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LEACHATE CHARACTERISTICS AND IMPACT ON GROUNDWATER QUALITY UNDERLAIN THE MUNICIPAL DUMPSITE IN IKOTO, OGUN, SOUTHWESTERN NIGERIA

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ABSTRACT: *Leachates by percolating through landfill liners and porous subsoil can cause groundwater pollution and adverse effects on public health depending on the chemical and biological composition of the leachate pollutants. Physico-chemical and bacteriological characteristics of leachate and water samples in/and around the Ikoto Municipal dumpsite, Ogun Southwestern Nigeria were assessed and compared to check for the impact of landfill leachate pollutants on the groundwater quality of the area. Twenty-five (25) leachate samples on the dumpsite and Ten (10) water samples around the dumpsite were collected and analysed following standard procedures. The results when compared showed that some tested parameters (with CO_3^{2-} having highest mean concentrations of 1509.7mg/L and 32.90mg/L in leachate and water sample respectively) were present in both samples at close concentration range thus indicating contamination of the groundwater by leachate percolation; thus, rendering the water unhygienic and unfit for consumption and domestic use without treatments.*

KEYWORDS: Dumpsite, Characterization, Leachate, Groundwater, Percolation, Quality, Impact, Nigeria

INTRODUCTION

Leachate generally refers to any liquid that extract soluble or suspended solids or any other component of the material/medium through which it passes **(**Henry and Heinke, 1996**)**. Leachates are environmentally harmfully substances draining from stockpile of putrescible land-fills or industrial wastes. Leachates generated from illegally dumped and poorly managed solid wastes, have mostly been implicated in environmental pollution, developmental anomalies, birth defects, surface and groundwater pollution worldwide (Aluko *et al.*, 2003, Lawal *et al.*, 2013). Solid waste encompasses all waste spawning from both human and animal activities **(**Okecha, 2000; Olukanni and Olatunji, 2018**)**. Some examples include by-products of materials such as household wastes like food leftovers, empty cartons, and polythene bags that may be obligatory to be disposed of by law (Olukanni and Nwafor, 2019). Municipal Solid Waste (MSW) management is one of the major problems facing city planners all over the world. The problem is especially severe in most developing-country cities where increased urbanization, poor planning, and lack of adequate resources contribute to the poor state of municipal solid waste management (Obirih-Opareh and Post, 2002). Although solid waste is an asset when properly managed, but in recent times, it has become a major concern in almost all communities in Nigeria owing to the fact that continuous demographic expansion and increased industrial and commercial activities among others is causing astronomical increases in the volume and diversity of solid wastes generated in Nigeria (Aluko, 2001).

Improper waste management techniques and poor sanitation practice are characteristic of many communities in Nigeria which results into massive discharge of wastes into open lands, surface water, groundwater and erosion causes further pose very serious threat to water quality (Orheruata and Omoyakhi, 2008). For instance, trace metals gain access into water bodies possibly through anthropogenic and natural sources. These trace metals can be accommodated in three basic reservoirs: water, biota and sediments (Florea and Busselberg, 2006; Hung and Hsu, 2004). Some trace metals are potentially toxic because they act on the cell membrane or interfere with cytoplasmic or nuclear functions after entry into the cell. Hence, their accumulation in the human body could result to malfunctioning of organs (Jarup, 2003). At high concentrations, they cause acute systemic poisons. Also, the use of raw water with high salts result to nauseous, saline taste with purgative tendency and dehydration. Of great concern are salts containing nitrates and nitrites. These are known to cause methemoglobinemia in children (Oduyiga and Oduyiga, 2014).

In view of the above, this paper therefore aims at assessing and comparing the microbial and physio-chemical quality of landfill leachate and water samples from shallow wells in Ikoto Dumpsite and environs, Ogun State Southwestern Nigeria in order to ascertain the impact of leachates from the dumpsite on the underground water body within the area.

Theoretical Underpinning

According to CIA 2020 report, Nigeria has an estimated population of about 214 million people with an annual growth of 2.53% and an estimated population of 319 million by 2050. 52% of this population live in urban areas and they are known to be one of the largest producers of solid waste (Bakare, 2018). The sad reality however is that despite the much that has been, and/or is being invested on municipal solid waste management in many cities, little progress has been made thus far, because of severe financial, technological and institutional constraints within the Public and the private sectors apart from erratic growth of housing units in the inner core of urban cities (Ojeshina, 1999; Omishakin and Sridhar, 1985). Another problem of waste management in Nigeria is the lack of public policy enabling legislation and an environmentally stimulated and enlightened public (Olukanni and Nwafor, 2019). Even though laws and regulations were formulated and presented in the past, there has not been any functional infrastructure for their implementation. These regulations set for operations became unsuccessful because of the absence of effective sanctions, coupled with economic considerations that are deficit of knowledge of interdependent linkages among various processes involved in both human and environmental resources to mitigate the myriad of waste management challenges (Olukanni and Akinyinka, 2012; Olukanni *et al.,* 2014; Sridhar *et al.,* 2017).

In spite of several attempts on waste avoidance, reduction, reuse and recovery (recycling, composting and energy recovery), landfill and waste disposal sites are still the major focus for ultimate disposal of residual wastes and incineration residues all over the world

(Charlotte, 1998; Waite, 1995). Dumping wastes in open dumpsites is the commonest, simplest and cheapest method of waste disposal and primary means of waste management in many developing countries. This stock-pilling and compaction of municipal wastes in landfills facilitates the development of facultative and anaerobic conditions that promotes biological decomposition of landfills wastes and leads to production of leachates of diverse composition, based on site construction and operational practices, age of the landfill, landfill method, climatic and hydrogeological conditions and surface water ingress into the landfill (Campbell, 1993). The disadvantage of this goes beyond environmental impact into severe adverse health issues such as cancer (Popoola and Adenuga, 2019; Ige, 2014), it's terrible implication in contaminating waste sources especially the groundwater cannot be over emphasized, as adverse health related issues with death threat can result from such. The realisation of the polluting effects of landfill leachates on the environment has prompted a number of studies. These include studies on domestic wastes (Sridhar *et al,* 1985), leachate quality assessment (Aluko *et al*, 2000), as well as underground water quality (Loizidou and Kapetanios, 1993). Previous reports revealed that communities near open dumpsites are liable to drinking contaminated water and substantial negative health outcomes (Taylor and Allen, 2006). Common chemical pollutants found in the groundwater around open dumpsites are dependent on components of disposed wastes and the by-products of the natural degradation of waste products. Pollutants may also include inorganic metals, volatile organic compounds, polycyclic aromatic hydrocarbon (PAHs), chlorinated solvents and more (Iwegbue *et al.*, 2010). Residents can therefore be exposed to these pollutants through dermal absorption, consumption of contaminated water, inhalation of toxic fumes and through the food chain. Also, industrial and domestic wastes pollutants on human life have been reported (Moore *et al.,* 2011).More so, according to the research previously carried out by (Lawal *et al* 2013) using geophysical- Schlumberger array method, it was revealed that hydro-geologically that the study area consists of earth materials that are highly porous and permeable which can aid infiltration of contaminants (leachate) into the underground when adequate measures are not taken. The study area consists of sand, dry sand and sandstone which shows that the dumpsite of the study area is situated on aquiferous materials. The knowledge of the quantity and composition of leachates in terms of biological, chemical and trace metals usually give an insight into the associated health risks within the neighbourhood where land-fill wastes abound. With this in mind, this current research compares the biological and chemical characteristics of the leachates from the study area and well-water samples around the area to investigate the extent of the infiltration of leachates contaminants into the underground water.

MATERIALS AND METHODS

Research Design

The study adopted an experimental research design

Study location

The study area is located within the sedimentary terrain of Southwestern region of Nigeria with coordinates, 6° 56´ 391″N to 6°56´ .565″N and 3°47´.501″E to 3°47´.572″E. Ikoto dumpsite is located at Ikoto community along Ijebu Ode-Benin Express road, Ogun State, Nigeria.

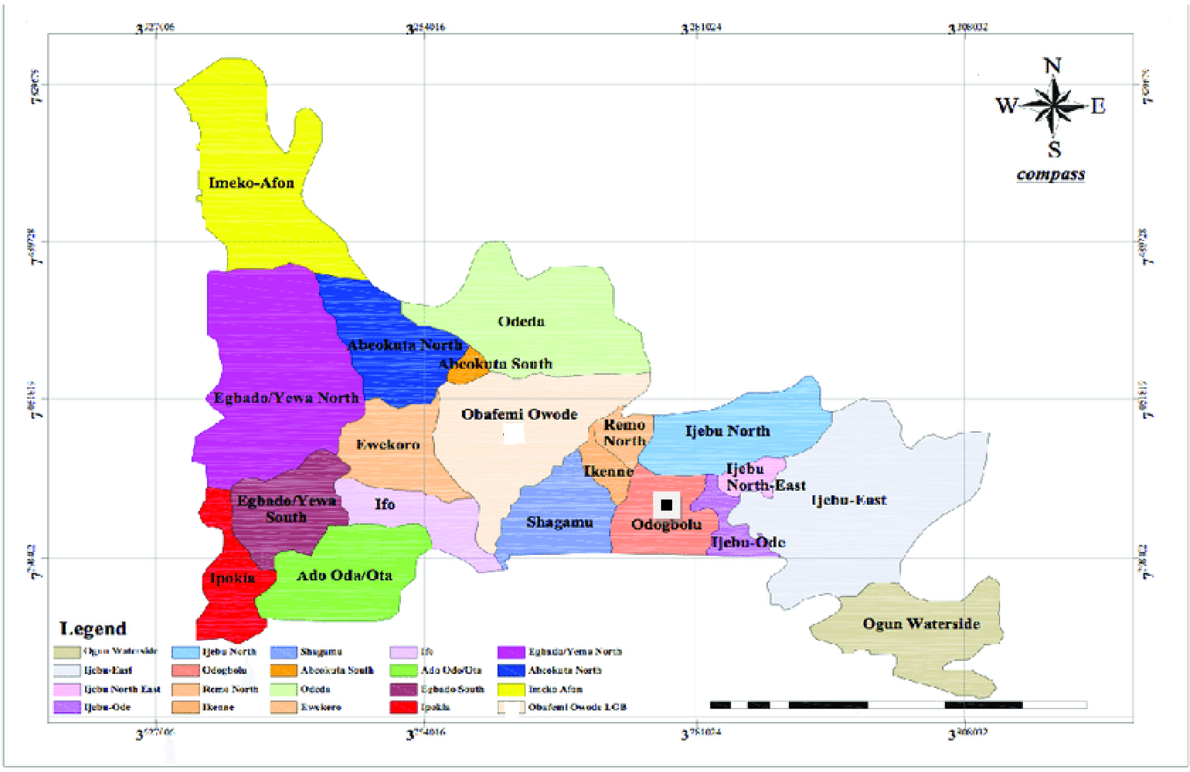

Figure 1: Map of Ogun State showing the study area.

Source: Survey Department, Ministry of Works, 2016; Oyinloye et al., 2017.

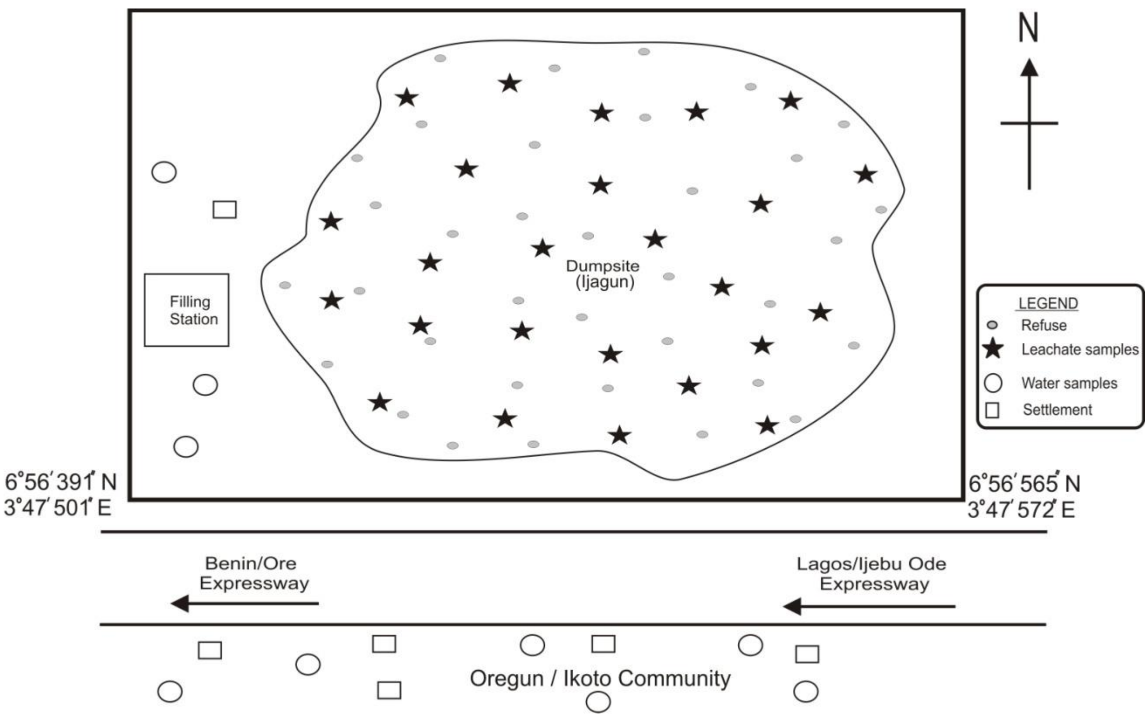

Figure 2: Sketch Map of the Dumpsite

Collection of Samples and Analysis

The methodology employed in Leachate collection and sampling was as adapted from Aluko *et al* (2003). Twenty-Five (25) leachate samples from randomly selected leachate drains at the dumpsite and Ten (10) water samples from borehole situated in residential houses built few meters away from the dumpsite to serve as control in assessing the influence of the dumpsite on household water sources. Analysis of the samples were carried out in Federal Ministry of Water Resources laboratory, Alausa, Ikeja, Lagos Nigeria according to standard method for examining water and wastewater (APHA, 1998). Determination of Conductivity and Total Dissolve Solids were done using JENWAY 470 Conductivity meter while the pH was determined using HANNA HI4212 pH Meter following standard procedures and manufacturer's instruction.

Method of Data Analysis

Data collected from the result of the analysis of the water and leachate samples will be analysed by comparing the two results to the WHO standard using statistical tools such as mean, correlations and the use of a bar chart for pictorial representation.

RESULTS AND FINDINGS

Table 2: Temperature, pH, Conductivity, Total Dissolved Solids (TDS) Leachate and Water Samples from the Study Area

Parameters	Sample Type		Standards
	Leachate	Water	WHO (2006)
Temp (°C)	29.94±0.18	29.33±0.33	-
pH	6.89±0.14	4.99±0.19	6.5-8.5
EC (µS/cm)	3027.90±1039.3	100.57±47.76	1200
TDS (mg/L)	1968.7±672.60	64.57±31.33	1000

Values are expressed as mean ± S.E.M. of the determinations.

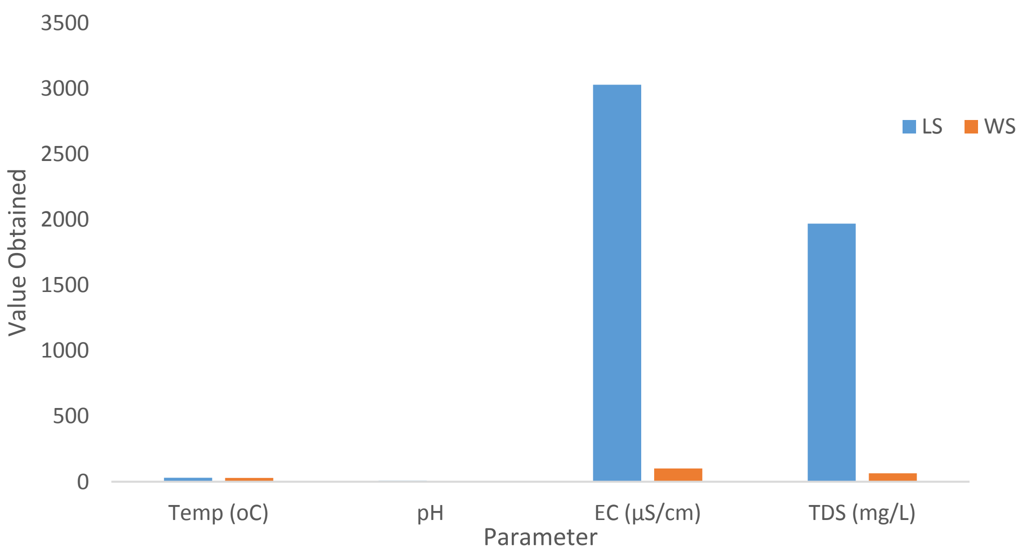

Figure 3: Bar Chart showing the Comparison between Physio-chemical parameters of Leachate Samples (LS) and Water Samples (WS)

The result of the physio-chemical analysis of the leachate and groundwater samples are presented in table 2 and table 3 which shows the maximum permissible limit for drinking water as recommended by Federal Ministry of Water Resources and World Health Organization.

The physio-chemical parameters are presented in Tables 2 and Table 3. The temperatures recorded at the point of collection for all the samples ranged between 29.3ºC to 30.6ºC, with a mean of 29.33ºC and 29.94ºC for Water Samples and Leachate samples respectively depending on the environmental condition at the time of collection. The pH range of all the samples in both analytes was 7.18 – 7.56 with a mean of 6.89 and 4.99 for Leachate and Water samples respectively. Furthermore, the electrical conductivity (EC) and Total Dissolved Solids (TDS) measured parameters of all the samples ranged between 33.50 and 6300µs/cm (with mean EC values of 3027.90µs/cm and 64.57µs/cm for the Leachate Samples and Water Samples respectively), and 20 and 4090mg/L (with respective mean TDS values of 1968.70mg/L and 64.57mg/L for Leachate samples and Water Samples) respectively.

Table 3: Metallic ion and Non-metallic ion levels in Leachate and water Samples from the Study Area

Parameters	Sample Type		Standards
	Leachate	Water	WHO
Na^+	151.71±46.46	4.30±0.87	200
Ca^{2+}	94.21±22.06	4.01±1.23	100
Mg^{2+}	85.43±22.72	2.67±1.28	150
Pb^{2+}	0.45±0.17	0.34±0.09	0.5
Cd^{2+}	0.02±0.00	0.00±0.00	1
NH_4^{2+}	199.90±50.73	0.00±0.00	30
F^-	1.57±1.27	0.01±0.00	0.05
Cl^-	323.23±76.38	7.95±2.00	250
CO_3^{2-}	1509.7±456.17	32.90±16.55	10

Values are expressed as mean ± S.E.M. of the determinations.

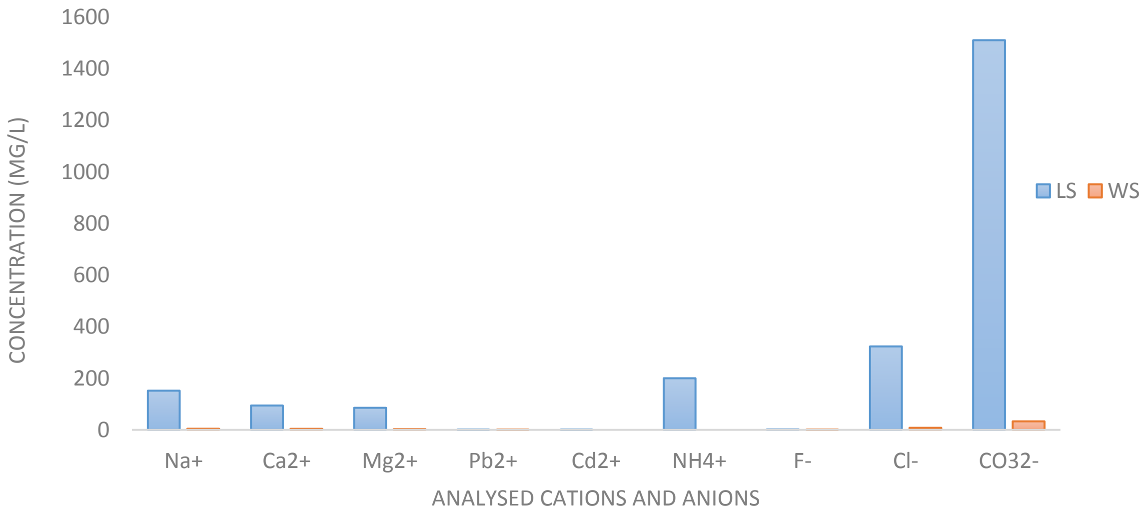

Figure 4: Bar Chart Showing Comparison of Cations and Anions Present in Leachate Samples and Water Samples from the Study Area

The chemical analysis to ascertain the presence and levels of some metals and non-metals in the water samples (Table 3) showed that the concentration of Na^+ in all the samples ranged between 3.10 and 300mg/L with mean concentrations of 151.71±46.46mg/L and 4.30±0.87 for Leachate Samples and Water Samples respectively. Ca^{2+} concentration ranged between 1.60mg/L and 176.00mg/L (with mean concentrations of 94.21±22.06mg/L and 4.01±1.23mg/L for Leachate Samples and Water Samples respectively) while Mg^{2+} concentration ranged between 0.24mg/L and 178.00mg/L for all the samples (with respective mean concentrations of 85.43±22.72mg/L and 2.67±1.28mg/L for Leachate and Water Samples). Furthermore, $Pb^{2+}$and Cd^{2+} hadrange of concentrations of 0.11 – 0.78mg/L (with mean Pb^{2+} concentrations of 0.34±0.09mg/L and 0.45±0.17mg/L for Leachate Samples and Water Samples respectively) and <0.01 – 0.05mg/L (with mean Cd^{2+} concentrations of 0.02±0.00mg/L and 0.00±0.00mg/L for Leachate Samples and Water Samples) respectively; whileNH_4^{2+}concentrations in all the analysed samples ranged between <0.01mg/L and 361.00mg/L with mean concentrations of 199.90±50.73mg/L and 0.00±0.00mg/L for Leachate samples and water samples respectively. The analysed anions revealed that F^- and Cl^- had concentrations ranging between <0.01mg/L and 9.00mg/L (with mean F^- concentrations of 1.57±1.27mg/L and 0.01±0.00mg/L for Leachate Samples and Water Samples respectively) and between 4.86mg/L and 524.00mg/L (with respective average Cl^- concentrations of 323.23±76.38mg/L and 7.95±2.00mg/L for Leachate Samples and Water Samples) respectively while CO_3^{2-} is present in all the samples in the range of 2.10mg/L – 2730mg/L with mean concentrations of 1509.7±456.17mg/L and 32.90±16.55mg/L(table 3). These results show that all the physio-chemical parameters are more in the Leachate Samples than in Water Samples in the all samples.

Table 5: Correlation Matrix of the Physio-chemical Parameters of all Water Samples

	temp	ph	EC	TDS	Ca	Mg	Na	Cd	Pb	Cl^-	F^-	NH_4^+	CO_3^{2-}
Temp	1												
pH	.713*	1											
EC	.201	.655*	1										
TDS	.203	.657*	1.00**	1									
Ca	.117	.544	.341	.343	1								
Mg	.345	.548	.226	.228	.909**	1							
Na	.142	.653*	.979**	.978**	.456	.294	1						
Cd	.692*	.296	-.253	-.248	.217	.461	-.250	1					
Pb	-.061	-.249	-.637*	-.635*	-.270	-.262	-.641*	.252	1				
Cl^-	.110	.665*	.819**	.819**	.465	.188	.882**	-.185	-.358	1			
F^-	-.069	.351	.636*	.637*	.558	.432	.615	-.204	-.376	.483	1		
NH_4^+	.381	.784**	.956**	.958**	.298	.220	.911**	-.100	-.501	.816**	.564	1	
CO_3^{2-}	.041	.605	.843**	.843**	.328	.037	.883**	-.353	-.378	.977**	.478	.833**	1

*Correlation is significant at 0.005 level (2-tailed)
**Correlation is significant at 0.01 level (2-tailed)

Correlation matrix of all the physio-chemical parameters carried out to obtain positive and negative Pearson correlation coefficients among the parameters is presented in Table 5. The result showed that the parameters influenced each other. For instance, significant coefficients ($p \leq 0.01$) were obtained between EC and TDS ($r = +1.00$), Na^+ and EC ($r = 0.979$), Na^+ and TDS ($r = 0.978$), CO_3^{2-} and Cl^- ($r=0.977$), NH_4^+ and TDS ($r=0.958$), NH_4^+ and EC ($r=0.956$), NH_4^+ and Na^+ ($r=0.911$), Mg^{2+} and Ca^{2+} ($r=0.909$), CO_3^{2-} and Na^+ ($r=0.883$), Na^+ and Cl^- ($r = +0.882$), CO_3^{2-} and EC ($r=0.843$), CO_3^{2-} and TDS ($r=0.843$), CO_3^{2-} and NH_4^+ ($r=0.833$), EC and Cl^- ($r = +0.819$), TDS and Cl^- ($r = +0.819$), NH_4^+ and Pb^{2+} ($r=0.816$), among others.

The results of the microbiological analyses are presented in Table 4. The quantitative microbial analysis of almost all the samples (Table 3) revealed that all the samples contain significant numbers of bacteria in them when compared with the WHO (2006) standards for drinking water. The mean Bacteria counts in X 10^4 CFU/ml obtained were 30.80±6.70 and 2.95±2.53 for Leachate Samples and Water Samples respectively. Mean *E. coli* (Coliform counts) also in X 10^4 CFU/ml gave values of 6.26±1.08 and 0.11±0.07 for Leachate Samples and Water Samples respectively. This thus showed that all the samples from Leachate Samples and Water Samples were polluted with pathogenic bacteria which of significant health implication.

Table 4: Mean Total Coliform and *E. coli* Counts (CFU/ml) of Leachate and Water Samples from the Study Area

Sample Type	Coliform Count (X 10^4)	E. coli Count (X 10^4)
Leachate	30.80±6.70	6.26±1.08
Water	2.95±2.53	0.11±0.07
WHO[22] standard	NONE	NONE

Values are expressed as mean ± S.E.M. of the determinations.

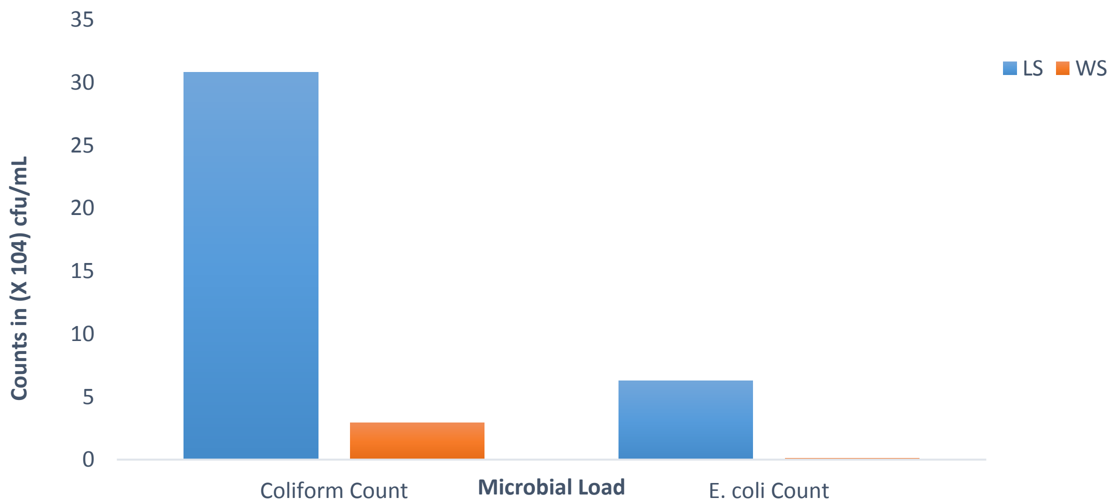

Figure 5: Bar Chart showing the Comparison of Microbial Load Present in Leachate Samples and Water Samples

DISCUSSION OF RESULTS

From the results obtained, the groundwater is clear, tasteless and odourless while the leachate samples are not clear and possesses odour. This is expected as the water samples are from deep wells and agrees with the findings of Adeyemo *et al*. (2002) and Adekunle *et al* (2007). The temperature regimes of both the Leachate and groundwater samples are virtually constant and ranged between 29.3ºC to 30.6ºC. Although this largely depends on the environmental conditions at the time of collection, but according Awofolu *et al.* (2007) water temperature may affect the chemistry of the groundwater as well as metals toxicity. pH values of the samples are in the normal range of the WHO (2006) standards in drinking water of 6.50 – 8.50. This result compares well with the findings of Adeyemo *et al* (2002) on the water quality and sanitary conditions in a major abattoir (Bodija) in Ibadan, Nigeria and that of Longe and Enekwechi (2007). Electrical Conductivity (EC) indicates the presence of dissolved solids and contaminants especially electrolytes but does not give information about specific chemical. Most drinking waters have conductivity measurement below 2000µS/cm but the WHO recommended value is ≈250 µS/cm. Conductivity increases as the concentrations of ions in water and any liquid sample increases. Although the conductivity levels of the Leachate samples from the study area is very high (above the WHO recommended value), that of the groundwater samples from wells studied were all less than 200µS/cm (Figure 3). The total dissolved solid (TDS) content of the water samples in some cases (Nwodo *et al.*, 2011). The total concentration of dissolved solids (TDS) in water, which is a general indication of its suitability for any particular purpose (Omofonmwan and Eseigbe, 2009), obtained from the analysed water samples falls within the WHO (2006) standards for drinking water of <500mg/L (Table. 2). But in comparison, that of the Leachate Samples was significantly higher than in the water samples and the WHO acceptable standards (Figure3)

From Table 3, all the assessed cations and anions (i.e. Na^+, Ca^{2+}, Mg^{2+}, Cd^{2+}, NH_4^+, F^-, Cl^-, CO_3^{2-}) in the water samples fell within WHO permissible limits for portable water, but were all significant above the WHO standards and the water samples in all the Leachate samples (Figure2). Although the presence of these ions at their current concentrations in the groundwater sampled may not be of significant health effects on humans, but with the very high and significant concentrations observed in the Leachate samples and the tendency for the leachate to travel rapidly, the groundwater resource in this area stands the risk of contamination in no distance time and will need remediation to safe the health of the inhabitants of the area. Reported and observed factors, part of which is the underground geological formations peculiar to the terrain of the study area (as reported by Lawal *et al.*, 2013), the prevalent anthropogenic activities (as observed in the course of the field survey of this current work) among many other factors will accelerate the groundwater contamination index in the area.

The positive significant correlation obtained between some of the parameters (table 5) indicated that the presence of one of the parameters positively influence the other. For instance, the pH values obtained is influenced to a significant degree by the presence of Sodium and calcium salts in the water samples. Both metals produce acidic salts with weak tetraoxosulphateIV acid which have tendency of reducing the pH of a solution (Ababio, 2008). Similarly, metallic ion salts in water readily form mobile ions and can affect the electrical conductivity of water significantly Adekunle *et al.*, 2007; Ababio, 2008; Orebiyi *et* *al.*, 2010; Adegbola and Adewoye, 2012). This explains the observed positive correlation between EC, TDS and ions in Table 5.

An important indicator of water quality is the number of bacteria present in the water. Though it would be difficult to determine the presence of all bacteria in a sample, certain types of microorganisms can serve as indicators of pollution (Oparaocha *et al.*, 2010; Oduyiga and Oduyiga, 2014). Chief among these are the coliform bacteria which survive better, longer and are easier to detect than other pathogens (Kegley and Andrew,1998; Agunwanba, 2000). The concept of coliforms as bacterial indicator of microbial water quality is based on the premise that coliforms are present in high numbers in the faeces of humans and other warm-blooded animals. If faecal pollution has entered groundwater; it is likely that these bacteria will be present, even after significant dilution (Mor *et al.*, 2005). From the results, the mean values of bacteria count in both water and leachate samples were significantly high when compared with the WHO standards (Fig. 4). The World Health Organization has recommended a zero value of bacteria and total coliform count in drinking water. Also, the significantly high mean values of E. coli count in the samples is an indication of heavy pollution with pathogenic organisms of the groundwater which among others could possibly be due to leachate (generated from the wastes that percolates into the groundwater Lawal *et al*., 2013).

Among the pathogenic bacteria possibly present is *Escherichia coli*. *E. coli* is regarded as the most sensitive indicator of faecal contamination. Its presence in the borehole water samples is of a major health concern and calls for remedial attention (Centre for Disease Control (CDC), 1999). The presence of this pathogen in the samples was an indication of the likely presence of other enteric pathogens (Petridis *et al*., 2002).

Implication of Research

The discussion has shown that if government are not proactive and manage the Ikoto dumpsite there is likelihood of the dumpsite leachate penetrating to the water source thereby affecting the health of the community in the process.

CONCLUSION

The study of leachate and groundwater quality in the area of study reveals that there is a significant risk of the leachate percolating to the groundwater thereby polluting it and not making it good for consumption considering the concentration of leachate being generated and the anthropogenic activities of man and animals around the dumpsite. In view of the above, care should be taken to implement a good and scientific disposal of municipal solid waste (MSW) in the study area which will facilitate the proper treatment of the generated leachates before it is exposed to the environment thereby protecting the groundwater from contamination.

Future Research

In view of this, it is recommended among others, that Governmental policies on waste disposal and management should be enacted and strictly enforced; Dumpsite should be sited far away from residential areas to minimize pollution of nearby well water or water sources;

Waste sorting and treatment before disposal should be encouraged; Re-designing of sanitary dumpsite with clay or plastic liners should be done to prevent leachate from getting to water table; waste recycling and secondary use of trash should be looked into and more public awareness should be created to the people to stop disposing wastes incessantly in the environment.

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