 10.5 mg/l have previously been reported for boreholes in Calabar municipality [5] and 47.6 -140 mg/l for Akim town, Essien Town, Ediba and Ikot Effanga Mkpa all in Calabar Municipality [7]. Mean values of 31.25±0.32 mg/l, 67.9±0.45 mg/l and 37.23±0.19 mg/l were reported for Okoro Agbor, Orok Orok and Mount Zoin areas of Calabar [8]. TDS values ranging from 8mg/l - 342mg/l was reported for groundwater Supplies in Akure, Nigeria [21]. A range of 208 – 370mg/l was reported for ground water in Kubwa, Bwari Area Council, FCT, Nigeria [22]. Mean values of 456.60±24.31mg/l and 450.65 ± 30.80mg/l were reported for groundwater in West Thrace, Turkey [25]. World Health Organization does not directly consider electrical conductivity in guidelines for drinking water quality [18], but it does give recommendations for dissolved solids because of taste considerations [24]. Total dissolved solid produces no major health hazards but high concentrations decreases the palatability of water and may also cause gastro-intestinal irritation in humans and laxative effects [30]. It also makes the water corrosive, salty, thus resulting in scale formation which interfere and decrease efficiency of hot water heaters.

The total suspended solid found in water is the sum of the total quantity of insoluble matter contained in the water. It consist of silt, clay, fine particles of organic and inorganic matter, which is regarded as a type of pollution because water high in concentration of suspended solid may be aesthetically unsatisfactory for domestic use. The effect of presence of total suspended solids is the cloudiness of the water as a result of particulate matter being suspended within it. The mean TSS value recorded in this study (0.02±0.02 mg/l for Satellite town, 0.26±0.09 mg/l for Etta Agbor, 0.62±0.22 mg/l for Lemna road) revealed the trend Lemna road > Etta Agbor > Satellite town which suggest that the refuse dumpsites have reasonable influence on the TSS of borehole water in the study area. Digha and Ekanem [7] have previously reported similar TSS values ranging from 0.00 – 2.00 μs/cm for Akim town, Essien Town, Ediba and Ikot Effanga Mkpa all in Calabar Municipality. Mean values of 0.07±0.001, 0.001±0.00 and 1.79±0.02 have been reported for Okoro Agbor, Orock Orock and mount Zion areas of Calabar [8]. Higher values ranging from 208- 284 mg/l was reported for ground water in Kubwa, Bwari Area Council, FCT, Nigeria [22], 143.2- 154.2 for Samaru area, Zaria [24].

4.2.2 Metals content of borehole water

The mean lead concentration of borehole water obtained in the study (0.005±0.00 mg/l for Satellite town, 0.041±0.01 mg/l for Etta Agbor road and 0.07±0.02 mg/l for Lemna road) displayed the pattern State housing > Etta Agbor > Lemna road. The significantly (ANOVA, $p < 0.05$) higher lead concentration observed at Lemna road may be explained on the account of closeness to the final solid waste dumpsite, which suggest that the dumpsite actually influenced the concentration of the metal in the area. This observation is in agreement with Eni *et al*., [5] who in their studies concluded that dumpsite through the process of percolation and infiltration contaminates the groundwater in Calabar municipality. Lower mean lead content of 0.002±0.00 mg/l [8] and 0.07±0.01mg/l [31] have been previously reported for some parts of Calabar. World Health Organization, European Union and The Nigerian Standards for Drinking Water Quality limits for lead in drinking water is 0.01mg/l. Lead concentrations of borehole water from Satellite town where found to be within the permissible standards thus fit for use as drinking water with particular respect to lead contamination. Lead content of borehole water from Lemna road was found to be seven times permissible limit and that from Etta Agbor road about four times the limit. These findings indicate that borehole water from these areas poses serious toxicological risk with respect to lead intoxication. Lead is one of the limited classes of element that can be described as purely toxic. Most other elements though toxic at high concentration are actually required nutrients at lower levels [32]. There is no exposure level below which lead appear to be safe. Lead is number 2 in the Agency for Toxic Substances and Disease Registry (ATSDR) Top 20 list, and account for most of the cases of pediatric heavy metal poisoning. It interferes with the normal development of a child's brain and nervous system; therefore children are at greater risk of lead toxicity. The effect on peripheral nervous system on the other hand, is more pronounced in adults. Lead absorption constitutes serious risk to public health. It induces reduced cognitive development and intellectual performance in children, increased blood pressure, and cardiovascular diseases in adult as well as liver and kidney dysfunction [3].

The mean cadmium, copper and zinc content of boreholes water in this study also displayed the pattern, State housing > Etta Agbor > Lemna road, with statistically significant (ANOVA, $p < 0.05$) differences between them. The higher concentrations of these metals observed at Lemna road where the final dumpsite in Calabar as a whole is located followed by Etta Agbor area where there are a few sporadic dumps also suggest that the dumpsite actually influenced the concentration of the metals in borehole water from area under study.

The mean concentration of cadmium in the study (0.007±0.00 mg/l for Satellite town, 0.02±0.01 mg/l for Etta Agbor road and 0.03±0.01 mg/l for Lemna road) revealed that the cadmium content of borehole water in the study area were all above the World Health Organization and European Union standards of 0.005 mg/l and The Nigerian Standards for Drinking Water Quality limits for cadmium in drinking water of 0.003 mg/l. This implies that borehole water in the study area poses health risk with respect to cadmium intoxication. Cadmium concentration ranging from 0.0145 to 0.2657 mg/l was reported for boreholes around Solous landfill at Igando in Alimosho Local Government Area of Lagos State, Nigeria [33]. Cadmium is one of the most abundant, naturally occurring elements; it is a soft, malleable, ductile, bluish-white bivalent metal and is highly carcinogenic for living beings. Cadmium is an extremely toxic metal and number 7 on ATSDR's "Top 20 list". It is used in nickel-cadmium batteries, PVC plastics, and paint pigments. It can be found in soils because insecticides, fungicides, sludge, and commercial fertilizers that use cadmium are used in agriculture. Cigarettes also contain cadmium. Other known sources of exposure are electroplating, motor oil, and exhaust. It has been found that cadmium has not a single physiological function within the human body. Even low concentration of cadmium can adversely affect the number of metabolic processes in the human body. Once absorbed, it accumulates in the body even throughout the life. Cadmium intoxication can lead to kidney, bone and pulmonary damages. 2-7% of ingested cadmium is absorbed in the gastrointestinal system. Target organs are the liver, placenta, kidneys, lungs, brain, and bones [34, 35]

The mean concentration of copper in the study (0.66±0.23 mg/l for Satellite town, 1.62±0.12 mg/l for Etta Agbor road and 3.01±0.11 mg/l for Lemna road) shows that the level of copper in borehole water from Lemna road and Etta Agbor road were above the World Health Organization and the Nigerian Standards for Drinking Water Quality limits for copper in drinking water of 1 mg/l and European Union standards of 2.00 mg/l. This implies that borehole water in the study area poses health risk with respect to copper intoxication. The mean copper content of borehole water from Satellite town on the other hand was found to be within the permissible limits and poses no toxicological risk. Mean values of 0.03±0.01 mg/l was previously reported for boreholes around landfill areas such as Atimbo, Anantigha, Ibom layout in Calabar municipality [31]. 0.001 mg/l was reported for boreholes around Okoro Agbor area of Calabar municipality [8]. At levels above 2.5 mg/litre, copper imparts an undesirable bitter taste to water; at higher levels, the colour of water is also impacted [8]. Although copper toxicity in humans is rare, both acute and chronic exposure to Copper leads to it induced toxicity. Most of the absorbed Copper is stored in the liver and bone marrow. Liver, bone and the central nervous system are the primary targets of Copper induced toxicity. Acute Copper toxicity causes vomiting, diarrhea, hypertension, and cardiovascular collapse. Abnormal accumulation of Copper in the tissue and blood causes Wilson disease [8]

The mean concentration of zinc in the study (0.97±0.24 mg/l for Satellite town, 2.00±0.18 mg/l for Etta Agbor road and 4.08±0.15 mg/l for Lemna road) indicates that the zinc content of borehole water in the study area were all within the World Health Organization and European Union standards of 5 mg/l. The mean zinc content of borehole water from Lemna road was however above the Nigerian Standards for Drinking Water Quality limits for zinc in drinking water of 3 mg/l. Mean values of 0.05±0.02 and 0.03±0.01were previously reported for boreholes around landfill areas such as Atimbo, Anantigha, Ibom layout in Calabar municipality [31]. Agbor et al [8] reported that zinc level of borehole water from Orok Orok, Okoro Agbor and Mount Zion areas of Calabar Municipality are below detectable limits. Dissolved zinc can cause the water to have a bitter, medicinal taste. Concentrations of 30 mg/L may give the water a milky appearance. When the water is heated, elevated levels of zinc may produce a greasy film on top of the water [8]. Zinc is an important element the body needs to function properly. A small amount of Zinc is necessary for a balanced human diet. However, exposure to excess amount of Zinc can result to Zinc poisoning. Zinc is an intestinal irritant, and the first sign of Zinc poisoning is usually intestinal distress. This includes vomiting, stomach cramps, diarrhea, and nausea. Further symptoms of Zinc poisoning are low blood pressure, urine retention, jaundice, seizures joint pain, fever, coughing, and a metallic taste in the mouth as well as induced Copper deficiency [3].

4.2.3 Correlation between physicochemical parameters of water quality

A significant ($p < 0.01$) positive correlation was observed between each of the metals indicating that an increase in one metal is associated with an increase in the other metals (Table 7) suggesting that a similar source is responsible for the presence of these metals at the concentration determined. Significant ($p < 0.01$) positive correlations were also observed between metals concentrations and TDS, TSS and EC indicating that increase in metal concentration is associated with increase in TDS, TSS and EC. On the other hand, significant ($p < 0.01$) negative correlations were observed between metal concentrations and pH, temperature and dissolved oxygen indicating that decreasing pH, temperature and dissolved oxygen is associated with increase in metal concentrations. Significant positive correlations were observed between temperature and pH, temperature and DO, pH and DO, TDS and EC, and between TSS and EC while negative correlations were observed between EC and temperature, EC and pH, EC and DO, TDS and temperature, TDS and pH, TDS and DO, TSS and temperature, TSS and pH and between TSS and DO. The correlations were significant at 99% confidence level (Table 7). Conductivity shows significant correlation with all the parameters studied. Kumar and Sinha [36] in their studies on drinking water quality management through correlation studies among various physic- chemical parameters, suggested that underground drinking water quality can be checked effectively by controlling conductivity of water and this may also be applied to water quality management of study areas. It is measured with the help of EC meter which measures the resistance offered by the water between two platinized electrodes. The instrument is standardized with known values of conductance observed with standard KCl solution

5.2 Conclusion

Solid waste disposed in open dumpsite is usually subjected to series of complex biochemical and physical processes, which lead to the production of both leachate and gaseous emissions. When leachate leaves the dumpsite and reaches the water table, it results in borehole contamination. Assessment of the impact of solid waste dumps on ground water quality in Calabar municipality carried out in this study revealed that solid waste dumps have significant adverse influence on the ground water quality. When compared with World Health Organization, European Union and the Nigerian Standards for Drinking Water Quality standards, borehole water in the study area especially in the vicinity of the final dumpsite at Lemna road was seriously implicated. Continuous use of the water for drinking or other domestic purposes without any form of physical or chemical treatment could pose serious toxicological risk. This study therefore recommended that groundwater in Calabar municipality should be put under continuous surveillance in other to protect it from further degradation and safeguard public health.

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