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Assessment of the Water Quality of Selected Boreholes Close to a Dumpsite in Agbor Metropolis, Delta State, Nigeria

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ABSTRACT: Dumpsite utilization for municipal solid waste disposal produces leachate which is a threat to groundwater resources. The study was aimed at determining the suitability of groundwater for drinking and domestic usages using physical, chemical and microbial indices, with a view to assessing the vulnerability of boreholes close to dumpsite to groundwater pollution. The results showed that except for pH and lead, the concentrations of other physico – chemical parameters were within acceptable limits of NSDWQ and WHO. Microbial parameters showed that the mean values for total coliform count; mesophilic count; *Escherichia coli* count and fungi count were above the NSDWQ and WHO standards for drinking water in all borehole locations. Water Quality Index (WQI) vales ranged from 4.15 to 5.54 an indication of excellent water quality in the study area, which is suitable for human consumption and use for other domestic purposes. The observed inconsistency in the spatial concentration pattern of water parameters in the study, suggest that the dumpsite is not a point source of groundwater pollution in the study area. However, there is need for improvement of public hygiene to minimize microbial contamination, improve public health and prevent outbreak of water borne diseases.

Keywords: Water quality, Groundwater, Dumpsite, Pollution, Agbor, Delta State.

Introduction

Globally, groundwater is the largest available and most important source of fresh water, which caters for an estimated 1.5 billion people worldwide daily and especially for meeting rural water demand in the sub-Saharan Africa (DFID, 2001; Harvey, 2004). In Nigeria, groundwater plays a vital role as an important source of potable water in both rural and urban areas, and thus plays a vital role in the water supply chain (Adeyemi *et al.,* 2003). Water quality refers to the chemical, physical and biological characteristics of water, which is determined by the presence of both organic and inorganic compounds that are either suspended or dissolved in it. It is also a measure of the condition of water relative to the requirements of one or more biotic species and or to any human need or purpose (Diersing and Nancy, 2009). Water quality assessment is frequently based on the monitoring of the physical, chemical and microbial parameters due to natural occurrences and anthropogenic activities; with the aim of developing strategies for the protection of fresh water resources from pollution (Al-Harbi *et al.,* 2006).

Groundwater resources are commonly vulnerable to pollution, which degrade their quality (Tyagi, *et al*., 2002; Palamuleni and Akoth, 2015). The intensity of human activities and large scale industrial growth has caused serious concerns regarding the susceptibility of groundwater to contamination due to the discharge of waste materials. Also, the unplanned expansion of urban centres has led to a serious pollution threat to the groundwater supplies; due to its overexploitation and the absence of organized domestic waste disposal and uncontrolled industrial and commercial activities (UNEP, 2002).

A dumpsite is a location where waste materials are dumped. It is the oldest and most common method of waste treatment and disposal in so many places around the world (ISWA, 2006). In Nigeria, like many other developing countries, open dumping has been the only management option of solid waste disposal (Arukwe *et al.,* 2012). The different types of waste materials deposited at the dumpsite and subsequent practices carried out at the dumpsite such as open burning and informal recycling determine both the health and the environmental impacts of dumpsites. Open dumps have been identified as one of the major threats to groundwater sources, as movement of leachates from dumpsites through the soil and the aquifers pollute the groundwater system (Mor *et al.,* 2006; Adeolu *et al.,* 2011, Amadi *et al.,* 2012; Bayode *et al.,* 2012; Charles *et al.,* 2013). Leachate percolating into the groundwater is a mixture of highly complex contaminants such as potentially toxic metals such as lead, mercury, cadmium, chromium etc; persistent organic pollutants (POPs), inorganic compounds, as well as bacterial contamination – total coliform and feacal coliform (Mor *et al.,* 2006; Longe and Balogun, 2010; Oyeku and Eludoyin, 2010; Agrawal *et al.,* 2011; and Galarpe and Parilla, 2012).

Groundwater contamination originating from dumpsites can potentially have negative environmental and human health impacts in the communities. Polluted water, irrespective of the pollutants when consumed, may lead to a variety of diseases such as cholera, typhoid, dysentery, skin rashes and mental disorder (Eni *et al.,* 2014). In recent times, a number of studies have been conducted on the impact of dumpsite leachate on groundwater across various locations (Adeolu *et al.,* 2011; Ogbeibu, *et. al.,* 2012; Ohwoghere – Asuma and Aweto, 2013; David and Oluyege, 2014; Eni *et al.,* 2014; Magda *et al.,* 2015; Maiti *et al.,* 2016).

Water of good drinking quality is of basic importance to human physiology and man's continued existence depends very much on its availability (Chinedu *et al.,* 2011; Dimowo, 2013). With the majority of the inhabitants in Agbor metropolis and specifically the neighbourhood close to the Ika South Local Government Area dumpsite relying on private boreholes as their source of portable water; this study was aimed at evaluating the quality of the groundwater of selected boreholes located close to the dumpsite, to determine the levels of physico-chemical and microbial parameters, with a view to assessing their suitability for drinking and domestic purposes using the Water Quality Index (WQI).

Materials and Methods

Study area: The study was conducted in Agbor town, situated in Ika South Local Government Area in Delta State, Nigeria. It lies within longitudes 6°05' E and 6°20' E; and latitudes 6°07' N and 6°25' N, and covers an area of about 650 km^2 (Fig. 1). The area lies within the equatorial climate with two distinct seasons; the wet (April to September) and dry (October to March) seasons; high humidity and atmospheric temperature of between 24 °C – 27 °C which supports the rainforest vegetation (Iloeje, 1981; Olobaniyi *et al.,* 2007; Odjugo, 2008).

The physiography of the area shows two topographic heights separated by a valley. Within the valley is the River Orogodo, which flows in a southwest-northeast direction. The subsurface geology of Agbor indicates that it lies within the Benin formation which is capped by lateritic soil in the first few metres, followed by fine grained sand that varies in thickness from 9 to 58 metres. Underlying the fine grained sands is a sequence of medium to coarse grained sand with several horizons of intercalated discontinuous lenses of clay which constitute the main aquifer. Groundwater occurs at a depth generally greater than 60 metres, predominantly under unconfined conditions. Deductions from groundwater level contouring shows that River Orogodo which is the main river that drains the area is partly recharged from the aquifer (Nwajide, 2006; Olobaniyi *et al.,* 2007; Akpoborie *et al.,* 2011).

The Ika South Local Government Area municipal solid waste dumpsite emanated from landfill activities which commenced over 30 years ago, as the site was previously a laterite sand excavation pit. Municipal waste types deposited at the dumpsite consists of organic, non–organic, hazardous and non–hazardous, and waste originating from domestic, agricultural, industrial and institutional activities. On-going scavenging activities have resulted in a significant reduction in the residual volume of metal/aluminium wastes.

Sampling procedure: Groundwater from the borehole were sampled once a month between October 2016 and March 2017 from four (4) borehole points: Borehole 1 (BH 1), located approximately 55 m from the dumpsite; Borehole 2 (BH 2), located about 75 m from the dumpsite and Borehole 3 (BH 3), located approximately 100 metres from the dumpsite and the control station (Borehole 4; BH 4), located 5 km from the dumpsite. Water samples were collected in pre–washed 1 litre plastic containers and analysed *in situ* for pH and conductivity and thereafter transported in ice chests for further analysis. Other physico-chemical parameters were analyzed later according to standard methods (APHA, 1998).

The determination of heavy metals was carried out in two stages. The samples were digested in concentrated nitric acid and analyzed by atomic absorption spectrometer, AAS (Varian Techtron Spectra B). Microbiological characteristics were determined as described by Bezuidenhout *et al.,* (2002). Microbial analysis for total coliform count, mesophilic count, and fungi were determined using the Pour plate technique.

Statistical analysis: Comparisons between sampling points were carried out using the Analysis of Variance (ANOVA) and the source of significant difference located using Duncan's Multiple Range (DMR) Test. All statistical analyses were computed using Microsoft excel and Statistical Package for Social Sciences (SPSS 16.0).

A water quality index provides a single number that expresses overall water quality at a certain location and time, based on several water quality parameters, and can be used as a tool in comparing the water quality of different sources and it gives the public a general idea of the possible problems with water in a particular region (Asadi *et al.*, 2007; Yisa and Jimoh, 2010; Jagadeeswari and Ramesh, 2012). Water Quality Index (WQI) was calculated by using the Weighted Arithmetic Mean method as described by Chauhan and Singh (2010) and Shweta *et al.* (2013).

The calculation of WQI was made by using the following equations:

$$WQI = \frac{\sum Q_i W_i}{\sum W_i}$$

The quality rating scale (Qi) for each parameter is calculated by using the expression:

$$Q_i = 100 \left[\frac{V_i - V_0}{S_i \quad V_0}\right]$$

Where,

V_i = Estimated Concentration of the i th parameter of interest in the analysed water.

V_o = The ideal value of the i th parameter in pure water. $V_o = 0$ (except pH = 7.0; and DO = 14.6 mg/l)

S_i = Recommended Standard value of the i th parameter

The unit weight (Wi) for each water quality parameter is calculated by using the following formula:

$$W_i = \frac{K}{S_i}$$

Where,

K = proportionality constant and can also be calculated by using the following equation:

$$K = \frac{1}{\Sigma\left(\frac{1}{S_i}\right)}$$

Table 1: Percentage Composition/Kg of Municipal Solid Waste Ika South Local Government Area dumpsite in Agbor, Delta State

S/N	Composition	Average	%/ Kg
1	Plastics/ Polythene Products	0.27	**27**
2	Paper Products	0.13	**13**
3	Metal/ Aluminium Products	0.07	**07**
4	Vegetative materials/ Organic Compost	0.42	**42**
5	Ceramics	0.03	**3**
6	Textile Materials	0.05	**5**
7	**Others e.g. Batteries, foams etc.**	**0.03**	**3**

The rating of water quality according to this WQI is given in Table 2.

Table 2: Water quality rating as per Weighted Arithmetic Mean Method (Shweta *et al.,* 2013)

WQI Value	Rating of Water Quality	Grading
0 – 25	Excellent water quality	A
26 – 50	Good water quality	B
51 – 75	Poor water quality	C
76 - 100	Very Poor water quality	D
Above 100	Unsuitable for drinking purpose	E

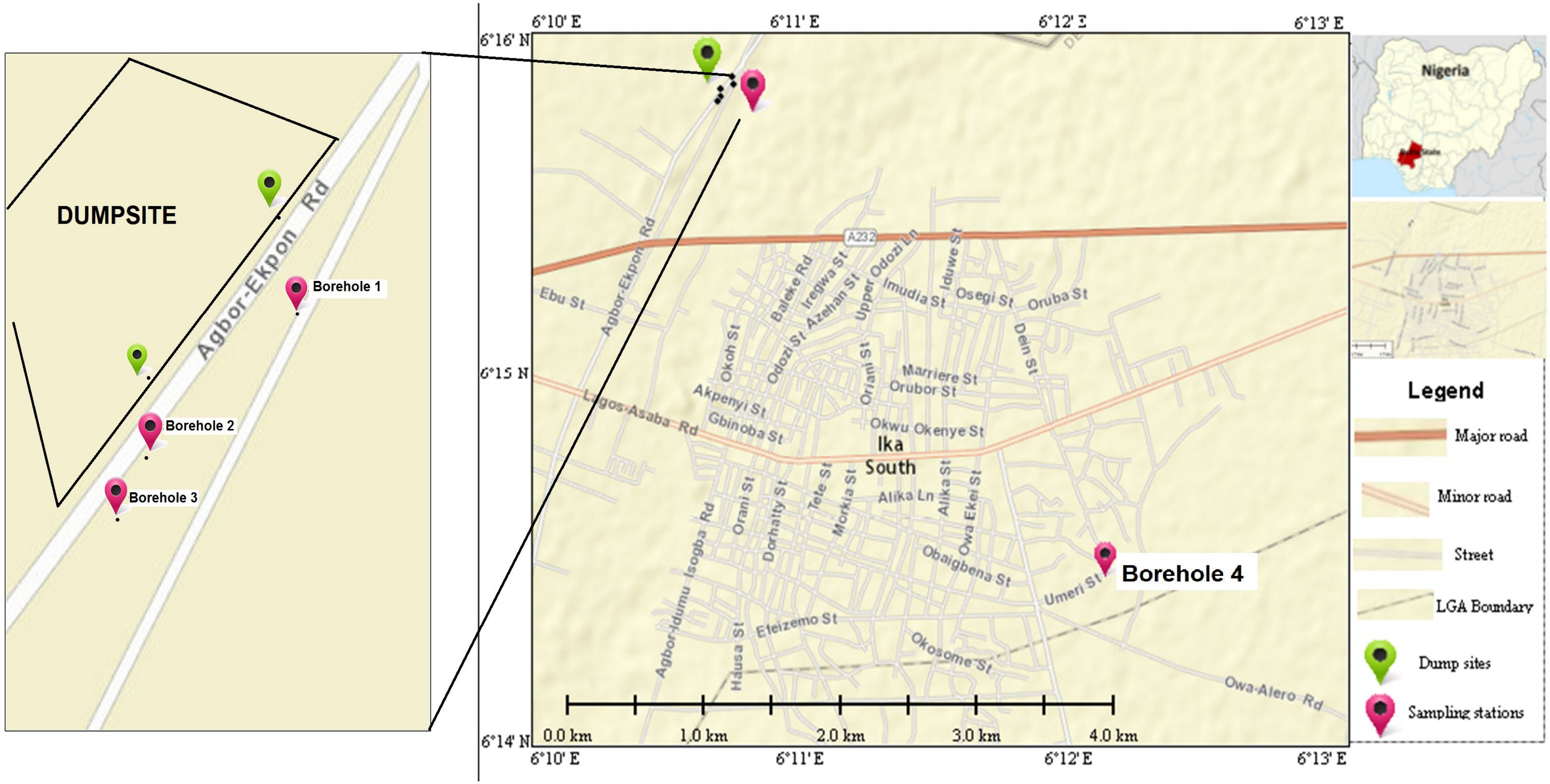

Figure 1: Map of study area showing borehole locations in Ika South Local Government Area, with inserts (Agbor, Delta State, Nigeria.)

Results

The physico-chemical parameters including the heavy metal contents and the microbial parameters of the studied stations are presented in Tables 3 and 4, respectively. The pH values revealed that the borehole water was moderately acidic with a range of 5.61 (BH4) to 6.05 (BH3). There was no significant difference ($P > 0.05$) in the pH values across the four locations. Electrical conductivity (EC) values was lowest (10 µS/cm) at BH 2 and highest (50 µS/cm) at BH 1. There was a significant difference ($P < 0.05$) across the four boreholes, and Duncan Multiple Range (DMR) test reveal that BH 1 and BH 4 were significantly lower than BH 2 and BH 4. Turbidity of groundwater was lowest at BH 1 and BH 4 with mean values of 0.67 NTU and highest in BH 2 with a mean value of 1.50 NTU. There was no significant difference ($P > 0.05$) in turbidity values across the four locations.

Total Suspended Solids (TSS) mean values ranged from 1.33 mg/l (BH 1 and 3) to 1.67 mg/l (BH 2 and 4), with lowest value recorded in all boreholes in November, and highest value of 4 mg/l in October (BH 1 and 3) and February. No significant difference ($P > 0.05$) across the four locations was observed in TSS values. The mean Total Dissolved Solids (TDS) values ranged from 17.12 mg/l in BH 2 to 27.92 mg/l in BH 4. There was a significant difference ($P < 0.05$) in TDS across the locations, which was caused by the high values of BH 4 that was at its peak in February.

Dissolved Oxygen was highest (6.20 mg/l) at BH 2 and BH 3 in the months of February and March respectively, and lowest (5.40 mg/l) at BH 4 in March. Mean DO varied from a minimum of 5.56 mg/l in BH 4 to 5.93 mg/l in BH 2. There was a significant difference ($P < 0.05$) in DO values across the locations, caused by BH 4. The values of BOD_5 ranged between 0.52 mg/l at BH 2 and 1.13 mg/l at BH4with station BH 1 being significantly different ($p<0.05$).The sulphate concentration ranged between 0.14 mg/l and 1.53 mg/l in a regular temporal variation. There was a significant different ($P < 0.05$) between mean sulphate concentrations caused by the control borehole (BH 4). Nitrate concentrations ranged from 0.23 mg/l to 0.06 mg/l, with BH 1 recording the highest value in February and lowest value at BH 3 in October. There was no significant difference ($P > 0.05$) in nitrate levels recorded across the locations.

Phosphate mean value was lowest (0.18 mg/l) in BH 4 and highest (0.30 mg/l) in BH 1. There was a significant difference ($P < 0.05$) between the mean phosphate concentrations caused by the low value of BH 4. Chloride content varied from 6.5 mg/l recorded at BH 4 to 14.12 mg/l was recorded across BH 1, 2 and 3. There was a significant difference ($P < 0.05$) in chloride concentration across the four borehole locations caused by BH 4. Copper concentration was very low with values ranging from 0.02 mg/l to 0.69 mg/l. There was a significant difference ($P < 0.05$) in copper concentrations across the locations, and this was caused by BH 2 and BH 4. Lead concentrations was inconsistent across all boreholes, with mean concentration ranging from 0.005 mg/l to 0.007 mg/l, with no significant difference ($P > 0.05$) observed across the study locations. Cadmium was not detected in water samples collected in all months across all four (4) boreholes studied. Iron concentrations recorded was generally low (0.08 mg/l to 0.29 mg/l) and varied inconsistently across all locations. And no significant difference ($P > 0.05$) was observed across the boreholes. The mean concentration of zinc varied from 0.01 mg/l (BH 3) to 0.03 mg/l (BH 4), with observed significant difference ($P < 0.05$) in mean values across the locations caused by the high values of BH 4.

Microbiological examination of water samples using various indicator organisms have been used as surrogate markers of risk (Barrell, *et. al.,* 2000). The mean values of total coliform count ranged from 10 cfu/ml at BH 2 to 16.67 cfu/ml at BH 1. Also, spatial and temporal variation showed inconsistency throughout the study. Mean values for the mesophilic count ranged from 6.67 cfu/ml to 20 cfu/ml. *Escherichia coli* was only detected in BH 1 and BH 3 in November with mean values of 1.67 cfu/ml. Mean fungi count ranged from 1.67 cfu/ml to 6.67 cfu/ml, with the highest value of 20 cfu/ml was recorded at BH 1 and BH 3 in November. There was no significance difference ($P > 0.05$) in the mean values of the total coliform count, mesophilic count, *Escherichia coli* count, and fungi count across the borehole locations.

Table 3: Summary of the physical and chemical parameters of selected borehole water in Agbor, Delta State from October, 2016 to March, 2017

	BH 1			**BH 2**			**BH 3**			**BH 4**			**P - Value**	**Limits**	
Parameter	**Mean ± SD**	**Min**	**Max**	**Mean ± SD**	**Min**	**Max**	**Mean ± SD**	**Min**	**Max**	**Mean ± SD**	**Min**	**Max**		**NSDWQ 2007**	**WHO 2011**
pH	5.68 ± 0.43	5.00	6.20	5.73 ± 0.47	5.200	6.50	6.05 ± 0.24	5.700	6.30	5.62 ± 0.29	5.30	6.10	P>0.05	6.5 – 8.5	6.5 – 8.5
EC	$32.17^{B} \pm 10.30$	20.0	50.0	$20.50^{A} \pm 7.18$	10.00	30.0	$22.67^{A} \pm 6.09$	15.00	33.00	$34.00^{B} \pm 2.61$	30.00	37.00	P<0.05	1000	1000
Turbidity	0.67 ± 0.82	0.00	2.00	1.50 ± 1.38	0.00	4.00	0.83 ± 0.75	0.000	2.00	0.67 ± 0.82	0.00	2.00	P>0.05	5	3
TSS	1.33 ± 1.51	0.00	4.00	1.67 ± 1.21	0.00	3.00	1.33 ± 1.51	0.000	4.00	1.67 ± 1.63	0.00	4.00	P>0.05	0	N/A
TDS	$17.63^{A} \pm 5.07$	12.7	26.5	$17.12^{A} \pm 3.27$	13.60	21.6	$19.12^{A} \pm 4.77$	12.60	25.30	$27.92^{B} \pm 5.53$	21.70	35.90	P<0.05	500	500
DO	$5.85^{B} \pm 0.19$	5.60	6.10	$5.93^{B} \pm 0.18$	5.70	6.20	$5.83^{B} \pm 0.26$	5.500	6.20	$5.57^{A} \pm 0.14$	5.40	5.80	P<0.05	7.5	5.0
BOD	$0.90^{AB} \pm 0.38$	0.50	1.50	$0.517^{A} \pm 0.12$	0.40	0.70	$0.93^{B} \pm 0.44$	0.400	1.50	$1.13^{B} \pm 0.28$	0.80	1.50	P<0.05	0.05	0.05
Sulphate	$0.14^{A} \pm 0.09$	0.07	0.30	$0.198^{A} \pm 0.07$	0.09	0.30	$0.27^{A} \pm 0.08$	0.190	0.40	$1.53^{B} \pm 0.39$	1.00	2.00	P<0.05	100	100
Nitrate	0.118 ± 0.06	0.07	0.23	0.118 ± 0.03	0.08	0.15	0.105 ± 0.03	0.060	0.15	0.13 ± 0.03	0.09	0.17	P>0.05	50	50
Phosphate	$0.30^{B} \pm 0.10$	0.18	0.46	$0.26^{AB} \pm 0.09$	0.15	0.38	$0.25^{AB} \pm 0.08$	0.160	0.36	$0.18^{A} \pm 0.07$	0.09	0.26	P<0.05	5	10
Chloride	$12.94^{B} \pm 1.35$	10.5	14.12	$13.41^{B} \pm 1.04$	11.5	14.12	$13.66^{B} \pm 1.43$	11.60	15.6	$8.06^{A} \pm 1.45$	6.50	10.12	P<0.05	250	250
Copper	$0.036^{A} \pm 0.008$	0.026	0.050	$0.051^{B} \pm 0.01$	0.04	0.069	$0.04^{A} \pm 0.01$	0.022	0.05	$0.05^{AB} \pm 0.01$	0.035	0.06	P<0.05	1.0	2.0
Lead	0.006 ±0.009	0.00	0.020	0.005 ± 0.01	0.00	0.015	0.005 ± 0.01	0.000	0.017	0.007 ± 0.01	0.00	0.014	P>0.05	0.01	0.01
Cadmium	0.000 ±0.000	0.00	0.000	0.00 ± 0.00	0.00	0.00	0.00 ± 0.00	0.000	0.00	0.00 ± 0.00	0.00	0.00	P>0.05	0.003	0.003
Iron	0.156 ±0.069	0.095	0.287	0.12 ± 0.03	0.086	0.170	0.13 ± 0.05	0.080	0.199	0.113 ± 0.03	0.085	0.15	P>0.05	0.3	0.1
Zinc	$0.016^{A} \pm 0.007$	0.009	0.026	$0.015^{A} \pm 0.01$	0.009	0.021	$0.011^{A} \pm 0.01$	0.005	0.018	$0.033^{B} \pm 0.01$	0.025	0.05	P<0.05	3.0	1.5

Note: P < 0.05 – Significant; P > 0.05 – Not Significant; N/A – Not available. No superscript indicates no significant difference, Unsimilar superscript indicates significant difference.

Table 4: Summary of microbial composition of selected borehole water in Agbor, Delta State from October, 2016 to March, 2017

Parameter	**Station 1**			**Station 2**			**Station 3**			**Station 4**			**P - Value**	**Limits**
	Mean ± SD	**Min**	**Max**	**Mean ± SD**	**Min**	**Max**	**Mean ± SD**	**Min**	**Max**	**Mean ± SD**	**Min**	**Max**		**WHO 2011**
Total Coliform Counts (cfu/ml)	16.67 ± 8.16	10	30	10.0 ± 6.32	0	20	13.3 ± 8.16	0	20	11.7 ± 4.1	10	20	P>0.05	10
Mesophillic (cfu/ml)	8.33 ± 7.53	0	20	10.0 ± 8.9	0	20	6.67 ± 516	0	10	8.33 ± 9.83	0	20	P>0.05	0
E. coli counts (cfu/ml)	1.67 ± 4.08	0	10	0 ± 0	0	0	1.67 ± 408	0	10	0 ± 0	0	0	P>0.05	0
Yeast/ Fungi (cfu/ml)	5.0 ± 8.37	0	20	1.67 ± 4.08	0	10	6.67 ± 816	0	20	1.67 ± 4.08	0	10	P>0.05	0

Note: P < 0.05 – Significant; P > 0.05 – Not Significant; N/A – Not available. No superscript indicates no significant difference, Unsimilar superscript indicates significant difference.

The Water Quality Index (WQI) values ranged from 4.15 at BH 3 to 5.54 at BH 4 (Table 5). Based on the standard classification (Table 2) all four boreholes had excellent water quality.

Table 5: Summary of WQI values of sampled boreholes

Borehole	BH 1	BH 2	BH 3	BH 4
WQI Value	5.098	4.40	4.15	5.54
Remark or Quality	Excellent	Excellent	Excellent	Excellent

Mean WQI of study area = 4.8 (Excellent water quality)

Discussion

Monitoring of water quality is one of the major tools for ensuring sustainable development; as it provides the necessary information required for water resources management (Al-Harbi *et al.,* 2006). Water quality of any specific area or specific source can be assessed using physical, chemical and biological parameters whose concentration values are found to be harmful to human health, when they exceed certain defined permissible limits (WHO, 2012).

The observed pH values (5.0 – 6.5) indicate acidic water for the sampled boreholes. These values are below the 6.5 to 8.5 acceptable limits for drinking water recommended by NSDWQ (2007) and WHO (2011), and can be attributed to the geology of the area and the mineral salts dissolved in the groundwater (USGS, 2015). Similar pH values were reported by Olobaniyi *et al.,* (2007), Ogbeibu *et al.,* (2012) and Oyem *et al.,* (2014). Electrical conductivity (EC) values were within the acceptable limits of the NSDWQ and WHO; higher EC values in BH 1 and BH 4 can be attributed to the proximity of BH 1 to the dumpsite, and the exposure of BH 4 to high anthropogenic activity in the urban centre. Olobaniyi *et al.,* (2007), Akpoveta *et al.,* (2011), Ohwoghere - Asuma and Aweto (2013), recorded similar concentrations in Agbor, Benin city and Warri respectively. The observed turbidity values (0.00 – 4.00 NTU) in this study are generally low and within the NSDWQ and WHO permissible limits for drinking water, which is in contrast with that of Eni *et al.,* (2014) were higher EC values was reported for groundwater samples close to a municipal dumpsite.

Total suspended solids (TSS) mean concentrations across the borehole locations exceeded the NSDWQ and WHO permissible limits, which is similar to reports of Ogbeibu *et al.,* (2012) and Oluseyi *et al.,* (2014). This study reported low Total dissolved solids (TDS) values which were far below the NSDWQ and WHO permissible limits of 500 mg/l. This is characteristic of hills and upland areas that represent areas of recharge, which is a vivid topographical description of the study area (Olobaniyi *et al.,* 2007). Dissolved Oxygen values were below the NSDWQ stipulated value of 7.5 mg/l but within the WHO value of 5 mg/l, while BOD values (0.40 – 1.50 mg/l) exceeded the acceptable limits of 0.05 mg/l stipulated by NSDWQ and WHO. Similar results were reported by Akinbile and Yusoff (2011), Akpoveta *et al.,* (2011) and Ogbeibu *et al.,* (2012). The concentration of sulphate recorded was generally low and below the NSDWQ and WHO permissible limits, with significantly higher values in Borehole 4 attributed to the typical anthropogenic activities in an urban centre resulting in the discharge of chemical wastes from laundry, mechanical workshops etc. (Olobaniyi *et al.,* 2007).

Unpolluted natural waters usually contain very minute amount of nitrate, and an increase in nitrate in drinking water indicates leaching of nitrates from nearby pit latrines and dumpsites (Purandara *et al.,* 2003). Nitrate values (0.06 – 0.23 mg/l) recorded in this study were generally low and below the NSDWQ and WHO permissible limit of 50 mg/l, with similar values reported by Akpoveta *et al.* (2011) and Ogbeibu *et al.* (2012). In contrast, Akinbile and Yusoff (2011) recorded a high nitrate value of 61.00 mg/l in groundwater close to dumpsites in Akure. The observed phosphate values (0.09 – 0.46 mg/l) were below the NSDWQ and WHO permissible limits of 5 mg/l and 10 mg/l respectively. However BH 1, BH 2 and BH 3 showed significantly higher phosphate concentrations than BH 4; and this can be attributed to the high agricultural activity that took place around the dumpsite vicinity, since it was previously a farmland reserve. Phosphate can be introduced into water bodies from runoffs from agricultural lands and soil percolation of agricultural lands were NPK fertilizers have been applied over a period of time (USGS, 2017). Chloride concentration values recorded were below the NSDWQ and WHO permissible limits of 250 mg/l. similar results were reported by Olobaniyi *et al.,* (2007) Akpoveta *et al.,* (2011), and Eni *et al.* (2014).

The observed copper and zinc concentration values were below the NSDWQ and WHO permissible limits. Significantly higher concentration of zinc observed in BH 4 can be attributed to the long usage of zinc roofing sheets within the location of BH 4, as zinc being a constituent of roofing sheets especially in urban areas, can be leached into groundwater by rainfall through soil percolation over time (Oyem *et al.,*2015). Corroborating findings were reported by Akpoveta *et al.* (2011), Ohwoghere – Asuma and Aweto (2013), and Oluseyi *et al.,* (2014). In contrast, Eni *et al.,* (2014) and Akoteyon (2012) reported high Copper and Zinc concentrations in groundwater studies. Lead concentrations (0.00 – 0.02 mg/l) in this study were above the NSDWQ and WHO permissible limits of 0.01mg/l, with similar values reported in studies by Olobaniyi *et al.* (2007) and Akpoveta *et al.* (2011) in Agbor and Benin City respectively.

The observed Iron concentrations were within the NSDWQ permissible limit of 0.3 mg/l, but exceeded the WHO limit of 0.1 mg/l. Similar results were reported by Akpoveta *et al.* (2011), Ohwoghere – Asuma and Aweto (2013), while Ogbeibu *et al.* (2012) and Akinbile and Yusoff (2011) reported higher values of iron concentration. Although the NSDWQ and WHO guideline concentration values for cadmium in drinking water is 0.003 mg/l; cadmium concentration was below detectible limit (BDL) in this study, with similar findings reported by Ogbeibu *et al.* (2012) and Oluseyi *et al.* (2014). While higher cadmium values of 0.005 to 0.007 mg/l and 0.13 mg/l in groundwater close to an active dumpsite were reported by Akpoveta *et al.* (2011) and Akoyeton (2012) respectively.

Safe guarding the microbial quality of drinking water is affirmed by water management experts to be the most important objective, even ahead of its physical and chemical quality, since water represents an obvious mode of transmission of enteric diseases. The WHO total coliform count (TCC) for drinking water is zero MPN/100mL (WHO, 2004). Recorded TCC values (0.00 - 30 cfu/ml) exceeded the WHO permissible limit, and similar results were obtained by Ogbeibu *et al.* (2012) and Eni *et al.* (2014). A mesophile is a term mainly applied to microorganisms that grows best in moderate temperature, typically between 20 and 45 °C, with an optimal temperature of 37 °C (Willey *et al.,* 2008). All sampled boreholes in this study indicated the presence of mesophilic microorganisms (0.00 – 20 cfu/ml). The presence of *Escherichia coli* in water is nearly always associated with recent faecal pollution and it is the preferred indicator organism for this purpose (Oyedeji *et al.,* 2010). Recorded *Escherichia coli* values (0.00 – 10 cfu/ml) exceeded the WHO permissible limit of zero cfu/ml. All the water samples examined, showed evidences of contamination with fungi species (1.67 – 6.67 cfu/ml). Similar results were reported by Akinbile and Yusoff (2011), Ogbeibu *et al.,* (2012), Eni *et al.,* (2014) and Oluseyi *et al.,* (2014).

The application of water quality index (WQI) in this study has been profoundly useful in the assessment of the overall quality of the groundwater. The WQI of the sampled boreholes and the overall WQI of 4.8 were within the permissible limits for excellent drinking water (Shweta *et. al.,* 2013). This suggests that the water in the study is of excellent quality and so suitable for drinking and other domestic uses. The soil stratigraphy being predominantly laterite and clayed sand have influenced the low levels or near absence of contaminants especially heavy metals in the groundwater samples (Adeolu, *et al.,* 2011; Egbai, 2011). It further gives credence to the dumpsite not being a point source of groundwater pollution. Similar results were reported by Ishaku *et al.* (2012), Etim *et al.* (2013) and Odiba *et al.* (2014).

Conclusion

Groundwater still remains the preferred source of water because of its high quality with reference to portability and the minimum treatment requirement in most cases (Okoro *et al.*, 2012). Considering the increase in demand for fresh water due to rapid population growth and industrialization (Ramakrishnaiah *et al.,* 2009), it becomes imperative to regularly monitor groundwater quality and risk assessment in relation to dumpsite operations (Akoyeton, 2012). Moreover, groundwater monitoring or risk assessment conforms to the normative principles of sustainability, as water pollution not only affects water quality and human health, it is also a threat to economic development and social prosperity (Bosselmann *et al.*, 2008; Olatunji *et al.,* 2015).

The study revealed that all the physicochemical parameters considered were within the NSDWQ and WHO permissible limits for drinking water quality, except for pH and Lead. Water quality index (WQI) assessment further revealed excellent water quality suggesting that the dumpsite at present is not a point source contaminant to groundwater in Agbor, Delta State. However, the indication of microbial pollution of groundwater by anthropogenic activities is a cause for concern. Therefore, consideration should be given to the siting of boreholes at a safe distance from septic tanks in order to mitigate the observed microbial contamination, and the need to check and forestall the further residential land use expansion and encroachment towards the dumpsite.

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