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Research Paper

IMPACT OF OPEN SEWAGE DUMPSITES ON GROUNDWATER QUALITY IN IGWURUTA, RIVERS STATE, NIGERIA

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Abstract
This study investigated groundwater quality around an open sewage dumpsite at Igwuruta, Rivers State, Nigeria. Six monitoring boreholes sited within the vicinity of the dumpsite and a reference borehole sited about 5 km away was sampled during the rainy season of 2012. *In situ* determination of water temperature, pH, conductivity, salinity and dissolved oxygen concentration (DO) were made using a Horiba U-10 water quality checker and water samples collected in replicates. Heavy metals, oil content and other physicochemical parameters were also determined. The quality parameters varied as follows: pH 6.40 - 7.84 (6.79 ± 0 .07); DO 5.20 - 6.30 (5.76 ± 0.09) mg/L; Biological Oxygen Demand (BOD) 1.20 - 4.60 (3.63 ± 0.22) mg/L, Chemical Oxygen Demand 2.10 - 7.00 (5.65 ± 0.34) mg/L, Total Dissolved Solids (TDS) 14.00 - 26.00 (20.59 ± 0.73) mg/L, total coliform counts 1.00 - 6.50 (4.48 ± 0.37) MPN; salinity 0.000 - 0.004 (0.002 ± 0.0002) ‰; SO_4^{2-} 1.10 -10.00 (4.07 ± 0.57) mg/L; NO_3^- 1.00 - 6.80 (3.75 ± 0.49) mg/L; PO_4^{2-} 0.04 - 0.66 (0.42 ± 0.05) mg/L; oil 0.000 - 0.005 (0.0020 ± 0.0003) mg/L; Pb 0.000 - 0.038 (0.022 ± 0.002) mg/L; Cr 0.001 - 0.085 (0.047 ± 0.007) mg/L; Ni 0.012 - 1.110 (0.362 ± 0.102) mg/L and Hg 0.000 - 0.001 (0.00067 ± 0.0001) mg/L. The levels of BOD, total coliform counts, PO_4^{2-}, TSS, Cu, Fe, Cr and Ni exceeded the Nigerian Federal Ministry of Environment maximum permissible limit for drinking water, indicating pollution of groundwater within the sewage disposal site. Treatment of raw sewage before disposal at the dumpsite is therefore recommended.
Key words: Sewage dumpsite, ground water, borehole, heavy metals, coliform.

INTRODUCTION

Sewage is a water-borne waste in solution or in suspension that is intended to be removed from a community's pollution load. It may contain up to 99% water and characterized by volume or rate of flow, physical conditions, chemical constituents and bacteriological organisms. It may be derived from different sources such as domestic, municipal or industrial liquid waste products disposed through pipe or sewer, and cesspools (UNEP, 2006).

Many pollutants have been identified in groundwater accessed in different parts of Nigeria (Okoli et al., 2005; Okoli, 2007a). Some of these pollutants arise from chemical components resulting from progressive breakdown and leaching of wastes from surface and subsurface origins (Ogbonna *et al*., 2008). Sewage effluents can also find their way through diffused contamination points to groundwater, especially if the dumpsite receptacles are unlined within the surrounding soil and bedrock (Ogbonna *et al*., 2008). Furthermore, organic and microbiological constituents of sewage can cause physicochemical changes in soil nutrients and other edaphic variables and increase pathogen levels in the groundwater (Dawes and Goonetilleke, 2001). Migration of these pollutants can also cause high levels of other nitrogen based contaminants such as ammonia, bicarbonate and chloride ions, especially in shallow groundwater and this can create toxicity in groundwater resources (Anzecc and Armcanz, 2000).

Contamination of the overlaying soil with untreated sewage is a wide spread phenomenon in Nigeria that posses long term risk to groundwater quality, plants, animals, and even human health (Okoli, 2007a and b). Proper waste disposal has become a serious problem in most cities of Nigeria. According to Odukoya *et al*. (2000) leachates from sewage dumpsites constitute both soil and water pollution in the environment, even as (Jumma *et al*., 2012) observed that improper sewage management methods could lead to contamination of groundwater. While most of the contaminants contained in the sewage are being washed away by runoff into streams and rivers, some that infiltrate the soil contaminate the groundwater aquifers (Ogbonna *et al*., 2006; Ogbuagu *et al*., 2011a and b).

Recent studies have also revealed that waste dumpsites can transfer significant amounts of toxic and persistent metals into the soil environment (Gurnnadha *et al*., 2011). Eventually these metals are taken up by plant parts and get incorporated into the food chain (Erah *et al*., 2002). However the rate of metal uptake by crops could be influenced by factors such as metal species, plant age and plant part (Akhionbare, 2009). According to (Ogbonna *et al*., 2008) the prevalence and levels of heavy metals, and other physicochemical constituents in sewage-impacted segment of the ecosystem is encouraged by anthropogenic activities like indiscriminate dumping of sewage and unregulated sewage standard treatment processes.

The United Nations Environmental Programme (UNEP, 2006**)** observed that in the past two or three decades, rapid urbanization across Africa has led to the growth of large areas of unplanned sub-standard housing in most cities and those residents of such cities or areas usually resort to groundwater as a source of inexpensive, quality domestic water supply. The study further revealed that the uncontrolled expansion of this kind of housing together with sewage and effluent leakage, indiscriminate waste disposal and uncontrolled industrial and commercial activities all led to the increasing pollution and deteriorating quality of groundwater and mounting public health problems. Since this emergent African urban scenario is characteristic of most cities in Nigeria today, there is the need to characterize groundwater quality at locations such as Igwuruta, a suburb of Port Harcourt, the capital city of Rivers state, Nigeria where sewage management has become grossly compromised (Ogbonna *et al.,* 2008).

This study investigated the impact of open sewage dumping on groundwater quality at Igwuruta, Rivers State Nigeria.

MATERIALS AND METHODS

Study site: Igwuruta is located on latitude 4^0 57^1 18” N and longitude 7^0 01^1 14” E (Figure I) and is a moderately populated sub-urban environment. The sun rises at 08:10 and sets at 20:17 local time, and standard time zone for the area is GMT+1(UMRS, 1998). The Shell Petroleum Development Company of Nigeria Limited (SPDC) sewage disposal site at the Agbada oilfield receives raw sewage from many of her eastern on-shore oil locations and is finally dumped as untreated sewage at the Uguruta site.

Samples collection: Samples were collected from six monitoring boreholes located within the sewage disposal site and another located about 5 km away from the sewage disposal site (reference borehole). Borehole water samples were collected according to the method earlier described by Okoli *et al.* (2005) in 250 ml plastic containers from the seven sampling boreholes and were coded BH1, BH2, BH3, BH4, BH5, BH6 and BH_{REF}. Samples for the determination of oil and grease contents were collected separately in similarly labeled plastic bottles that had been washed with detergent, rinsed with water and finally rinsed with trichlorotrifluoroethane to remove any residue that might interfere with the analysis.

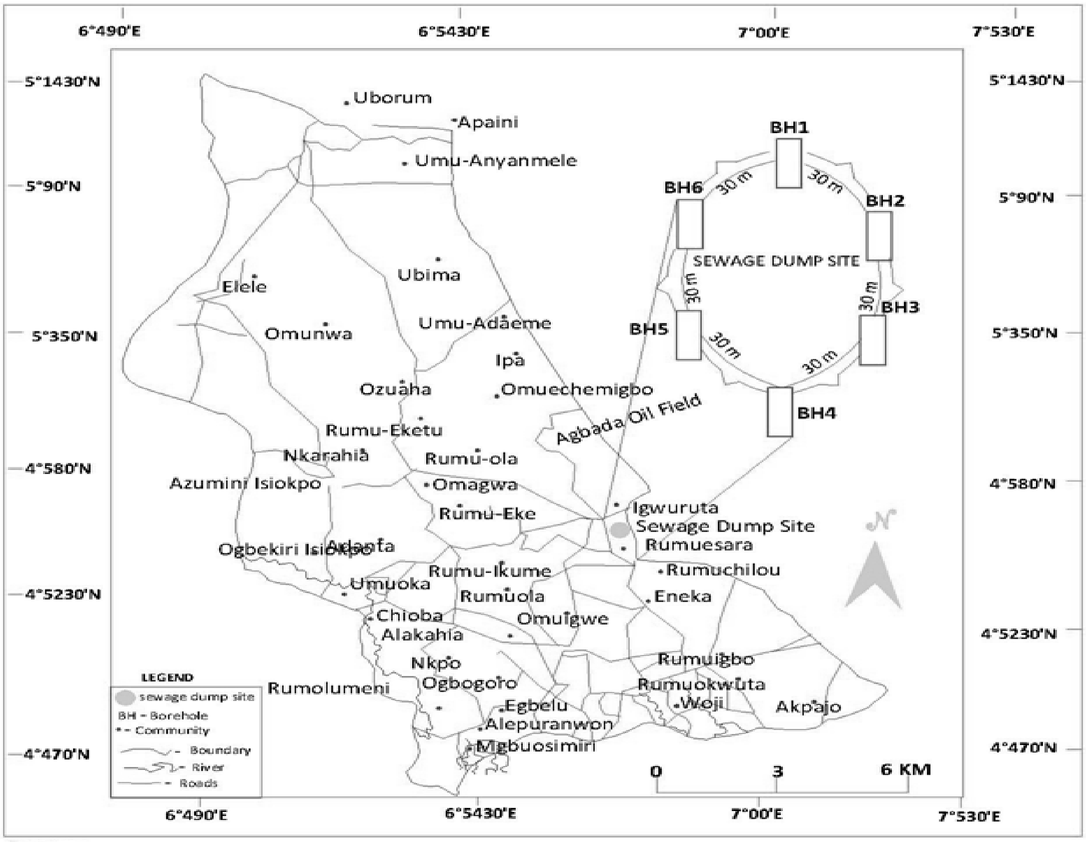

Fig. I: Map of Ikwerre and Obio/Akpor Local Government Areas of Rivers State showing Igwuruta, the study area

Samples for Biological Oxygen Demand (BOD) determination were collected in 250 ml brown (BOD) bottles. Water samples for heavy metals concentration were collected in 30 ml plastic containers and fixed with concentrated HNO_3 in the ratio of 2:500. They were further acidified to pH 2 or lower with 1 ml conc. HCL/80g and transported to the laboratory in an ice-packed cooler. Samples for the other physicochemical parameters were collected with 500 ml plastic containers and taken to the laboratory as soon as possible to maintain their integrity.

Water analyses: The Horiba U-10 water quality checker was used to determine pH, water temperature, dissolved oxygen, conductivity, and salinity *in situ.* The meter was pre-calibrated with the standard phthalate calibration solution and the desired physicochemical parameter read off the LCD of the meter. Total Dissolved Solids (TDS) was also determined *in situ* electrometrically with HACH conductivity meter (Model CO 150) with an inbuilt automatic TDS and values were read off directly in mg/L from the LCD display screen.
Heavy metal concentrations were determined with the use of Atomic Absorption Spectrophotometer (AAS), (Varian Spectra AA 600) after digestion (APHA, 1998).
BOD was determined after five days incubation period at 20 $\pm$ 1^{0}C with same HORIBA U-10 water quality checker.
Calculation:

$$BOD_5\,(mg/l) = \frac{D_1 - D_2}{P}$$

Where D_1 is Dissolved Oxygen (DO) of the dilution sample 15 minutes after preparation.D_2 is Dissolved Oxygen (DO) of the dilution sample after incubation period of 5 days and P, decimal fraction of sample used.
Serial dilution procedure was employed for cultivation and enumeration of coliform bacteria, in accordance with standard methods. 1.0 ml of water sample was mixed with 9.0 ml of sterile distilled water from where serial dilution was made up to 10^{-3} dilution. Appropriate volumes of undiluted samples were inoculated into test tubes of suitable liquid medium. All inoculated media were incubated at 37 ^{0}C for 24 hours. Enumeration of total coliform bacteria was carried out by the most probable number (MPN) method.
Data analyses: SPSS version 17.0 and MS Excel 2007 were used to analyze the data generated from the study. Specifically, descriptive statistics were used to compute mean, range, standard deviation etc. Mean spatial variations of different parameters across borehole water samples were represented in histograms.

RESULTS AND DISCUSSION

The levels of the groundwater physicochemical and mineral characteristics measured across the seven sampling points are shown in tables 1 and 2. Wide variations were observed in the levels of electrical conductivity (range = 12.*50* µS/cm*),* Total Dissolved Solids (TDS) (range = 12.00mg/L) and Total Suspended Solids (TSS) (range = 19.50 mg/L). Temperature varied from 26.00–26.90 (26.31 ± 0.06) ^{0}C, pH varied from 6.40–7.84 (6.79 ± 0.07), and Dissolved Oxygen (DO) varied from 5.20–6.30 (5.76 ± 0.09) mg/L (Table 1).

Table 1: Descriptive statistics of the physicochemical characteristics of groundwater samples around the SPDC disposal site at Ogwuruta

Parameters	Minimum	Maximum	Range	Mean	SE	FME
Temperature (^{0}C)	26.00	26.90	0.90	26.31	0.06	NS
pH	6.40	7.84	1.44	6.79	0.07	6.5- 8.5
DO (mg/L)	5.20	6.30	1.10	5.76	0.09	7.5
BOD (mg/L)	1.20	4.60	3.40	3.63	0.22	20-25
Conductivity (µS/cm)	24.50	37.00	12.50	29.47	0.84	NS
COD (mg/L)	2.10	7.00	4.90	5.65	0.34	NS
TDS (mg/L)	14.00	26.00	12.00	20.59	0.73	500
T. coliform (MPN)	1.00	6.50	5.50	4.48	0.37	0
Salinity (‰)	0.000	0.004	0.004	0.002	0.0002	NS
TSS (mg/L)	1.50	21.00	19.50	10.68	1.23	<10.0
Oil and Grease (mg/L)	0.000	0.005	0.005	0.0020	0.0003	0.05
Ammonia (mg/L)	1.20	6.56	5.36	4.98	0.37	<1.0

SE = standard error of mean, NS = Not specified
FME =Federal Ministry of Environment

Conductivity, Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), and Total Suspended Solids (TSS) varied from 24.50–37.00 (29.47 ± 0.84) µS/cm, 1.20–4.60 (3.63 ± 0.22) mg/L, 2.10–7.00 (5.65 ± 0.34) mg/L, 14.00–26.00 (20.59 ± 0.73) mg/L respectively from 0.000–0.004 (0.002 ± 0.0002) ‰, TSS varied from 1.50–21.00 (10.68 ± 1.23) mg/L. Total coliform counts varied from 1.0–6.50 (4.48 ± 0.37) MPN, salinity varied sulphate, nitrate, phosphate and Oil and Grease varied from 1.10–10.00

Table 2: Descriptive statistics of minerals in the groundwater sampled around the SPDC disposal site at Agbada Oilfield

Parameters	Minimum	Max imum	Range	Mean	SE	FME
Sulphate (mg/L)	1.10	10.00	8.90	4.07	0.57	500
Nitrate (mg/L)	1.00	6.80	5.80	3.75	0.49	10.0
Phosphate (mg/L)	0.04	0.66	0.62	0.42	0.05	>5.0
Ca (mg/L)	0.008	0.63	0.62	0.18	0.41	NS
Cu (mg/L)	0.004	3.50	3.50	1.95	0.21	0.1
Zn (mg/L)	0.12	1.31	1.20	0.61	0.08	5.0
Fe (mg/L)	2.00	4.40	2.40	3.23	0.17	1.0
Pb (mg/L)	0.000	0.038	0.038	0.022	0.003	0.002
Ag (mg/L)	0.000	0.0017	0.001	0.0004	0.0001	0.5
Cr (mg/L	0.001	0.085	0.084	0.047	0.007	0.05
Ni (mg/L)	0.012	1.110	1.098	0.362	0.102	0.05
V (mg/L)	0.000	0.001	0.001	0.00052	0.0001	0.01
As (mg/L)	0.000	0.002	0.002	0.00076	0.0001	0.2
Hg (mg/L)	0.000	0.001	0.001	0.00067	0.0001	0.001

SE = standard error of mean, NS = Not specified
FME =Federal Ministry of Environment

(4.07 ± 0.57) mg/L, 1.00-6.80 (3.75 ± 0.46) mg/L, 0.04-0.66 (0.42 ± 0.05) mg/L, and 0.000-0.005 (0.00 ± 0.0002) mg/L respectively. However, ammonia varied from 1.200–6.56 (4.98 ± 0.37) mg/L, calcium varied from 0.008–0.63 (0.18 ± 0.04) mg/L, and copper varied from 0.004–3.50 (1.95 ± 0.21) mg/L. Zn, Fe, Pb, and Ag, varied from

0.12–1.31 (0.61 ± 0.08) mg/L, 2.00–4.40 (3.23 ± 0.17) mg/L, 0.000–0.038 (0.022 ± 0.002) mg/L, 0.000–0.001(0.0004 ± 0.0001) mg/L respectively.

Cr varied from 0.001-0.085 (0.047 ± 0.007) mg/L, Ni varied from 0.012–1.110 (0.362 ± 0.102) mg/L, while V, As and Hg varied from 0.000–0.001 (0.00052 ± 0.0001) mg/L, 0.000–0.002 (0.00076 ± 0.0001) mg/L and 0.000-0.001(0.00067 ± 0.0001) mg/L respectively.

The levels of BOD, total coliform counts, PO_4^{2-}, Cu and Fe ions in all of the sampling point and those of TSS, Cr and Ni in some sampling points exceeded the Federal Ministry of Environment permissible limits for drinking water in Nigeria.

Spatial variations were observed in the levels of groundwater quality parameters measured. Minimum temperature (26.00^{0}C), conductivity (24.50 µS/cm) and TDS (14.00 mg/L) were recorded in BH $_{REF}$, BH 4, and BH $_{REF}$ respectively (Figure 2). However the maximum values (26.00^{0}C, 37.00 µS/cm, and 26.00 mg/L) were recorded in BH 5, BH 1, and BH 5 respectively.

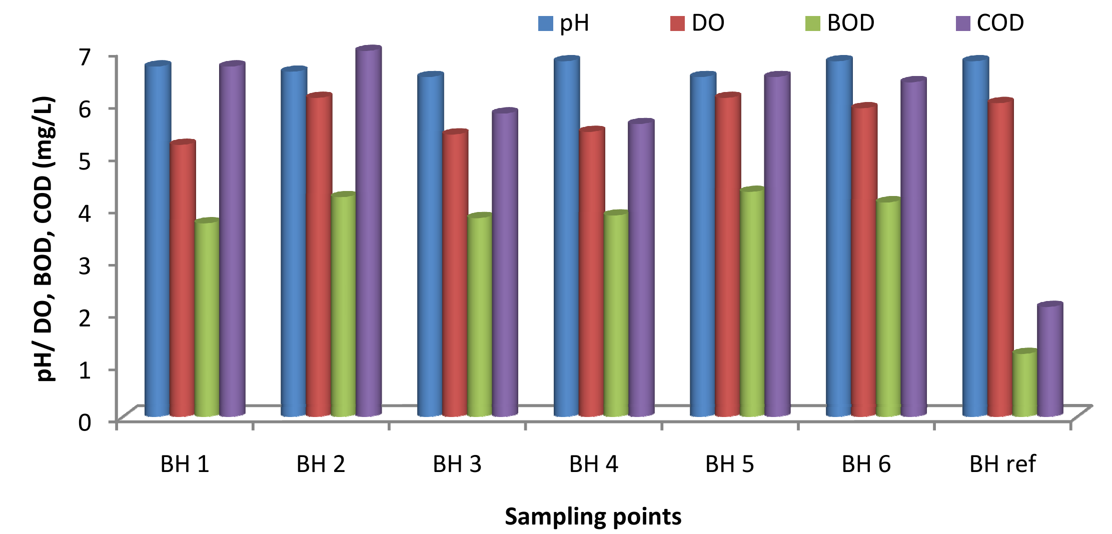

Fig. 4.2. Mean spatial variations in pH, dissolved oxygen, biological oxygen demand and chemical oxygen demand in groundwater sources around the SPDC sewage disposal site at the Agbada oil field

Minimum pH (6.40), DO (5.20 mg/L), BOD (1.20 mg/L), and COD (2.10 mg/L) were recorded in BH 3 & BH 5, BH 1, BH $_{REF}$ and BH $_{REF}$ respectively (Figure 2). However their maximum values (7.84, 6.30, 4.60 and 7.00 mg/L) was recorded in BH 4, BH 5, BH 5 and BH 1 respectively. Minimum total coliform count (1.00 MPN), TSS (1.50 mg/L), sulphate (1.10 mg/L) and nitrate ions (1.00 mg/L) were all recorded in BH $_{REF}$ (Figure 4.3). Their maximum values (6.50 MPN, 21.00 mg/L, 10.00 mg/L, and 6.80 mg/L) were recorded in BH 2, BH 6, BH 5, and BH 3 respectively.

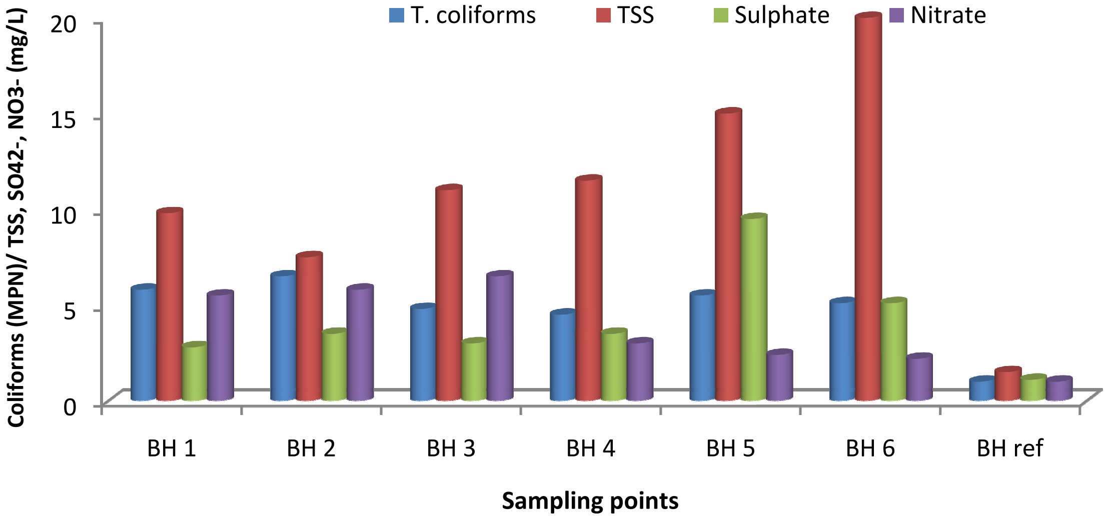

Fig. 4.3. Mean spatial variations in total coliform counts, total suspended solids, sulphate and nitrate ion concentrations in groundwater sources around the SPDC sewage disposal site at the Agbada oil field

The least levels of salinity (0.000‰), oil and grease (0.000 mg/L), vanadium (0.000 mg/L), arsenic (0.000 mg/L) and mercury (0.000 mg/L) were recorded in BH REF, BH REF, BH 3, BH 5 and BH 4 respectively (Figure 4.4). However their maximum values (0.004 ‰, 0.005 mg/L, 0.001 mg/L, 0.002 mg/L and 0.001 mg/L) were recorded in BH 1, BH 1, BH 3, BH 4, and BH 2 respectively. Minimum value of phosphate (0.04 mg/L), ammonia (1.20 mg/L) copper (0.00 mg/L), iron (2.00 mg/L) and Zinc (0.12 mg/L) were recorded in BH 4, BH REF, BH REF, BH REF, and BH REF respectively (Figure 4.5). Minimum Ca (0.008 mg/L), Pb (0.000mg/L), Cr (0.001 mg/L), Ni (0.012 mg/L) and Zn (0.12 mg/L) were all recorded in the reference borehole respectively (Figure 4.6). However their maximum values of 0.63 mg/L, 0.04 mg/L, 0.09 mg/L, 1.11mg/L and 1.31 mg/ L were recorded in BH 5, BH 1, BH 5, BH 5, and BH 1 respectively.

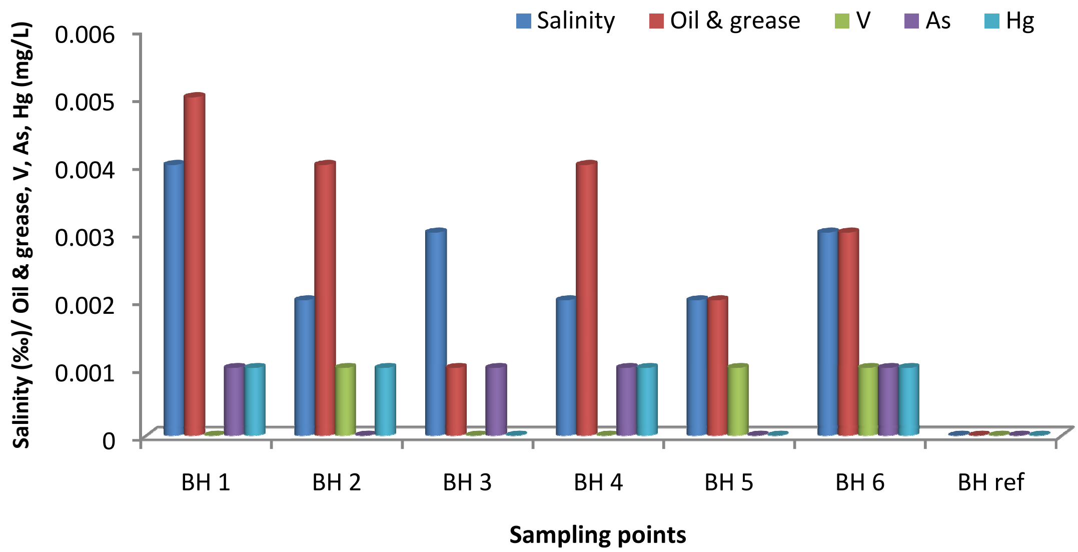

Fig. 4.4. Mean spatial variations in salinity, oil and grease, vanadium, arsenic and mercury contents in groundwater sources around the SPDC sewage disposal site at the Agbada oil field

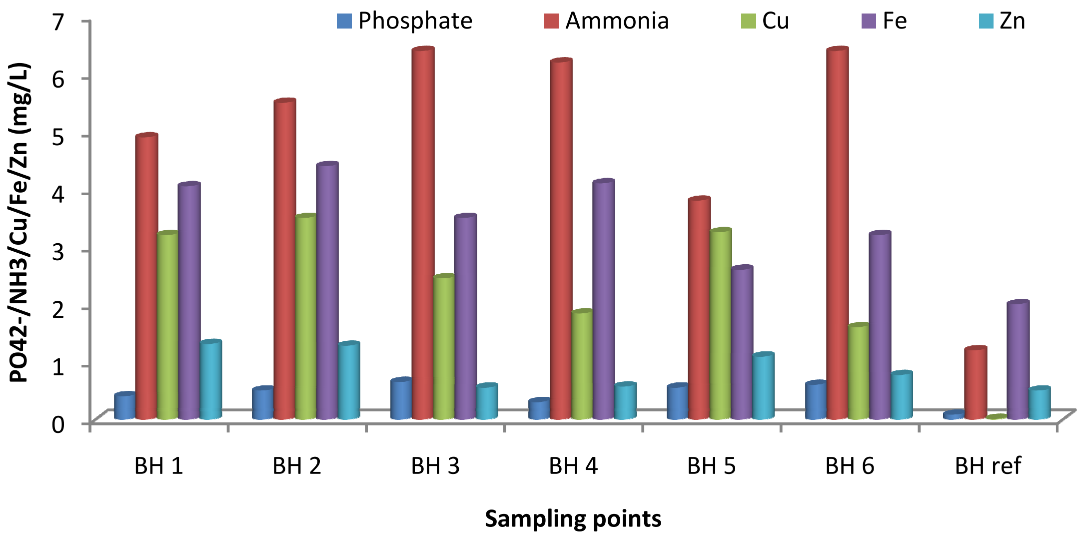

Fig. 4.5. Mean spatial variations in phosphate, ammonia, copper, iron and zinc contents in groundwater sources around the SPDC sewage disposal site at the Agbada oil field

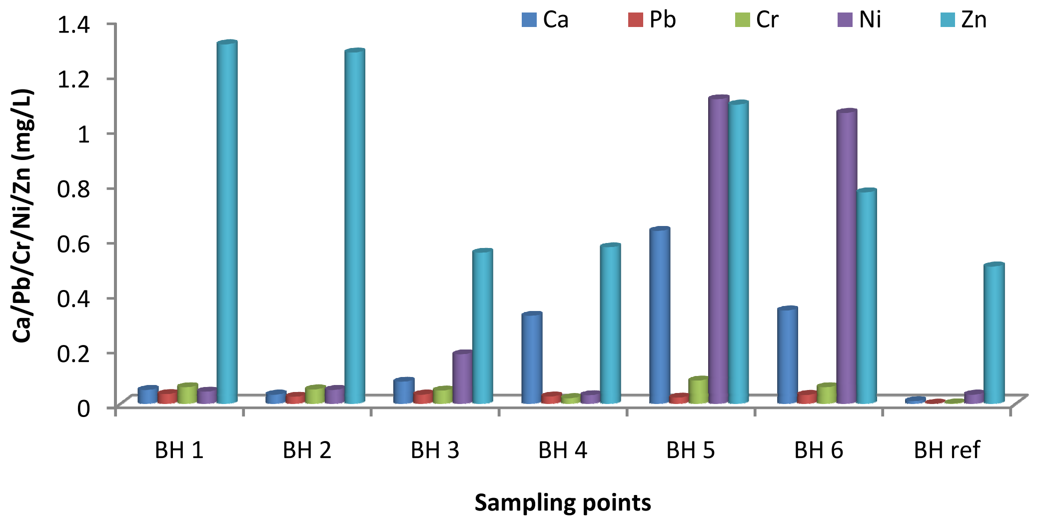

Fig. 4.6. Mean spatial variations in calcium, lead, chromium, nickel and zinc contents in groundwater sources around the SPDC sewage disposal site at the Agbada oil field

Water pollution is any damage to the quality of water that reduces its fitness for a specific purpose such as drinking, agriculture, laundry etc. Accordingly, Sharaf (2010) stated that even when water is unsuitable for a purpose, it could still be useful for another. Sewage systems are considered one of the biggest source of waste and pollutants discharge to the environment (Jumma *et al*., 2012). Subsequently, polluted water becomes the main vehicle for the prevalence of some serious diseases to humans. The health crisis in some cities has been exacerbated due to high rates of drinking water contaminated with sewage and high proportion of salt (Jumma, 2006).

The wide variation observed in EC, TDS and TSS indicates high levels of both suspended and dissolved solid pollutants (many of which are electrically charged and so constituted conductivity) that infiltrated the groundwater aquifers from the surface, open dump origin.

However, the narrow variations observed in the levels of the other pollutants in the aquifers could be related either to longer retention time and the pathway through which the water moves through the soil to the groundwater, or to the relatively trace availability of the pollutant species in the surface sewage source point of pollution.

The ascendances observed in the levels of pollutants such as BOD, total coliforms, PO_4^2, Cu, Fe, TSS, Cr and Ni over the Federal Ministry of Environment (FME) regulatory standards reflects high pollutional loads from the surface open dumpsite. BOD is the measure of the dissolved oxygen required by microorganisms in the biological oxidation of organic matter. It is a widely used indicator parameter of organic pollution of water and so, indicates the presence of large amounts of organic pollution. The high levels of heavy metals such as Ni, Cr, Fe, and Cu could portend environmental hazards, as some of these heavy metals are carcinogenic in nature (Akhionbare, 2009). Heavy metals concentrations in gas streams are diverse and also dangerous to health and the environment. For example, Cu affects the kidney, while Ni and Cr affect the skin, bone, or teeth (Akhionbare, 2009).

Fe causes brownish coloration of groundwater, which renders it unfit for drinking. Faecal coliform bacteria can be found in water contaminated by domestic sewage or other sources of human and animal wastes. The presence of total coliform over the FME standard further reveals that the sewage dumpsite infiltrated and percolated groundwater. This could eventually lead to ill health conditions such as inflammation of the bowel wall and poisoning in worst cases, fever, acidity in the blood and effect on kidney as well (Al-Tairah, 20004). High TSS leads to high turbidity and could cause water to harbor pathogenic organisms. This is because colloidal materials provide adsorption site for chemicals that may be harmful to health or cause undesirable taste or odour to drinking water (APHA, 1998). High levels of PO_4^{2-} reflects elevated concentrations of leached organic materials from the sewage dumpsite which can increase the nutrient contents of the groundwater and so, could further alter the aquatic ecosystem by stimulating bacteria activities, and hence, the resultant depletion of DO.

This study also observed marked spatial difference in levels of the pollutants between the impacted and reference boreholes; indicating that the open dumpsite actually contributed significant amounts of the pollutants in the groundwater aquifers. The presence and concentrations of total coliforms in the boreholes corresponded with high BOD levels, and indicate faecal pollution. This form of pollution has been associated with the prevalence of such diseases as dysentery, cholera, salmonellosis, diarrhea, etc (Akhionbare, 2009).

The level of TDS recorded in this study was lower than those recorded by some other authors elsewhere in Nigeria. For example, Unyimade and Enekwechi (2004) recorded 615-800 mg/L in Ojota, Lagos, while Adekunle *et al.* (2007) recorded mean value of 322 ± 40 in Abeokuta. However, TDS values recorded in this study was below the FME (2001) maximum permissible limit of 500 mg/L.

Temperature in this study meets the WHO (1998) limit for drinking water, though; Adekunle *et al*. (2007) reported a higher value of 29^0C in Abeokuta, Nigeria. Temperature is the most important parameter in aquatic environment, because almost all the physical, chemical and biochemical properties are governed by it (and it directly influences the amount of DO and other gases that are available to aquatic organisms). Temperature also has influence on water treatment and immunological evaluations (John de Zuane, 1997).

The observed significant correlation in levels of the pollutants between the impacted and reference boreholes indicates relatedness in the aquifers of the study area sampled. There were wide variations in the levels of electrical conductivity, total dissolved solids and total suspended solids of the groundwater aquifers.

The levels of biological oxygen demand, total coliforms counts, phosphate, copper and iron ions, as well as total suspended solids, chromium and nickel ions in ground waters exceeded the Federal Ministry of Environment maximum regulatory limits for drinking water. Spatial variations were observed in the levels of the pollutants between the impacted and reference boreholes and total suspended solids, temperature and total dissolved solids contributed the variability most.

CONCLUSION

This study revealed that the groundwater quality parameters within the sewage disposal site has been compromised, sequel to infiltrations from the surface source point of pollution. Pollutants types included organic and inorganic, as well as biological species that migrated from the sewage dump origin.

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