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GROUNDWATER CONTAMINATION FROM A MUNICIPAL SOLID WASTE DUMPSITE: CASE STUDY OF OBOSI, SOUTHEASTERN NIGERIA

*Emereibeole E. I, **Enenebaku C. K, *Uyo C.N, *Mgbeahuruike L. U, *Egbuawa I.O, *Edo F.A, *Nmecha I.M and *Acholonu C.A.
*Department of Environmental Management
**Electrochemical and Material Science Unit (EMRU), Department of Chemistry
Federal University of Technology, Owerri, Nigeria.
Corresponding author email: emereibeole@futo.edu.ng, emereibeolee@yahoo.com Phone number +2348036735195

ABSTRACT
The assessment of groundwater quality around a municipal solid waste dump in Obosi, Anambra state was carried out. This was done in order to determine the suitability of groundwater around the dump site for drinking, domestic and agricultural purposes. Four privately owned water boreholes were sampled at various locations around the dumpsite during the rainy season. Similarly, two leachate samples were collected for analysis. The physicochemical parameters of the groundwater samples were analyzed using standard methods as described in APHA, (2014). The heavy metals were determined using Atomic Absorption Spectrophotometer (AAS). Physicochemical and heavy metals characterization of the groundwater samples revealed that many of the water samples were not suitable for drinking purpose owing to noncompliance to standard in levels of some parameters such as pH, sulphate, phosphate, cadmium, iron, mercury, and manganese. Suitability for irrigation too, was low since most of the water sources had high concentrations of cadmium and contained medium to high salinity hazards. The pH (BH1- 6.1, BH2- 5.8, BH3- 5.5, BH4- 5.9), phosphate (BH1- 10.30, BH2- 10.10, BH3- 9.90, BH4- 9.70) mg/l, sulfate (BH1- 109.6, BH2- 105.0, BH3- 160.0, BH4- 390.1) mg/l, ammonium (BH2-16.8 and BH4- 0.27) mg/l, iron (BH3-1.019, BH4-0.387) mg/l, cadmium (BH2- 0.045, BH3- 0.056, BH4- 0.067)mg/l and mercury (BH1- 0.099, BH2- 0.092, BH3- 0.133, BH4- 0.123)mg/l were all found above acceptable standards. It is therefore recommended that the operation of the Obosi dumping site must be discontinued as soon as possible so as to avoid groundwater and public health problems.

KEY WORDS: Groundwater, waste dump, heavy metals, leachate, salinity hazard.

INTRODUCTION

Water is one of the most important natural resources required for the existence of life. In most urban cities in many countries of the world, including Nigeria, it is the responsibility of governments to provide potable water for its citizenry, but most often the responsibility is not adequately discharged, causing the inhabitants of those cities to seek for alternative sources to meet their water needs. These alternatives such as boreholes or wells, and stream/river water may be unwholesome (Ogbuneke *et al*., 2020). However, Pollution of groundwater is one of the major areas of concern to environmentalists. Groundwater pollution can be described as degrading of water quality for any usage. Amongst themajor sources of pollution of groundwater are saltwater intrusions (Afolabi *et al*., 2012), untreated waste rock piles from abandoned mine sites (Blackmore *et al.,* 2018). Several models have been advanced for hydrogeological and geochemical assessment of contaminant pathways from these point sources into pristine groundwater tables and some receiving fluvial channels (Pedretti *et al.,* 2017).Others include seepages from underground storage tanks, oil wells, septic tanks, landfills, waste dumps andagricultural leaching (Adewuyi *et al.*, 2010). Shallow and permeable water table aquifers are most susceptible to contamination (Al Hallaq and Elaish, 2012). The potential of such water to harbor microbial pathogens is well documented for both developed and developing countries (Emereibeole *et al.*, 2019). The unprecedented population growth along with improving living standards in lower middle-income countries (LMIC) has caused a significant challenge in the handling of huge quantities of municipal solid waste (MSW) generated per day(Anju *et al*., 2019). Municipal solid wastes (MSW) in open landfills usually contain potentially toxic and hazardous substances, which are constantly subjected to various decaying processes (Aromolaran *et al.*, 2019). When percolating rainwatermixes with these decaying solid wastes, it extracts soluble and suspended materials from the wastes and facilitates chemical and microbial processes that result in the formation of leachates (Fernandez *et al.,* 2014).Leachates from solid waste disposal facilities are the main pollutants of groundwater resources, as they contain varying concentrations of inorganic and xenobiotic organic pollutants (Aromolaran *et al*., 2019). The practice of open waste dumping and unregulated waste disposal method has its attendant effects on the groundwater quality. According to a previous study carried out by Egboka, Cherry, Farvolden and Frind, (1983), groundwater sources of the Obosi area are being polluted by leachate seepage, and according to Ezeabasili, Anike and Okoro, (2015), the prevalence of water-borne diseases with high effects in children was observed. The degradation of the groundwater resources quality has increased rapidly in the past decades throughout the world and Anambra State is not an exception, most cities in the country face solid waste management problems such as poor waste collection, inadequate waste disposal equipment and facilities, indiscriminate dumping of wastes on streets and canals, and unregularly siting of waste disposal sites mainly within residential areas without regard to local geology and hydrogeology of the area. Most of the rural population in Onitsha depends on groundwater for drinking, domestic and agricultural uses. The demand for quality drinking and irrigational water had changed considerably with urbanization. Injudicious and indiscriminate use of agrochemicals, dumping of wastes in un-engineered landfills, disposal of untreated or partially treated sewage, industrial and domestic effluents has rendered the groundwater unfit for drinking and agriculture or both (Bruce & McMahon, 1996). The quality of irrigation water can affect the soil fertility and productivity. Soil may develop saline and alkaline character if excessive soluble salts or exchangeable sodium are allowed to accumulate in the soil as a result of improper irrigation or inadequate drainage. The present study was conducted to characterize and assess the suitability of groundwater particularly around the popular Obosi dump site for drinking, domestic and irrigational purposes.

MATERIALSANDMETHODS

Description of the research area:

Obosi is proximally located to Onitsha in Anambra State, which is one of Nigeria's 36 states and one of 5 states in the country's south-east geo-political zones. The other states in the zone are Abia, Ebonyi, Enugu, and Imo. The new Anambra State was created in August 1991, together with Enugu State from the old Anambra State, with its state capital at Awka. The state is divided into 21 local government areas for administrative purposes, each with itsheadquarters. It is located on latitude 6.1°N and longitude 6.8°E in the Anambra North Senatorial Zone of AnambraState. Onitsha is a commercial town in the eastern region of Nigeria and has one of the largest markets in Nigeria,which attracts people from different parts of Africa. Onitsha municipal is an area with high population density andincreased anthropogenic activities. The Obosi dumpsite is located between latitudes 06° 06′ 07 .8″ N and longitude006° 47′ 59.2″ E, along the Onitsha-Owerri Express Road, opposite the Metallurgical Training Institute. It is aboutfour hectares with an elevation of 40m and is surrounded by a stretch of residential buildings. The groundwater depth for the area is 40m. This waste dumpsite has received wastes streams for over 50 years. Bagchi (2004), rightly opined that certain pollutants including toxic substances could be contained in such waste streams. Obosi is located in the rainforest eco-zone of Nigeria where precipitation could reach as high as 2000mm per annum (NIMET, 2014),therefore, it is expected that toxic pollutants such as heavy metals, xenobiotic organic substances, dissolved organicmatters and inorganic compounds including ammonium, calcium, magnesium, sodium, iron, phosphates, sulphatesand chlorides could leach from such waste streams and migrate through seepage and other physical processes tocontaminate groundwater aquifers in its environment(Lee & Jones-Lee, 2004 ; Christensen T., Kjeldsen, Bjerg,Jensen, Christensen, J. & Baun, 2001). Figure 1.0 shows map of the study area with the sampling points.

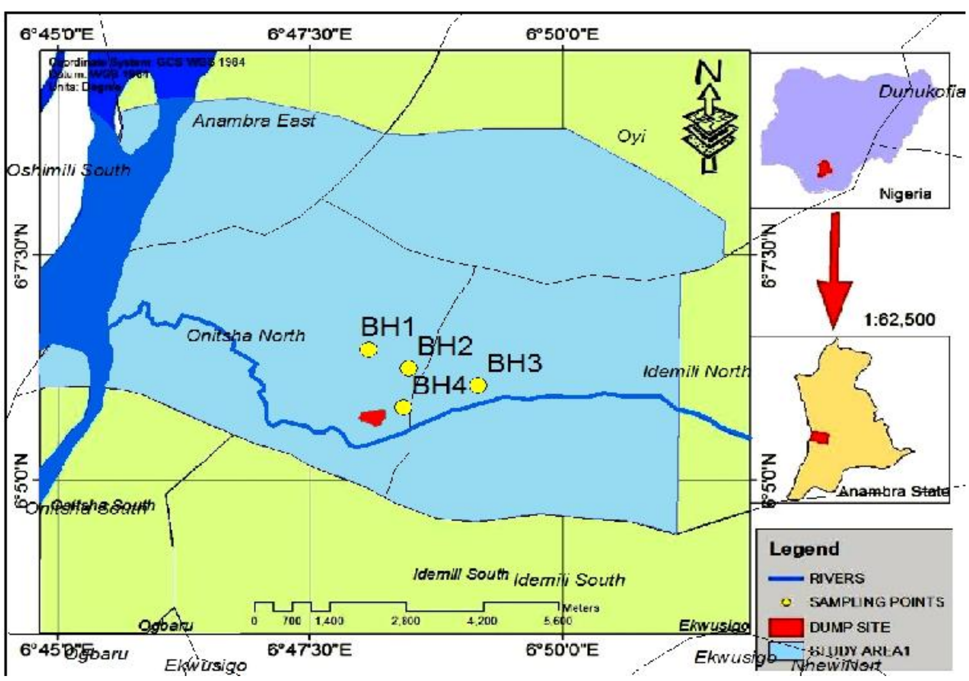

FIGURE 1.0: Digitized map of the study area showing the sampling points.

Geology and Hydrogeology of the Study Area:

The study area is underlain by the Nanka Sands. Lithologically, it consists predominantly of sand units, minor clay stones and shales. The sand units are sequence of unconsolidated to poorly consolidated sands and are medium to coarse grained. Within this area, the Nanka Sands is capped by thick mantle of laterite formed due to the leaching and ferruginization of the sandy unit as reported by Nwajide, (1979). This could be attributed to the geology of the area, topography and the effect of running water. The Ogwashi-Asaba of Oligocene-Miocene overlies the Ameki Group. It consists of alternating coarse grained sandstone, lignite seams and clay(Kogbe, 1989). The geology map of the study area is shown in figure 2.0

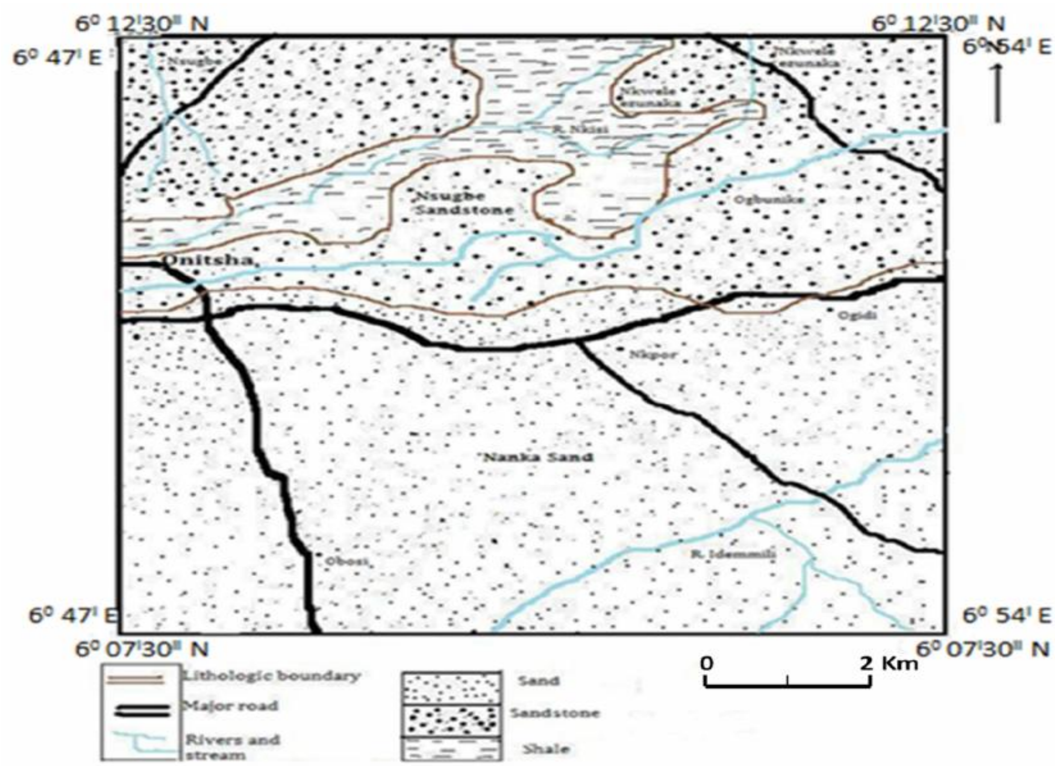

FIGURE 2.0: Geological map of the study area showing Obosi.

Sample Collection

Groundwater samples were collected from five privately owned boreholes (BH1, BH2, BH3, BH4 and BH5) in the immediate vicinity of the dump site in wet season (June, 2014) of the year. Leachate samples were also collected from two sampling locations within the waste dump. These sources of groundwater are being used for drinking and irrigational purpose. Samples were collected in clean polyethylene bottles of two-litre capacity. During sampling, bottles were thoroughly rinsed thrice with the water to be sampled. Parameters such as pH, DO, EC, Temperature and TDS were measured insitu with the help of water analysis kit.

Chemical Analysis

All other parameters of the groundwater samples were analyzed in the laboratory using standard recommended methods (APHA, 2014). The parameters analyzed are pH, Temperature, conductivity, TDS, TSS, turbidity, color, alkalinity, acidity, NO_3^-, PO_4^{3-}, SO_4^{2-}, DO, NH_4^-, salinity, BOD, COD, As, Fe, Pb, Cd, Cu, Hg, CO_3^{2-}, HCO_3^-, Cl^- ,Ca^{2+}, Na^+, Mg^{2+}, K^+, and Mn.

Application of different Models in the Computation of % Na, SAR, RSC, PI and determination of thehydrogeochemical facies of the groundwater

Assessment of suitability of the groundwater for irrigational use was done using different indices. Percent sodium (% Na), sodium adsorption ratio (SAR), residual sodium carbonate (RSC) and permeability index (PI) were calculated as per Wilcox (1955), Richards (1954), Eaton (1979) and Reghunath (1987), respectively. The Piper and Schoeller diagrams were applied to determine the water types and levels of pollutants in the samples respectively.

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

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

$$RSC\ (meq/l) = (CO_3^{2-} + HCO_3^-) - (Ca^{2+} + Mg^{2+})$$

$$PI = (Na^+ + \sqrt{HCO_3^-}) \times 100 / (Ca^{2+} + Mg^{2+} + Na^+ + K^+)$$

Where, ionic concentrations of sodium, potassium, calcium, magnesium, carbonate and bicarbonate are expressed inppm.

RESULTS AND DISCUSSION

The collected groundwater samples were analyzed for their physicochemical, bacteriological and trace elements tocheck their suitability for drinking and agricultural purposes.

***TABLE 1.0**: Results of tested physic-chemical parameters at various sampling stations*

S/N	PARAMETERS	BH1	BH2	BH3	BH4	RANGE	MEAN±SD	WHO STD
1	pH	6.1	5.8	5.5	5.9	5.5-6.1	5.8±0.753	6.5-8..5
2	TEMPERATURE ^{O}C	27.7	28.8	27.8	32.0	27.7-32.0	29.08±2.012	20-30
3	CONDUCTIVITY (us/cm)	350	547	131	143	131-547	292.75±197.069	100
4	TDS, (mg/l)	42.9	724.1	32.5	27.3	27.3-724.1	206.7±344.994	500
5	TSS,(mg/l)	1	2	1	1	1.0-2.0	1.25±0.500	5
6	TURBIDITY, (NTU)	2.03	3.08	2.29	1.63	1.63-3.08	2.258±0.612	5
7	COLOUR (PCU)	18	60	144	24	18-144	61.5±58.043	15
8	ALKALINITY (mg/l)	ND	250	40	10	0-250	75±117.898	200
9	NITRATE (mg/l)	22.1	39.2	21.4	26.1	21.4-39.2	27.2±8.264	50
10	PHOSPHATE (PO_4^{3-}) (mg/l)	10.30	10.10	9.90	9.70	9.70-10.30	10.00±0.258	5
11	SULPHATE (mg/l)	109.6	105.0	160	390.1	105.-390.1	191.18±134.937	100
12	DO, (mg/l)	5.2	3.6	4.6	4.4	3.6-5.2	4.45±0.661	>4
13	AMMONIUM (mg/l)	0.1	16.8	0.24	0.27	0.1-16.8	4.353±8.299	0.2
14	SALINITY (%Brix)	ND	ND	ND	ND	ND	ND	
15	BOD (mg/l)	1.2	0.2	1.5	1.3	0.2-1.5	1.05±0.580	10
16	COD (mg/l)	1.92	1.32	2.4	2.08	1.32-2.4	1.93±0.453	15
17	ARSENIC	ND	ND	ND	ND	ND	ND	0.01
18	IRON	ND	ND	1.019	0.387	0-1.387	0.352±0.481	0.3
19	LEAD	0.022	0.012	0.037	0.020	0.012-0.037	0.025±0.010	0.05
20	CADMIUM	0.052	0.045	0.056	0.067	0.045-0.067	0.055±0.009	0.05
21	COPPER	ND	0.022	0.007	0.049	0.00-0.049	0.020±0.022	1.0
22	MECURY	0.099	0.092	0.133	0.123	0.092-0.133	0.1118±0.019	0.002
23	CARBONATE, mg/l	900	600	1000	1300	600-1300	950±288.675	350
24	BI-CARBONATE, mg/l	620	520	420	380	380-620	485±107.548	380
25	FREE CHLORINE	0.08	0.05	0.13	0.22	0.05-0.22	0.12±0.074	0.2-2.5
26	CALCIUM (Ca^{2+}), mg/l	0.35	0.52	0.54	0.45	0.35-0.54	0.47±0.086	500
27	SODIUM (Na^{+}), mg/l	0.33	0.39	1.53	2.35	0.33-2.35	1.15±0.972	5
28	MAGNESSIUM (Mg^{2+}), mg/l	0.08	0.13	0.31	0.04	0.04-0.31	0.14±0.119	50
29	MANGANESE, mg/l	1.244	1.314	1.022	0.726	0.726-1.314	1.077±0.265	0.2
30	POTASSIUM, mg/l	0.021	10.5	0.021	0.079	0.021- 10.50	2.66±5.230	

BH means boreholeDomestic Useability

Tables1.0 shows the physicochemical and heavy metals levels in the groundwater samples. Most of the aquatic organisms are adapted to average pH and do not with stand abrupt changes (Shyamala*etal*.,2008).The pH in all the groundwater sampling sites was slightly acidic in the range of 5.5-6.1with lowest valueatBH3.pHvaluesin all the bore holes remained well below the WHO(2004) set limit for drinking water. The average pH for the entire area groundwater showed acidic nature and was unsuitable for drinking purpose. Electrical conductivity (EC) varied in the range from 131-547(µsm/cm). Generally, high value for conductivity indicates proportionately high values of ions such as calcium, magnesium, sodium and potassium. Conductivity in water samples remained well within the WHO guideline for drinking water.

To be suitable for any purpose, the total dissolved solids (TDS) in a water sample should be below500mgl^{-1} (Caroll, 1962; Freeze and Cherry, 1979). Water with high dissolved solids (>1000mgl^{-1}) may cause noticeable change in taste or make the water unsuitable for drinking. During the study, TDS values in groundwater samples varied from 27.3at BH4to 724.1 mg/l at BH2.Dissolved solids in the groundwater samples were below the WHO set limit for drinking water except in BH2.

Carbonates concentration ranged from 600-1300 mgl^{-1} with the highest concentration (1300 mgl^{-1}) in BH4.Bicarbonates concentration ranged from380-620. All these concentrations were well above the WHO standard range for drinking.

Free chlorine anged from a minimum 0.05 mgl^{-1} to a maximum 0.22 mgl^{-1}at BH4.Ingeneral, the free chlorine values of all bore hole samples fell well within the standard of WHO (2004)for drinking. Sulphate concentrations in all the four borehole samples were above the standard of WHO (2004) for drinking and ranged from105-390.1mgl^{-1}.These concentrations were not suitable for drinking. Phosphate concentration varied from a minimum of 9.70 at BH4 to a maximum of 10.30 mg/l at BH1. The phosphate concentration was above the WHO (2004) standard for drinking water. The elevated value of this nutrient could be as a result of high organic content of the land fill. Sodium was found intherangeof0.33-2.35mgl^{-1}.In all the sampling sites, Na^{+}concentration was with in the WHO prescribed limit for drinking.

Calcium values in water samples ranged from a minimum of 0.35 at BH1 to a maximumof0.54mg/latBH3 which were well within the WHO guideline for drinking.

Trace metals are generally responsible for various health hazards when present in excessive amounts. They may have severe toxicological effects on human beings at increased levels (Chapman, 1992). Cadmium concentration in the borehole samples ranged from 0.045ppm to 0.067ppm.In BH3 and BH4, cadmium concentration was found a little above the prescribed limit for drinking whereas in BH1 and BH2, cadmium contents were within the prescribed limit for drinking. In the groundwater samples, mercury concentration was varied from0.092-0.133 ppm. Mercury concentrations in all the groundwater samples are above the prescribed range of the WHO for drinking. The concentration of iron in groundwater samples rangedfrom0-1.387ppm.At BH3 and BH4, concentration shad crossed the WHO (2004) limit and hence water was not suitable for drinking.

Copper in the groundwater samples ranged from0-0.049 ppm. In all the borehole samples, concentrations remained within the WHO (2004) limit for drinking water. For lead, concentrations ranged from 0.012-0.037andtheyremained well within the WHO (2004) range of drinking. The concentration of lead in groundwater depends upon the chemistry and texture of the soil profile because of high affinity of the metal for adsorption. Soil chemistry plays an important role in the distribution of lead in groundwater.

Irrigation

The concentration and composition of dissolved constituents in water determine its suitability for irrigation use, (Ayers, 1975). The various constituents such as EC, Na^{+}, K^{+}, Ca^{2+}, Mg^{2+}, CO_3^{2-} and $HCO_3^{-}$and trace elements have been utilized by various agencies and workers to a scerta in the suitability of water for agricultural purposes. Different formulae were used to determine irrigation related parameters. In the research area, borehole water is commonly abstracted for the cultivation of vegetables and ornamental plants. Important parameters with respect to the use in irrigation are:

Electric Conductivity (EC)

The total concentration of soluble salts in irrigation water can be expressed in terms of electrical conductivity for purposes of diagnosis and classification. Water having electrical conductivity<750 µmhos/cm is satisfactory for irrigation purpose. Water intherangeof750-2,250µmhos/cm is generally used, and satisfactory crop growth is obtained under good management and favorable drainage conditions, but saline conditions will develop if leaching and drainage are not proper. Excess salinity reduces the osmotic activity of plants and interferes with absorption of water and nutrients from the soil.

TABLE 2.0: Quality of Irrigation water based on electrical conductivity

Salinity Hazard Class	Specific conductance (µS/cm)	Characteristics	Samples
Low	0-250	Low salinity water can be used for irrigation on most soil with minimal likelihood that soil salinity will develop	BH3,BH4
Medium	250-750	Medium-salinity water can be used for irrigation if a moderate amount of drainage occurs	BH1,BH2
High	750-2,250	High-salinity water is not suitable for use on soil with restricted drainage, even with adequate drainage, special management for salinity control may be required	NIL
Very high	More than 2,250	Very high salinity water is not suitable for irrigation under normal conditions	NIL

The EC values ranged from 131 –547 µS/cm as shown in Table 4.7. BH1 and BH2 have medium salinity value and can be used for irrigation with a moderate amount of drainage, while BH3 and BH4 were suitable for irrigation purposes with minimal likelihood that soil salinity will develop, (Table 2.0).

Sodium Adsorption Ratio (SAR)

It is a measure of sodium hazards to crops. Sodium replacing species such as adsorbed calcium and magnesium is a hazard as it causes damage to the soil structure as it becomes compact and impervious.

TABLE 3.0: Sodium Adsorption Ratio (SAR) values of the groundwater

Samples	SAR values
BH1	0.13
BH2	0.15
BH3	0.42
BH4	0.89

TABLE 4.0:SAR Values Compared to four Sodium Hazard Classes

SAR	Water – Suitability for Irrigation
0-10	Suitable for all types of soils except for those crops which are highly sensitive to sodium
10-18	Suitable for coarse-textured or organic soils with good permeability. Relatively unsuitable in fine-textured soils
18-26	Harmful for almost all types of soils. Requires good drainage, high leaching and gypsum addition
>26	Unsuitable for irrigation

SAR values varied from 0.13 to 0.89 (Table 3.0). These SAR values fall under the category of low sodium hazard, which reveals that ground water of the study area was free from any sodium hazard. Therefore, the water is safe for irrigation, and planting of other ornamental landscape plants.

Sodium Percentage (%Na)

High levels of Sodium concentration in water affects its quality for irrigation as it increases the hardness of the soil and reduces its permeability.

TABLE 5.0: Sodium Percentage (%Na) Values of the Groundwater

Samples	%Na values
BH1	35.90
BH2	38.64
BH3	56.30
BH4	79.69

TABLE 6.0: Quality of Groundwater based on % Sodium

%Na	Quality of water	Samples
<20%	Excellent	Nil
20-40%	Good	BH1 and BH2
40-60%	Permissible	BH3
60-80%	Doubtful	BH4
>80%	Unsuitable	Nil

Based on table 5.0, the Sodium percentage values of the groundwater samples range from 35.90 – 79.69. Table 6.0 shows the categorization of the different boreholes. The table indicates that the water quality for borehole 1, 2 and 3 were suitable for irrigation purposes while borehole 4 was doubtful for irrigation.

Hydro-geochemical analysis of ground water samples:

To further evaluate and interpret the groundwater composition in the study area, major ions were expressed in units of milliequivalents per liter (meq/L) and plotted on Piper trilinear and Schoeller diagrams as shown in figures 3.0 and 4.0 respectively. The graphical treatment of the hydrogeochemical parameters in Piper allows for easy separation of distinct water types and/or characters by plotting in various sub-areas of the diamond. Details regarding the geochemical interpretation of water samples can be found in Piper (1953) and Hem (1985).The characterization of groundwater composition of the study area using Piper and Schoeller plots revealed that the study area is predominantly of $Na\text{-}HCO_3+CO_3$ water type. This water type is typical of deeper groundwater influenced by ion exchange. There are other observed water type variations in the study area apart from $Na\text{-}HCO_3+CO_3$. These other water type combinations are not common water types in the study area and are an indication of chemical inputs originating from pollution.

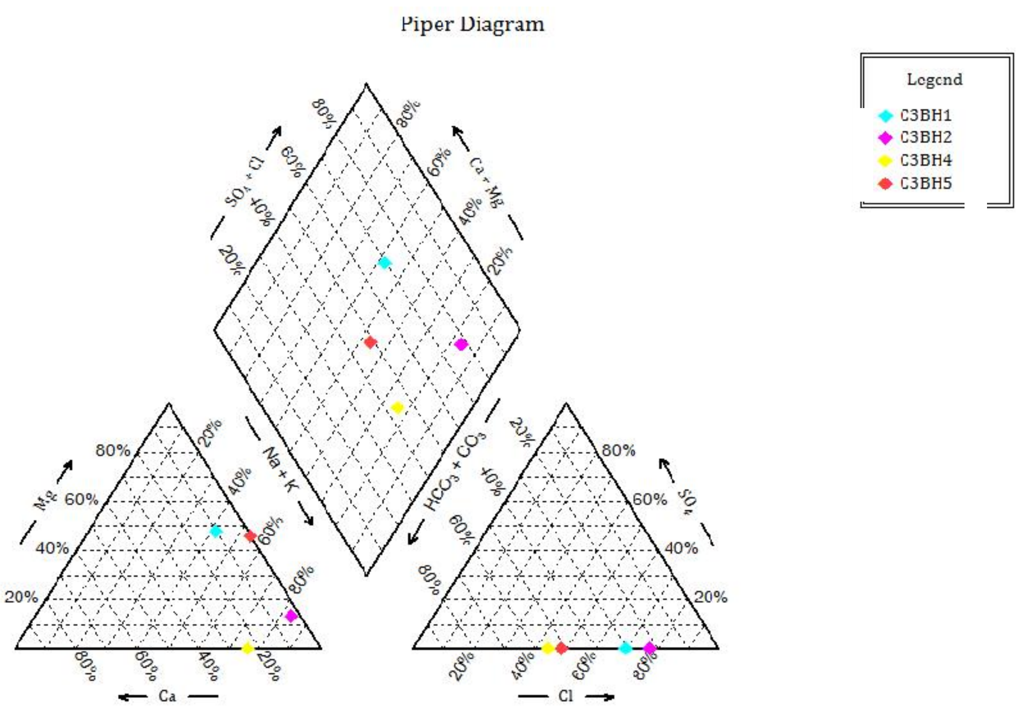

Figure 4.0: Piper plot of groundwater composition

Schoeller plots:

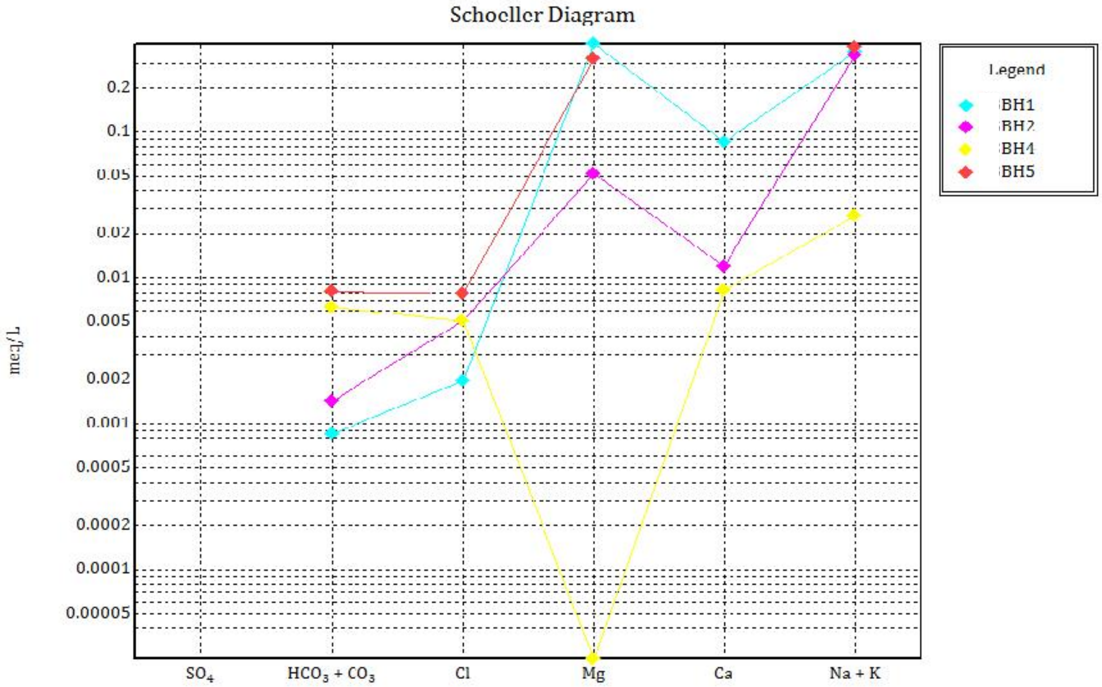

FIGURE 5.0: Schoeller diagram showing ion concentrations and their ratios.

CONCLUSION

The water of many sampling sites was unsuitable for drinking since some of the sensitive parameters like pH, sulphate, phosphate and concentrations of some heavy metals such as cadmium, iron, mercury, and manganese were found above the WHO (2004) limits for drinking water. For irrigation purpose, most of the sample shad high concentration of cadmium and water from the sesites is not suitable for irrigation. Most of the water sources were in excellent to good or good to permissible category based on %Na and EC but most of the samples had medium to high salinity hazard. It is suggested that the ground water of the study area should either be treated before its use or be used intermittently for drinking and agricultural uses.

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