Evaluation of the Impacts of Dumpsite Leachate on Groundwater Quality in Omuooke-Ekiti, Southwestern Nigeria

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Abstract

This study focused on the impacts of leachate from dumpsite on groundwater in Omuooke-Ekiti, Southwest Nigeria. Twelve groundwater samples collected close and far to the dumpsite were subjected to cations determination employing Atomic Absorption Spectrometer while SO_4^{2-}, Cl^- and NO_3^- were evaluated using Turbidimetric, Mohr's and Spectrophotometer methods respectively. Portable meter was used to measure in-situ parameters. The pH (5.00 - 6.97) signified acidic groundwater; EC (µs/cm) (480 – 6980) indicated that 33% of the groundwater samples had concentrations above approved standard for drinking water. Furthermore, SO_4^{2-}(av. 1263.54mg/L.) and NO_3^-(av. 95.58mg/L) with the exception of Cl^- (av. 28.74mg/L) had concentration above the approved standards for potable water. All cations' concentrations except Mg^{2+} and Pb^{2+} were within the approved standards. Estimated irrigation parameters revealed that the groundwater was suitable for irrigation. This study revealed that the leachate from the dumpsite could be a precursor to human health, environmental and agricultural related problems.

Keywords: Groundwater; dumpsite; leachate; in-situ; concentration and irrigation.

Introduction

The recent industrial growth and population explosion in Nigeria has led to increase in the indiscriminate disposal of refuse. This is in accordance with the submission of Varma and Sarath (2015) that population growth and industrialization contribute to enormous amount of solid waste generation in the urban environment. Relatedly, Uwakwe (2012) was of the opinion that the rapid urbanization has put heavy pressure on land and water resources in cities resulting in serious environmental and social problems. Man's activity including uncontrolled population, agricultural activities and industrial development is the major factor responsible for increased municipal solid waste generation. Solid waste is non-gaseous and sewage emission created within and disposed-off by a municipality, including household garbage, commercial refuse, construction and demolition debris, dead animals and abandoned vehicles (Okpanachi, 2015).

Areas within the dumpsite have a bigger likelihood of environmental problems such as, surface water, groundwater and soil contamination because of the probable pollution source of leachate emanating from the site. Bhalla *et al*. (2013) perceived leachate as the liquid that infiltrates through the dumped waste, which is formed from snowmelt, rainwater, natural humidity and intrinsic water content of wastes or intrusion of groundwater. According to Ikem *et al*. (2002), leachate movement from wastes sites or landfills and the release of contaminants from sediments under certain conditions, pose a great danger to groundwater resource if not adequately managed.

As submitted by Bjerg *et al*. (2003), municipal landfills generate strongly anaerobic leachate with high contents of the Dissolved Organic Carbon (DOC), salts, NH_4^+, organic compounds and metals released from the waste. Also, Cossu (2013) opined that the detection of NH_4^+, Cl^-, Chemical Oxygen Demand (COD), SO_4^{2-}, Fe^{2+}, Mn^{2+} and some heavy metals are used as the main indicators of groundwater pollution from landfill leachate.

In view of the negative perception of the impacts of dumpsite leachate on groundwater quality, this research evaluated the impacts of dumpsite leachate on groundwater quality in Omuooke-Ekiti, Southwestern Nigeria with a view to ascertain the impacts and make suggestions towards ameliorating the impacts.

Study area

Omuooke Ekiti is an ancient town in the eastern part of Ekiti State. It is a border community that linked Ekiti
State with Kogi State, which has led to the rapid growth of the community. The waste dump is an open dumpsite at Arufe Street, covering an area of about 57,600 square meters with a height of about 3-4m. It is located between latitudes $7^0$46'00.00"N and $7^0$46'18.44"N and longitudes $5^0$44'00.00"E and $5^0$45'10"E (Figs. 1). The dumpsite is un-engineered and poorly managed. The waste in this dumpsite include glass bottles, rags, vegetable parts, polythene bags, egg shells, cans, rubbles, residues suggesting a partly domestic and agricultural types of waste. The activities of birds, rodents, reptiles and micro-organisms abound. The dumpsite is the only and most active dumpsite for the whole of Omuooke-Ekiti.

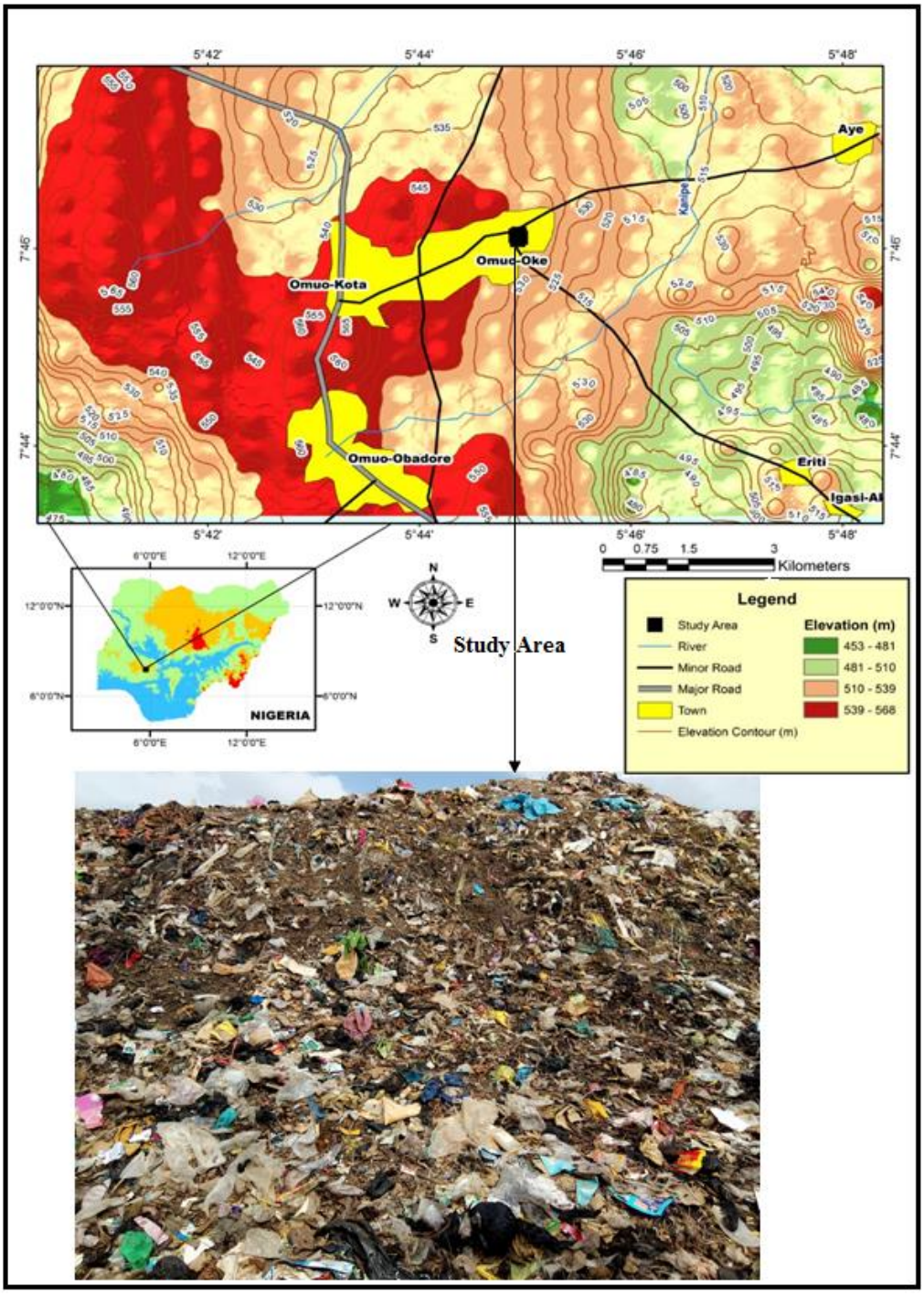

Fig. 1 Location map of the study area.

Omuooke-Ekiti enjoys a tropical climate which is characterized by two distinct seasons (dry and rainy) in a year. The dry season occurs between November and March. The month of December and January are the driest. The rainy season lasts between April and October, with July and September recording the highest rainfall. The temperature ranges from 21^0C to 29^0C with high humidity. In the rainy season, the wind tends to be south-westerly while the northeast trade winds (Harmattan) predominate the dry season. Omuooke-Ekiti has tropical and savannah forest (Iloeje, 1981).

Geology and Hydrogeology of the Study Area

The geology of Omuooke-Ekiti is part of the basement complex rocks of the Southwestern Nigeria. The study area is underlain by Precambrian crystalline rocks with ages greater than 300Ma to 450Ma (Matheis, 1976). Major lithological units are migmatite, granite gneiss, schist and quartzite, coarse grained charnokite, fine grained granite, medium grained granite and porphyritic granite with superficial deposit of clay and quartzite (Omotoyinbo, 1994). The rock exposure occurs as highly denuded hill of essentially fine-medium texture with closely spaced alternating bands of leucocratic and melanocratic minerals. They are characteristically low lying, fine grained, and conspicuously foliated with abundance of platy biotite minerals sandwiched into zones that are markedly distinguishable from light coloured quatzo-feldspartic portions (Talabi and Tijani, 2012). However, in the study area migmatite predominates covering the whole area (Fig. 2).

The hydrogeology of the study area is controlled by several factors, such as climatic, geological and structural features. The geological formations underlying an area and the structures determine the type of aquifer and their recharge process while the climatic factor determines the amount and rate of recharge of the aquifer (Ademilua and Olorunfemi, 2000). The major river draining the study area are the rivers Odogbo, Esiko, Amoye and Amote with their tributaries forming dendritic drainage pattern. Seasonal variations arise in volume of water in the rivers with increase in volume during the rainy season and a decrease or outright dry up during the dry season.

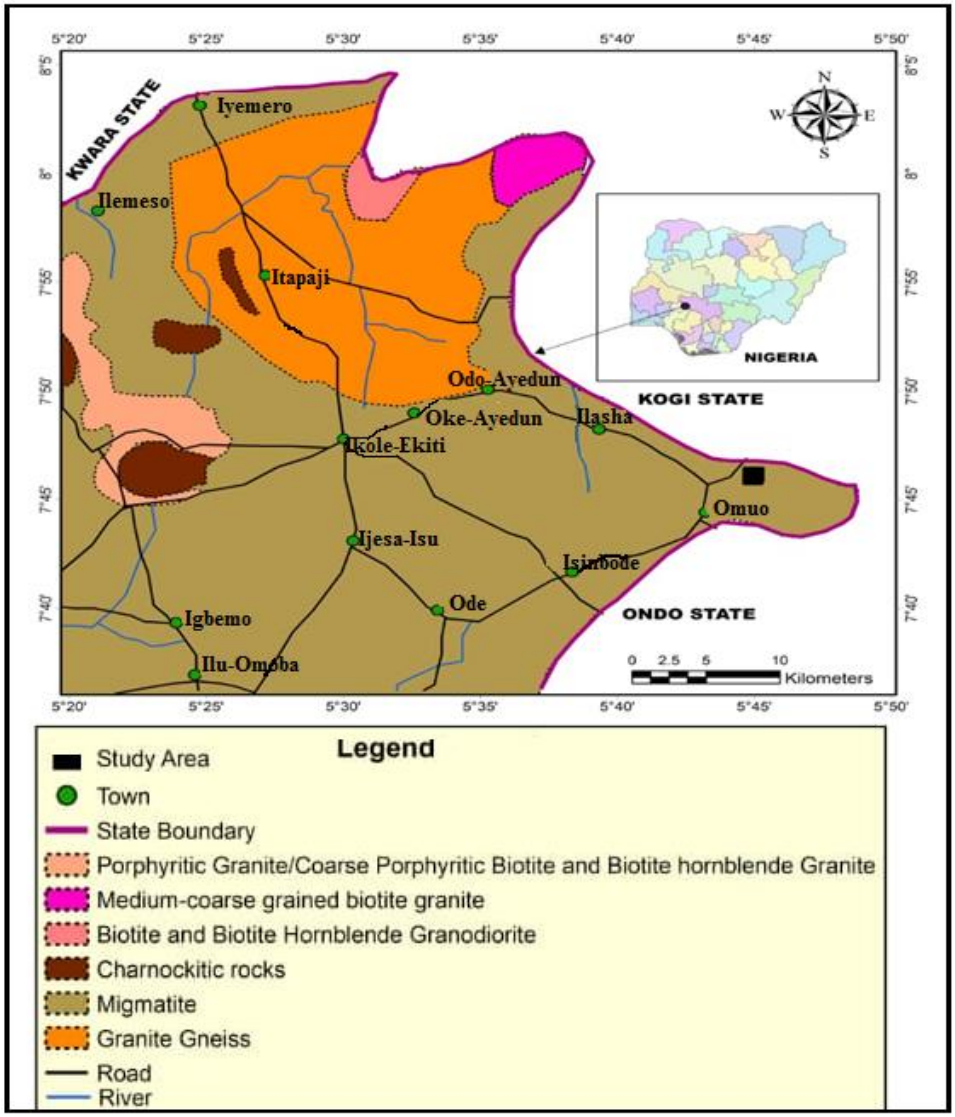

Fig. 2 Geological map of the study area (modified after NGSA, 2006).

According to Ako and Olorunfemi (1989), groundwater in any basement rock area occurs in the weathered layer or in the joints and fractured systems of the unweathered rocks and in buried stream channels. The highest groundwater yields in the study area are located where thick overbudden overlies fractured rocks. Groundwater supply in the study area is mainly from shallow hand dug wells and shallow boreholes.

Materials and Methods of study

Groundwater samples were collected from twelve hand-dug wells randomly distributed around the waste dumpsite (Fig. 3). Two sets of samples were collected from each well into a pre-cleaned polyethylene bottles. The first set of water samples used for cations and metals determination were acidified with concentrated nitric acid to prevent precipitation of metals while the second set for anions determination were left unacidified, airtight to prevent evaporation and stored at 4^0C. All sampling points were geo-referenced employing 12 Channel GPS etrex Garmin. The physical parameters such as pH, temperature, electrical conductivity and total dissolved solids of groundwater samples were measured in-situ using Multiparameter Portable Meter (Model Testr-35).

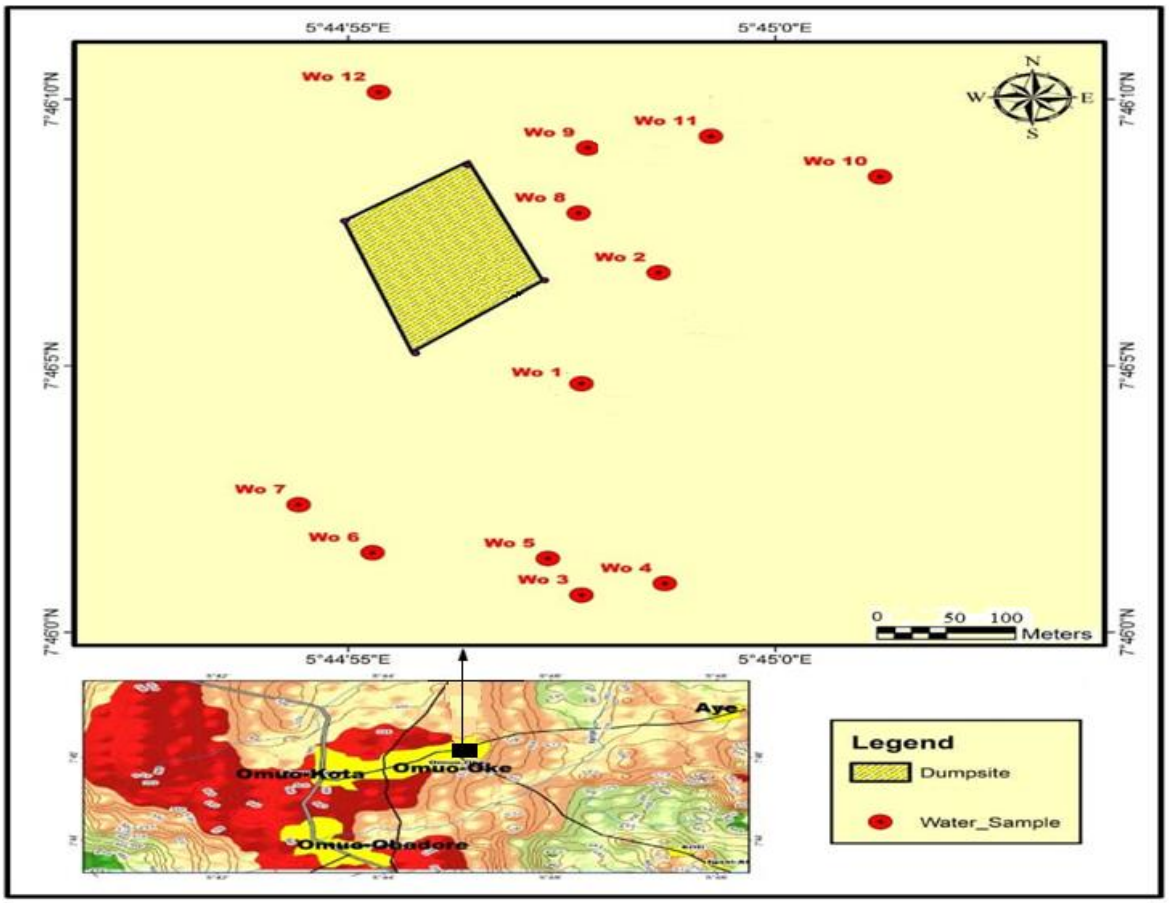

Fig. 3 Map indicating Groundwater Sampling Points in the Study Area

Hydrochemical analysis of water samples (groundwater) were done with respect to some major anions (Cl^-, SO_4^{2-} and NO_3^-), major cations (Ca^{2+}, Mg^{2+}, Na^+ and K^+) and heavy metals (Fe, Mn, Cu, Pb, Zn, Ni, Cr, and Cd). These parameters were selected based on their relative importance in municipal landfill leachates composition and their pollution potential on groundwater resources in particular (Bagchi, 2004). The hydrochemical analysis was carried out at Professor Julius Okojie Central Research Laboratory, Federal University of Technology, Akure. Chloride, Sulphate and Nitrates ions in groundwater were evaluated by Mohr's method, Turbidimetric and Spectrophotometric methods respectively. The cations and heavy metals were determined using Atomic Absorption Spectrophotometer (AAS). The parameters were determined following the recommended standards of AOAC (2010). Total hardness (TH) was estimated using: TH (mg/L) = 2:497 Ca^{2+} + 4:115Mg^{2+} (UNESCO, 2007) and TDS (mg/L) 0.67 EC (μS/cm) (Ali et al., 2012).

Results and Discussion

A brief description of the various groundwater sampling locations in this study is presented in Table 1. Most wells in the study area were protected but seven out of the total 12 groundwater samples were colourless and odourless. However, two of the remaining samples were odourless light brown coloured water while the remaining three had light brown colour with some fouling odour. In view of the fact that few of the wells were not properly covered, they are therefore prune to contamination from surface anthropogenic activities. Water level ranged from 4.87m to 6.56m with an average of 5.65m while the depth of well ranged from 10.83m to 15.72m with an average of 12.41m indicating that all wells in the study area are shallodw wells. The elevations of the study area ranged from 519.00m to 538.00m with an average of 527.17m. The variation observed in the water level could be consequent of many factors among these are the size and depth of the wells apart from the different elevations recorded at different locations. The water level in each well increase with decreased elevation and vice versa.

The physical parameters revealed that the temperature of the groundwater in the study area ranged from 28.10^{0}C to 29.50^{0}C with an average of 28.33^{0}C. The temperature in the study area fell outside the recommended value (25^{0}C) of (WHO, 2011). According to Hamaidi and Chergui (2004), temperature, apart from being one of the most essential parameters of water playing a significant role with regards to growth and activity of ecological life, it also greatly affects the solubility of oxygen in water. Many aquatic organisms are sensitive to change in water temperature. Ojo *et al*. (2012) submitted that the growth rate of micro-organisms, some of which produced bad tasting metabolites is positively associated with temperature. The odour of substance is also influenced by temperature because of the relationship between odour and vapour pressure.

The pH values of groundwater in the study area ranged between 4.92 and 6.24 (av. 5.78) (Table 1). The results obtained for pH fell outside of 6.5-9.5 permissible limits of WHO (2011) and the 6.5-8.5 standard recommendations of NSDWQ (2007). The groundwater in the study area is acidic in nature based on their pH values. The pH values recorded in the study area are indicative of acidic water that could produce side effects such as increase in stomach acid which can lead to gastrointestinal diseases. It can also cause corrosion of metals especially in wells.

The Total Dissolved Solids (TDS) of groundwater samples in the study area ranged between 334.56 (mg/L) and 4865.06 (mg/L). The TDS values exceeded the recommended standard of WHO (2011) and NSDWQ (2007) in 50% sampled groundwater of the study area. The finding of Chandne (2014) revealed that water containing more than 500mg/L of TDS is not suitable for drinking but in unavoidable circumstances, 1500mg/L may be allowed. The TDS in the study area which is greater than the recommended limit could be as a result of difference in organic matter that remains as residue in the wells water. This observed trend in TDS values suggest the dumpsite as a possible source of contaminants which increased the TDS of groundwater. The Electrical Conductivity (EC) of groundwater in the study area ranged between 480µS/cm and 6980µS/cm with a mean of 1796.67µS/cm. Well water samples $W_0$8, $W_0$2, and $W_0$9 closer to the dump zone showed a significantly high EC that are above WHO (2011) and NSDWQ (2007) permissible limits (Table 1) indicating the negative impacts from the dumpsite leachate.

Water from wells' $W_0$1 and $W_0$12 fell within the permissible limits of WHO (2011) and NSDWQ (2007) while $W_0$10, W06, $W_0$5, $W_0$3 and $W_0$4 fell below the recommended limits. Fluctuation in electrical conductivity may be due to many factors of which the most prevalent is from differential weathering of the mineral contents released into the wells from different rock units. Riemann (2013) in his work submitted that there is little direct health risk associated with EC but high values are related with poor taste and increased percentage of total dissolved solids.

Water hardness is a measure of the capacity of water to react with soap with hard water requiring considerably more soap to form lather with water. Water hardness is predominantly as a result of calcium and magnesium cations in water though other cations (aluminium, barium, iron, manganese, strontium and zinc) also contribute (WHO, 2009). In the present research TH (mg/L) ranged from 14.27 – 130.13 (av. 65.79). General guidelines for classification of waters hardness are: 0 to 60mg/L as calcium carbonate is classified as soft; 61 to 120mg/L as moderately hard; 121 to 180 mg/L as hard; and more than 180 mg/L as very hard (Srinivasan et al., 2013). Six (50%) out of the twelve groundwater samples fell into the low hardness category, 5 samples (41.67%) were in the moderately hard class while only one (1) (8.33%) sample was in the hard class.

The concentration of calcium ion in the study area ranged from 5.5mg/L to 43.0mg/L (av. 21.67mg/L) while that of magnesium was from 0.13mg/L to 5.63mg/L (av. 2.839mg/L) (Table 2).

Table 1 Physical Parameters of Groundwater from the study Area

Water sample	Northing	Easting	Elev. (m)	Water level (m)	Depth (m)	Temp. (°C)	pH	EC (µS/cm)	TDS (mg/L)	TH	Description
W_01	$07^0$46'04.59"	$05^0$44'57.65"	528.00	6.41	14.33	29.00	5.67	1040.00	724.88	86.06	Colourless/odourless water. Well covered/lined.
W_02	$07^0$46'06.73"	$05^0$44'58.64''	527.00	5.82	11.88	29.50	6.12	6980.00	4865.06	119.30	Light brown water. Well partially covered.
W_03	$07^0$46'00.68''	$05^0$44'57.72''	525.00	5.71	11.89	28.50	5.54	500.00	348.5	14.27	Colourless/odourless water. Well covered.
W_04	$07^0$46'18.44''	$05^0$45'04.97"	538.00	5.66	11.69	28.50	4.92	480.00	334.56	19.53	Colourless/odourless water. Well covered.
W_05	$07^0$46'01.38''	$05^0$44'57.34"	530.00	5.22	10.83	28.10	5.92	530.00	369.41	34.76	Colourless/odourless water. Well covered.
W_06	$07^0$46'01.49'	$05^0$44'55.28"	528.00	5.58	11.38	28.10	6.02	620.00	432.14	35.88	Light brown water. Well partially covered.
W_07	$07^0$46'02.39''	$05^0$44'54.43"	531.00	5.12	11.66	28.30	5.57	700.00	487.9	53.85	Light brown water. Well partially covered.
W_08	$07^0$46'07.86''	$05^0$44'57.69"	523.00	5.86	11.93	28.10	5.37	5350.00	3728.95	130.13	Colourless/odourless water. Well covered.
W_09	$07^0$46'09.08''	$05^0$44'57.82"	524.00	5.10	13.52	29.50	5.89	2880.00	2007.36	96.19	Colourless/odourless water. Well covered.
W_010	$07^0$46'08.54''	$05^0$45'01.24"	519.00	4.91	12.43	29.40	6.02	660.00	460.02	51.03	Odourless, light brown water. Well covered.
W_011	$07^0$46'09.29''	$05^0$44'59.25"	532.00	4.87	11.64	29.50	6.24	820.00	571.54	63.57	Odourless, light brown water. Well covered.
W_012	$07^0$46'10.12''	$05^0$44'55.34"	521.00	6.56	15.72	28.10	6.12	1000.00	697.00	84.86	Colourless/odourless water. Well covered.
Min.	-	-	519.00	4.87	10.83	28.10	4.92	480.00	334.56	14.27	-
Max.	-	-	538.00	6.56	15.72	29.50	6.24	6980.00	4865.06	130.13	-
Mean	-	-	527.17	5.57	12.41	28.72	5.78	1796.67	1252.28	65.79	-
Stdev	-	-	5.24	0.55	1.41	0.62	0.38	2168.50	1511.45	37.80	-
NSDWQ (2007)			-	-	-	-	6.5-8.5	1000.00	500.00		
WHO (2011)			-	-	-	-	6.5-9.5	1500.00	500.00		

The Ca^{2+} concentrations in the groundwater of the study area were generally low and all fell within the approved WHO (2011) and NSDWQ (2007) standard for drinking water. However, the Mg^{2+} concentrations were generally high with values above the recommended permissible limits of WHO (20011) and NSDWQ (2007) (Table 2). Relative increased concentrations closed to the dumpsite were observed in both Ca^{2+} and Mg^{2+} which may be attributed to leachate movement/percolation through the unlined dumpsite. Sharma and Walia (2016) submitted that calcium and magnesium caused both carbonate and non-carbonated hardness of water.

The concentration of sodium ion in groundwater in the study area ranged from 0.16mg/L to 6.27mg/L (av. 2.76mg/L). The Na^{+} concentrations in groundwater in the study area was observed to be relatively low as they fell below the recommended permissible level of WHO (2011) and NSDWQ (2007). The Na^{+} concentration of well water samples within the dump zone slightly showed relatively high concentrations compared with those that are far from the zone. This indicated that the leachate from dumpsite is possibly the source of Na^{+} contamination of groundwater samples in the proximity of the dumpsite. Low trend was equally observed in potassium ion concentrations ranging from 0.36mg/L to 12.99mg/L with a mean value of 4.67mg/L (Table 2). The concentrations of K+ ions close to the dump site were above the recommended limits of WHO (2011) and NSDWQ (2007) for drinking water which may be attributed to leachate movement/percolation through the unlined waste dumpsite.

Chloride (Cl^{-}) ions have low concentrations (3.99mg/L - 71.77mg/L) that fell within approved standards for drinking water. However, groundwater samples that are closed to the dump zone have higher Cl^{-} concentrations compared to those far away from the zone. The slightly high chloride in these groundwater samples could possibly be the impact of the leachate from the dumpsite due to their closeness to the dumpsite. Chloride in reasonable concentrations are not harmful but it causes corrosion in concentrations above 250 mg/L, while at about 400 mg/L, it causes a salty taste in water. An excess of chloride in water is usually taken as an index of pollution and considered as tracer for groundwater contamination (Loizidou and Kapetanios 1993).

Table 2 Major ions concentrations of Omuooke-Ekiti groundwater samples collected around the study area.

Water sample	**Ca^{2+} (mg/L)**	**Mg^{2+} (mg/L)**	**Na^{+} (mg/L)**	**K^{+} (mg/L)**	**Cl^{-} (Mg/L)**	**SO_4^{2-} (mg/L)**	**NO_3^{-} (mg/L)**
$W_0$2	38.5	5.63	6.22	12.99	70.78	3106.13	115.56
$W_0$3	5.5	0.13	0.18	0.43	3.99	15.08	ND
$W_0$4	6.75	0.65	0.16	0.36	4.98	42.25	ND
$W_0$5	12.75	0.71	0.63	0.46	6.98	121.5	35.16
$W_0$6	13	0.83	0.75	0.56	6.98	173.5	59.56
$W_0$7	18.5	1.86	1.49	1.54	14.95	690.03	85.06
$W_0$8	43	5.53	6.27	12.46	71.77	2992.13	186.04
$W_0$9	30.25	5.02	6.57	12.4	52.83	2181.5	114.84
$W_0$10	17.75	1.63	0.85	1.18	8.97	358	70.17
$W_0$11	20.25	3.16	3.5	3.12	22.93	1534	90.68
Wo12	26.75	4.39	3.52	3.29	38.87	1805.45	93.61
Minimum	5.5	0.13	0.16	0.36	3.99	15.08	35.16
Maximum	43	5.63	6.57	12.99	71.77	3106.13	186.04
Mean	21.67	2.84	2.83	4.67	28.74	1263.54	95.58
NSDWQ (2007)	100.00	0.20	200.00	10.00	250	100	50
WHO (2011)	100.00	-	200.00	10.00	-	250	45

ND: Not detected.

The concentration of sulphate in the study area ranged from 15.08mg/L to 3106.13mg/L with a mean of 1263.54mg/L (Table 2). All the water samples that were close to the dumpsite recorded a very high SO_4^{2-} concentration that fell outside the permissible limits of drinking water standard indicating the impacts of the dumpsite on the SO_4^{2-} concentrations. The concentration levels of NO_3^{-} in the study area ranged from 35.16mg/L to 186.04mg/L with a mean of 95.58mg/L. The average concentration level of NO_3^{-} (95.58mg/L) was higher than the approved standard for drinking water revealing the impacts of the dumpsite.

The heavy metals concentrations (Table 3) revealed that some of the metals (Mn, Pb and Cr) in the groundwater of the study area had concentrations above approved standard of WHO (2011). However, similar trends of increased concentrations observed in major ions vis-a-vis the dumpsite were repeated in the heavy metals. Concentrations of the heavy metals were generally high close to the dumpsite and decrease with increased distance from the waste dump suggesting that the leachate from the dumpsite as a possible source of increase observed in the concentrations of the metals close to the dumpsite. Excess heavy metals in

groundwater can have deleterious effects on humans and ecosystem. Manganese may form deposits within pipes and break off as black particles that give water an unpleasant appearance and taste. It increases the growth of unwanted bacteria that form a slimy coating in water pipes (Rahman, 2000). Kavitha and Elangovan (2010) reported that Cu is a trace element essential for human health, but large concentrations of Cu can cause health problems such as liver and kidney diseases.

Table 3 Concentrations of heavy metals in the groundwater samples from the study area.

Water sample	Fe mg/L	Mn Mg/L	Cu mg/L	Pb mg/L	Zn mg/L	Ni mg/L	Cr mg/L
$W_0$1	0.13	0.05	0.01	0.07	ND	ND	0.03
$W_0$2	0.17	0.17	0.01	0.08	0.01	0.03	0.06
$W_0$3	0.03	0.01	ND	ND	ND	ND	ND
$W_0$4	0.04	0.02	ND	ND	ND	ND	ND
$W_0$5	0.06	0.02	ND	0.01	ND	ND	ND
$W_0$6	0.06	0.03	ND	0.03	ND	ND	ND
$W_0$7	0.08	0.04	0.01	0.03	ND	ND	ND
$W_0$8	0.17	0.08	0.01	0.09	0.03	0.03	0.08
$W_0$9	0.16	0.05	0.01	0.07	ND	ND	0.06
$W_0$10	0.08	0.03	ND	0.03	ND	ND	ND
$W_0$11	0.08	0.04	ND	0.04	ND	ND	0.02
$W_0$12	0.10	0.04	0.01	0.06	ND	ND	0.02
Min.	0.03	0.01	0.000	0.00	0.00	0.00	0.00
Max.	0.17	0.17	0.01	0.09	0.03	0.03	0.08
Mean	0.10	0.05	0.01	0.05	0.02	0.03	0.05
NSDWQ (2007)	0.30	0.01	1.00	0.01	3.00	0.02	0.05
WHO (2011)	0.20	0.05	1.00	0.01	3.00	0.07	0.1

ND: Not detected

Liver and Wilson's disease are highly prone to copper toxicity. Pb is a toxic metal that occurs naturally in an environment. It is useful in several products found in and around homes. Small concentration of Pb can cause several health complications, especially in the case of children that are mostly at risk. According to Ayotte (1999), Pb can increase blood pressure and kidney damage as well as disruption of the biosynthesis of haemoglobin etc. CrO_3 dusts may cause cancer and damages to the respirational system whereas hexavalent chromium is highly toxic. It causes allergic and asthmatic reaction. It is more carcinogenic than trivalent chromium (Lemly, 2002).

Correlation analysis for groundwater around the dumpsite

Correlation is a method used to estimate the level of interrelationship and association between two variables (Nair *et al*., 2005). A correlation with positive (+) values of 1, 0.70, 0.50 and 0.30 indicates perfect, strong, moderate and weak positive relationships between two variables respectively while a correlation of 0.00 indicates that there is no relationship between the two variables. A correlation of negative (-) values of 1.00, 0.70, 0.50, and 0.30 indicates perfect, strong, moderate, and weak negative relationships respectively. A negative (-) correlation indicates that one variable changes inversely with relation to the other (Kapil *et al*., 2009).

Table 4 represents the correlation matrix of groundwater parameters of the study area. The table revealed that TDS, EC, Cl, SO_4, NO_3, Mg, Na, K, Fe, Mn, and Pb with $0.59\leq r \leq 0.94$, $0.58\leq r\leq 0.94$, $0.69\leq r\leq 0.98$, $0.62\leq r\leq 0.99$, $0.64\leq r\leq 0.95$, $0.53\leq r\leq 0.97$, $0.56\leq r \leq 0.96$, $0.63\leq r\leq 0.98$, $0.61\leq r\leq 0.96$, $0.52\leq r\leq 0.85$ and $0.59\leq r\leq 0.89$ respectively at $p \leq 0.01$ level of significance showed a correlation from moderate to strong positive relationships. Cu with $0.39\leq r\leq 0.81$ at $p \leq 0.01$ level of significance showed a weak to strong positive correlation with other major water quality parameters while Ca, Ni and Cr with $0.7\leq r\leq 0.97$, $0.74\leq r\leq 0.88$ and $r=0.77$ at $p\leq 0.01$ level of significant showed a strong positive correlation with a linear relationship. The presence of these substances in groundwater with their strong positive correlation justified the provenance as the same and mostly from the waste dumpsite.

Effects of distance from dumpsite on physico-chemical parameters

A gradual decrease in the values of the anions (Cl^-, SO_4^{2-}, and NO_3^-) was observed at increased distance from the dumpsite. This trend was also observed for cations (Ca^{2+}, Mg^{2+}, Na^+ and K^+) and heavy metal (Fe, Mn, Cu, Pb, Zn, Ni and Cr). The gradual decrease in the values of these parameters could arise from the fact that they were far away from the dumpsite where the groundwater contamination by leachate has reduced.

Table 4: Correlation matrix of water quality parameters of the study area

	TDS	EC	Cl	SO_4	NO_3	Ca	Mg	Na	K	Fe	Mn	Cu	Pb	Zn	Ni	Cr
TDS	1															
EC	0.89	1														
Cl	0.88	0.89	1													
SO_4	0.81	0.82	0.98	1												
NO_3	0.82	0.69	0.87	0.88	1											
Ca	0.87	0.84	0.97	0.63	0.95	1										
Mg	0.75	0.75	0.96	0.99	0.88	0.96	1									
Na	0.80	0.81	0.96	0.97	0.86	0.94	0.97	1								
K	0.85	0.88	0.96	0.93	0.81	0.91	0.91	0.96	1							
Fe	0.82	0.83	0.96	0.95	0.81	0.97	0.95	0.96	0.97	1						
Mn	0.69	0.92	0.81	0.79	0.60	0.78	0.73	0.73	0.78	0.77	1					
Cu	0.59	0.58	0.80	0.79	0.74	0.80	0.83	0.76	0.74	0.81	0.58	1				
Pb	0.78	0.75	0.95	0.96	0.94	0.97	0.97	0.94	0.89	0.96	0.71	0.81	1			
Zn	0.94	0.75	0.69	0.62	0.70	0.70	0.53	0.56	0.63	0.61	0.52	0.39	0.59	1		
Ni	0.91	0.94	0.78	0.71	0.64	0.76	0.61	0.64	0.73	0.69	0.85	0.45	0.64	0.88	1	
Cr	0.92	0.87	0.96	0.94	0.84	0.92	0.90	0.96	0.98	0.94	0.72	0.69	0.89	0.74	0.77	1

Suitability of Groundwater in the Study area for Irrigation

Part of the major reasons for analysing water is to investigate the effects of the water on the soil and the ultimate impacts on the plants grown on the soil. Hence, part of the interpretations of the water analysis is based on a prediction of the consequences on the soil. The interpretation of any hydrochemical data is in many instances depends on the purposes for which it is intended to be used as some plants have much different tolerance levels. In this study, Sodium Adsorption ratio (SAR), Percentage Sodium (PS), Kelley Ratio (KR) and Magnesium Adsorption Ratio (MAR) were computed to assess the suitability of groundwater in the study area for irrigation (Table 5).

Sodium Adsorption Ratio (SAR)

Sodium Adsorption Ratio (SAR) is a very important parameter for determining the suitability of groundwater for irrigation purposes (Karanth, 1987). It is defined as:

$$SAR = Na^{+} / \{[(Ca^{2+} + Mg^{2+})/2] 1/2\}$$

Where the concentrations are in meq/L.
The SAR values in groundwater samples in this study ranged from 0.08 to 1.56 with an average value of 0.71. The estimated SAR for all water samples in the study area were less than 10. Hence, they fell under low sodium (S1) class. This suggested that there was no alkali hazard and the water can be applied on all soils for irrigation.

Percentage Sodium
The sodium in irrigation waters is usually denoted as percentage of sodium. According to Wilcox (1955), in all natural waters, percentage sodium is a common parameter to assess its suitability for irrigational purposes. The sodium percent (Na %) values were obtained using the following equation:

$$Na\ \% = (Na^{+} + K^{+}) \times 100 / (Ca^{2+} + Mg^{2+} + Na^{+} + K^{+})$$

Where the concentrations are in meq/L.
The percentage sodium in groundwater samples in this research ranged from 6.56% to 34.97% (av. 16.18%) suggesting that the groundwater in the study area fell under excellent to good limits for irrigation. According to Anandakumar *et al*. (2009), when the range of sodium is high, it will be absorbed by the clay particles, which will displace Mg^{2+} and Ca^{2+} ions. Collins *et al*. (1996) and Saleh *et al*. (1999) opined that the exchange process of Na^{+} in water for Mg^{2+} and Ca^{2+} ions in soil reduces the permeability and eventually results in soil with poor internal drainage.

Kelly Ratio (KR)

The Kelly Ratio indicates balance among Na^{+}, Ca^{2+}, and Mg^{2+} ions in water. The hazardous effects of sodium on water quality for irrigation usage in terms of Kelly's ratio (KR) were computed as stipulated by Kelly (1940);

$$KR = Na^{+} / (Ca^{2+} + Mg^{2+})$$

Where the concentrations are in meq/L

The estimated value of KR in groundwater samples in the study area ranged from 0.022 to 0.186 (Table 5). Kelly Ratio of more than 1 indicates an excess level of Na^+ in water. Kelly (1940) suggested that the ratio for irrigation water should not exceed 1. None of the estimated KR in the study area exceeded 1, indicating the suitability of the groundwater for irrigation.

Magnesium Adsorption Ratio (MAR)

In some waters, calcium and magnesium maintain a state of equilibrium. A ratio known as index of magnesium hazard was developed by Paliwal (1972) signifying that high magnesium hazard value (>50 %) has an adverse effects on the crop yield as the soil becomes more alkaline.

Magnesium ratio = $Mg^{2+} \times 100/(Ca^{2+} + Mg^{2+})$

Where the concentrations are in meq/L.
In the study area, the magnesium hazard values fell in the range of 2.31% to 14.37% (Table 5). In the study area, 100% of the samples collected showed MH ratio less than 50% indicating the suitability of the groundwater for irrigation.

Table 5. Estimated Irrigation Parameters (PS, SAR, KR and MAR) in the study area.

Sampling Points	PS (%)	SAR	KR	MAR (%)
W_{01}	26.04	1.00	0.12	14.37
W_{02}	30.33	1.32	0.14	12.76
W_{03}	9.78	0.11	0.03	2.31
W_{04}	6.56	0.08	0.02	8.78
W_{05}	7.49	0.24	0.05	5.27
W_{06}	8.65	0.29	0.05	6.00
W_{07}	12.95	0.47	0.07	9.14
W_{08}	27.85	1.27	0.13	11.40
W_{09}	34.97	1.56	0.19	14.23
W_{010}	9.48	0.27	0.04	8.41
W_{011}	22.04	1.02	0.15	13.50
W_{012}	17.94	0.89	0.11	14.10

Conclusions

The study assessed the hydrogeochemical impacts of waste dumpsite leachate on groundwater quality in Arufe area of Omuooke-Ekiti, Southwestern Nigeria. The findings of the study revealed that the physical parameters (Temperature, pH, TDS and EC) in the sampled groundwater had values above the recommended permissible limits of WHO and NSDWQ except for the EC values far from the waste dump that were within the approved standards. Groundwater in the study area is not potable in view of the acidic nature of the water and the high TDS.

Majority of the groundwater samples have SO_4^- and NO_3^- concentrations above the approved National and International standards while Cl^- fell within the approved standards. All anions concentrations in the study area were high close to the dumpsite compare to the values far from it, indicating that the leachate from the dumpsite influenced their concentrations.

Most of the cations (Ca^{2+}, Mg^{2+}, Na^+ and K^+) and heavy metals (Fe, Mn, Cu, Zn, Ni, Pb, Cr and Cd) in the groundwater have low concentrations, lower than the approved National and International standards.

Correlation analysis signified same source for the ions as they were positively correlated with one another. The study also revealed a progressive decrease in the values of measured parameters with increasing distance away from the dumpsite, indicating that the groundwater contamination arose from the leachates that emanated from the waste dumpsite.

Irrigation evaluation using parameters such as Sodium Percentage (SP), Sodium Adsorption Ratio (SAR), Magnesium Absorption Ratio (MAR) and Kelly Ratio (KR) revealed the suitability of groundwater in the study area for irrigation.

The study concluded that the leachate from Arufe dumpsite, Omuooke-Ekiti, Southwestern Nigeria had negative impacts on the groundwater of the area and was capable of causing health, environmental and agricultural problems for the people living within the area. A well-coordinated clean-up operation should be undertaken at the sampled dumpsite to curtail the spread of leachate to the surrounding groundwater zones as well as connecting rivers.

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