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A Comparative Study on the Effects of Leachate on Groundwater in Selected Dumpsites in Rivers State, Nigeria

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Authors' contributions

This study was carried out between both authors. Author NUJ managed the general theoretical frame work/literature review, design analysis and ensured that the results met objectives of the study while author NB performed the field sampling, data analysis and raised the initial draft. Both authors met severally, agreed and approved the final manuscript.

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ABSTRACT

The health and environmental risk associated with unlined open waste dumpsites are worrisome. This study, therefore, evaluated the leachate and its final fate on groundwater pollution at selected solid wastes dumpsites in Rivers State. Leachate samples collected near the dumpsites were analyzed to determine the physical and biochemical characteristics. The two studied dumpsites indicated that the computed TCB were 296.33±6.22 cfu/100 ml and 182.68±21.33 cfu/100 ml respectively which were within the permissible limits of 400cfu/100 ml specified by World Health Organization (WHO) and Federal Ministry of Environment (FMEnv); which suggest low quantities of disease-causing agents in the groundwater. The total heterotrophic bacteria (THB) were $21x10^4$ cfu/ml and $17x10^4$ cfu/ml. These high values of THB may not be an indication of contamination of groundwater but it indicates a gradual decline in raw water quality. The values of SO_4^{2-}, PO_4^{3-}, TDS, DO, BOD and COD at the dumpsites were 196.52±6.26 mg/l and 9.12±0.59 mg/l, 139.23±3.19 mg/l and 3.81±0.68 mg/l, 5952.23±72.52 mg/l and 12663.33±490.95 mg/l;1.51±0.42. mg/l and 2.02±0.16

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mg/l; 31.22±4.12 mg/l and 21.33±3.51 mg/l, and313.30±6.57 mg/l and 270.33±26.16 mg/l respectively which exceeded the standards of the WHO and FMEnv. The high values of analyzed parameters were an indication of the groundwater contamination. Heavy metals in the Rumuosi dumpsite indicated 11.31±1.33 mg/l, 11.01±0.67 mg/l, 361.84±12.31 mg/l, 118.03±5.74 mg/l and 84.77±4.84 mg/l for Pb, As, Mn, Fe and Zn respectively. While Heavy metals thresholds at Igwuruta were 0.004±0.005 mg/l, 0.04±0.07 mg/l, 0.05±0.08 mg/l, 0.08±0.14 mg/l and 0.15±0.04 mg/l respectively. Rumuosi thresholds exceeded the standards, indicating that the exposed local people in the nearby communities may experience cases of non-carcinogenic and carcinogenic health risk by drinking the groundwater. The leachate pollution index (LPI) at the studied dumpsites indicated 13.58 and 12.9 which exceeded the internationally accepted benchmark of 7.38; indicating that the Rumuosi leachate was more polluted than Igwuruta leachate. The analysis of variance (ANOVA) of the pollutant characteristics indicated a significant difference at p=0.05 across the physicochemical and biological indicators at Rumuosi dumpsite over Igwuruta dumpsite. The researcher recommended the practice of sanitary landfill which may reduce the risk of leachate percolation, a primary source of groundwater contamination.

Keywords: Leachate; groundwater contamination; pollution; heterotrophic; leachate pollution index.

1. INTRODUCTION

The extent of dependence on groundwater for domestic and commercial use without any form of treatment at various communities within and around dumpsites calls for action. Municipal solid wastes (MSW) are disposed of indiscriminately in unlined and poorly managed dump sites with runoff water from this dump containing hazardous fluid [1,2,3,4].

Leachate is a by-product of liquid percolation from MSW deposited in open dumps. Its contamination of groundwater stemmed from flooding, percolating runoff, inappropriate management of all forms of wastes; agricultural runoff water and industrial wastewater [5,6]. The problem of leachate pollution is worse in developing countries where MSW is not properly managed [1,2,7]. Many developed nations have been able to address the problem of leachate production in waste dumpsites through sanitary landfill systems, various wastes to wealth agenda and modern waste recycling and reuse technology [8,9,10,11,12]. Many studies have been carried out on dumpsites in Nigeria [13,14, 15,16,17,18,19] but these are dumpsite specific. Sackey and Meizah [20] revealed that waste dumpsites can be grouped into three distinctive grades by their ages (young, intermediate and old), which influence contamination levels. The waste dumpsites within five years are classified as young with huge biodegradable contents and high COD range of 10,000 to 20,000 mg/l. The dumpsites between 5 to 10 years are classified as intermediate with attendant COD of 3,000 to 15,000 mg/l and the very old dumpsites above 10 years have less biodegradation with attendant COD of less than 2,000 mg/l.

Agbozu et al. [16] stated that Nigeria generates about 25 million tonnes of municipal solid wastes (MSW) in a year and forecasted that MSW would increase due to the uncontrolled population growth and fast urbanization. One overwhelming challenge to environmentalists and government of the developing countries is the poor handling of MSW and the leachate percolation to groundwater aquifer from wastes dumpsites [14,17,12]. The problems caused by the leachate percolation include contamination of soil, surface and groundwater [21,22,23]. This research addressed the major concerns of Rumuosi and Igwuruta communities given the proximity of dumpsites to residential areas and utility boreholes. It evaluated the leachate characteristics from two open dumpsites and their Leachate Pollution Index (LPI).

2. MATERIALS AND METHODOLOGY

2.1 Study Area

The selected study areas were very active wastes dumpsites. These dumpsites are located at a geographic coordinates of 4°53'5''N; 6°55'36''E and 4°57'15''N and 7°0'45''E, respectively. The Rumuosi solid waste dumpsite is located along the new Airport Road, Port Harcourt, while the Igwuruta dumpsite is accessible through the Eneka - Igwuruta road, Port Harcourt.

Rumuosi and Igwuruta dumpsites received about 4,500 and 5,600 metric tons of MSW per day respectively. A composite of the wastes in the two dumpsites was generated from the slaughterhouses, industries, hospitals, markets, demolition and construction yards. The study areas have an estimated water table depth of 33-35 m. On-sites observation revealed that the dumpsites were abandoned pits of construction companies Figs. 1 and 2 marked out the locations of the waste dumpsites.

2.2 Instrument and Sample Collection

The study was designed to evaluate the physicochemical properties, heavy metals, microbial impacts and LPI effects of the selected dumpsites. The mobilized field instruments include odometer, Global Positioning System (GPS), masking tape, camera, chest cooler and an indelible marker. Sampling bottles were thoroughly washed and rinsed with 1mol/L of nitric acid. The physicochemical parameters that were analyzed include Leachate, Colour Temperature, Hydrogen ion concentration (pH), Electrical conductivity (EC), Sulphate (SO_4^{2-}), Phosphate (PO_4^{3-}), Total dissolved solids (TDS), Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total coliform Bacteria (TCB), Total Heterotrophic Bacteria (THB), Total Hydrocarbon Content (THC) and some heavy metals (Lead, arsenic, Iron, Zinc and Manganese).

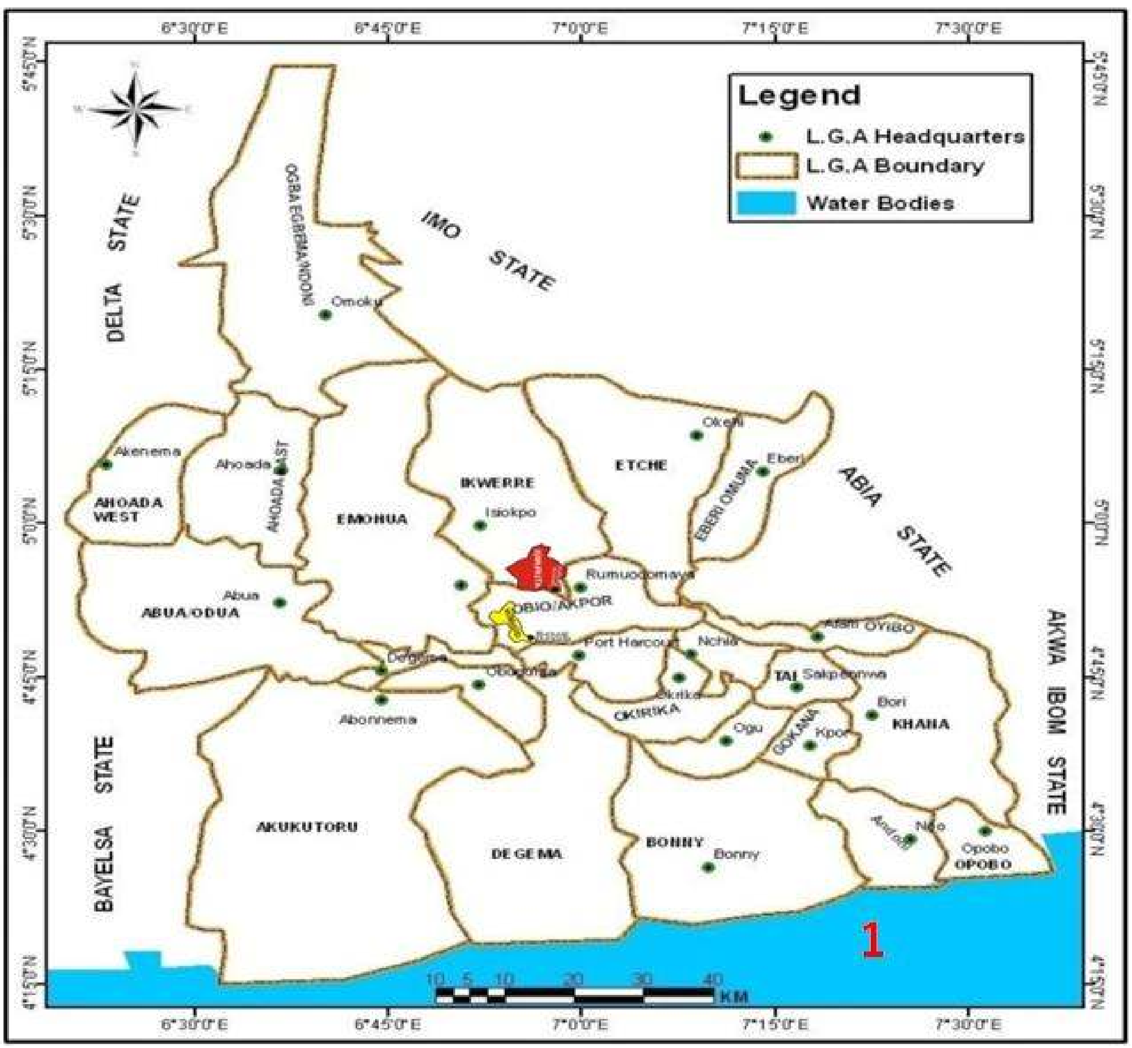

Fig. 1. Map of Rivers State

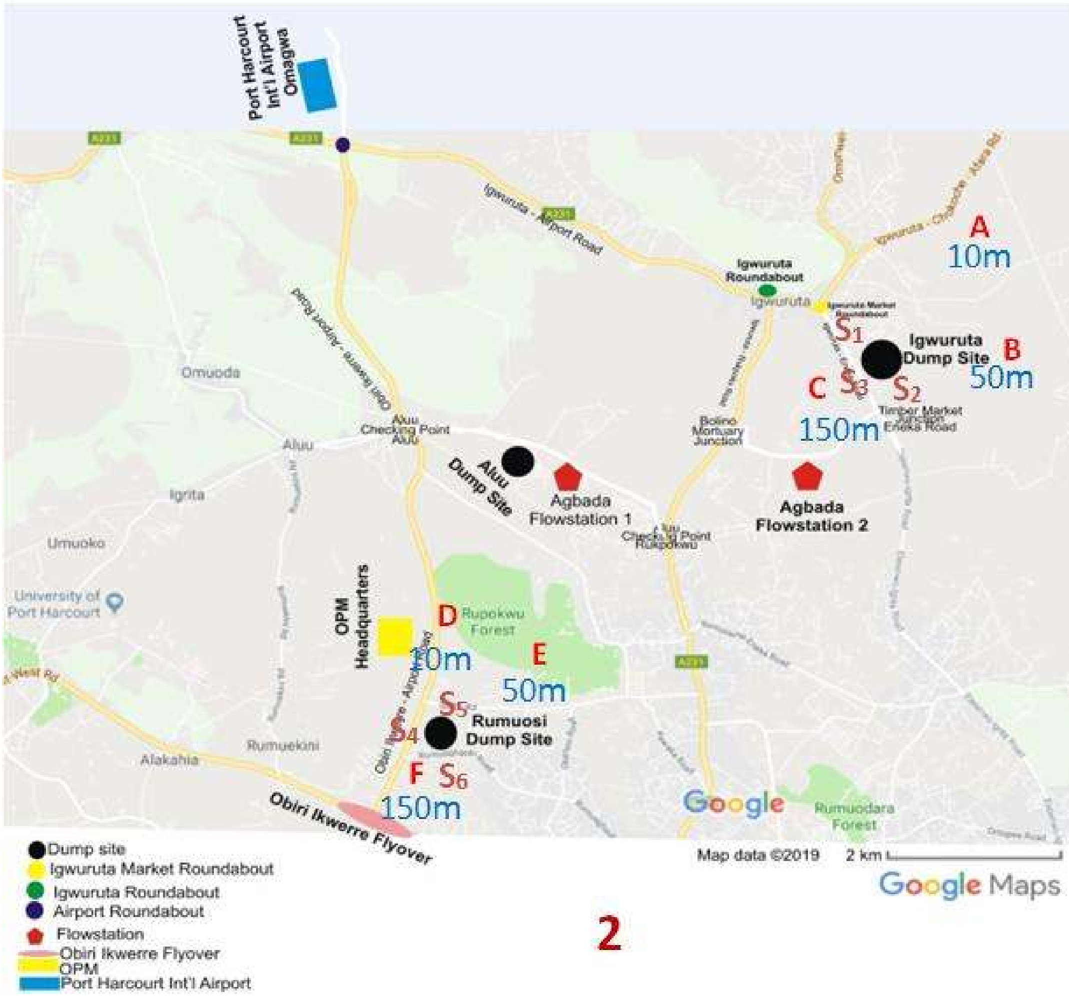

Fig. 2. Two un-engineered Dumpsites at Rumuosi and Igwuruta

Leachate samples were taken from the two waste dumpsites at 3 points each and a total of 6 points (S_i, S_2, S_3, S_4, S_5, S_6) were sampled randomly. The samples of selected boreholes at station A, B and C were 10 m, 50 m and 150 m respectively away from the Rumuosi dumpsite and selected boreholes D, E and F at the same distances to Igwuruta dumpsite (see Fig. 2). Agbada2 borehole water as Control was at the distance of 9540 m from Rumuosi and 1350m from Igwuruta dumpsites. This is a drinking water source from an Oil-based flow station within the study areas.

The LPI was expressed as shown in equation 1 [16,24].

$$LPI = \frac{\sum_{i=j}^{n} WiPi}{\sum Wi} \tag{1}$$

Where Wi = weight value of the i^{th} leachate pollutant variable and n is the total number of pollutant variables. Pi = Sub-index value of the i^{th} leachate pollutant variables.

SO_4^{2-} and PO_4^{3-} content in the leachate was determined using the Stannous method [25]. EC and temperature were assessed via in-situ using the Horiba water meter (model U-10) after calibration with the standard horiba solution. TDS was by the gravimetric method [25]. LBOD101 probe was used to measure the dissolved oxygen (DO) and BOD in BOD_5 testing bottles. Heavy metals samples were digested with a reagent in the ratio 1:1 conc. trioxonitrate (v) to water and after mild steering of the solution, it was analyzed with Atomic Absorption spectrophotometer (AAS-AA500). COD was determined using open reflux method with titration with the following instruments such as water traps, heating mantle with thermostat, condensers and reflux system and 250 ml flask [19].

Biological parameters such as total coliform Bacteria (TCB) and total heterotrophic bacteria (THB) count on both leachate and groundwater were nurtured at 37˚C for 24 hours and analyzed in accordance to Obire and Wemedo [26] and WHO [27] using the nutrient agar medium and Mac Conkey broth medium.

2.3 Statistical Evaluation

Analyzed values were subjected to standard protocols to evaluate leachate pollution index for each of the studied dumpsites. Sampled parameters were analyzed and results averaged. The standard deviation for all sets of studied characteristics was evaluated using Excel® 2010. Sampled parameters were subjected to a two-way without replication employing analysis of variance (ANOVA) to check the statistical differences at p=0.05.

3. RESULTS

Table 1 indicated the physical and biochemical characteristics of the dumpsites as compared with WHO and FMEnv standards [27,28]. These parameters showed leachate pollution, high THB, BOD, COD, pH, TDS and EC. Table 1 showed that the pH of the two selected dumpsites was basic with a threshold of 6.87 - 8.66 which was above [27] and [28] limits of 6 for leachate benchmark.

4. DISCUSSION

4.1 Physical and Biochemical Characteristics of Leachate and Groundwater

pH: Tables 1, 2, 4 and 5 showed that leachates and groundwater parameters were examined. pH of the two studied dumpsites were 6.63±31-8.66±0.22 which fall within the permissible limits WHO and FMEnv. pH value of 8.66±0.22 at Igwuruta dumpsite may be due to carboxylic acid and bicarbonate ions in long exposed dumpsite given rise to increased alkaline and this corroborated with El-Salam and Abu-Zuid [29] who established that dumpsites leachate are often high in pH due to early acidic phases. The borehole water samples were slightly acidic below the WHO and FMEnv standard limits but increased along measured distance from the dumpsite. These findings corroborated with works of Bromssen [30,5,19,23]. While pH from the Agbada 2 (control) was 6.98. High acidic content may lead to health risk such as dermatosis; and corrosion of construction apparatus and equipment. Similarly, leachate infiltration to borehole water samples may have resulted in odour and bad taste [31,32].

Table 1. Physicochemical and bacteriological characteristics of the leachate and acceptable standards of [27] and [28]

Parameter	Rumuosi dumpsite			Igwuruta dumpsite			[27]	[28]
	S_1	S_2	S_3	S_4	S_5	S_6	WHO	FMEnv
Temperature (˚C)	31	29	30	32	30	32	35	35
pH	6.78	7.22	6.63	8.43	8.87	8.69	6	5
EC (µS/cm)	1285	3487	3583	1942	2003	2295	1500	125
TDS (mg/l)	5898.78	10000	9849	12100	12890	13000	1000	500
SO_4^{2-}(mg/l)	189.45	289.15	320.67	8.5	9.2	9.67	50	100
PO_4^{3-}(mg/l)	135.56	174.79	170.34	3.63	4.56	3.23	2	50
DO (mg/l)	1.67	1.03	1.83	1.9	2.2	1.97	0	5
BOD(mg/l)	35.67	30.46	27.54	18	21	25	50	30
COD(mg/l)	312.59	320.20	307.12	246	298	267	250	75
Pb(mg/l)	12.67	10.02	11.24	<0.001	<0.001	0.1	5	0.05
As(mg/l)	10.34	11.01	11.67	<0.001	<0.001	0.12	0	0.01
Mn(mg/l)	347.76	367.21	370.56	<0.001	<0.001	0.14	0	0.05
Fe(mg/l)	120.67	111.45	121.98	<0.001	<0.001	0.25	10	0.05
Zn(mg/l)	89.45	85.09	79.78	0.11	0.18	0.16	5	6.0-9.0
THC(mg/l)	87.19	95.45	110.56	20.98	24.67	27.89	0	15
THB(cfu/ml)	200,789	211,067	220,000	160,000	176,400	180,000	0	0
TCB (cfu/100 ml)	289.24	349.87	352.89	160	185.7	256.34	400	400

Table 2. Leachate characteristics (Mean ± SD) at Rumuosi and Igwuruta dumpsites in Rivers State and comparison with standard values

Parameter	Rumuosi dumpsite	Igwuruta dumpsite	[WHO 27]	[FMEnv28]
Temperature (°C)	30.00±1.00	31.33±1.15	35	35
pH	6.88±31	8.66±0.22	6	5
EC (µS/cm)	2785.00±1299.92	2080.00±188.68	1500	125
TDS (mg/l)	5952.23±72.52	12663.33±490.95	1000	500
SO_4^{2-} (mg/l)	196.52±6.26	9.12±0.59	50	100
PO_4^{3-} (mg/l)	139.23±3.19	3.81±0.68	2	50
DO(mg/l)	1.51±0.42	2.02±0.16	0	5
BOD (mg/l)	31.22±4.12	21.33±3.51	50	30
COD (mg/l)	313.30±6.57	270.33±26.16	250	75
THB cfu/ml	2.1×10^5±9613.34	1.7×10^5±10660.83	0	0
TCB (cfu/100 ml)	296.33±6.22±6.22	182.68±21.33	400	400

Table 3. Concentration of heavy metals (Mean±SD) in leachate and the standard values

Parameter	Rumuosi dumpsite	Igwuruta dumpsite	[27]	[28]
Pb (mg/l)	11.31±1.33	0.004±0.005	5	0.010
As (mg/l)	11.01±0.67	0.04±0.07	0	0.01
Mn (mg/l)	361.84±12.31	0.05±0.08	0	0.05
Fe (mg/l)	118.03±5.74	0.08±0.14	0.10	0.3
Zn (mg/l)	84.77±4.84	0.15±0.04	5	5
THC (mg/l)	97.73±11.85	24.51±3.46	0	15

Table 4. Physicochemical and bacteriological characteristics of Rumuosi groundwater

Parameter(s) /Units/Distance(s)	Borehole water samples			Control	[27]	[28]
	A	B	C	Agbada2		
	10 m	50 m	150 m	9540 m		
pH	5.61	5.75	6.39	6.89	6.5-8.5	6.5-8.5
TDS (mg/l)	35.3	31.5	<1.00	<1.00	600	100
SO_4^{2-} (mg/l)	0.29	0.26	0.24	<1.0	250	150
PO_4^{3-} (mg/l)	0.11	0.13	0.10	<0.01	-	0.3
DO (mg/l)	4.97	4.42	4.08	4.18	-	7.2
BOD (mg/l)	3	2.5	2.9	<1.00	-	<10
COD (mg/l)	9	8	9	<1.00	<10	5
pb (mg/l)	<0.001	<0.001	<0.001	<0.001	0.01	-
As (mg/l)	<0.001	<0.001	<0.001	<0.001	0.01	-
Mn (mg/l)	<0.001	<0.001	<0.001	<0.001	0.4	150
Fe (mg/l)	<0.001	<0.001	<0.001	<0.001	0.3	20
THC (mg/l)	<1.0	<0.1	<0.1	<0.1	-	-
THB (cfu/ml)	6.0×10^3	4.8×10^3	2.9×10^3	40	-	-
TCB (cfu/100ml)	1500	1120	959	0	2	-
EC (µs/cm)	950	850	1000	1000	1400	100
Odour	very bad	Bad	Mild	Odourless	odourless	odourless
Taste	very bad	Bad	Mild	Tasteless	Tasteless	Tasteless
Temperature°C	26.1				20-30	20-30

Temperature: Tables 1, 2, 4 and 5 showed the studied dumpsites leachate temperature conditions as stable for both leachates (Rumuosi-30.00±1.00ºC; Igwuruta-31.33±1.15ºC) and groundwater (Rumuosi-26.1ºC; Igwuruta-27.8ºC) respectively. This stability congruent the previous study from Adeyi and Majolagbe [15] who stated that temperature has a significant role to play in both leachate and groundwater; this can affect the value of dissolved oxygen in the water.

Table 5. Physicochemical and bacteriological characteristics of Igwuruta groundwater

Parameter(s) /Units/Distance(s)	Borehole water samples			Control	[27]	[28]
	D	E	F	Agbada2		
	10 m	50 m	150 m	1350 m		
pH	5.93	6.05	6.41	6.88	6.5-8.5	6.5-8.5
TDS (mg/l)	37.2	34.6	31.10	<1.00	600	100
SO_4^{2-} (mg/l)	0.35	0.31	0.22	<1.0	250	150
PO_4^{3-} (mg/l)	0.16	0.19	0.13	<0.01	-	0.3
DO (mg/l)	4.75	4.89	4.11	4.97	-	7.2
BOD (mg/l)	3.6	3.9	2.4	<1.00	-	<10
COD (mg/l)	12	10	8	<1.00	-	5
pb (mg/l)	<0.001	<0.001	<0.001	<0.001	0.01	-
As (mg/l)	<0.001	<0.001	<0.001	<0.001	0.01	-
Mn (mg/l)	<0.001	<0.001	<0.001	<0.001	0.4	150
Fe (mg/l)	<0.001	<0.001	<0.001	<0.001	0.3	20
THC (mg/l)	<0.1	<0.1	<0.1	<0.1	-	-
THB (cfu/ml)	$5.7x10^3$	$4.4x10^3$	$3.1x10^3$	42	100	-
TCB (cfu/100ml)	300	220	200	0	2	-
EC (µs/cm)	930	950	980	1000	1400	1300
Odour	very bad	bad	Mild	Odourless	odourless	odo urless
Taste	very bad	bad	Mild	Tasteless	Tasteless	Tasteless
Temperature°C	27.8				20-30	20-30

SO_4^{2-}: SO_4^{2-}concentration of 196.52±72.52mg/l at Rumuosi dumpsite (see Tables 1, 2, 4 and 5) was higher above permissible limits which agreed with works of Adeyi and Majolagbe [15]. High concentrations and possible intake can lead to hydration, diarrhoea, laxative impact and intestinal irritation. SO_4^{2-} concentration of 9.12±0.59 mg/l at Igwuruta dumpsite was also noticed to be within the permissible limits of WHO and FMEnv. The low concentrations of SO_4^{2-}at Igwuruta dumpsite and environs were due to the low permeability of geologic formation and age of the affected dumpsites as stated by Agbozu and Nwosisi [18] in their study of active and closed dumpsites in Port Harcourt metropolis. High concentration in water is harmful to human health as this may lead to dehydration and diarrhoea in children more than adults according to Longe & Balogun [33].

PO_4^{3-}: Tables 1, 2, 4 and 5 showed that PO_4^{3-} concentration of 139.23±3.19 mg/l at Rumuosi leachate dumpsite was higher than the stated permissible limits and this corroborated with the studies of Adeyi and Majolagbe [15] who established that high level of detergents and other chemical pollutants from the dumpsites may have contributed to the high concentration. On the contrary, Igwuruta leachate concentration of 3.81±0.68 mg/l was lower than the permissible limits and maybe due to the low level of chemicals and detergent pollutants at the dumpsite [15]. The groundwater conditions of PO_4^{3-} concentration (Tables 4 and 5) of the studied dumpsites were within the permissible limits. The presence of high PO_4^{3-} from leachate into groundwater is harmful as it enhances the growth of algae and causes increased eutrophication Agbozu & Nwosisi [18].

EC: Tables 1, 2, 4 and 5 showed that EC values for the two dumpsites ranged between 2785±1299.92 mg/l and 2080±188.68 mg/l which were above the stated permissible limits of WHO and FMEnv. Sackey and Meizah et al. [20] congruent that high values of EC were due to nutrient enrichment from nitrogen, nitrite, nitrate, ammonia, phosphate and sulphate concentrations causing unbearable odour and also increased eutrophication in water bodies.

TDS: TDS leachate concentrations (59552.23±72.52 mg/l) and (12663.33±490.95 mg/l) of the studied dumpsites (Rumuosi and Igwuruta) respectively showed in Tables 1, 2, 4 and 5 were high and above the permissible limits for potable drinking water which may be caused by inorganic composition in these dumpsites. This high TDS confirmed the work of El-Salam and Abu-Zuid [29] who established that unlined dumpsites may lead to increased TDS. While the TDS concentrations in groundwater samples were below the stated permissible limits for potable drinking water. This may be due to the low permeability and infiltration capacity of the soils [34] as cited by Agbozu and Nwosisi [18].

Table 6. ANOVA summary for Tables 3 and 4 of Rumuosi and Igwuruta leachate concentration

Summary	Count	Sum	Average	Variance		
Temperature(°C)	2	61.33	30.665	0.88445		
pH	2	15.54	7.77	1.5842		
EC (µS/cm)	2	4865	2432.5	248512.5		
TDS (mg/l)	2	18615.56	9307.78	22519431.61		
Sulphate (mg/l)	2	205.64	102.82	17559.38		
Phosphate (mg/l)	2	143.04	71.52	9169.2882		
DO (mg/l)	2	3.53	1.765	0.13005		
BOD (mg/l)	2	52.55	26.275	48.90605		
COD (mg/l)	2	583.63	291.815	923.21045		
THB cfu/ml	2	382752	191376	740563006.6		
TCB (cfu/100 ml)	2	479.01	239.505	6458.16125		
Pb (mg/l)	2	11.314	5.657	63.912818		
As (mg/l)	2	11.05	5.525	60.17045		
Mn (mg/l)	2	361.89	180.945	65446.00205		
Fe (mg/l)	2	118.11	59.055	6956.10125		
Zn (mg/l)	2	84.92	42.46	3580.2722		
THC (mg/l)	2	122.24	61.12	2680.5842		
RUMUOSI	17	221055.6	13003.27118	2595586485		
IGWURUTA	17	187430.7	11025.33788	1733011292		
ANOVA						
Source of variation	**SS**	**df**	**MS**	**F**	**P-value**	**F crit**
Rows	68527374408	16	4282960900	93.84868562	9.19779E-13	2.333483627
Columns	33253870.99	1	33253870.99	0.728662287	0.405915964	4.493998478
Error	730190028.3	16	45636876.77			
Total	69290818307	33				

SS = Sum of square, df = Degree of freedom, MS= Mean of square, P-value = Probability value, f = Frequency

Table 7. Leachate pollution index for Rumuosi and Igwuruta dumpsites

S/N	Parameter	Wi		Ci		Pi		WiPi	
		Rumuosi	Igwuruta	Rumuosi	Igwuruta	Rumuosi	Igwuruta	Rumuosi	Igwuruta
1	pH	0.056	0.055	6.88	8.66	5.4	6	0.3024	0.33
2	TDS	0.051	0.052	5952.2	12663.3	30	25	1.53	1.3
3	BOD	0.062	0.06	31.22	21.33	25	28	1.55	1.86
4	COD	0.061	0.062	313.30	270.33	25	27	1.53	1.67
5	Pb	0.064	0.063	11.31	0.004	7	6	0.45	0.38
6	As	0.06	0.061	11.01	0.04	6	6	0.36	0.37
7	Mn	0.048	0.051	361.84	0.05	7	5	0.34	0.26
8	Fe	0.045	0.05	118.03	0.08	5	5	0.23	0.25
9	Zn	0.054	0.05	84.77	0.15	6	7	0.32	0.35
10	TCB	0.051	0.052	296.33	182.68	10	15	0.51	0.78
Total		0.552	0.556					7.1224	7.55
LPI								12.9	13.58

LPI = Leachate Pollution Index, Wi = Variable weights, Ci = Sample results, Pi= Sub-index

Studies from Adeyi and Majolagbe [15] established that the palatability of water with TDS value lower than 500mg/l is considerably good, while water with TDS concentration above 1000 mg/l is intolerable due to offensive taste. WHO [35] related that high concentrations of TDS are an indication of a large number of anions and cations of inorganic materials which may lead to reduced potability of water and promote health complications such as gastro-intestinal disorder in humans and laxative impact.

DO: Table 2 showed DO concentration of 1.51±0.42 mg/l at Rumuosi dumpsite while in contrast to Igwuruta dumpsite, DO concentration (2.02±3.51 mg/l) [20]. Generally, the lower DO at Igwuruta corroborated with the findings of Ojoawo et al. [33] who stated that low DO could be factored to dumpsite stability and methanogenic stages. A low DO can lead to the anaerobic condition.

BOD: The BOD of Rumuosi dumpsite leachate concentration of 31.22±4.12 mg/l was slightly higher than the stated standards of WHO and FMEnv (30 mg/l) corresponding to studies of El-Salam and Abu-Zuid [29]. This same trend was observed at Igwuruta leachate dumpsite with a lower concentration value of 21.33±3.51 mg/l which indicated aged dumpsite. The groundwater concentration values at the studied dumpsites were moderately low as compared to other studies within Port Harcourt metropolis as confirmed by Agbozu and Nwosisi [18] and Ugwoha et al. [19] indicating low biodegradability.

COD: COD of Rumuosi as shown in Tables 1, 2, 4 and 5 indicated concentrations of 313.30±6.57 mg/l which was slightly above Igwuruta leachate dumpsite concentration (270.33±26.16 mg/l). The low concentration at Igwuruta dumpsite corroborated with the views of El-Salam and Abu-Zuid [29] who stated that very aged dumpsites produce stable leachate with low biodegradability. However, the concentrations of COD at Rumuosi dumpsite indicated that there was high organic and inorganic degradation at the dumpsites which corroborated with the findings of Talalaj [36] who also observed a similar trend in their research. Rumuosi and Igwuruta groundwater sampled boreholes ranged between 8-12 mg/l which was slightly higher than stated standards for WHO [27] and FMEnv [28]. The high COD concentrations in the groundwater samples of both dumpsites revealed the presence of some chemically oxidized organic contaminants in the groundwater which may reduce dissolved oxygen level [17].

TCB: Tables 2, 4 and 5 showed TCB concentration of 296.33±6.22 mg/l and 182.68±21.33mg/l at Rumuosi and Igwuruta dumpsites respectively which was below permissible limits 400 cfu/100 ml. These values suggested low quantities of disease-causing agents in the groundwater of the studied dumpsites. High coliform bacteria in groundwater may cause illness, and their presence in drinking water indicates that disease-causing organism can be in the water samples.

THB: The THB at Rumuosi and Igwuruta were 2.1×10^5cfu/ml and 1.7×10^5cfu/ml. When corroborated with other researchers [37] and WHO [27] there are 4.5 billion cases of intestinal infections every year, of which 1.9 million ends in death. It also presents a breeding ground for more dangerous bacteria such as E.coli, Legionella, causes foul taste water, leads to corrosion and slime growth in the pipe.

Heavy Metals: The results in Table 5 indicated that traces of heavy metals at the Rumuosi dumpsite were Mn (361.84±12.31 mg/l), Fe (118.03±5.74 mg/l), Zn (84.77±4.84 mg/l), Pb (11.31±1.33 mg/l) and As (11.01±0.67 mg/l) respectively which were higher than permissible limits. The heavy metals at Igwuruta dumpsite were 0.004±0.005 mg/l, 0.04±0.07 mg/l, 0.05±0.08 mg/l, 0.08±0.14 mg/l and 0.15±0.04 mg/l respectively; these were within the permissible limits. The high presence of heavy metals at the Rumuosi leachate was due to the presence of certain hazardous wastes such as chemicals from the photographic system, dry batteries, roofing sheets, electronic equipment, spent oils, lubricants and ceramic wastes which may increase the risk of groundwater contamination [8]. Several author [21,38] stated that the most common health risk was high oral exposure, ingestion, inhalation and absorption of zinc and anaemia.

Table 5 showed a summary of the two-way ANOVA examined to show the differences in leachate pollution at the studied dumpsites. The results showed significant differences (p=0.05) for the row source of pollution variability while there was no sign at the column source of variability in the physicochemical and biological indicators of the dumpsites as Rumuosi dumpsite had more concentrations of pollutants than Igwuruta dumpsite. This result suggests that the contaminations are independent and in tandem to the nature of waste deposits.

5. CONCLUSION

The impact of leachate from unlined waste dumpsites on groundwater quality was evaluated using two studied dumpsites in Rivers State Nigeria. The acquired field and analyzed data for the dumpsites on leachate and groundwater samples were compared with WHO and FMEnv Standards for potable drinking water. The two studied dumpsites indicated that the computed values of pH, SO_4^{2-}, PO_4^{3-}, TDS, DO, BOD, and COD at the dumpsites were 6.88 and 8.66, 196.52±3.19 mg/l and 9.12±0.59 mg/l, 139.23±3.19 mg/l and 3.81±0.68 mg/l, 5952.23±72.52 mg/l and 12663.33±490.95 mg/l; 1.51±0.42 mg/l and 2.02±0.16 mg/l; 31.22±4.12 mg/l and 21.33±3.51 mg/l; 313.30±6.57mg/l and 270.33±26.16 mg/l respectively which exceeded the standards of the WHO and FMEnv. The high values of analyzed parameters were an indication of possible groundwater contamination. Heavy metals in the Rumuosi dumpsite indicated 11.31±1.33 mg/l, 11.01±0.67 mg/l, 361.84±12.31 mg/l, 118.03±5.74 mg/l and 84.77±4.84 mg/l for Pb, As, Mn, Fe and Zn respectively. While Heavy metals thresholds at Igwuruta were 0.004±0.005 mg/l, 0.04±0.07 mg/l, 0.05±0.08 mg/l, 0.08±0.14 mg/l and 0.15±0.04 mg/l respectively. Rumuosi thresholds exceeded the standards, indicating that the exposed local people in the nearby communities may experience cases of non-carcinogenic and carcinogenic health risk by drinking the groundwater. TCB was 296.33±6.22 cfu/100 ml and 182.68±21.33 cfu/100 ml respectively which were within the permissible limits of 400 cfu/100 ml specific by WHO and FMEnv; which suggest low quantities of disease-causing agents in the groundwater. The total heterotrophic bacteria (THB) were $21x10^4$ cfu/ml and $17x10^4$ cfu/ml. These high values of THB may not be an indication of contamination of groundwater but it indicates a gradual decline in raw water quality. The leachate pollution index (LPI) at the studied dumpsites indicated 13.58 and 12.9 which exceeded the internationally accepted benchmark of 7.38; indicating that the Rumuosi leachate was more polluted than Igwuruta leachate. The researcher recommended the practice of sanitary landfill which may reduce the risk of leachate percolation, a primary source of groundwater contamination.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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