Groundwater Quality Assessment around Municipal Solid Waste Dumpsite in Abeokuta, South-West Nigeria.

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ABSTRACT

To assess the effect of a dumpsite on groundwater quality, water samples were obtained from twenty randomly selected hand-dug wells; leachates were also obtained from the dumpsite. Physico-chemical, bacteriological and heavy metals were determined using standard procedures. The trend of dispersion of each parameter was assessed. The quality of water from hand-dug wells within 600 m radius of the dumpsite was not suitable for human consumption.

(Keywords: dumpsite, hand-dug well, groundwater, leachate, physico-chemical)

INTRODUCTION

Accessibility to safe drinking water is one of the priorities of the World Health Organization for everybody irrespective of their social and economic status. A majority of the populations in developing countries have health-related problems due to water-borne diseases such as diarrhea, cholera, typhoid, hepatitis, etc. (WHO, 2008). Groundwater is mostly threatened by human activities, although harmful substances are sometimes introduced by natural processes (Longe and Balogun, 2010). Wastes in open-dumps often have effects on groundwater through either groundwater underflow or infiltration from precipitation. The surrounding areas of the dumpsite have greater tendency for groundwater contamination because of the potential pollution source of leachate originating from the nearby site (Adekunle *et al.,* 2007). This contamination of groundwater resources poses substantial risk to local dwellers and to the natural environment.

In this study, the effect of leachate percolation on groundwater quality was estimated with experimental determination from an open dumpsite site in Abeokuta, southwestern Nigeria. Various physico-chemical parameters, heavy metals and quality indicator microbes were analyzed in leachate and in groundwater samples to understand the possible link of groundwater contamination.

MATERIALS AND METHODS

Study Area

Abeokuta, the Capital of Ogun state, situated in southwest Nigeria covers an approximate area of about 40.63 km^2. It lies between latitude 70^0 10' N and 70^0 15' N and longitudes 30^0 17' E and 30^0 26' E (Ufoegbune et al., 2008). Abeokuta is a historic Yoruba town, formed by the Egbas in 1830. The town has become increasingly cosmopolitan as a result of the elevation in status of Abeokuta to State Capital in 1976. The town is within the rain forest zone of Nigeria and its geographical location makes it easily accessible to Lagos, the commercial capital of Nigeria, industrial state and main seaport. Abeokuta is located on basement complex of igneous and metamorphic origin. The basement rocks are overlain by various sedimentary rocks. The rugged rock-strewn relief is prominent towards the north, in the central and south-eastern parts of the city. The city is drained by two major rivers, Ogun and Oyan and many small streams. Some of these streams take their source from local rocky hills while some are distributaries to the two major rivers.

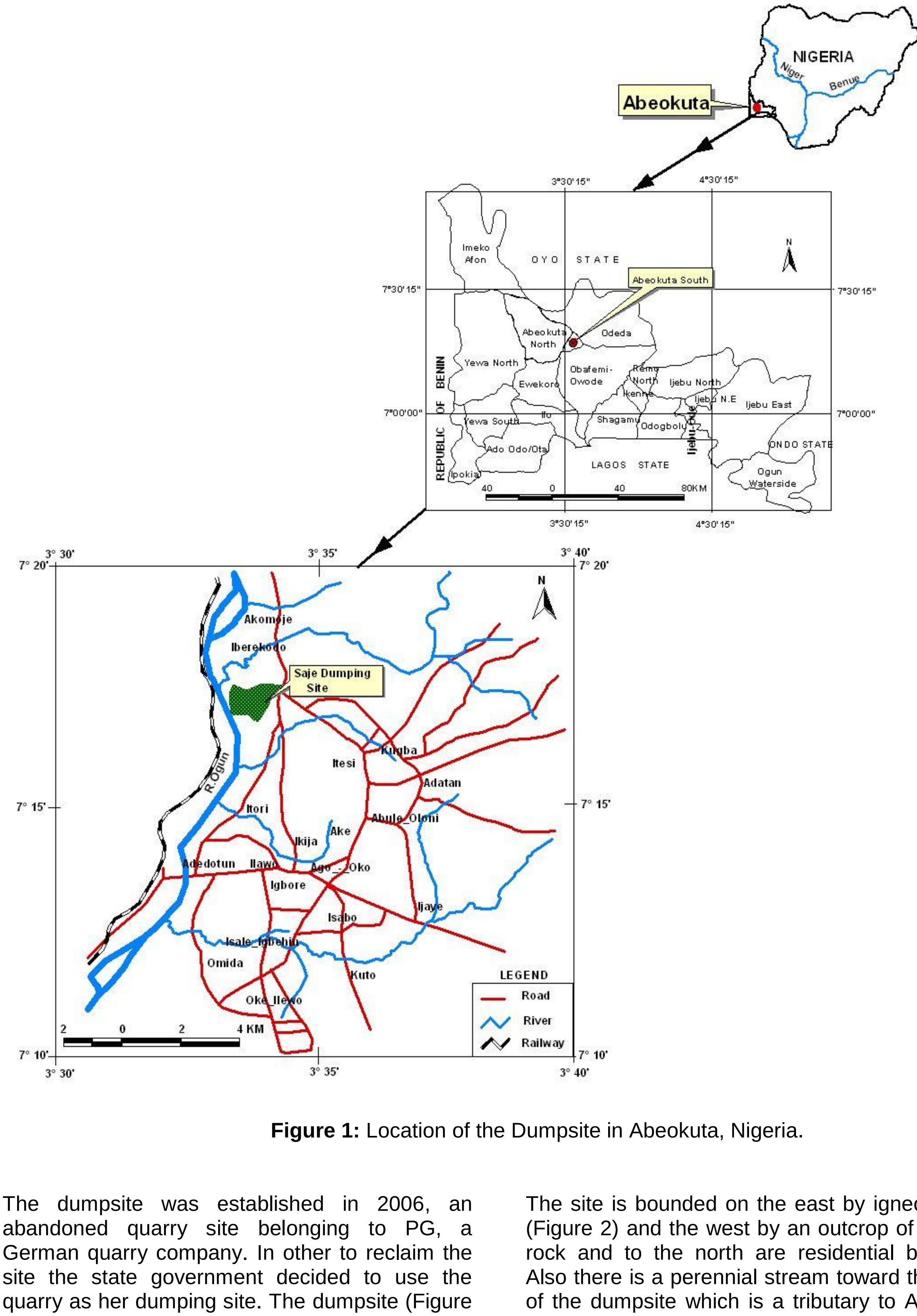

Figure 1: Location of the Dumpsite in Abeokuta, Nigeria.

The dumpsite was established in 2006, an abandoned quarry site belonging to PG, a German quarry company. In other to reclaim the site the state government decided to use the quarry as her dumping site. The dumpsite (Figure 2) is the only dumpsite used in the Abeokuta metropolis and is about 4ha in area.

The site is bounded on the east by igneous rock (Figure 2) and the west by an outcrop of igneous rock and to the north are residential buildings. Also there is a perennial stream toward the south of the dumpsite which is a tributary to Arakonga stream, in Abeokuta.

Figure 2: Open Dumpsite in Abeokuta, May 2012.

Sampling

The choice of the sampling stations was considered with the following criteria: location, accessibility, proximity to residential areas and the topography of the study area. The coordinate of the dumpsite and groundwater points locations were obtained with a hand held Global Positioning System (GPS, Garmin MAP 76CSx model) with position accuracy of less than 3m.

Twenty (20) hand-dug wells were randomly selected for this study within 2 km radius from the center of the dumpsite (Figure 4). Three (3) water samples were taken from each selected groundwater points given a total of 60 samples (3 samples from each of the 20 hand dug wells) and three (3) samples were also taken from the dumpsite.

The physical parameters analysed include temperature, electrical conductivity (EC), potential hydrogen (pH), the chemical parameters include: sodium (Na^+), potassium (K^+), calcium (Ca^{2+}), magnesium (Mg^{2+}), Nitrite (NO_3^-), Sulphate (SO_4^{2-}), carbonate (CO_3^{2-}); pH and EC was determined using pH/conductivity meters (Jenway model) while the other parameters were determined using titration (0.05-N EDTA for $Ca^{2+}$and Mg^{2+}, H_2SO_4 for CO_3^{2-}) at the Environmental laboratory of the University of Agriculture, Abeokuta. All the samples were analyzed for selected relevant physico-chemical parameters, heavy metals and total coliform (TC) and faecal coliform (FC) according to internationally accepted procedures and standard methods (APHA, 1994). Estimation of COD was done by reflux titrimetry, while Total Alkaline, Total Hardness, Ca^{2+}, Mg^{2+} and Cl^- were estimated by titrimetry, Na^+ and K^+ by flame photometry (Systronic-128). SO_4^{2-} and NO^{3-} were also determined by using Jenway UV/VIS Lambda 2 spectrophotometer.

The data were statistically analyzed by setting up and calculating a correlation matrix for the various parameters using Statistical Package for Social Sciences (SPSS) software package (Norusis and SPSS Inc, 1997) and Minitab statistical software.

RESULTS AND DISCUSSION

The results of both physico-chemical and bacteriological analysis are present in Tables 1 and 2. Table 1 revealed the location and the distance of groundwater sampled wells around the dumpsite. Table 2 shows average values of the physico-chemical parameters of the samples wells while Table 3 gives the statistical summary of the parameters in comparison with WHO standards and NSDWQ (Nigerian Standard for Drinking Water Quality) standards. Figure 3 shows the surface chart of the groundwater sources against the parameters tested.

Table 1: Physical Parameters of Hand-Dug wells within 2 km radius of the Dumpsite.

Point	Easting	Northing	Dist. from Dumpsite (m)	pH	EC (μs/cm)	Temp (°C)
Dumpsite	540366	794470	0.00	7.53	819.00	30.00
1	540923	794454	490.83	6.61	203.67	29.50
2	540834	794731	546.95	6.70	195.67	29.60
3	540818	793917	578.33	6.32	137.67	29.80
4	539866	794179	604.58	5.80	163.00	29.50
5	540983	794649	607.46	6.27	166.67	29.70
6	541013	794652	643.56	6.69	504.67	29.40
7	541053	794553	647.50	6.19	204.67	29.30
8	540631	793631	745.39	7.10	406.67	28.30
9	539593	794387	852.72	5.60	222.00	29.20
10	540274	793460	905.33	5.27	477.00	29.10
11	539710	793813	917.50	5.42	199.00	29.60
12	539615	793847	983.93	6.48	366.67	31.20
13	540672	793281	1097.56	6.66	1017.00	29.70
14	539945	793350	1143.00	6.10	317.67	30.20
15	539718	793405	1191.37	6.49	260.00	30.30
16	540836	793137	1271.52	6.18	903.67	30.10
17	539836	793128	1379.97	6.27	228.33	29.50
18	539495	793181	1508.42	6.09	398.00	30.30
19	538706	794400	1746.35	6.72	306.33	29.30
20	539811	795990	1761.34	7.08	400.33	28.40

Table 2: Physico-Chemical Parameters of Hand-Dug Wells within 2 km radius of the Dumpsite.

Point	COD	Total Coliform Count	Total *E. coli* Count	Hard-ness	Alkalinity	Ca	Na	K	Mg	SO_4^{2-}	NO^-_3	Cl^-
Dumpsite	580.00	288	0	314.00	26.00	216.00	700.00	1600.00	98.00	25.80	25.40	161.00
1	35.33	229.67	0	114.00	9.33	65.00	17.00	5.67	49.00	13.07	39.40	56.00
2	0.37	121.00	0	134.67	15.33	90.67	17.67	8.67	44.00	24.87	46.33	64.33
3	2.33	25.00	0	122.67	18.33	90.67	12.67	6.00	32.00	26.60	23.73	55.67
4	41.00	103.00	0	44.67	7.00	35.33	11.67	1.00	9.33	4.53	35.93	40.00
5	256.67	149.67	0	79.33	16.67	56.00	9.00	1.00	23.33	10.33	23.50	45.00
6	412.00	259.00	0	67.33	16.67	41.33	9.67	4.00	24.67	10.33	22.07	27.67
7	173.33	170.33	0	66.00	10.67	56.00	17.33	3.00	10.00	33.60	35.80	43.67
8	182.00	620.00	0	95.00	19.33	72.00	15.67	10.00	23.00	49.40	36.53	35.00
9	0.67	154.00	0	100.67	12.00	62.67	18.00	7.33	38.00	21.93	29.23	78.00
10	351.33	42.00	0	77.33	43.33	50.33	8.33	1.00	27.00	10.77	54.83	61.33
11	293.33	134.00	2	127.33	9.00	85.67	24.33	11.00	41.67	23.00	23.97	87.00
12	517.33	134.00	0	57.00	12.67	35.00	12.00	4.00	22.00	11.40	23.87	43.67
13	1.33	73.67	0	69.00	23.33	47.00	11.33	1.00	22.00	15.27	30.30	35.67
14	48.00	183.00	0	221.00	25.33	166.33	140.00	46.67	54.67	79.50	34.47	179.00
15	118.67	80.00	0	77.00	16.00	52.00	15.67	4.67	25.00	14.33	37.80	49.67
16	47.67	62.67	0	211.33	20.00	125.33	125.33	11.67	85.33	29.50	29.27	163.00
17	460.00	98.00	0	74.33	20.00	63.33	15.33	4.00	11.00	23.13	49.93	30.33
18	260.33	63.67	0	99.00	10.00	84.00	21.00	6.67	15.00	15.97	23.97	78.00
19	176.00	152.33	0	64.00	25.33	39.33	15.00	1.00	24.67	18.83	17.17	38.33
20	479.33	145.00	0	70.67	26.33	40.67	21.33	3.00	30.00	49.20	68.53	28.33

Table 3: Statistical Summary of Physico-Chemical Parameters of Hand-Dug Wells within 2km of Saje Dumpsite.

Parameter	MIN	MAX	AVG ± SD	Normally found in ground water	Nigerian Standard (2007) Max level permitted	Samples within Nigerian (MLP)	Samples beyond Nigerian (MLP)	Health based guideline by the WHO	Samples within/ below WHO Standard	Samples beyond WHO standard
pH	5.27	7.53	6.36 ± 0.6		6.5-8.5	38%	62%	6.5-8.5	38.00%	62%
EC (µs)	137.67	1017.00	376.08±250		1000 µs/cm	95%	5%	250 µs/cm	43%	57%
TDS (ppm)	68.67	507.00	187.52±124.9		500 mg/l	95%	5%	No guide-line		
Temp (°C)	28.30	31.20	29.62±0.64							
Total Coliform Count	25.00	620.00	156.57±126.13		10.00	nil	100%			
Total E.coli Count	0.00	2.00	0.1±0.44		0.00	nil	5%	5.00%	100%	nil
COD	0.37	580.00	211.29±191.9		1000 mg/l	100%	nil			
HARDNESS	44.67	221.00	108.87±65.67		150 mg/l	86%	14%	No guide-line		
Alkalinity	7.00	43.33	18.22±8.35							
Ca	35.00	216.00	74.98±45.41							
Na	8.33	700.00	58.97±151.1	< 20 mg/l	200 mg/l	95%	5%	No guide-line		
K	1.00	1600.00	82.92±347.74					No guide-line		
Mg	9.33	85.33	33.79±22.9		0.2 mg/l	nil	100%			
SO_4^{2-}	4.53	79.50	24.35±17.3		100 mg/l	100%	nil	No guide-line		
NO^{-}_3	17.17	68.53	33.91±12.6		50 mg/l	95%	5%	50 mg/l	95%	5%
Cl^-	27.67	179.00	66.70±45.46					No guide-line	100%	nil

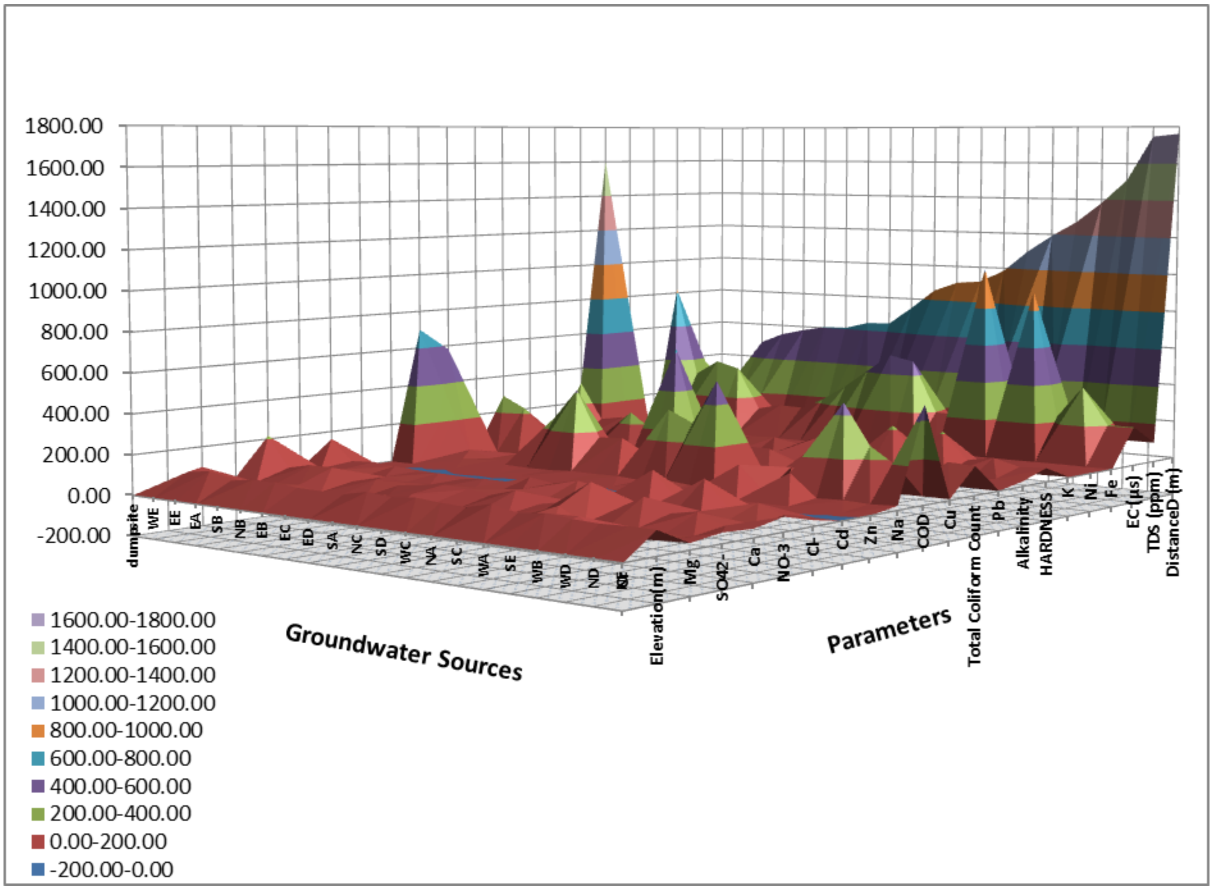

Figure 3: Surface Chart of Groundwater Sources against Parameters.

a. pH: The results of the analysis indicated that the pH has an average value of 6.36 ± 0.6. This shows that about 38% of the samples are below the desirable limits set by NSDWQ standards while about 62% are within the standards. There is no WHO guideline although pH usually has no direct impact on consumers or health concerns at levels found in drinking-water but is one of the most important operational water quality parameters. For effective disinfection with chlorine, the pH should preferably be less than 8; however, lower- pH water (approximately pH 7 or less) is more likely to be corrosive. Failure to minimize corrosion can result in the contamination of drinking-water and in adverse effects on its taste and appearance.

b. Electrical Conductivity: From the analysis, the results obtained indicated that EC has average value of 376.08 ± 250. This shows that about 95% are within NSDWQ standard values while 5% are above the standard. Also 43% are within the desirable limits set by WHO standards of 250 µs/cm while 57% were above the standard.

c. Total Dissolved Solids: Values of total dissolved solids ranged between 68.67 mg/l and 507 mg/l with average value of 187.52±124.9 mg/l. This shows that the values were within the desirable limits set by NSDWQ standards except for one well of value 507 mg/l. The palatability of water with a total dissolved solids (TDS) level of less than about 600 mg/l is generally considered to be good; drinking-water becomes significantly and increasingly unpalatable at TDS levels greater than about 1000 mg/l. The presence of high levels of TDS may also be objectionable to consumers, owing to excessive scaling in water

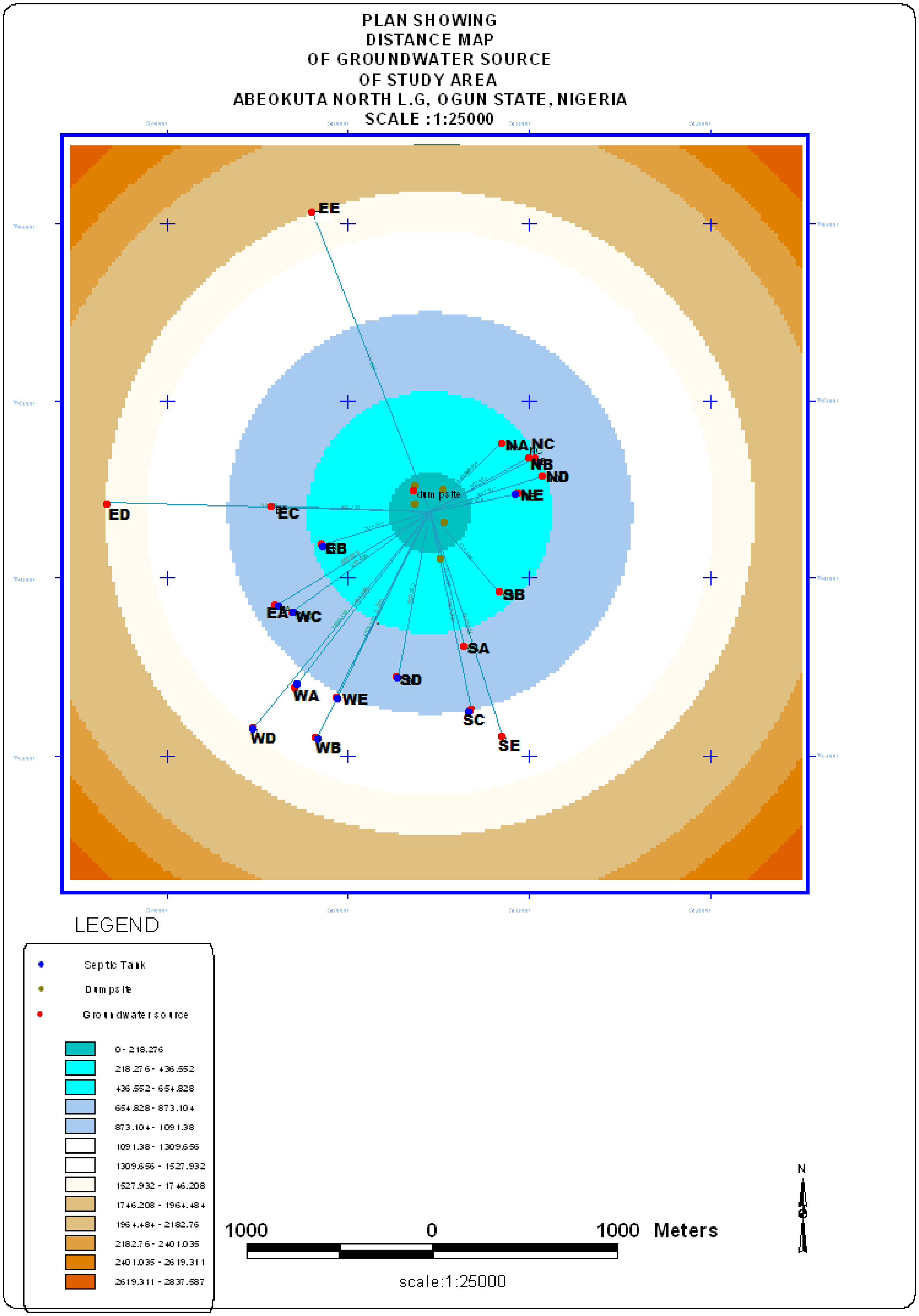

Figure 4: Distance of the Groundwater Sources.

pipes, heaters, boilers and household appliances. No WHO health-based guideline value for TDS has been proposed. Total dissolved solids (TDS) comprise inorganic salts (principally calcium, magnesium, potassium, sodium, bicarbonates, chlorides and sulphates) and small amounts of organic matter that are dissolved in water. TDS in drinking-water originates from natural sources, sewage, urban runoff and industrial wastewater. Salts used for road de-icing in some countries may also contribute to the TDS content of drinking-water. However, the presence of high levels of TDS in drinking-water may be objectionable to consumers

d. Calcium: The results of the analysis indicate the calcium values range between 35 and 216 mg/l, while the average value is 74.98±45.41 mg/l. There is no health-based guideline value for calcium. The taste threshold for the calcium ion is in the range of 100–300 mg/l, depending on the associated anion, and the taste threshold for magnesium is probably lower than that for calcium.

e. Magnesium: The results of the analysis indicate the magnesium values range between 9.33mg/l and 85.33 mg/l, while the average value is 33.79±22.9mg/l. There is no health-based guideline value for Magnesium.

f. Sodium: From the result sodium revealed average value of 58.97±151.1mg/l. Results from 20 out of the 21 wells indicated that values of sodium were above the desirable limits set by NSDWQ standards of 200 mg/l but there is no WHO health-based guideline value has been derived for it. Sodium salts (e.g. sodium chloride) are found in virtually all food (the main source of daily exposure) and drinking-water. Although concentrations of sodium in potable water are typically less than 20 mg/l, however, concentrations in excess of 200 mg/l may give rise to unacceptable taste.

g. Potassium: This recorded higher values at the dumpsite, and then lower values at other groundwater samples. Potassium values ranged between 1 mg/l and 1600 mg/l and average value 82.92±347.74mg/l. There are no guidelines or standards for potassium since the recommended daily requirement is greater than 3000 mg. It occurs widely in the environment, including all natural waters. Potassium is an essential element for humans and is absorbed mainly from ingested food. Health concerns would be related to the consumption of drinking-water treated by potassium-based water treatment (principally potassium chloride for regeneration of ion exchange water softeners), affecting only individuals in high-risk groups (i.e. individuals with kidney dysfunction or other diseases, such as heart disease, coronary artery disease, hypertension, diabetes, adrenal insufficiency and pre-existing hyperkalaemia).

i. Chloride: The results of the analysis indicate that the chloride values ranged between 27.67 mg/l and 179 mg/l and average value of 66.7±45.46mg/l. No health-based guideline value is proposed for chloride in drinking-water; however, chloride concentrations in excess of about 250 mg/l can give rise to detectable taste in water but some consumers may become accustomed to low levels of chloride-induced taste. High concentrations of chloride give a salty taste to water and beverages. Taste thresholds for the chloride anion depend on the associated cation and are in the range of 200–300 mg/l for sodium, potassium and calcium chloride. Chloride in drinking-water originates from natural sources, sewage and industrial effluents, urban runoff containing de-icing salt and saline intrusion. The main source of human exposure to chloride is the addition of salt to food, and the intake from this source is usually greatly in excess of that from drinking-water.

j. Sulphate: The results of the analysis indicate that the sulphate values ranged between 4.53 and 79.5 mg/l and average value 24.35±17.3mg/l. This shows that the values were all within the desirable limits set by NSDWQ standards. Sulphates occur naturally in numerous minerals and are used commercially, principally in the chemical industry. They are discharged into water in industrial wastes and through atmospheric deposition; however, the highest levels usually occur in groundwater and are from natural sources. In general, the average daily intake of sulphate from drinking-water, air and food is approximately 500 mg, food being the major source. No WHO health-based guideline is proposed for sulphate. However, because of the gastrointestinal effects resulting from ingestion of drinking-water containing high sulphate levels, it is recommended that health authorities be notified of sources of drinking water that contain sulphate concentrations in excess of 500 mg/l. The presence of sulphate in drinking-water may also cause noticeable taste and may contribute to the corrosion of distribution systems.

k. Hardness: Results of the wells analyzed indicate that hardness (14%) was higher than the desirable limits of 150 mg/l of NSDWQ and there no WHO Health based guidelines for drinking water. The range of values was between 44.67 mg/l and 221 mg/l and average of 108.87±65.67 mg/l which are not above the excessive limit of 500 mg/l for consumers tolerate water hardness. Hardness in water is caused by a variety of dissolved polyvalent metallic ions, predominantly calcium and magnesium cations. It is usually expressed as milligrams of calcium carbonate per liter. The degree of hardness of drinking-water is important for aesthetic acceptability by consumers and for economic and operational considerations. Public acceptability of the degree of hardness of water may vary considerably from one community to another. The taste threshold for the calcium ion is in the range of 100–300 mg/l, depending on the associated anion, and the taste threshold for magnesium is probably lower than that for calcium (WHO, 2011).

l. Alkalinity: The results of the analysis indicate that the sulphate values ranged between 7 and 43.33 mg/l and average value 18.22±8.35mg/l. there are no standards or guidelines for Alkalinity but could be a determining factor for other contamination. Excessive chloride concentrations increase rates of corrosion of metals in the distribution system, depending on the alkalinity of the water. Alkalinity and calcium management also contribute to the stability of water and control its aggressiveness to pipes and appliances. The major water quality factors that determine whether the precipitate forms a protective scale are pH and alkalinity.

m. Total Coliform Count: The results of the analysis indicate the values range between 25 and 620 mg/l, while the average value is 156.57±126.13 mg/l. This shows that the values are within the desirable limits set by WHO standards. Indicator for cleanliness and integrity of distribution systems Total Coliform bacteria are not acceptable as an indicator of the sanitary quality of water supplies, particularly in tropical areas, where many bacteria of no sanitary significance occur in almost all untreated supplies.

n. *E. coli*: Well SD recorded the presence of *E. coli* among others. *Escherichia coli* has traditionally been used to monitor drinking-water quality, and it remains an important parameter in monitoring undertaken as part of verification or surveillance. *Klebsiella spp.* are not considered to represent a source of gastrointestinal illness in the general population through ingestion of drinking-water. *Klebsiella spp.* detected in drinking-water are generally biofilm organisms and are unlikely to represent a health risk.

Therefore, the presence of the pit latrines might have affected the quality of water in the wells.

QUALITY OF GROUNDWATER IN RELATION TO PUBLIC HEALTH

In this study three properties (nitrite, manganese and E. coli) as shown in Tables 2 and 3, were observed to be in excess considering the limits set by WHO. The presence of *E. coli* in drinking water indicates fecal contamination. *E. coli* strains cause intestinal disease by a variety of mechanisms. Infections may resemble cholera, dysentery or gastroenteritis due to salmonellae. After checking the medical records of, there were confirmed cases of cholera, dysentery (gastroenteritis) almost annually. The reported cases were more during the rainy season, than the dry season. This could be linked with either the fact that there is more infiltration during the rainy season, and or that the people use surface water during the season.

The ranking of the wells from the most polluted well to the least shows that well 3 was the most polluted while well 7 was the least polluted. Similarly, the most polluted boreholes were boreholes 3, 4, and 7 while boreholes 8, 17, and 18 were the least polluted.

These may have either mild or devastating health effects as a result of short or prolonged consumption of water from the sources.

o. Nitrate: The results of the analysis indicate the values range between 17.17 and 68.53 mg/l, while the average value is 33.91±12.6 mg/l. About 95% of the sampled well were within the WHO and NSDWQ standards except one. Nitrate (NO_3^-) is found naturally in the environment and is an important plant nutrient. It is present at varying concentrations in all plants and is a part of the nitrogen cycle. Nitrate can reach both surface water and groundwater as a consequence of agricultural activity (including excess application of inorganic nitrogenous fertilizers and manures), from wastewater disposal and from oxidation of nitrogenous waste products in human and animal excreta, including septic tanks. Nitrate: 50 mg/l as nitrate ion (or 11 mg/l as nitrate-nitrogen) to protect against methaemoglobinaemia in bottle-fed infants (short-term exposure)

CONCLUSION

Based on the findings of the study, it could be ascertained that there is evidence of both chemical and biological pollution of the groundwater around the solid waste dump site (about 600 m from the dumpsite). Because of the importance of groundwater as a source of drinking water to many communities and individuals, the best way to guarantee continued supplies of clean groundwater is to reduce pollution. The government should inform and educate the farmers about voluntary actions through which the farmers can better manage animal waste, fertilizers, and pesticides according to plant needs and properly schedule irrigation.

Individuals can help by improving their house keeping practices, by learning how to properly dispose of household products containing hazardous substances. Proper safety measures should be taken by individuals by not situating their wells along the flow path of potential pollution sources such as septic tanks, latrines and waste disposal sites and by providing covers for wells and not allowing stagnant water to pond close to the top of the wells. There is need to have, a program of effective monitoring of ground water quality.

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