Nutrient Status of Leachates from Selected Dumpsites in Port Harcourt Metropolis, Nigeria.

[1]Iyama, William Azuka; [2]Boisa Ndokiari and [2]Maduelosi, Jane N.

[1] School of General Studies, Rivers State College of Health Science and Technology, PMB 5039 Port Harcourt, Nigeria. E-mail:willy4a@yahoo.com;

[2] Department of Chemistry Rivers State University, PMB 5080, Port Harcourt, Nigeria

Author IYA designed the study, carried out the investigation and drafted the first manuscript. Author BN supervised and read the first manuscript. Author MJN also supervised the work. All authors read and approved the final manuscript as submitted.

Abstract

This study was carried out to determine the levels of available nutrient parameters present in leachates from some selected dumpsites in Port Harcourt metropolis. Leachates from the 3-selected dumpsites were analyzed and compared with the seasons, controls and established standards using descriptive and analytical designs. Integrated samples were collected during both wet and dry seasons and analyzed for NO_3^- PO_4^{3-} , SO_4^{2-} and NH_4^+. The use of 2-way ANOVA, t-test and mean variation were applied to explain trend and seasonal variations. The results showed that there was no significant difference in temporal dimension (seasonally) but there was a high level of spatial variation (stations) in most measured parameters. Though some of the parameters were relatively low compared to standard limits; the study revealed that these dumpsites remain major polluting and nutrient enriching sources to the ecosystem. In order to reclaim these dumpsites from acute contamination, government at all levels should ensure the introduction of active remediation processes alongside physico-chemical methods which can ameliorate the effects of pollution in the environment.

Original Research Article

Keywords: Nutrient, Eutrophication, Leachates, Dumpsites, Landfill

INTRODUCTION

According to Weli and Adekunle (2014), Landfilling has been one of the best forms of waste disposal management as it reduces environmental hostility mostly for reducible, recyclable and combustible wastes. Research has shown that about $\frac{3}{4}$ of the developing countries practice open dumping which is considered old-fashioned and even unfriendly to ecosystem [1].

According to Inyang and Onwuteaka [2], leachates are liquids emanating from water collecting contaminants as it flows through wastes and agricultural applications such as fertilizers and pesticides. Leaching can occur in waste dumps, farms and landfills which may lead to the pollution of surface water, groundwater and even air and soil.

Therefore, the leaching of substances produces a collection of liquids known as leachates which are usually very odoriferous and offensive to the ecosystem.

According to Anikwe and Nwobodo [3], a major environmental issue in our cities today is improper solid waste handling and disposal. Though Njoku [4] suggested that disposal of organic waste into agricultural land improves its properties. The major in our country cities do not sort generated waste as to identify the unit impact of their inorganic components. Pollutants even in waste dumps are potential threats to the ecosystem [5]. According to Amadi et al., [6], dumpsites in Nigeria are abandoned burrow pits and acquired areas which were not selected following any legal environmental impact assessment studies. Afterwards, these waste dumps become hazards and potential threats to the soil and groundwater as a result of percolation of leachates with time [7]. Hazardous materials which dissolve in leachate may contaminate soil and groundwater [8,9]. Leachates are water that flows and passes through waste disposal sites leading to contamination [10] thereby causing alteration or changes in the nature and composition of the contaminated environment.

This study therefore, was undertaken to investigate the nutrient status of leachates from selected dumpsites within Port Harcourt metropolis. These dumpsites were selected because of their proximity to inhabited areas of the city.

MATERIALS AND METHODS

Port Harcourt is the capital city of the oil rich Niger Delta State of Rivers Nigeria. It lies along the Bonny River and between Longitudes of $6^{o}59^{'}55^{"}$ and Latitude of $4^{0}47^{'}21^{"}$. Port Harcourt has a population of about 1,382,592 as of 2006 which has grown to 1,865,000 inhabitants as at 2016 [11]. This is about 34% increase in population within a period of 10 years. The area covered by Port Harcourt was $15.54km^2$ in 1914 but grew to $360km^2$ by the 1980s due to modernization and urbanization [12]. The study by Ogbonna et al. [12], estimated a total of 207.3 tons of solid waste generation giving per capita annual waste generation rate of 0.53tonnesequivalent to a waste generator rate of 1.45kg per capita daily.

Three active dumpsites were chosen for this study within the Port Harcourt Metropolis. These are located primarily in two local governments of Obio-Akpor and Etche. These stations were labeled according to the dumpsite but using the letters A, B and C where C was the control station taken away from the dumpsite. Port Harcourt is the capital city of Rivers State and the hub of the petroleum industry in the Niger Delta Region of Nigeria. It has an estimated population of about 1,356,000 people but Rivers State has a total population of about 5,198,716 people [13].

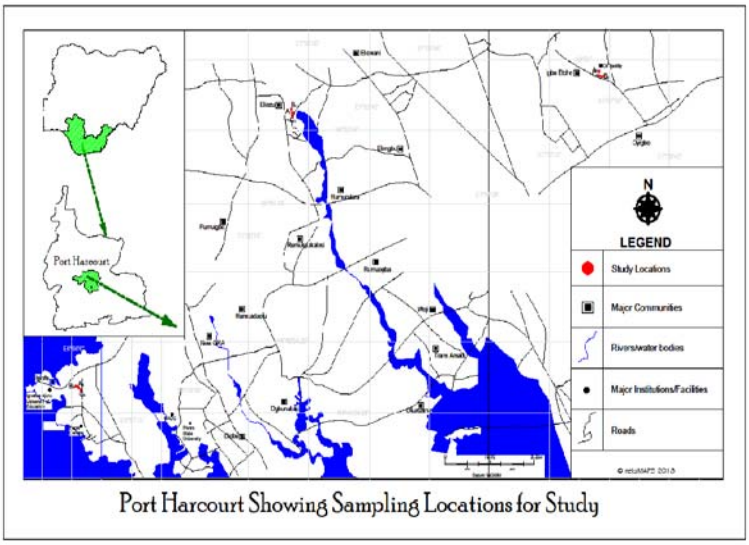


Figure 1: Map of Port Harcourt city showing the studied dumpsites

Figure 5: Sampling Dumpsites at Igbo-Etche, Eluozo and Rumuolumeni

The longitudinal survey research design was adopted because samples were collected at different points or stations in time. Integrated samples were collected using the

simple random sampling technique but controlled by the availability of leachates. Three samples were taken in each of the sample stations and month of sampling. Sampling was done in December 2017 and June, 2018 representing the dry and wet season respectively.

Leachate water samples were collected from two stations labeled A and B whereas the third station labeled C was taken some distances away from the dumpsite. The control samples were taken from pockets of water retained due to rains (wet season) whereas nearby surface pond water were used as control during the dry season especially in the Igbo-Etche dumpsite. These stations were given corresponding identifications so as to identify them for wet season sampling. This was scientifically noted using a Germin 45 Ground Positioning System (GPS) as shown in Table 1.

Table 1: Geographical coordinates of the sampled dumpsites

Dumpsite Location	Longitude	Latitude
Igbo-Etche	04° 53'44"	007° 06' 58"
Eliozu	04° 53'06.2"	007° 00' 52"
Rumuolumeni	04° 52'56.9"	007° 00' 46"

Samples collected were finally transported same day to the laboratory at Diamond standard integrated services (Nig.) Limited located at 2 pure water road, Rumuodara, Port Harcourt. In the laboratory, samples were made to maintain a temperature of 4°c until analysis was done. All the leachate samples from the 3-selected dumpsites were collected, preserved, transported and analyzed in accordance with standard methods for the examination of water and waste water as applied by Eaton and Franson [14]. Dumpsite studies, according to Bashir et al., [15], included measurements of pollutants such as NH_4^+ and NO_3^- etc and other soluble salts which is in agreement with this research study. Figures 1-5 shows the maps of the study locations (sampled dumpsites at Igbo-Etche, Eluozo and Rumuolumeni).

Data from the field were tabulated and analyzed using SPSS version 11.0 software package [16]. This included mean, standard deviation, mean variation, t-test, ANOVA and 95% confidence intervals. Similarly, statistical difference between the means of leachates during dry and rainy seasons were done using t-test at p-value less than and equal to 0.05, $p \leq 0.05$ [16].

RESULTS AND DISCUSSIONS

Results of analysis from leachates obtained in 3-selected dumpsites in Port Harcourt Metropolis; Igbo-Etche, Eluozo and Rumuolumeni for both the dry and rainy season is presented in Tables 2, 3 and 4. Table 2 showed the result of the nutrient parameters recorded during the dry season for the Igbo-Etche dumpsite. Nitrate recorded an average of 0.314±0.38, Phosphate 0.512±0.25, Sulphate 1.931±2.43 while ammonium ion 0.963±0.65mg/l. The above Table 3 gives the results of Eluozo dumpsite leachate during the dry season. Similarly at the Eluozo dumpsite, Nitrate mean value was 2.537±3.27, Phosphate 5.16±7.18, Sulphate 219.87±191.24 and Ammonium 10.439±13.05. Table 4 gives the concentration of the nutrient parameters as at the dry season for Rumuolumeni dumpsite. The mean values for NO_3^-, PO_4^{3-}, SO_4^{2-} and NH_4^+

were 77.77±2.03, 2.526±0.82, 34.69±18.84 and 19.37±0.09 respectively. Table 3 is the analytical result for the nutrient parameters of nitrate, phosphate, sulphate and ammonium whose mean concentration for the Eluozo dumpsite during the rainy season were 5.78±1.9, 0.242±0.13, 7.682±7.15 and 20.22±27.87respectively. Table 2 shows the result of the nutrient parameters for Igbo-Etche dumpsite during the rainy season. The result indicated that the mean concentration of nitrate 6.342±0.68, phosphate, 1.158±1.46; sulphate 8.432±1.46.49 and ammonium was 1.193±0.88. Similarly, Table 4 represents the results of nutrient parameters analyzed from samples collected at the Rumuolumeni dumpsite during the rainy season. The result showed that nitrate, phosphate, sulphate and ammonium recorded mean values of 4.79±0.08, 5.16±0.06, 0.89±0.08 and 1.01±0.01 respectively. Figures 2, 3 and 4 show the graphical relationship for the nutrient parameters in the 3-selected dumpsites.

The nutrient parameters studied include nitrate (NO3-), Phosphate (PO43-), Sulphate (SO42-) and ammonia (NH4+). Results from the study revealed that the nitrate concentration during the dry season recorded averages of 0.314, 2.537 and 77.77 (mg/l) at the Igbo-Etche, Eluozo and Rumuolumeni study stations respectively. Spatial variations showed that Be, Ao and Ar recorded the highest values and Rumuolumeni has the highest concentration of nitrates during the dry season which was above WHO and FMENV standards as shown in Tables 5, 6 and 7. The mean value for nitrates during the dry season was also recorded as 15.44 and 19.50 which were though higher than Igbo-Etche and Eluozo but lower than that of Rumuolumeni. Similarly, by the rainy season, Igbo-Etche, Eluozo and Rumuolumeni had mean nitrate concentrations of 6.342, 5.78 and 4.79 mg/l. The result showed that the Igbo-Etche dumpsite recorded the highest concentration during the rainy season, but were below WHO and FMENV standards. This may be associated with the influence and impact of dilution on the organic and inorganic salts. Solubility of nitrates in water may be responsible for this significant variation between the concentrations seasonally. Aboho et al., [17] recorded rainy season values which were 11.78 and 13.76 at two study stations. Nartey et al., [18] recorded lower mean nitrate concentrations during the dry (1.95) and rainy (2.125) seasons. This trend of higher nitrate values during the rainy season confirms similar trend in this study. Similarly, Hossain et al. [19] recorded seasonal concentration of nitrate as 2.9 (Dry) and 1.8 (rainy) which was at variance with this study. Abd El-Salam and Abu-Zuid [20] confirmed the concentration of nitrate as the characteristics of the leachate, which were highly variable with severe contamination of salts inclusive but were below the WHO and EPA limits and also APHA, [21] and APHA, AWWA and WEF, [22]. The high nitrogen or nitrate concentration in most study stations is a typical indication of high organic matter around the dumpsites [23]. Low concentrations of range 0.11 to 0.36 were recorded at the dumpsite along Enugu-Port-Harcourt expressway [24]. Nitrate concentration in groundwater which may have been affected by leachate percolation in dumpsite recorded a range of 0.16-95.02 (mean 61.07) showing similar trend as recorded in earlier works [25]. In a similar trend, the concentration of nitrate (NO_3^-) was 0.58 mg/l which fell within the values recorded for leachates from municipal solid waste landfill site in Ibadan, Nigeria [26], which was within acceptable limits recommended by regulatory bodies in Nigeria. Conversely, the concentration of nitrates (NO_3^-) in the leachate of Effurun ranged from 19.47 to 28.70 mg/l [27,28], which was within same range observed in this study. The results are shown in Tables 2, 3 and 4 for all the dumpsites in both seasons whereas graphs graphs were used to illustrate trends and are shown in Figures 2, 3 and 4 for the three

dumpsites. The Igbo-Etche, Eluozo and Rumuolumeni study stations during the dry season recorded mean concentrations of Phosphate as 0.314, 5.160 and 2.526 mg/l. These concentrations are in agreement with those earlier observed in other researches for leachates [18,19,26,28]. Phosphates values were all below the permissible limits by both WHO and FMENV standards.

Table 2: Nutrient Level for Igbo-Etche Dumpsite Leachates (Both Seasons)

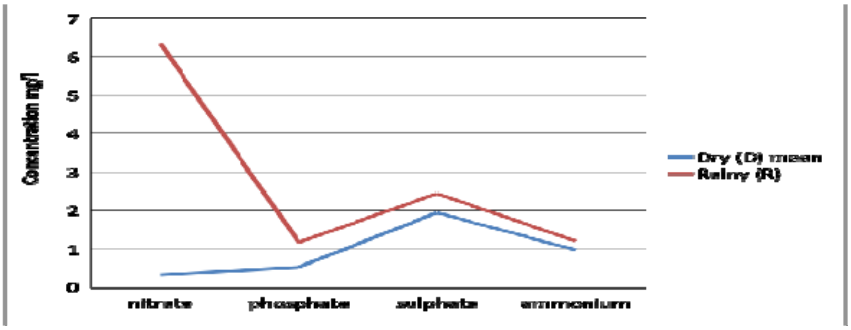
Study Stations	NO_3^-		PO_4^{3-}		SO_4^{2-}		(mg/l)	
	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
A_E	0.582	5.860	0.689	2.182	3.646	10.49	0.963	1.80
B_E	0.314	6.820	0.512	0.122	1.931	6.37	1.520	0.57
D_E	0.045	6.346	0.335	1.170	0.215	8.43	0.506	1.21
Mean	0.314±0.38	6.34±0.68	0.512±0.25	1.16±1.46	1.931±2.43	8.4±1.46	0.96±0.65	1.19±0.88
% mean Var.	21.70	66.60	43.75	97.84	66.70	68.88	52.23	64.04
A_C	0.401	2.118	0.286	0.025	0.643	2.625	0.462	0.429
B_C	0.402	2.119	0.288	0.026	0.642	2.624	0.460	0.428
D_C	0.400	2.117	0.290	0.024	0.644	2.623	0.458	0.430
Mean Control	0.401±0.0008	2.118±0.0008	0.288±0.0016	0.025±0.0008	0.643±0.0008	2.624±0.0008	0.460±0.0016	0.429±0.0008

Table 3: Nutrient Level for Eluozu Dumpsite Leachates (Both Seasons)

Study Stations	NO_3^- (mg/l)		PO_4^{3-}(mg/l)		SO_4^{2-}		(mg/l)	
	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
A_O	0.227	7.12	10.24	0.151	355	2.62	19.67	0.501
B_O	4.846	4.40	0.079	0.332	84.6	12.70	1.21	39.93
D_E	2.537	5.81	5.160	0.242	220	7.73	10.44	20.22
Mean	2.537±3.27	5.78±1.9	5.160±7.18	0.24±0.13	219.87±191	7.68±7.15	10.4±13	20±27.87
% mean Var.	68.89	57.96	43.93	87.19	99.90	80.49	96.25	98.23
A_C	0.764	2.44	2.893	0.030	0.215	1.490	0.391	0.356
B_C	0.762	2.43	2.890	0.031	0.214	1.499	0.392	0.358
D_C	0.766	2.42	2.896	0.032	0.216	1.508	0.390	0.360
Mean Control	0.764±0.0016	2.43±0.008	2.893±0.0024	0.031±0.0008	0.215±0.0008	1.499±0.007	0.391±0.0008	0.358±0.0016

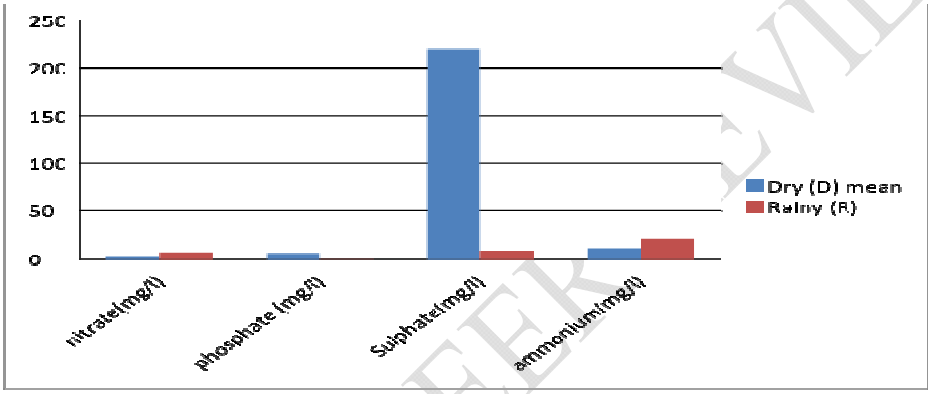
Table 4: Nutrient Level for Rumuolumeni Dumpsite Leachates (Both Seasons)

Study Stations	NO_3^-		PO_4^{3-}		SO_4^{2-}		NH_4^+	
	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
A_R	76.33	4.80	3.11	5.20	21.37	0.81	19.30	1.00
B_R	77.80	4.71	1.94	5.10	34.69	0.92	19.37	1.01
D_R	79.20	4.86	2.53	5.18	48.01	0.93	19.43	1.02
Mean	77.78±2.03	4.79±0.08	2.53±0.82	5.16±0.06	34.69±18.84	0.89±0.08	19.37±0.09	1.01±0.01
% mean Var	1.85	55.11	97.43	78.68	53.79	43.82	56.73	6.93
A_C	76.33	2.16	0.065	1.16	16.03	0.56	8.38	0.90
B_C	76.32	2.15	0.066	1.10	16.00	0.58	8.35	0.90
D_C	76.34	2.14	0.064	1.04	16.06	0.36	8.41	1.02
Mean Control	76.33±0.0082	2.15±0.008	0.065±0.0008	1.10±0.049	16.03±0.024	0.50±0.099	8.38±0.024	0.94±0.057



Nutrients

Fig.2: Seasonal Variation for Nutrient Parameters for Igbo-Etche Dumpsite Leachates.



Nutrient

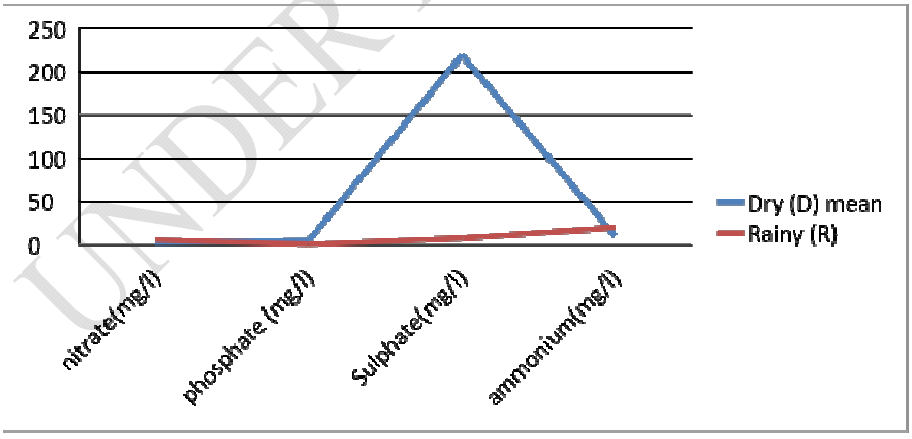


Fig.3: Seasonal variation for nutrient levels in Eluozo dumpsite leachates.

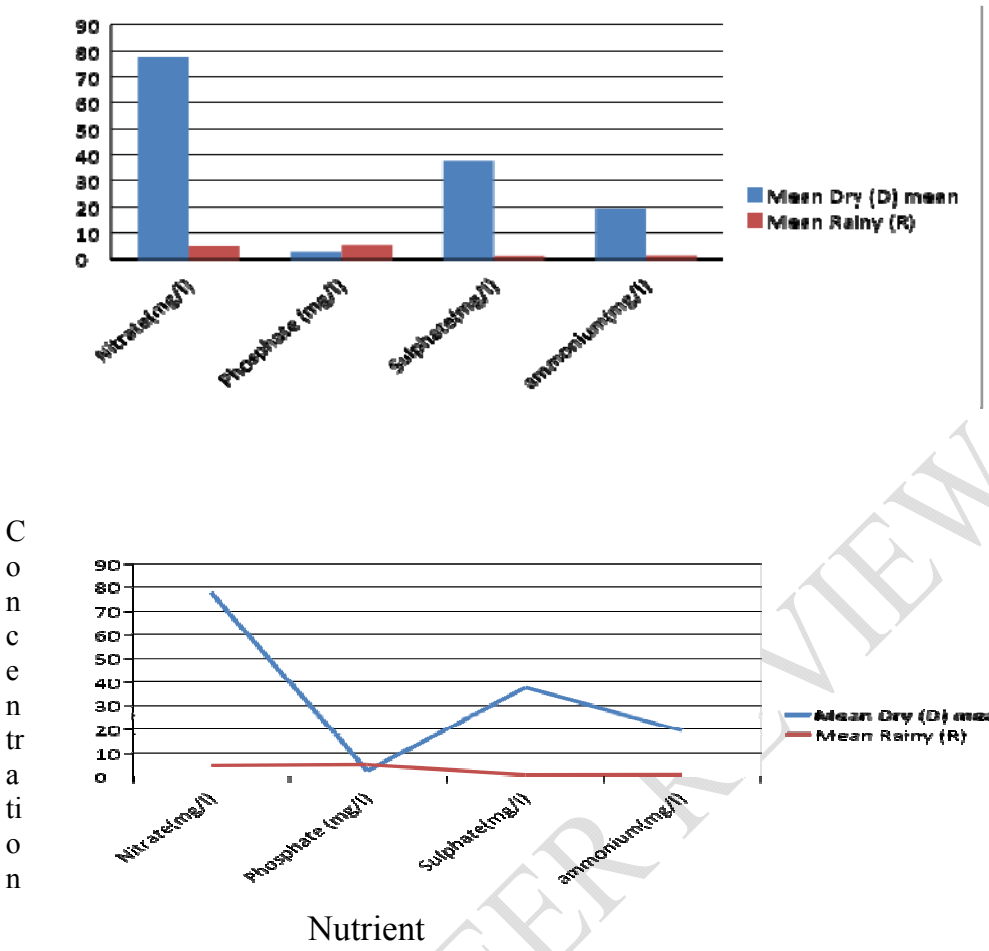


Fig.4: Seasonal Variation in Nutrients at Rumuolumeni Dumpsite

Table 5: Summary of Mean Concentrations for Season/ Standard Limits in the three sample stations (Dumpsites)

Parameters	Igbo-Etche		Eliozu		Rumuolumeni		FMENV/FEPA /WHO STDS	STDS for wastewater Discharge
	Mean (dry)	Mean (wet)	Mean (dry)	Mean (wet)	Mean (dry)	Mean (wet)		
NO_3^- mg/l	0.314	6.342	2.537	5.75	77.77	4.79	20	-
PO_4^{3-} mg/l	0.512	1.158	5.160	0.242	2.526	5.16	0-5 (WHO, FEPA,1991)	1.0
SO_4^{2-} mg/l	1.931	8.431	219.87	7.682	34.69	0.89	100-600 WHO, FEPA, 1991)	1.0
NH_4^+ mg/l	0.963	1.193	10.439	20.22	19.37	1.01	< 10	4.0

Research has shown that concentrations of phosphates over 0.05mg/l may likely have effects but at greater than 0.1 mg/l will impact on river systems. When compared to the control of 0.288mg/l (Igbo-Etche), the concentration showed that negligible concentration existed but the B_e station recorded the highest. Similarly in Eluozo study station, the control was higher than the B_o but lower than A_o. During the rainy

season, the mean concentration of phosphate was 1.158, 0.242 and 5.16 (mg/l) at the Igbo-Etche, Eluozo and Rumuolumeni sampling sites respectively. The result showed comparatively that phosphate concentrations during the dry season were higher than those of rainy season. This could be attributed to poor dilution hence increased presence per given volume of leachate. These values were far below those recorded in Effurun dumpsite within same geographical location [27]. The phosphate concentration was far lower compared to those of leachate characterization in semi-aerobic and anaerobic sanitary landfills measuring as high as 21, 17 and 19mg/l [29]. Similarly, low concentrations of phosphate in leachates were recorded in Ibadan abandoned dumpsites (similar to the Rumuolumeni old site) of mean value 1.98mg/l [30]. The concentrations recorded during the dry and rainy season for the phosphate in the 3-selected dumpsites were below standard limits by FEPA and WHO [31,32,33,34] standards of 5mg/l except those recorded at the Rumuolumeni dumpsites. This arbitrary increase in the phosphate concentration at the Rumuolumeni dumpsite may be related to the age, biochemical processes and amount of unsegregated waste, volume and nature of the leachate formation.

According to the National biological assessment and criteria workshops NBACW, [35] the common sources of phosphate are agricultural and urban uses of fertilizer, agricultural use of manure and combustion of fossil fuels, but most importantly is its potential effects on the ecosystem. Similarly, notable specific effects also include eutrophication (High) and cultural oligotrophic impact at low concentration.

Sulphate (SO_4^{2-}) is another prominent nutrient parameter known to emanate from mining activities, in naturally occurring coal seam, sulphur containing rocks or soils, component of acid rain and from irrigation practices [35]. Its effects are poor taste and odour and variation in surface water chemistry and the marine biota.

The sulphate mean concentrations recorded during this study during the dry season for the Igbo-Etche, Eluozo and Rumuolumeni dumpsites are 1.931, 219.87 and 34.69 (mg/l) respectively. When compared to the control station, the mean variation (%) were 66.70, 99.90 and 53.79 (mg/l), which showed that the dumpsite had significant spatial variations especially at the Eluozo dumpsite. This showed the impact of sulphate inducing substances around the study leachate dumps. These values were far above those reported by Aboho *et al.,* [17] during the dry season except that of Igbo-Etche but agreed with the results of Aluko *et al.*. [26] on municipal solid waste landfill site in Ibadan, Nigeria. This fluctuation may be accounted for by the nature, characteristics and volume of waste generated which is affected by the kind of staple food forming the bulk density of domestic waste around different study sites. The concentrations recorded during the dry season were far below the recommended standard limits for industrial waste water and also above the measurements from the control samples [31]. The result was also in agreement with those obtained during the dry season (mean, 65.3 mg/l) for leachates in solid waste landfill in Ibadan, Nigeria [26]. Similarly, during the wet (rainy) season the Igbo-Etche, Eluozo and Rumuolumeni recorded mean concentrations of sulphate as 8.431, 7.682 and 0.89 with corresponding % mean variation from the control as 68.88, 80.49 and 43.82 mg/l. This is an indication of gradual increase in the concentration of sulphate in the dumpsite. The reduction of 43.82% in mean variation may be as a result of reduced activity due to aging. Though these values were far below those recorded during the wet season by Aluko *et al.*, [26], it agrees favorably with those recorded by Aboho *et al.,* [17] on similar environment and at variance with those of Nubi *et al.* [28] at the dumpsite of Eku, Oyo state Nigeria. Comparing both seasons, it is obvious that those of the dry season were relatively higher, which may be attributed to dilution effect

during the wet season. Though the sulphate concentration was far below FEPA standards for industrial effluents and water quality test, efforts must be made not to allow fresh water intrusion.

The ammonia concentration (NH_4^+) described either as ammonium ion or ammonia-nitrogen is generally toxic to fish [35]. Research has shown that the environmental damage from waste leachate emanates from its high organic contaminants concentration assisted by high ammoniacal nitrogen. This study recorded mean concentrations of ammonia in the leachate (NH_4^+) during the dry season as 0.963, 10.439 and 19.37 at the Igbo-Etche, Eluozo and Rumuolumeni dumpsites with corresponding mean variations % from the control of 52.23, 96.25 and 56.73. The mean leachate concentrations of the above dumpsites showed that the Rumuolumeni waste dumpsite recorded the highest, which may be due to the age of the dumpsite and the anthropogenic inputs. These values were all far above the recommended permissible limit of 4 mg/l from general industrial waste water discharge standards and surface water quality standards of 0.2mg/l [31,34,36]. The mean concentration of ammonia (NH_4^+-N) in the studied dumpsites leachate was lower than those recorded in similar researches [17,24,37]. Conversely, the leachate concentrations of ammonia were grossly higher than certain results from similar ecosystems [38,39]. The mean concentration of ammonia in the dumpsite leachate for the rainy season in the studied stations of Igbo-Etche, Eluozo and Rumuolumeni were 1.193, 20.22 and 1.01 mg/l. The result also showed high mean variations (%) from the control, corresponding to 64.04, 98.23 and but relatively low for the Rumuolumeni dumpsite. This reduced variation may be attributed to the age of the use of the site. These concentrations are in agreement with those of earlier researches [17,24]. The low concentrations of NH_3-N and low BOD may indicate a mixture of methanogenic and acetogenic waste dumpsite [40].

The release of soluble nitrogen from the waste into leachate is a long time process hence the concentration of ammonia nitrogen increases with the increase in age of the dumpsite resulting from hydrolysis, decay and fermentation of nitrogenous components of biodegradable waste [41,42]. Research has also shown that ammonia is a major long-term pollutant due to its stability aerobically. Ammonia concentration greatly vary from one dumpsite to another but the mean concentration of NH_3 in dumpsites lies around 500 and 1500 mg/I over a mean period of 5.5 years and can last up to 50 years [41,43,44,45]. This means that these dumpsites require treatment to avoid percolation into water bodies, Since ammonia-nitrogen has been confirmed a major toxicant to living resources and its toxic potential is known to disrupt biological treatment of leachate processes [46,47]. At the rainy season, relatively lower percentage variations were observed for sulphate (43.8) and ammonium (6.93).

Conclusion and Recommendation

Though there was no significant difference between dry and rainy season concentrations for nitrate, sulphate, phosphate and ammonia; there was high spatial variation (station) for all the parameters relative to the control except for nitrate, phosphate at Igbo-Etche, phosphate at Eluozo and nitrate at Rumuolumeni by dry season. Similarly, during the rainy season; only sulphate and ammonium at Rumuolumeni recorded low % mean variation. It is worthy to note the arbitrary increase in the mean concentration of nitrate (77.77mg/l) at the Rumuolumeni station by the dry season. The government should periodically monitor the water quality

status of these acquired dumpsites to control the spread of pollutants and contaminants. This is based on the findings in the present work. Also, the natives should avoid the use of surface well water and boreholes close to these dumpsites to avoid toxicity resulting from contamination. Due to financial constraints, only Port Harcourt approved dumpsites were assessed; so there is the need to expand this research to the remote areas of Rivers State and the Niger Delta Region especially considering the oil exploration and exploitation activities in the zone.

REFERENCE

1. Kumar, S., Mondal, A.N., Gaikwad, S.A., Devotta, S. & Singh, R.N. (2004). Qualitative Assessment of Methane emission inventory from municipal solid waste disposal sites: A Case Study. *Atmospheric Environment* 38, 4921-2929.

2. Inyang, L.D. & Onwuteaka, J.N. (2004). *Environmental ready reference, volume 1(1st edition).* Port Harcourt, Kehnalf and Co publishers.

3. Anikwe, M.A.N and Nwobodo, K.C.A. (2002). Long term effect of municipal waste disposal on soil properties and conductivity of sites used for urban agriculture in Abakaliki, Nigeria. *Bioresource Technology*, 83: 241-250.

4. Njoku, C. (2015). Effect of waste on selected soil properties in Abakaliki South Eastern, Nigeria. *International Journal of Plant and Soil Science*, 4(1):94-99.

5. Ogunji, J.O., Okogwu O. & Mgbeafuruike, J. (2004). *Environmental Biology and Waste Management Principles. Enugu, Ruga Enterprises.*

6. Amadi, A.N., Ameh, M.I., & Jisa, J. (2010). The impact of dumpsites on groundwater quality in Markurdi Metropolis, Benue State. *Natural and Applied Science Journal,* 11(1):90-102.

7. Praveena, G.S., & Rao, P.V.V. (2016). Impact of leachate on soil properties in the dumpsite; A case study of Greater Visakhapatnam. International Journal of Engineering Research and General Science, 4(1):235-241.

8. Adelekan, B.A. and Alawode, A.O. (2011). Contributions of municipal refuse dumps to heavy metals concentrations in soil profile and groundwater in Ibadan Nigeria. *Journal of Applied Bioscience,* 40, 2727-2737.

9. Iyama, W.A., Brown, H. & Okpara, K.(2018). Introduction to Environmental Toxicology and Pollution Studies. Port Harcourt, Nigeria: Obisco Nigeria Enterprises.

10. Bhatia, S.C. (2007). *Environmental Chemistry (1st edn.):* Darya Gary, New Delhi, India: CBS Publishers and Distributors.

11. Arizona-Ogwu, L.C. (2016). Port Harcourt PDP Rally Stampede: Irregular or Deregulated Police Action? Nigeria in America. Retrieved 25 June, 2014.

12. Ogbonna, D.N., Amangabara, G.T., & Ekere, T.O. (2007). "Urban solid waste generation in Port Harcourt Metropolis and its implication for waste management". Management of Environmental Quality: *An International Journal*, 18(1):71-88.

13. Igoni, A.H., Ayotamuno, M.J., Ogaji, S.O.T. & Probert, S.D (2007) Municipal solid-waste in Port Harcourt, Nigeria. Energy 84, 664-670.

14. Eaton, A.D., & Franson, M.A.H. (2005). American Water Works Association, Water Environment Federation. Standard Method for the Examination of water and wastewater 21st ed., America Public Health Association, Washington.

15. Bashir, M.J.K., Isa, M.H., Kutty, S.R.M., Awang, Z.B., Abdul-Aziz, H., Mohajeri, S.(2009). Landfill leachate treatment by electrochemical oxidation. *Waste management,* 29:2534-2541.

16. Van, G., Lloyd, D., Patrick, J. and Thomas, L. (2004). *Biostatistics: a methodology for the health sciences* (2nd ed). United States of America, John Wiley & Sons.

17. Aboho, S.Y., Anwange, B.A.,Onianwa, P.C. and Ekanem, E.O. (2012). Assessment of Surface Water Quality around Dumpsites in the City of Ibadan Metropolis, Oyo State, Nigeria. *International Journal of Chemistry;* 4(1):39-44.

18. Nartey, V.K., Hayford, E.K. and Ametsi, S.K.(2012). Analysis of Leachates from Solid Waste Dumpsites: A Tool for Predicting the Quality of Composts Derived from Landfills. Journals of Environmental and Earth Sciences, 2(11): 1-21.

19. Hossain, M.L., Das S.R., & Hossain, M.K. (2014).Impact of Landfill Leachate on Surface and Ground Water Quality. Journal of Environmental Science and Technology; 7:337-346.

20. Abd El-Salam, M.M. and Abu-Zuid, G.I.(2015).Impact of landfill leachates on ground water quality: A case study in Egypt . Journal of Advanced Research, 6(4): 579-586.

21. APHA, (1995). Standard methods for the examination of water and wastewater, American Public Health Association, 23-89.

22. APHA, AWWA & WEF (1995). American Public Health Association Water Works Association and Water Environment Federation. Standard methods for the examination of water and waste water.20th Edition, Washington DC.

23. Soheil, R.I., Hossien, M.H., Gholamreza, S., & Hassan, E.(2012). Effects of composted municipal waste and its leachate on some soil chemical properties and corn plant responses. International Journal of Agriculture: Research and Review 2(6):801-814.

24. Obasi, N.A., Akubugwo, E.I., Ugbogu, O.C & Otuchristain, G. (2012).Assessment of Physico-chemical Properties and Heavy Metals Bioavailability in Dumpsites along Enugu- Port Harcourt Expressway, South-East, Nigeria. Asian Journal of Applied Science; 5:342-356.

25. Amadi, A.N. (2011). Assessing the Effects of Aladimma Dumpsite on Soil and Groundwater Using Water Quality Index and Factor Analysis. Australian Journal of Basic and Applied Sciences; 5(11):763-770.

26. Aluko,O.O., Sridhar, M.K.C., & Oluwande, P.A. (2003). Characterization of Leachate from a Municipal Solid Waste Landfill site in Ibadan, Nigeria. Journal of Environmental Health Research; 2(1):32.

27. Ohwoghere-Asuma, O. & Aweto, K.E. (2013). Leachate Characterization and Assessment of Groundwater and Surface Water Quality near Municipal Solid Waste Dumpsite in Effurun, Delta State, Nigeria. Journal of Environment and Earth Science; 3(9):126-134.

28. Nubi, O.A., Osibanjo, O., & Nubi, T.A. (2008).Impact Assessment of Dumpsite Leachate on the Qualities of Surface Water and Sediments of River Eku, Ona-Ara Local Government, Oyo State, Nigeria. Science World Journal; 3(3):17-20.

29. Aziz, S.Q., Aziz, H.A., Yusoff, M.S., Bashir, M.J.K & Umar, M. (2010). Leachate Characterization in Sanitary Landfills: a Comparative study. Journal of Environmental Management; 91(12):2608-2614.

30. Adewuyi, G.O., & Opasina, M.A. (2010). Physiochemical and Heavy Metals Assessment of Leachates from Aperin Abandoned Dumpsite in Ibadan City, Nigeria. E-Journal of Chemistry; 7(4):1278-1283.

31. FEPA or FMENV (1991). Federal Environmental Protection Agency. National Guidelines and Standards for Industrial Effluents and Water Quality Test. FEPA (Nigeria) Official Gazette, Nigeria.

32. WHO, (1991). World Health Organization. Revision of the WHO Guidelines for Water Quality Report of the First Review Comp Meeting on Inorganics, Netherlands, World Health Organization, Geneva; WHO/PEP/91.18.1991.

33. WHO (1992). World Health Organizations International Standards for Drinking Water.

34. WHO (2009).World Health Organization, Guidelines for Drinking Water Quality, Volume1: Recommendations. Geneva:http://www.who.int/water_sanitation_health/dwq/GDWQ2004web.pdf.

35. NBACW (2003). National Biological Assessment and Criteria Workshop

36. USEPA (2009). US Environmental Protection Agency. Innovative uses of composts, www.epa.gov

37. Iyama, W.A., Boisa, N. and Maduelosi, J. (2016). Physico-chemical analysis of leachates from 3-selected dumpsites in Port Harcourt, Rivers State. PGD thesis submitted to the department of chemistry, Rivers University of Science and Technology, Port Harcourt.

38. Zakaria, S.N.F., & Aziz, H.A. (2018). Characteristics of Leachate at Alor Pongsu Landfill Site. Perak, Malaysia: A comparative study. Earth and Environmental Science; 140:1-9.

39. Chu, L.M., Cheung, K.C., & Wong, M.H. (1994). Variations in the chemical properties of landfill leachate. Environmental Management; 18(1):105-117.

40. Lo, I.M.C. (1996). Characteristics and treatment of Leachates from Domestic Landfills. Environment International; 22(4):433-442.

41. Kulikowska, D. and Klimiuk, E. (2008).The effect of Landfill age on Municipal Leachate Composition. Bioresource Technology; 99(13):5981-5985.

42. Abbas, A.A., Jingsong, G., Ping, L.Z., Ya, P.Y. & Al-Rekabi, W.S. (2009). Review on Landfill Leachate Treatments. Journal of Applied Sciences Research; 5(5):534-545.

43. Tatsi, A.A. & Zouboulis, A.I.(2002). "A field investigation of the quantity and quality of leachate from a municipal solid waste landfill in a Mediterranean climate (Thessaloniki, Greece)," .Advances in Environmental Research, 6(3):207–219.

44. Statom, R.A., Thyne, G.D., & McCray, J.E.(2004). Temporal changes in leachate chemistry of a municipal solid waste landfill cell in Florida, USA. Environmental Geology; 45(7):982-991.

45. Marttinen, S.K., Kettlunen, R.H. & Rintala, J.A. (2003) Occurrence and removal of organic pollutants in sewages and landfill leachates. Science of the Total Environment; 301(1-3):1-12.

46. Kurniawan, T.A., Lo, W.H., & Chan, G.Y.S. (2006). Physicochemical treatments for removal of recalcitrant contaminants from landfill leachate. Journal of Hazardous Materials B; 129(1-3):80-100.

47. Deng, Y., & Englehardt., J.D. (2007). Electrochemical Oxidation for landfill leachate treatment. Waste Management; 27(3):380-388.