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Impact of Inorganic Contaminants from Dumpsite Leachates on Natural Waters in the Enugu Metropolis, South Eastern Nigeria

Daniel Chukwuemeka Ozoko
Senior Lecturer, Department of Geology and Mining,
Enugu State University of Science and Technology, Agbani, Nigeria
Ifeoma Linda Onyekwelu
Student, Department of Geology and Mining,
Enugu State University of Science and Technology, Agbani, Enugu State, Nigeria

Abstract:
This study evaluates the impact of inorganic contaminants from dumpsite leachates on the quality of the natural water sources in the Enugu metropolis. The concentration of cations including sodium (Na^+), calcium (Ca^{2+}), and potassium (K^+) and anions such as manganese (Mg^{2+}), bicarbonates (HCO_3^-), sulphates ($SO4^{2-}$) and chlorides (Cl^-) were analyzed in 9 surface and groundwater samples collected from the study area. Laboratory analyses of the samples reveal a concentration range of 8.05 – 20.15 mg/l for sodium, 0.15 - 8.11 mg/l for calcium, 0.11 – 1.03 mg/l for potassium, 0.02 – 3.04 mg/l for magnesium, 16.88 – 65.66 mg/l for bicarbonates, 14.28 – 60.99 mg/l for sulphate and 10 – 22.69 mg/l for chlorides in the natural waters of the study area. A general trend among the mean values of the cations in the water show that $Na^+ > Ca^{2+} > K^+ > Mg^{2+}$ while the anion levels in the water samples are in the order $HCO_3^- > SO4^{2-} > Cl^-$. Three water types were identified, based on characterization in the Piper trilinear diagram. They include Na-Mg-HCO3, Ca-Mg-SO_4 and Ca-Mg-Na-K-Cl-SO_4^{2-} which are reflective of the contribution of various wastes in the area such as corrosive metals and sewage. In general, both water sources are alkaline to strongly acidic with all the tested inorganic parameters having concentrations that fall within the WHO acceptable limits. However, very high chloride values were recorded in the leachates indicating the possibility of organic contamination of the natural waters in the area.

Keywords: *Ugwuaji, landfill, inorganic contaminants, water quality*

1. Introduction

Water is undoubtedly the most beneficial resource of the earth available to man. Covering about ¾ of the earth's surface as oceans, streams, rivers, seas and lakes, water has proven useful to man for agricultural, industrial, domestic and other life sustaining purposes (Elueze et al., 2004). Aside the surface occurrence of water, water also occurs at the subsurface as groundwater. Over the last few years, attention has been directed towards assessing the quality of this surface and groundwater as well as how much their quality is being impacted by the activities of man (Norman et al., 2006). Enugu metropolis is an area blessed by an abundance of surface and groundwater resources; however, the citing of a major dumpsite in the area has raised concerns about the possible impact of leachate-yielding inorganic contaminants on the quality of the natural waters occurring within the area. Fawell, 1993 has carried out extensive studies on the impact of inorganic contaminants from dumpsite leachates on the quality of surface and groundwater. The unhealthy state of the Ugwuaji dumpsite, located within the Enugu metropolis and the presence of inorganic waste materials in the dumpsite necessitated this study. As is the case in most developing nations, the only available means of waste management is the use of municipal landfills which produce leachates that yield inorganic contaminants that don't just affect the surface and groundwater quality but also affects the health of humans adversely upon consumption. Diarrhea and chronic dehydration are attendant diseases and infections associated with the consumption of water polluted by inorganic materials.
Based on the above background, this study focuses on the evaluation of natural water sources within the Enugu metropolis with a view of ascertaining the impact of inorganic contaminants from the dumpsite leachates on their quality. In addition, this work examines the possible sources of such inorganic contaminants as well as the portability of the waters for consumption purposes.

2. Dumpsite Description

The Ugwuaji dumpsite is located at about 1.6km off the Enugu-Port Harcourt expressway in Enugu metropolis, Southeastern Nigeria. The Enugu metropolis is bounded by notable settlements such as Emene, Nkpologu and Ugwuaji and lies within latitudes N6^{0}24’00’ and N6^{0}30’00’ and longitudes E7^{0}30’00’ and E7^{0}36’00’ (fig 1). The Ugwuaji dumpsite is the final disposal ground for all wastes generated within and around the Enugu metropolis including industrial, agricultural and domestic wastes (fig. 2). It sits on a gently sloping terrain dipping in all directions away from its centre (fig. 3) and measures about 1.6km by 0.5km in land coverage. The thickness of the dumpsite ranges from 3m to 8m and there is a noticeable absence of bottom liners in the dumpsite making the surrounding surface and groundwater susceptible to leachable contaminants.

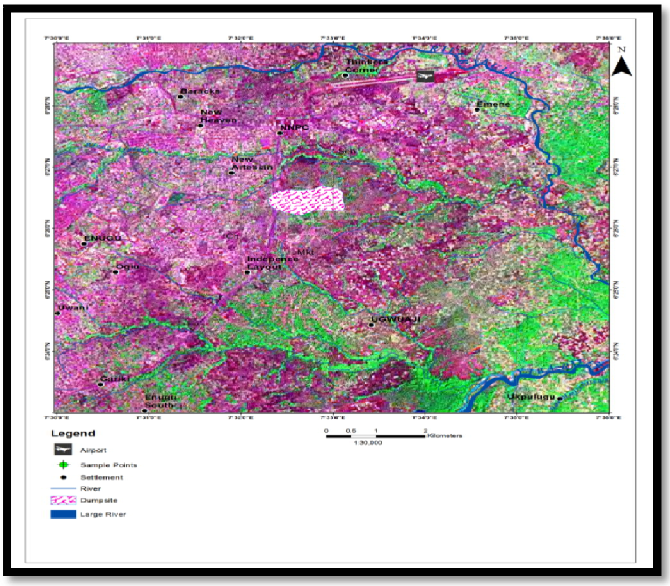

Figure 1: Satellite Map Showing Dumpsite Location

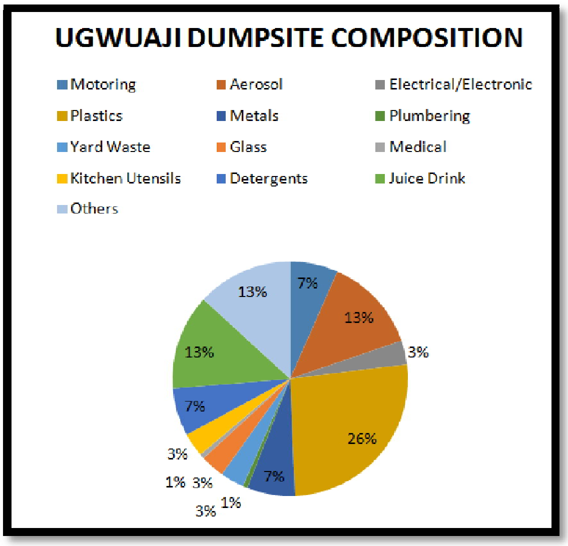

Figure 2: Chart of Waste Distribution in the Dumpsite

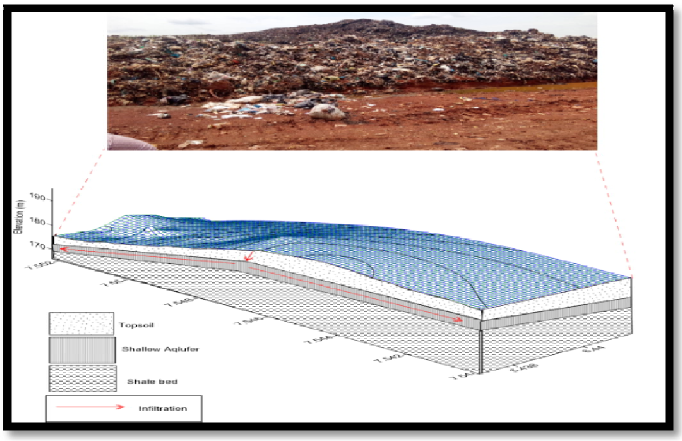

Figure 3: Schematic Diagram of the Dumpsite Showing Its Topography

3. Geology, Physiography and Hydrogeology of the Study Area

Two geologic formations underlie the study area namely- the Coniacian Agbani Formation and the Campanian Enugu Formation (fig 4). The older Agbani Formation marks the end of the deposition of the Southern Benue Trough and consists of medium to coarse grained, poorly sorted, moderately consolidated and cross bedded sandstones with claystones and lenticular shales. The Agbani Formation dips in the West-Northwest direction at a dip amount ranging between 3^0 and 12^0. The Enugu Formation on the other hand is a member of the Nkporo Group which lies within the Anambra Basin and consists mainly of dark grey marine shales, sandstones and siltstone interbeds. It dips at an amount ranging between 4^0 and 8^0 in the West-Southwest direction.

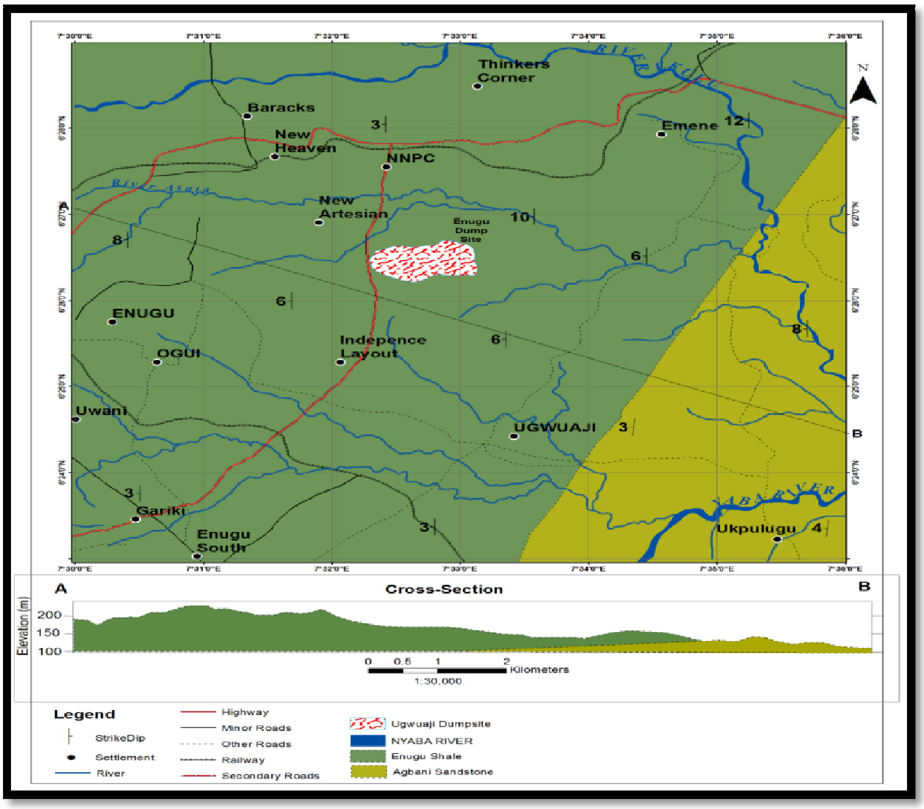

Figure 4: Geologic Map of the Study Area

Physiographically, the Enugu-Awguenscarpment is the most striking feature of the study area, occurring as part of the Nsukka-Okigwe Cuesta (Reyment, 1965). The elevation of the enscarpment ranges from 450m to 530m and slopes between 3% and 6% in the dip slope part to between 55% and 65% along the scarp face (Ofomata, 1985) (fig 5).

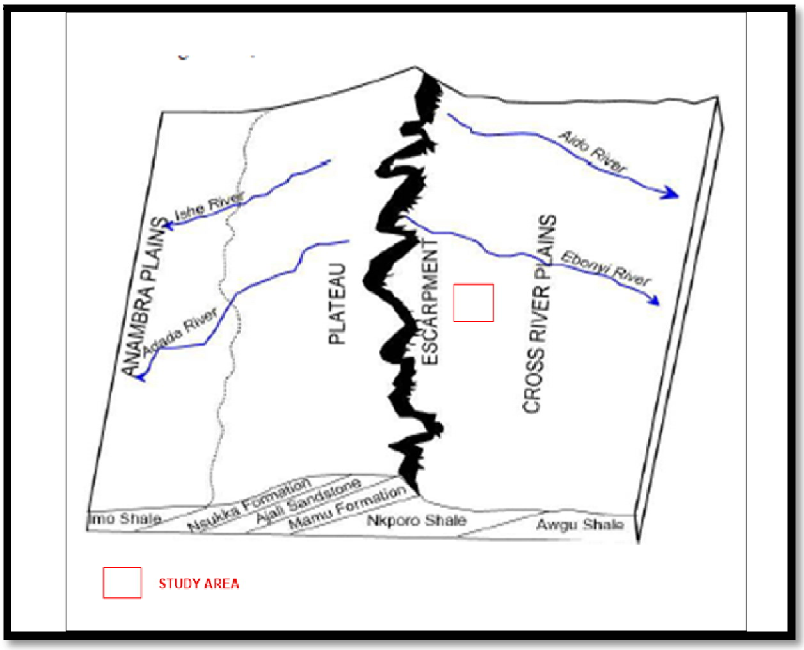

Figure 5: The Physiographic Provinces of the Study Area (After Ofomata, 1978)

The Enugu-Awguenscarpment is indented with river valleys which form the source of streams rising from an elevation of about 30m and flow down. Major rivers in the study area include Ekulu, Inyaba, Nyo and Asata rivers, all of which flow in a dendritic pattern due to the topography of the area (fig 6). The groundwater flow system on the other hand is in the northeast-southwest direction as defined by the structural and stratigraphic framework of the study area (Onyekuruet. Al, 2010).

The major source of recharge of surface water and groundwater in the study area is rainfall with the surface water infiltrating the groundwater system in a radial pattern due to the topographic outline of the area.

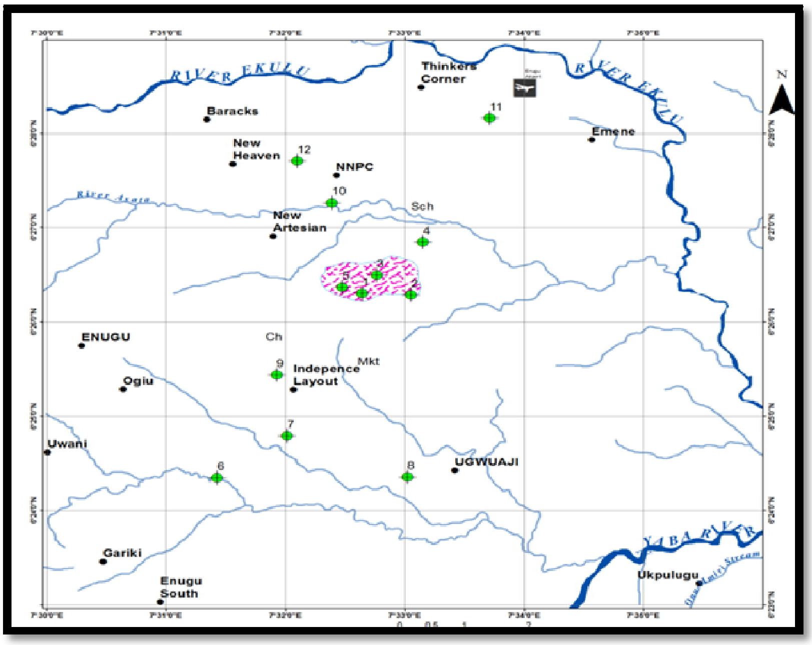

Figure 6: Drainage Map of the Study Area

4. Methodology

4.1. Sampling

12 water samples were collected from the study area comprising 7 hand-dug wells, 3 leachate samples and 2 rivers (table 1). The rivers and hand-dug wells constitute the major sources of water supply for inhabitants while leachate samples were collected from trenches dug into the dumpsite.

Sample bottles were flushed with phosphate-free detergent and rinsed with de-ionized water as well as with sample fluids prior to collection. The samples were adequately labeled and preserved in a refrigerator until they were taken to the laboratory for analysis.

Location	Georefernce Number		Distance From Dumpsite	Sample Type
	Latitude	Longititude		
Sample 1	N6^{0}26^{1}18.2^{11}	E7^{0}32^{1}37.6^{11}	5m	**Leachate**
Sample 2	N6^{0}26^{1}17.3^{11}	E7^{0}33^{1}02.2^{11}	6m	
Sample 3	N6^{0}26^{1}12.3^{11}	E7^{0}33^{1}20.2^{11}	0m	
Ebenizer Ang. Ch. HDW	N6^{0}26^{1}21.5^{11}	E7^{0}32^{1}28.8^{11}	20m	**Ground Water**
Goshen Estate HDW	N6^{0}26^{1}50.9^{11}	E7^{0}33^{1}08.8^{11}	200m	
Ike Ekweremadu HDW	N6^{0}25^{1}26.4^{11}	E7^{0}31^{1}54.6^{11}	900m	
Umunaji Ngene HDW	N6^{0}24^{1}48.3^{11}	E7^{0}32^{1}01.0^{11}	950m	
Obeagu HDW	N6^{0}24^{1}19.6^{11}	E7^{0}32^{1}59.2^{11}	970m	
Vission Comp. HWD	N6^{0}28^{1}9.57^{11}	E7^{0}33^{1}42.35^{11}	500m	
Thinkers Corner HDW	N6^{0}27^{1}43.1^{11}	E7^{0}32^{1}06.1^{11}	1000m	
Nyo River	N6^{0}24^{1}22.3^{11}	E7^{0}31^{1}27.0^{11}	1000m	**Surface Water**
Asata River	N6^{0}27^{1}18.7	E7^{0}32^{1}22.4^{11}	300m	

Table 1: Showing Locations of Samples Collected

4.2. Laboratory Analysis

Chemical analyses of the samples were initiated as soon as they arrived the laboratory in accordance with the APHA (1994) methods. Cations such as Ca^{2+}, Mg^{2+}, $Na^+$and K^+ were determined using the Buck model 210/211 AAS 220GF graphite furnace and 220 AS Autosampler, which was calibrated by 2-point calibration using the appropriate Matrix Blank for the flame and the standard set within the calmax range for each model. The conditions which the cations were done was by Air/Acetylene flame, N2O/Acetylene flame, Integrated mode, Normal parameter and the samples were digested using Nitric acid per chloric acid. On the other hand, anions such as Cl^-, HCO_3^-, SO_4^{2-} and NO_3 were determined by volumetric, titrimetric and colorimetric analysis using ascorbic acid and molybdate blue methods.

Parameters	1	2	3	4	5	6	7	8	9	10	11	12
Sodium (mg/l)	20.12	27.56	30.66	18.13	20.15	10.62	12.54	9.03	14.02	10.11	9.08	8.05
Calcium (mg/l)	6.08	6.08	9.65	6.12	8.11	4.15	7.06	0.15	2.11	5.13	1.14	3.11
Potassium (mg/l)	3.31	3.30	6.82	1.03	0.23	0.40	0.42	0.13	0.12	0.11	0.13	0.13
Magnesium (mg/l)	4.11	2.09	4.05	1.03	3.04	0.06	0.54	1.03	0.02	0.26	0.03	0.04
Bicarbonate (mg/l)	316.26	216.33	314.62	65.66	43.11	22.43	20.11	18.34	18.36	16.19	19.21	16.88
Sulfate (mg/l)	118.15	112.19	124.67	14.28	60.99	60.87	43.31	33.87	30.61	21.12	55.87	52.61
Chloride (mg/l)	40.00	45.00	61.41	20.75	22.69	11.08	10.00	10.00	10.00	14.00	14.00	21.12

Table 2: Concentration of Inorganic Elements

SAMPLE ID(1). Leachate(2). Leachate (3). Leachate (4). Back of Goshen Estate hand dug well(5). Ebenizer Anglican Church hand dug well(6). Nyo River(7). Hand dug well at Umunaji Ngene Ugwuaji(8). Hand dug well at Obeagu Ugwuaji (9). Hand dug well at Ike Ekweremadu Street (10). Asata River (11). Hand dug well at Vision Company (12). Hand dug well at Thinkers Corner.

5. Results and Discussion

The results of the analysis of the inorganic chemical parameters of the water samples are presented in table 2. Cations including Ca^{2+}, Mg^{2+}, Na^{+} and K^{+}as well as anions such as Cl^{-}, HCO_3^{-}, SO_4^{2-} and NO_3were tested in the samples due to their hazardous nature, high sorption and precipitation potential capable of polluting natural waters (surface and groundwater).
The general trend among the mean values of the cations in the water show that $Na^{+}>Ca^{2+}>K^{+}>Mg^{2+}$(fig 7) while the anion levels (mg/L) in the samples are in the order: $HCO_3^{-}>SO4^{2-}>Cl^{-}$(fig 8).

5.1. Assessment of Inorganic Contaminants

5.1.1. Sodium (Na^{+})

Sodium content, which is the most abundant of all the inorganic elements, vary between 20.12mg/l and 30.16 mg/l in LCH1, LCH2 and LCH3, while it ranged from 8.05mg/l to 20.15mg/l in shallow hand dug wells. Samples collected from surface water bodies however showed a sodium concentration range of 10.11mg/l to 10.62mg/l. Generally, the obtained values of sodium in the study area are lower than the 200mg/l limit stipulated by WHO (2011) and SON (2007) for portable drinking water. The relatively high content of sodium measured within the leachates samples indicates the presence of industrial materials or sewage.

5.1.2. Calcium (Ca^{2+})

Calcium which is next to sodium in abundance is responsible for the temporary hardness in water. Calcium content in the samples, vary between 6.08mg/l to 9.65mg/l at LCH1, LCH2 and LCH3 whereas, the concentrations within the shallow hand dug wells ranged between 0.15mg/l to 8.11mg/l while surface water bodies ranged from 4.15mg/l to 5.13mg/l.The obtained values are generally lower than the 200mg/l standard stipulated by FEPA (1991) for portable drinking water. A similar trend was also observed in the surface water samples. The highest level of calcium was recorded inthe leachate samples and the least at surface water bodies. Calcium is also biophile, and therefore its low concentration can be explained in terms of the low solubility of feldspartic minerals that comes in contact with the waters.

5.1.3. Potassium (K)

Potassium, a biophilous element [Kjeldsen et al., 2002] with low geochemical mobility comes next in term of concentration in the water samples. It ranged in concentration from 3.30mg/l to 6.82 mg/l within the LCH1, LCH2 and LCH3and ranged between 0.12mg/l to 0.42mg/l in the shallow hand dug wells. The surface water bodies showed a potassium concentration which varies between 0.11mg/l to 0.40mg/l. The potassium content in the waters is most likely sourced from the immature phase of organic materials dumped in the site.

5.1.4. Magnesium (Mg^{2+})

Magnesium concentrations in the samples ranged from 2.09mg/l to 4.11mg/l at LCH1, LCH2 and LCH3 and varied between0.02mg/l to 3.04mg/l in the shallow hand dug wells. It however ranged from 0.06mg/l to 0.26mg/l in the surface water bodies. The concentration of magnesium in the leachate samples is higher than shallow hand dug wells and surface water samples.

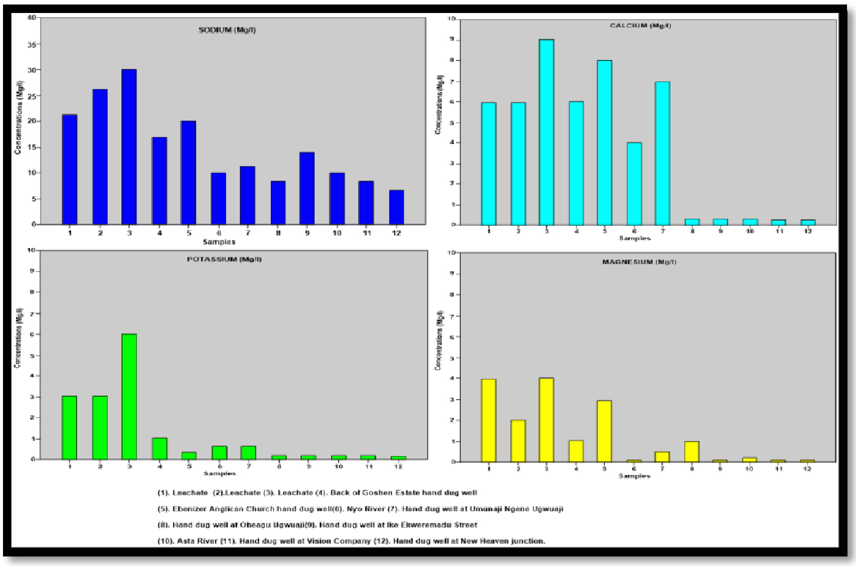

Figure 7: Anomalous Concentrations of Cations in the Samples Measured

5.1.5. Bicarbonate (HCO_3^-)

The values of bicarbonate observed in the area range between 216.33mg/l to 316.26mg/l within the LCH1, LCH2 and LCH3 samples, from 16.88mg/l to 65.66mg/l in the shallow hand dug wells and from 16.19mg/l to 22.43mg/l in the surface water bodies. Apart from leachate samples, all the other water samples like shallow hand dug wells and surface water bodies are below the 250mg/l prescribed by regulatory body. The high concentrations of bicarbonate within the leachates samples emanated from the metallic wastes dumped in the site which corrodes high bicarbonate in the leachate samples.

5.1.6. Sulfate (SO_4^{2-})

Sulfate which is the next abundant element in the study area ranges from 112.19mg/l to 124.67mg/l within LCH1, LCH2 and LCH3. Shallow hand dug wells showed sulfate concentrations ranging from 14.28mg/l to 60.99mg/l while surface water bodies comprised of sulfate ranging from 21.12mg/l to60.87mg/l. The leachate samples have the highest concentrations of sulfate which is above the 100mg/l limit stipulated by FEPA (1991) for portable drinking water while shallow hand dug wells and surface water bodies are below 100mg/lsulphate concentration limit. The high content of sulfate in the leachate samples may have been sourced from decomposition of inorganic contaminants in the dumpsite. The high concentration of sulphate observed in the leachates is dangerous as it causes dehydration and diarrhea in children (Longe and Balogun, 2010).

5.1.7. Chloride (Cl^-)

Chlorides are significant in perceiving the contamination of ground water by waste water. The acceptable limit of chloride in drinking water is 250 mg/L. The values of chloride observed in all sampling points were well above the standard acceptable limits prescribed by WHO (2011). The presence of chloride in greater amounts in LCH1, LCH2 and LCH3, may be an indication of pollution from industrial or domestic wastes.The high concentration of chloride indicates organic pollution and excess of chloride in water is an important index of pollution and considered as tracer for ground water contamination.

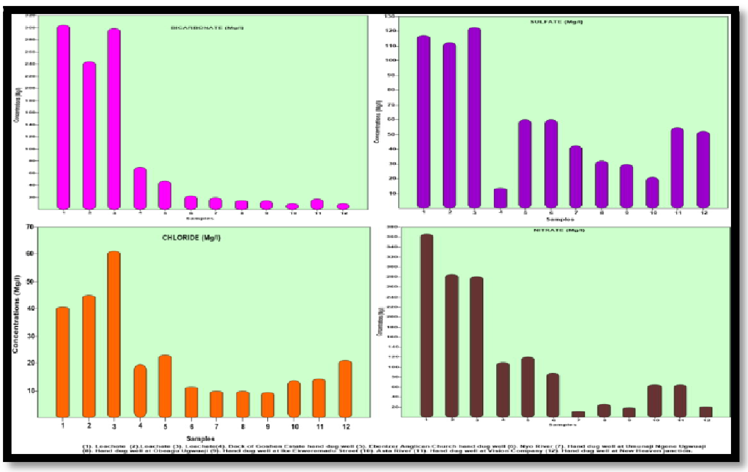

Figure 8: Anomalous Concentration of Anions in the Samples Measured

5.2. Water Types

The measured hydrochemical parameters of the leachates, shallow hand-dug wells and surface waters were plotted on a Piper trilinear diagram (fig 9) to properly discriminate the distinct water types in the study area.

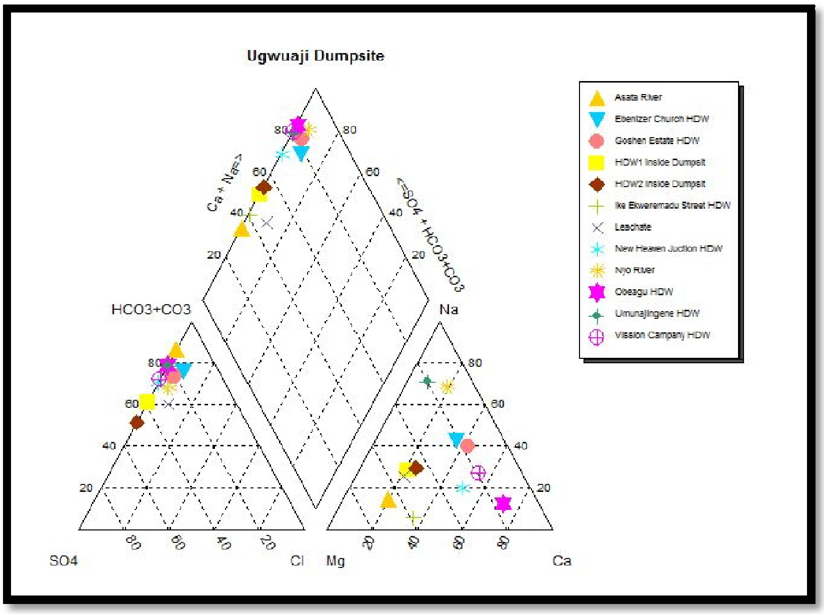

Figure 9: The Piper Trilinear Plots of Samples Measured in the Area

Based on the Deutsch (1997) classification, three important water facies were delineated.

i. Na-Mg-HCO_3
ii. Ca-Mg-SO_4
iii. Ca-Mg-Na-K-Cl-SO_4^{2-}

The results therefore imply that the natural waters in the study area has high SO_4^{2-}relative to HCO_3 (see anion triangle in Fig. 9), which indicates a total deviation from a carbonate aquifer type. In the cationtriangle, about 58% of the sample set (LCH1, LCH2 and LCH3) was Na-type, 33% of the sample set(shallow hand dug wells) showed no dominant type of cation andonly surface water samples were Mg-type indicating that the chemical properties of groundwater are dominated by alkaline earths (Na, Ca,) and strong acids (HCO_3, SO_4^{2-}).

6. Conclusion and Recommendation

Results of the hydrochemical studies of the water samples from and around the Ugwuaji dumpsite in the Enugu metropolis show that they yield inorganic elements including Na^+, Ca^{2+}, K^+,Mg^{2+}, HCO_3^-, $SO4^{2-}$ and Cl^-. These hydrochemical parameters reveal that the natural waters in the study area are mainly alkaline earth (Na, Ca) to strongly acidic ($HCO_{3,}$ SO_4^{2-}) which are reflective of the contribution of various wastes in the area such as corrosive metals and sewage.

Most of the measured hydrochemical parameters show relatively higher values in the leachates than the surface waters and shallow hand-dug wells which had values that satisfied the WHO standard for domestic, agricultural and industrial uses. However, the very high chloride values recorded in the leachates is a strong indication of possible organic contamination of the natural waters in the area.

Further studies should therefore be carried out to assess the microbial and organic parameters of the water sources so as to prescribe necessary treatment measures.

7. Acknowledgements

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