ASSESSMENT OF GROUNDWATER PHYSICO-CHEMICAL PARAMETERS NEAR WASTE DUMPSITES IN THE WESTERN NIGER DELTA, NIGERIA

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ABSTRACT
The effect of waste dumpsite on physico-chemical parameters was here evaluated for water samples in order to determine the effect of waste leachate on the water quality in the area. Ten water samples were randomly collected using sterile plain bottles and 1-litre plastic bottles. The depth to water table in the area ranged between 8.3m and 12.3m. The results of the physico-chemical parameters of the water samples showed that some parameters such as colour, pH, Fe, Pb and coliform bacteria exceeded the permissible standards. The water quality index (WQI) showed that the groundwater is of poor quality rating indicating that the leachate plume contaminants has migrated from the dumpsites to the groundwater aquifer due to weak/poor aquifer overburden layer implying some remediation before domestic usage. The existing waste dumpsites should be evacuated and relocated from the area and further dumping of waste be discontinued.

Index Terms: **Aquifer, Contaminants, Dumpsite Leachate, Groundwater, Leachate Plume, Physico-chemical Parameters, Water Quality**

1.0 INTRODUCTION

Wastes are materials that result from human activities or processes which does not have immediate economic value and demand, therefore must be discarded [1]. These wastes are generated daily in most of the urban centres in Nigeria and are disposed indiscriminately into the lakes, streams, rivers and landfills without consideration to the underground environment [2]. Solid waste landfills are abandoned or disused exhumed pits used for road construction, and are therefore, not engineered for the containment of landfill emissions into the environment [2]. Most of the dumping sites in Ogharefe are located within residential areas, markets, farms and roadsides. These wastes are generated by industrial activities as well as human/household activities (such as sewage, human and animal remains). Releasing such substances into the environment causes serious health problems. Dumpsite wastes contain toxic substances which decompose or biodegrade and in the presence of infiltrating water produce organic liquids or leachates (that comprises ions of nitrates, chlorides and sulphates) which contaminate groundwater with time as they migrate thereby resulting in environmental pollution and outbreak of diseases.

At the peak of the rainy season, dumpsites in Ogharefe are usually covered by flood water and this contributes to leachate formation. Leachate plumes normally have low resistivity values because of high ion concentration [3] thus giving the landfill or dumpsite low pH and high conductivity signatures thereby causing problems to groundwater purity. The intensity and extent of these problems are hardly investigated hence citing of boreholes as a source of potable water in this area has become a serious challenge to the inhabitants as the underground waters have become polluted. Little wonder why maintaining a potable ground water supply that is free from microbial and chemical contaminants is far from reality in most rural and urban centres. [3] and [4] opined that the pollutant load to the environment from a landfill or dumpsite is dependent on the quantity and quality of the water that percolates through the landfill and reaches the surroundings. The infiltration of rainfall into waste dumpsites as well as the chemical and biological breakdown of wastes by micro-organisms leads to the production of leachate that is high in suspended solids and in inorganic/organic contents. When the leachate migrates to surface and ground water it results to serious contamination before sufficient dilution occurs. Oghara lies in the tropics where rainfall is abundant. The mean annual rainfall ranges from 3000 to 4500mm [5] therefore it is expected that the contaminant load of the area to be high. Many authors such as [6], [7], [8], [9], [10] and [11] have carried out studies on the effect of waste dumpsites on physico-chemical parameters of groundwater in the Niger Delta environment. Yet, none of these studies was carried out in Ogharefe community of Ethiope West Local Government area, Delta State. This study therefore aimed to assess the effect of waste dumpsites on the physico-chemical parameters of groundwater so as to ascertain the groundwater quality index at Ogharefe community.

2.0 THE STUDY AREA

2.1 Regional Geology and Topography

Ogharefe, in Ethiope West Local Government Area of Delta State, Nigeria, is located approximately on Latitude 05^0 59′ North of the Equator and Longitude 05^0 42′ East of the Greenwich Meridian (Fig. 1). The area is part of the *Benin Formation* often referred to as *the Coastal Plain Sands* of the lower Quaternary period and Pliocene-Pleistocene epoch. The inclusive Aluvium belongs to the upper Quaternary (Recent Sediments) and consists of silty clayey sands, sand and gravels. Topographically, the area is flat lying with both marine and fluvial sediments. The flat-floored river Ethiope traversed the area and drains into the Atlantic Ocean. The flood plains are prone to flooding in the wet season mainly due to heavy rainfall, high ground water table and the flat-floored valleys.

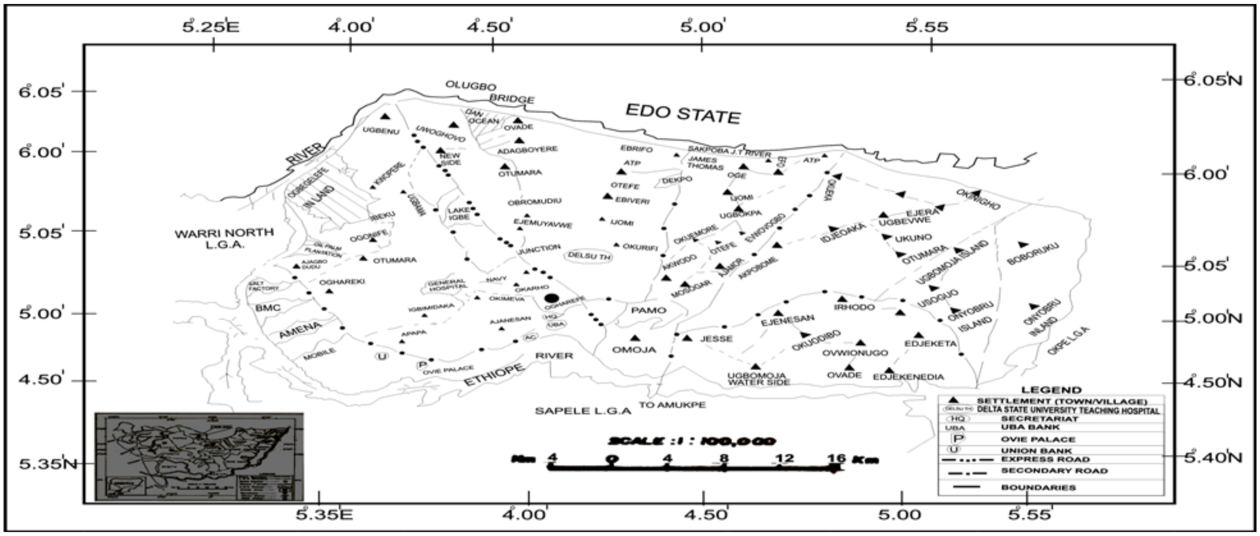

Figure 1: Map of Ethiope West Local Government showing Location of the study Area

2.2 Dumpsite Locations in the Study Area

Solid and liquid wastes are indiscriminately deposited in Ogharefe municipality in open dumpsites without regard to proximity of inhabited homes/houses, the nature of soil, and the hydrogeology of the area. The study investigated 2 dumpsites at Ogharefe community in Oghara town. One of the dumpsites is a burrow pit that lies within 5^{o} 56′ 50.10′′N and 5^{o} 39′ 34.12′′E located opposite Keldor hotel along Ibori road, Ogharefe. The dimension of the burrow pit is 20m by 40m and the age is conservatively between 20 and 30 years. The burrow pit is where the residents in the area dump their domestic and liquid wastes. The attendants of Keldor hotel also empty the liquid wastes from swimming pool, dirty dishes and laundry into the burrow pit which they channel through underground waste pipe (Fig. 2a and 2b). The second dumpsite is located within the residential area enclosed by Scot road and Sakponba road in Ogharefe which lies on on co-ordinates 5^{o} 56′ 52.58′′N and 5^{o} 39′ 34.45′′E. The dumpsite covers a total length of about 632m from Otorho road by Scot road junction to Sakponba road. It is the belief of the local inhabitants that this dumpsite has been in existence for over 50 years (Fig. 3a and 3b).

3.0 MATERIALS AND METHODS

3.1 Data Acquisition

3.1.1 Water Samples Collection

Water samples were collected from 5 existing boreholes and 5 hand-dug wells in the early hours of the day within the study area in order to determine the physico-chemical parameters in the water samples. The water samples were collected with well washed and sterilized 1.5 litres containers and sterile plain bottles. The Sterile plain bottles were used to collect water samples to test for the presence of coliform bacteria. The bottles were labeled as follows: BH_1: water sample collected from borehole at Keldor hotel, BH_2:

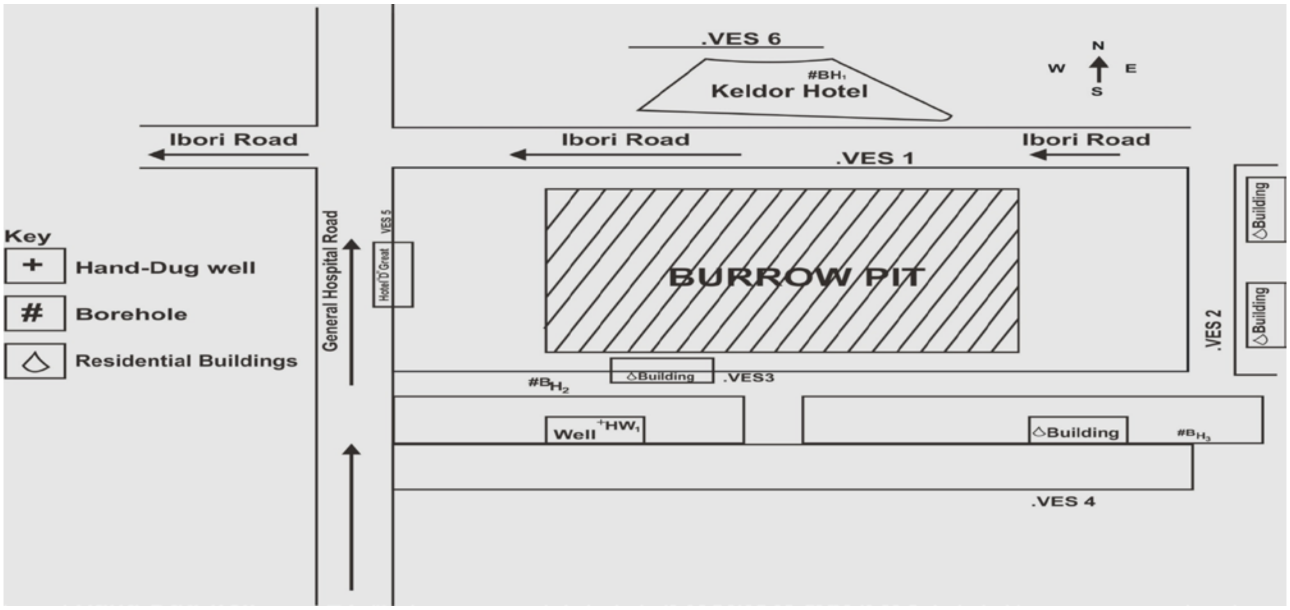

Figure 2a: Map Showing VES Locations at the burrow pit dumpsite

Figure 2b: Burrow Pit dumpsite opposite Keldor Hotel along Ibori Road

water samples collected from borehole in a building that is 5m away from the burrow pit dumpsite, BH_3: water samples collected from borehole in a building that is 200m away from the burrow pit dumpsite, BH_4: water sample collected from borehole from a building close to the dumpsite and BH_5: water sample collected from a building in Shrimp road. HW_1: water sample collected from hand-dug well, 200m away from the burrow pit dumpsite, HW_2: water sample collected from hand-dug well at the dumpsite, HW_3: water sample collected from hand-dug well at the dumpsite, HW_4: water sample collected from hand-dug well at the dumpsite. HW_5: water sample collected from hand-dug well in a building close to a dumpsite along Shrimp road.

The tap/borehole waters were collected after about 10 minutes of pumping in order to ensure that the waters were stirred-up and properly mixed together to give a true representative from the underground aquifer. The hand-dug well waters were collected with a bucket attached to a rope and was manually brought to the surface before pouring into the collection containers. All the containers were covered with black polyethelyene bags after collection of the water samples so as to avoid photolytic effect on the original sample content and were stored in coolers at a regulated temperature of about 4^oC. They were subsequently taken to the laboratory of Benin Owena River Basin Development Authority for analyses using international regulatory methods as recommended by [12], [13] and [14]. The laboratory analysis of the water samples was run for 9 physico-chemical parameters (ie Lead (Pb^{2+}), Iron (Fe^{2+}), Cloride (Cl^-), colour, total dissolved solids {TDS}, pH, conductivity, NO_3^- and coliform bacteria) and the results were compared with international permissible standards for portable water.

4.0 RESULTS AND DISCUSSION

The result of the physico-chemical parameters of the soil samples at the 2 dumpsites were compared to the international permissible limits (see Table 1) and it revealed that the parameters in both the tap/borehole and hand-dug well waters (ie TDS, Conductivity, NO^{3-} and Cl^-) are within the [13], [15] and [14] permissible standards of 1000mg/l, 1000mg/l, 50mg/l and 250mg/l respectively. However, the values of the other measured 5 parameters are above the permissible standards by [13], [15] and [14]. The parameters are as follows:

(i) **Colour:** Drinking water should ideally have no visible colour. Colour in drinking water is usually due to the presence of coloured organic matter (primarily humic and fulvic acids) associated with the humus fraction of soil and it is strongly influenced by the presence of iron and other metals, either as natural impurities or as corrosion products [15]. The colour of water gives the aesthetic appearance of the water as this may create concerns about the quality and acceptability of a drinking-water supply by consumers. In this study the value of the colour of water from the tap/boreholes and hand-dug wells respectively ranged from 0TCU to 79 TCU with a mean value of 46TCU, and from 39 to 97 TCU with an average value of 80.20 TCU. These mean and ranges of

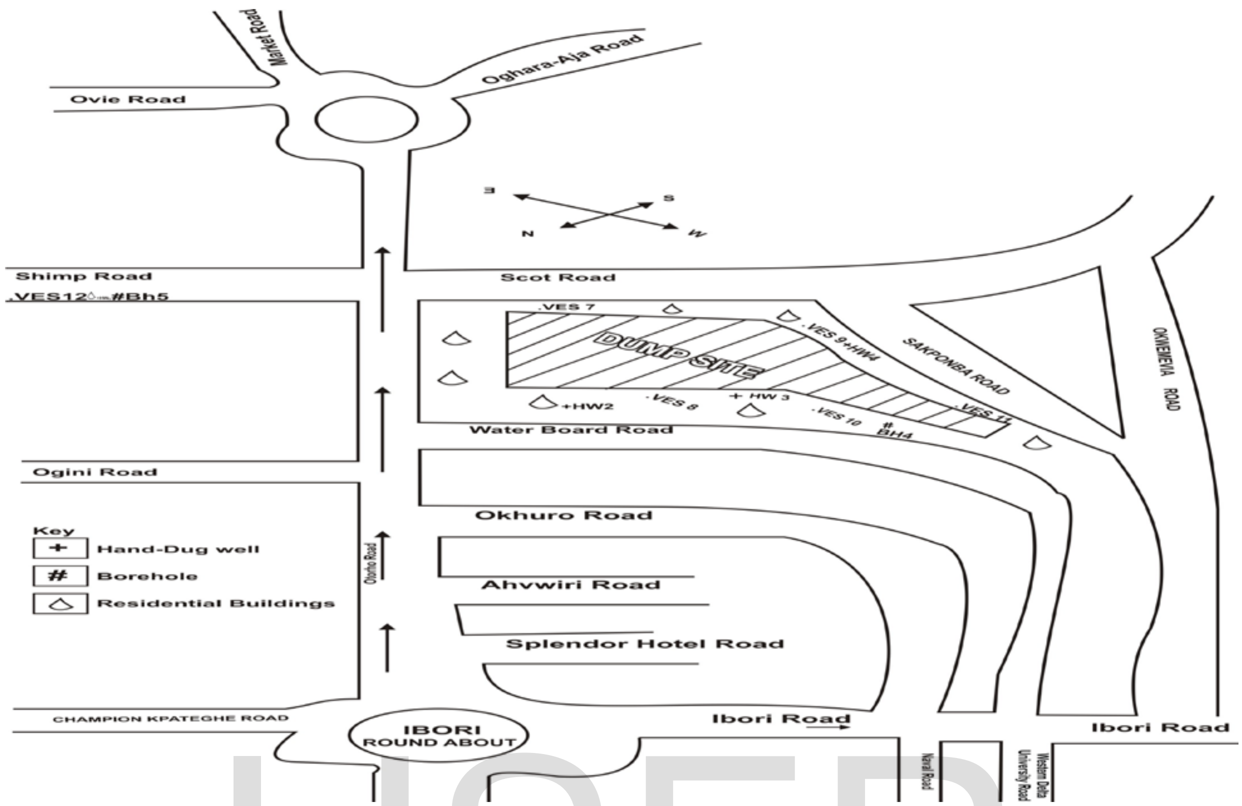

Figure 3a: Map Showing VES Locations at the dumpsite enclosed within Scot and Sakponba Road

Figure 3b: Dumpsite Enclosed within Scot Road and Sakponba Road (Residential Area)

Table 1: Physico-chemical Parameters of Groundwater Samples Compared with International Permissible Standards

TAP/BOREHOLE WATER

Sample No	Measured Parameters								
	Colour (TCU)	pH	TDS (mg/l)	Conductivity (µs/cm)	$NO3^-$ (mg/l)	Cl^- (mg/l)	Fe^{2+} (mg/l)	Pb^{2+} (mg/l)	Coliform Bacterial (Cfu/100ml)
BH_1	69	4.6	2.7	5	1.5	14.12	0.682	0.024	$8.2x10^3$
BH_2	79	5.6	5.3	10	1.6	14.12	1.403	0.018	$4.0x10^3$
BH_3	49	4.9	5.3	10	1.7	7.06	1.263	0.036	$6.0x10^3$
BH_4	33	5.0	5.3	10	2.8	21.18	0.726	0.027	0
BH_5	0	4.1	68.9	130	31.6	21.18	1.112	0.023	$2.0x10^3$
Mean	46	4.8	17.5	33	7.84	15.53	1.037	0.03	$4.04x10^3$
HAND-DUG WELL WATER									
HW_1	39	5.1	15.9	30	8.5	7.06	0.368	ND	$2.0x10^3$
HW_2	97	3.8	238.5	450	37.2	105.90	0.682	0.023	$4.1x10^3$
HW_3	88	5.0	68.9	130	14.7	14.12	0.428	ND	$2.7x10^3$
HW_4	88	4.0	127.2	240	42.0	42.36	0.263	ND	$2.8x10^3$
HW_5	89	4.2	74.2	140	14.9	35.30	0.311	ND	$2.0x10^3$
Mean	80.20	4.4	104.94	198	23.46	40.95	0.410	0.023	$2.72x10^3$
WHO (2006), NSDWQ (2007) Standard	15	6.5-8.5	1000	1000	50	250	0.30	0.01	≤100

values of colour for tap/borehole waters and hand-dug well waters are above the recommended permissible limit of 15 true colour units (TCU) by [15] and [14]. Purification of the waters is required to enhance the colour.

(ii) **pH:** The pH measures the degree of acidity and alkalinity of water. pH value <7 measures degree of acidity while pH>7 measures degree of alkalinity. [13], [15] and [14] set a permissible limit of 6.5-8.5 for portable water. The range of pH values for tap/borehole waters varied from 4.1 to 5.6 with an average of 4.8, and for hand-dug well waters it varied from 3.8 to 5.1 with an average of 4.4. These values are lower than the permissible limit thus confirming that the water from the 2 water supply sources is strongly acidic and are therefore corrosive. The most strongly acidic water was found at HW_2 (ie the hand-dug well close to the dumpsite within Scot road, Shrimp road and Sakponba road) and it is highly recommended that the inhabitants of the area should discontinue the use of water from this water supply well. The high acidic water content of these water supply sources in the study area could be a result of leachate migration due to the abundance of organic matter in the overlying soil as well as the presence of shale intercalations in the aquiferous coastal plain sands. It must be controlled to minimize corrosion of water mains and pipes in household water systems.

(iii) **Iron (Fe^{2+}):** The iron content in the tap/borehole water ranged from 0.682 to 1.403mg/l with a mean value of 1.037mg/l while for the hand-dug well water it ranged from 0.263 to 0.682mg/l with an average value of 0.410mg/l. these values are higher than the permissible standard of 0.3mg/l by [13], [15] and [14] indicating that the water in this area is high in iron content. Therefore, when water in this area is exposed to air, Fe^{2+} will be oxidized to Fe^{3+} and precipitate a rust coloured ferric hydroxide than can stain utensils. [16] noted that the water bearing aquifer of Benin formation from where groundwater seeps into the wells are ferruginous and contains iron minerals such as marcasite, hematite, goethite and limonite, thus the mobility and subsequent downward infiltration of these minerals through the porous and permeable formation account for the presence of iron in the water in the study area.

(iv) **Lead (Pb^{2+}):** The lead (Pb) content in tap/borehole water ranged from 0.018 to 0.036mg/l with an average value of 0.03mg/l while that in hand-dug well water ranged from ND to 0.023mg/l. These values of Pb in both water sources are higher than the acceptable limit of 0.01mg/l in drinking water by [15] and [14]. It was observed that Pb was detected only in HW_2 (ie the hand-dug well close to the dumpsite within Scot road, Shrimp road and Sakponba road) among the hand-dug wells sampled. The source of Pb in the hand-dug well and tap/borehole waters could be from decay of dead disposed batteries, metal scraps, metal jewelries, broken lead-glazed ceramics and used engine/motor oil that were deposited in the dumpsites which migrated into the soil. The presence of Pb in water above the recommended limit have a wide range of effects including various neuro-developmental effects, mortality (mainly due to cardiovascular diseases), impaired renal function, hypertension, impaired fertility and adverse pregnancy outcomes. Impaired neurodevelopment in children is generally associated with lower blood lead concentrations than the other effects; the weight of evidence is greater for neuro-developmental effects than for other health effects and the results across studies are more consistent than those for other effects. For adults, the adverse effect associated with lowest blood concentrations for which the weight of evidence is greatest and most consistent is lead-associated increase in systolic blood pressure [15].

(v) **Coliform Bacteria:** This parameter is used to detect the presence of faecal pollution in water and shown in Table 1, water samples collected from the 2 water supply sources contain coliform bacteria except the one at BH_4. The value of coliform bacteria for the tap/borehole water ranged from 0cfu/100ml to $8.2x10^3$cfu/100ml with a mean of $4.04x10^3$cfu/100ml. The coliform bacteria value for hand-dug well water ranged from $2.0x10^3$ to $4.1x10^3$cfu/100ml with an average value of $2.72x10^3$cfu/100ml. These values are above the permissible standard of 100cfu/ml by [15] and [14]. The presence of coliform bacteria in the water sources indicated recent contamination by human sewage or animal droppings and could be attributed to infiltration of faecal migration from the dumpsites and nearby sewage septic tanks. Their presence in water also indicates the potential of disease causing organisms which would cause serious human illness. These water sources should therefore be treated and purified before use and consumption by humans living in the area.

4.1 Overall Assessment of Groundwater Quality Rating in the Study Area and the Potential impact on Human Health

The physico-chemical parameters were also used to assess the water quality index (WQI) of the overall water (ie all the water samples) collected from tap/boreholes and hand-dug wells in the area. The WQI was calculated for the analyzed 9 parameters by using the weighted arithmetic index method and comparing the results with recommended international acceptable standards

ISSN 2229-5518

of drinking water by World Health Organization (WHO) and the Nigerian standard for drinking water quality (NSDWQ). The calculation of the quality rating scale for each parameter was done by using the equation [7]:

$$Q_i = C_i/S_i \times 100 \quad \text{-------------------------------------} \quad (1)$$

Where Q_i is the quality rating scale, C_i is the concentration of each parameter, and S_i is the recommended standard of each parameter. The inverse of the recommended standard gave the relative weight (W_i) proportional to the recommended standard (S_i) of the corresponding parameter.

$$W_i = 1/C_i \quad \text{--} \quad (2)$$

Therefore, the overall water quality index (WQI) was calculated using the following equation [7]:

$$WQI = \sum (Q_i W_i)/\sum W_i \quad \text{--------------------------------} \quad (3)$$

The summary of the statistical analysis of the physico-chemical parameters in relation to the water quality index (WQI) for the tap/borehole waters and hand-dug well waters are shown in Table 3 while the water quality rating index classification is shown in Table 2. For the tap/borehole the calculated WQI is 301 and the WQI for the hand-dug well is 198. Using the water quality index classification in Table 2 by [17], the tap/borehole water is rated unsuitable for drinking since $WQI>300$ while the quality of water from hand-dug wells was rated as poor since $WQI<200$. It was observed that the water quality rating (status) of tap/borehole is more severe than that of the hand-dug well due to the following reasons:

(i) Tap/borehole water is more acidic than those of hand-dug well as seen in their mean values in Table 1 and 3.

(ii) All the sampled tap/borehole waters have higher content of Pb whereas Pb was detected only in one of the hand-dug wells labeled as sample HW_2 which is located close to the dumpsite within Scot road, Sakpoba Road and Shrimp road although the Pb values of both water supply sources were above WHO and NSDWQ recommended standards. Pb was not detected in other hand-dug wells in the study area. The high presence of Pb in all the sampled tap/borehole water as well as in the hand-dug well water labeled HW_2 above the recommended limit would make the inhabitants of the area to have a very high chance of contracting various neuro-developmental effects, mortality (mainly due to cardiovascular diseases), impaired renal function, hypertension, impaired fertility and adverse pregnancy outcomes.

(iii) All the sampled tap/borehole waters have higher iron (Fe) content than those of the hand-dug well waters as observed in their mean values in Table 3. The mean value of Fe in tap/borehole water was 1.037mg/l while that of hand-dug well waters was 0.41mg/l. The high values of Fe in all the tap/borehole waters water above the recommended standard could lead to iron stain laundry and plumbing fixtures. Again, iron promotes the growth of “iron bacteria” which derive their energy from the oxidation of ferrous iron (Fe^{2+}) to ferric iron (Fe^{3+}) and in the process deposit a slimy coating (rust-coloured deposits) on the walls of tanks, pipes and channels, and carry over of deposits into the water. Formation of ferric iron in water may lead to corrosion and rusting of metallic pipes.

(iv) Again, all the sampled tap/borehole waters have higher value of coliform bacteria counts than those of the hand-dug well. This is because the mean value of coliform bacteria in tap/borehole water is 4.04×10^3 cfu/100ml while that of the hand-dug well water have a mean value of 2.72×10^3 cfu/100ml revealing more infiltration of faecal migration from the dumpsites and nearby sewage septic tanks/latrines into the groundwater aquifer due to weak aquifer overburden layer. Their presence in indicates the potential of disease causing organisms which would cause serious human illness.

Arising from above, we can conclude that the high value of coliform bacteria, Fe and Pb in tap/borehole waters more than those in hand-dug well waters were probably due porous and weak aquifer overburden protective capacity which accounts for the high infiltration rate of leachate contaminants into the aquifer. Moreover, proper geological and geophysical investigations were not carried out before the boreholes were drilled and this accounts for the fact that the boreholes were not drilled to a maximum depth to minimize contamination. Since the tap/borehole waters as well as hand-dug well waters were respectively rated as unsuitable (WQI=301) and poor (WQI=198) for drinking, the implication is that the water in the study area will require some level of purification before it is made available for use as potable water by the inhabitants.

5.0 CONCLUSION

The results of the water physico-chemical parameters showed that some parameters are lower than the permissible limit by WHO and NSDWQ except for colour, pH, Fe, Pb and coliform bacteria which exceeded the permissible standards indicating contamination of the groundwater in the area. The water physico-chemical parameter results was also used to assess the groundwater quality with the use of water quality index (WQI) and the findings revealed that groundwater (borehole water) was rated as poor quality indicating that the leachate plume contaminants have migrated from the dumpsites to the groundwater aquifer perhaps due to weak/poor aquifer overburden protective layer. The presence of coliform bacteria in the water sources indicated recent contamination by human sewage or animal droppings and could be attributed to infiltration of faecal migration from the dumpsites and nearby sewage or septic tanks. Their presence in water also indicates the potential of disease causing organisms which would cause serious human illness. Therefore the inhabitants of the area should be discouraged from drinking hand-dug well water due to its high acidic value as well as its Pb and coliform bacteria content because of the health implication. Water from the 2 water sources should also be treated and purified before use or consumption by the inhabitants of the area. Since the area is vulnerable to groundwater pollution, the existing waste dumpsites should be evacuated and relocated from the area and further dumping of waste be discontinued. A total clean up programme is highly recommended to be embarked upon in the area.

Table 2: Water Quality index Classification [17]

Water Quality Index Level	Water Quality Status
<50	Excellent
50-100	Good
100-200	Poor
200-300	Very Poor
>300	Unsuitable for drinking

Table 3: Statistical Summary of the Physico-chemical Parameters Analysis for Tap/Borehole and Hand-dug Well Water in the Study Area

	TAP/BOREHOLE WATER								
Parameters	**Standard Values (S_i)**	**Observed Values**			**Standard Deviation**	**Variance**	**Quality Rating (Q_i) %**	**Unit Weight (W_i)**	**Q_i W_i**
	WHO (2006, 2011); NSDWQ (2007)	**Minimum**	**Maximum**	**Mean**					
pH	**6.5-8.5**	4.1	5.6	4.8	0.49	0.24	73.85	0.154	11.373
Colour (TCU)	**15**	0	79	46	27.97	782.40	306.70	0.067	20.55
TDS (mg/l)	**1000**	2.70	68.90	17.5	25.72	661.50	1.75	0.001	0.0017
Conductivity (µs/cm)	**1000**	5	130	33	48.54	2356.00	3.30	0.001	0.0033
NO_3^- (mg/l)	**50**	1.5	31.60	7.84	11.89	141.35	15.68	0.02	0.314
Cl^- (mg/l)	**250**	7.06	21.18	15.53	5.28	27.91	6.21	0.004	0.025
Fe^{2+} (mg/l)	**0.30**	0.682	1.403	1.037	0.287	0.083	345.70	3.333	1152.22
Pb^{2+} (mg/l)	**0.01**	0.018	0.036	0.03	0.0059	0.000036	300	100	30,000
Coliform Bacteria (Cfu/100ml)	**≤100**	0	8.2×10^3	4.04×10^3	2.9×10^3	8.3×10^6	4.04×10^3	0.01	40.40
	Water Quality Index = $\sum(Q_i W_i)/\sum W_i$ = 301							**103.59**	**31,224.89**
	HAND-DUG WELL WATER								
pH	**6.5-8.5**	3.8	5.1	4.4	0.53	0.28	67.69	0.154	10.42
Colour (TCU)	**15**	39	97	80.20	20.87	435.76	5.35	0.067	0.358
TDS (mg/l)	**1000**	15.90	238.50	104.94	75.50	5701.15	10.49	0.001	0.010
Conductivity (µs/cm)	**1000**	30	450	198	142.46	20,296.00	19.80	0.001	0.020
NO_3^- (mg/l)	**50**	8.50	42.0	23.46	13.46	181.27	46.92	0.02	0.938
Cl^- (mg/l)	**250**	7.06	105.90	40.95	34.99	1,224.16	16.38	0.004	0.065
Fe^{2+} (mg/l)	**0.30**	0.263	0.682	0.410	0.146	0.021	136.67	3.333	455.520
Pb^{2+} (mg/l)	**0.01**	ND	0.023	0.02	8.0×10^{-3}	6.48×10^{-5}	200	100	20,000
Coliform Bacteria (Cfu/100ml)	**≤100**	2.0×10^3	4.1×10^3	2.72×10^3	7.7×10^2	5.9×10^5	2.72×10^3	0.01	27.20
	Water Quality Index = $\sum(Q_i W_i)/\sum W_i$ = 198							**103.59**	**20,494.53**

BH= Tap/borehole Water, HW= Hand-dug Well Water

ACKNOWLEDGMENTS

The authors sincerely acknowledge the management and staff of Dasamol (Nigeria) Limited and Darltec Georesources and Geo-Hazards (Nigeria) Limited for the acquisition of data during the field work and the subsequent interpretation of the data.

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