Journal of Applied Sciences Research

ISSN: 1819-544X
EISSN: 1816-157X

2020 September-October; 16(5): pages 7-21
DOI: 10.22587/jasr.2020.16.5.2

Research Article
AENSI Publications

Municipal solid wastes disposal in non-engineered landfills release deleterious chemicals that degrade water quality in a developing city, southeastern Nigeria

Gregory Sikakwe[1], God'swill Eyong[2], Bridget Igwe[1]

[1] Department of Physics/Geology/Geophysics Faculty of Science Alex Ekwueme Federal University Ndufu-Alike P. O. Box 1010 Abakaliki Ebonyi state Nigeria

[2] Department of Geology Faculty of Science University of Calabar, P.M. B 1115 Calabar Nigeria

Correspondence Author: Gregory Sikakwe, Department of Physics/Geology/Geophysics Faculty of Science Alex Ekwueme Federal University Ndufu-Alike P.O.Box 1010 Abakaliki Ebonyi State Nigeria.
E-mail: udiegesu@gmail.com

Received date: 23 May 2020, **Accepted date:** 27 July 2020

Abstract

This research analyzed the degradation of water quality due to municipal solid waste disposal in open dumpsites in a developing city, southeastern Nigeria. Ten water samples collected from boreholes, stream channels and hand-dug wells were analysed to assess the level of water pollution. Physical parameters such as acidity (pH), redox potential (Eh), temperature, turbidity, total dissolved solids and conductivity, were measured insitu with portable kits. Chemical parameters such as total hardness, carbonate, biological oxygen demand (BOD), chemical oxygen demand (COD), total dissolved solids, conductivity, sulphate (SO4), nitrate(NO3), bicarbonate(HCO3), BOD, COD and chloride were analysed by standard procedures. Flame test and atomic absorption spectrophotometer (AAS) were used to analyse for potassium (K), sodium (Na), calcium (Ca), magnesium (Mg), aluminium (Al), iron (Fe) and manganese (Mn) concentrations. World Health Organization (WHO 2011), United States Environmental protection Agency (USEPA 2006) and Nigerian Standards Department of Water Quality (NSDWQ 2007) stipulated standard values for potable water. Mean concentrations of BOD (199.0 mg/L), COD(507.6 mg/L), turbidity (36.6 mg/L), total hardness (300 mg/L), pH (6.3), sulphate (363.76 mg/L), chloride (283 mg/L), sodium (6.7 mg/L), and manganese(0.5 mg/L) exceeded their standard values. These indicated water pollution due to leachates from solid wastes dumpsites. This study is useful in solid waste pollution studies both in Nigeria and other parts of the world.

Keywords: Open dumpsites; physicochemical parameters; heavy metals; municipal solid waste; non-engineered landfill; water pollution

INTRODUCTION

Most developing cities in Nigeria exhibit features of unplanned growth, population explosion and informal settlement, leading to an irregular buildup of solid wastes. Wastes are unwanted and discarded materials from natural and artificial sources. Solid wastes can be classified based on source, environmental risk, utility and physical property. Based on source, solid wastes classification includes municipal solid wastes, industrial solid wastes, agricultural solid wastes, mining and mineral wastes. Municipal wastes include dust, leafy matter, building debris, treatment plants, residual sludge etc. [1]. Artificial sources of waste include household refuse, garbage, rubbish, street refuse, ashes, demolition debris and construction refuse wastes. Other types of solid wastes include junk automobiles, old furniture and wastes from slaughterhouses, schools, manufacturing plants, hospitals, agriculture and market waste [2]. Natural sources of wastes could be from dead wild animals and leaves from trees. Generally, wastes are materials discarded by the users and the pattern of generation depend largely on the level of urban status, industries and economic status of the society [3]. Solid wastes are the organic and inorganic materials such as product packaging, grass clippings, furniture, clothing, bottles, kitchen

Citation: Sikakwe et al.,2020. Municipal solid wastes disposal in non-engineered landfills release deleterious chemicals that degrade water quality in a developing city. Journal of Applied Sciences Research., 16(5): 7-21. DOI: 10.22587/jasr.2020.16.5.2

refuse, appliances, paint cans, batteries etc. These wastes are produced in society, which does not generally carry any value to the first user [4]. Solid wastes encompass both heterogeneous masses of wastes from the urban community as well as more homogenous accumulation of agricultural, industrial and mineral wastes. Solid wastes can be classified into municipal wastes, industrial wastes, hazardous wastes and biomedical or hospital wastes [5] The leachate from these solid wastes consist largely of solids, microbial organism and in some situations, chemicals can contaminate groundwater in shallow wells [3]. In order to reduce the hazardous effects of solid waste disposal on residents and enhance the quality of the environment, this problem needs to be tackled frontally in an embracing manner [6].

In locations where waste collection and management have not attained satisfactory levels, it leads to dire environmental consequences. Wastes disposal without adequate management leads to environmental degradation, such as atmospheric gaseous emissions and groundwater pollution. This study is on municipal wastes disposal effects on groundwater. Abakaliki city is characterized by indiscriminate waste disposal sites close to water sources such as hand dug wells, streams and boreholes. These are sources of water for drinking, irrigation of gardens and other domestic uses. There is the possibility of migration of contaminant plumes from these waste disposal sites to nearby water sources, which can lead to water contamination. Analysis of physicochemical parameters and metal content in these water sources will serve as a guide to assess water quality to forestall the consumption of contaminated water by the residents, which is injuries to human health. , The provision of potable water for the growing population, is one of the targets of the Sustainable Development Goals (SDGs).

Most places in Nigeria depend on landfills for solid waste disposal as part of waste management practice. Adebera et al., [5] analyzed physicochemical and bacteriological parameters of water samples collected around solid waste dumpsites. The result showed a pH range of 5.9-6.4 recorded in some water samples within solid waste dumpsites, indicating some levels of groundwater contamination. This rendered the water unsuitable for drinking. Unlined sanitary landfills and open dumps are well known to release large amounts of hazardous and otherwise deleterious chemicals into groundwater, surface water, and soil to air via leachate and landfill gas [5]. A study by Mor et al., [7] revealed that the COD and BOD of such wastes may be in the region of 12000mg/L and 700mg/L, respectively, with concentrations of inorganic chemical substances such as ammonia, iron and manganese.

The effects of solid waste dumps on groundwater in Nigeria can be found in Kola-Olusunya, [8]. The author analyzed for microbiological parameters in groundwater around dumpsites at Olisosun in Lagos metropolis. The study confirmed the presence of fecal coliform, suggesting that the water is not potable. In India, Sohail and Saddiqui [9] investigated the effect of open landfills containing all sorts of municipal solid wastes and established that the groundwater was contaminated with Cd, Cr, Cu, Fe, Ni and Zn. Open dumping of municipal solid wastes creates serious negative environmental impacts such as toxic gases, the attraction of rats and odor [10]. Afolayan et al., [3] tested groundwater quality in the urbanized area of Lagos in Nigeria to examine the impact of solid waste disposal sites on groundwater quality. Water quality parameters such as total suspended solids, temperature, pH and N recorded higher concentrations around closed landfills than operational landfills. Operational landfills contained higher levels of Cl, Cd, Fe and Pb than old landfills. Research conducted on solid waste accumulation phenomenon in Nigeria by Momodu et al. [6] proffered a solution to reduce the negative effects of solid waste on urban beautification and sanitation. In addition, to provide a solution towards minimizing the evolving solid waste encroachment in Nigerian cities. Omofunwanmwan and Eseigbe [11] examined the effects of wastes on groundwater quality in Benin Metropolis, Nigeria. Analysis of water samples collected close to refuse dumps for physical-chemical and biological parameters showed evidence of groundwater contamination. The work done by Omofunwamwan and Eseigbe [11] is similar to this research.

At Chennai in India, soil and groundwater samples were collected by Raman and Narayanan, [12], near Pallavaran solid wastes landfill sites to study the possible impact of solid wastes in soil and groundwater quality. The study revealed that concentrations of some water quality parameters such as temperature, pH, hardness, EC, TDS, and TSS and trace metals were above permissible limits for potable water. The approach in assessing groundwater quality by the authors is in agreement with this study. Other works on the effects of solid wastes disposal and management on groundwater are summarized in [13; 14 and 15] etc. Previous studies by Okeke et al., [16] and Ede and Paulinus [17] in the Abakaliki area anchored on hydrogeochemical quality. The studies did not include an emphasis on the effects of waste disposal on water quality as contained in this study. Nwofe [2] reported on the impact of waste management and disposal methods in some selected academic and economic institutions in the Abakaliki Metropolis. The method of investigation was by questionnaire while this

Citation: Sikakwe et al.,2020. Municipal solid wastes disposal in non-engineered landfills release deleterious chemicals that degrade water quality in a developing city. Journal of Applied Sciences Research., 16(5): 7-21. DOI: 10.22587/jasr.2020.16.5.2

study employed empirical analysis of water samples to assess the environmental impact of solid waste disposal in the Abakaliki area.

Open dumping of municipal solid wastes in Abakaliki is of serious environmental concern. Apart from defacing the aesthetics of the town also contaminate surface and groundwater. Abakaliki is noted for salty groundwater taste. Lack of engineered landfills for waste disposal has further exacerbated the problem of groundwater quality through the contamination of groundwater by leachate resulting from solid waste decomposition.

The ultimate aim of this study is to investigate the impact of municipal solid waste disposal at open dumpsites on groundwater quality near the dumpsites. These water sources are used for drinking, irrigation and other domestic uses. The objectives of the study are:
(1) To assess the level of physicochemical parameters in water samples near solid waste dumps.
(2) Analyze for potentially toxic metals such as manganese, iron and aluminum in groundwater around the dumpsites.
(3) Recommend remedial measures for groundwater where there is evidence of contamination by solid waste disposal. This study analyzed for both physicochemical parameters and potentially toxic metals compared to previous works in the study area that considered only physicochemical parameters.

1.2 Study area description
The study area is located in Abakalikiis in Ebonyi state Nigeria and is situated within latitudes 60 19' 2.628"N and 60 19' 21.3"N and longitudes 80 8' 7.037"E and 80 06 56.6"N (Fig. 1). The least elevation of 29m was obtained at location 1 (Rice mill waste dump) and the highest elevation of 73m was recorded at location 3 (Wansi Street Junction). Abakaliki Urban is accessible from Enugu, Afikpo and Ogoja-Abakaliki express roads. A network of intra-city roads within the study area includes Water Works road, Ogoja road, Ezza road and Onwe road. Apart from the tarred roads, footpaths crisscross the study area, which can be covered by tricycles and motorcycles. Prominent dumpsites within the Abakaliki metropolis include Iyiokwu, waterworks, rice mill and Meat Market dumpsites. The Iyiokwu dumpsite is situated along Abakaliki-Afikpo road beside Iyiokwu River. The rice mill dumpsite is found within the premises of Abakaliki rice mill along Old Ogoja road while Water Works dumpsite is located along with Union Bank and College of Agricultural Science Campus (CAS) of Ebonyi State University (Fig. 1).

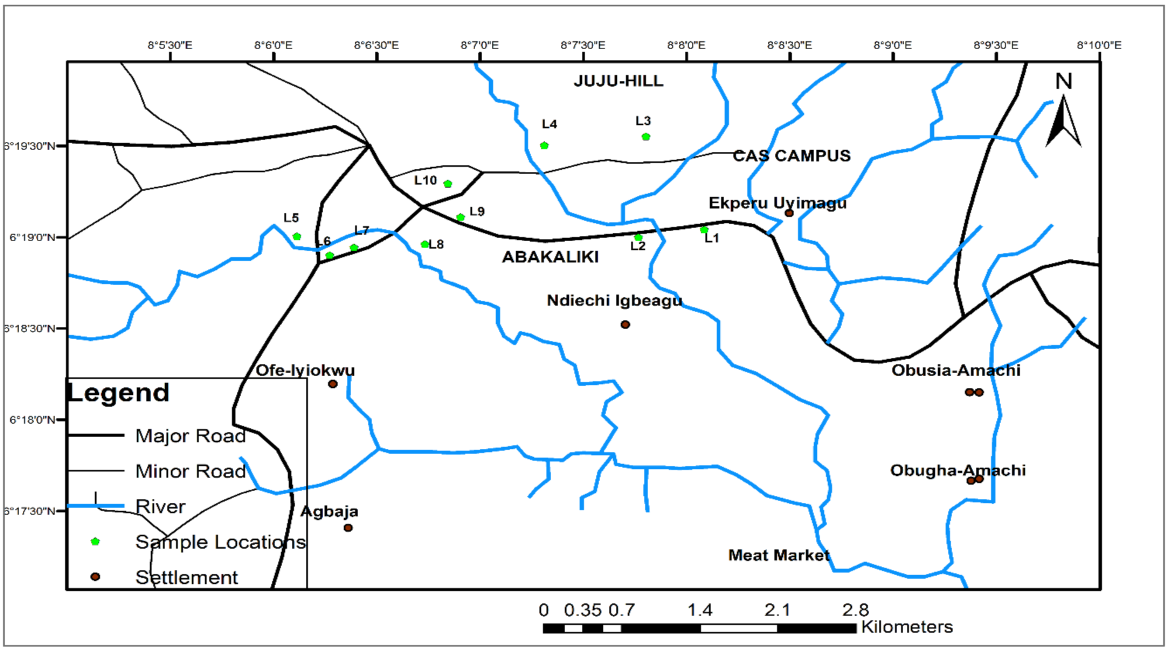

Figure. 1 Sample location map

Abakaliki area is characterized by a flat topography. Abakaliki basin is a subsidiary depression in the Benue Trough of Nigeria. The Abakaliki Basin is characterized by a tropical climate with an average rainfall of about 980 mm. In the study area, two seasons are observed, which are rainy and dry seasons. The rainy season starts in March and ends in October, while the dry season starts from November to February, characterized by

Citation: Sikakwe et al.,2020. Municipal solid wastes disposal in non-engineered landfills release deleterious chemicals that degrade water quality in a developing city. Journal of Applied Sciences Research., 16(5): 7-21. DOI: 10.22587/jasr.2020.16.5.2

seasonal water drought. The middle of this season is characterized by the harmattan, which is experienced within the months of December and January. The area is within the tropical rainforest. Surface drainage in the study area is irregular and consists of a number of small ephemeral streams. The streams generally flow through North-South (N-S) direction into the Ebonyi River. Ebonyi River is the major river that cuts across the study area. Other bodies of water are smaller streams, which drain into Udine, Iyiokwu and Okwerike rivers. These streams vary in size. Some are seasonal [17] and [18]. The drainage pattern in the study is dendritic, which is a function of lithological control. Abakaliki has luxuriant vegetation of the tropical rainforest characterized by trees, shrubs and varieties of other trees such as palm trees and coconut trees. Part of the vegetation is evergreen while some is deciduous [18].

1.3 Geology and hydrogeology

The study area is located in the southeastern part of the Lower Benue Trough of Nigeria. The Benue Trough is situated at the major re-entrant in the African continent and occupies an intra–continental portion and has a thick compressional folded cretaceous super crustal fill [19]; [20]; [21] and [22]. The study area is within the Asu-River Group, which consists of rather poorly bedded shale, occasionally sandy, splintery metamorphosed mudstones. Sandstone and sandy limestone lenses are highly jointed and fractured in the study (Fig.2). Younger intrusive rocks intrude the Albian Formation in the study area. The intrusive bodies have created fractures and secondary porosity in the study area in combination with numerous faults and joint systems.

Agumanu [23] and Obasi et al. [18] established that the Abakaliki shale formation has an average thickness of about 500m. The shale is dominantly dark, laminated, grey in color, blocky and indurated in some locations yet fissile, in some locations. The geologic history of the Abakaliki Basin is characterized by compressional tectonic stresses. The associated stresses cause metamorphism and fracturing of older marine volcanic rocks and primary porosity is low due to geologic conditions [16]. The authors suggested that the shale is of low primary porosity possessing very poor groundwater transmission and storage capabilities. However, the subsequent development of secondary porosity by fracturing and faulting has created increased bulk permeability of the fractured shale [24]. Abakaliki town is also characterized by the occurrence of pyroclastic rocks, which have been extensively weathered to give rise to shallow aquifers in the area [16; 25].

Citation: Sikakwe et al.,2020. Municipal solid wastes disposal in non-engineered landfills release deleterious chemicals that degrade water quality in a developing city. Journal of Applied Sciences Research., 16(5): 7-21. DOI: 10.22587/jasr.2020.16.5.2

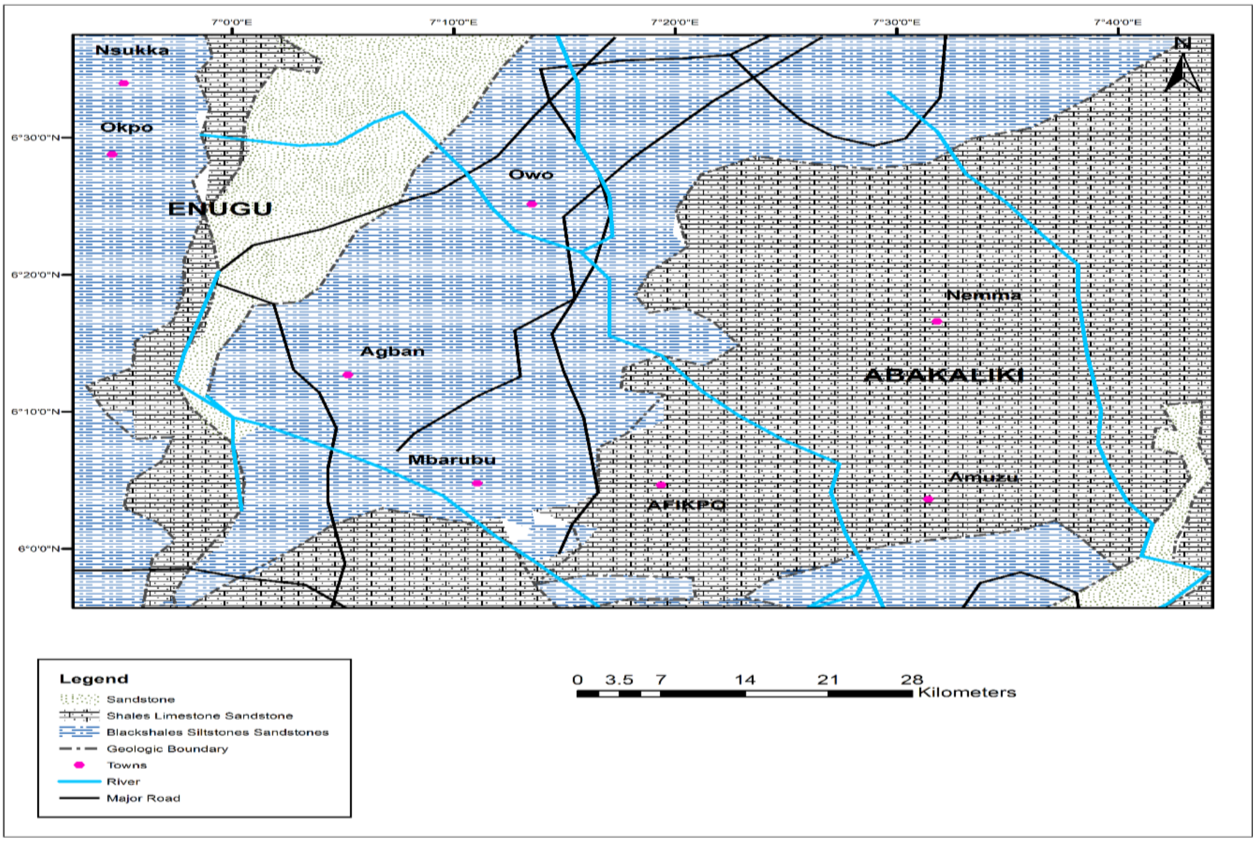

Figure. 2 Geological map of the study area and environs

2. MATERIALS AND METHODS

2.1 *Field sample collection*

Water samples were collected from a dumpsite at a rice mill located at the Abakaliki Rice Mill, characterized by thick rice husk wastes which are produced from the mill. The waste dumpsite located at waterworks along Union Bank and College of Agricultural Sciences Campus of Ebonyi State University consists of garbages, spoilt clothes or wares. A water sample was also collected at the Iyokwu dumpsite along Abakaliki-Afikpo road beside Iyokwu River before Sperando Junction. Other locations include a hand-dug well at Felix Memorial Hospital, a hand dug well at Nise Street around Hope High International School. A borehole water sample was also collected at 22 Uyamadu street at a distance of 30m away from Salt Lake Hotel. A borehole water sample was collected at Vanco Junction and from a hand-dug well at Onuiyi Street off Meat Market as a control. A water sample was also collected from a borehole at 5 Lagos Street off meat market and another borehole sampled at Ebonyi State University Nursery/Primary School at College of Agricultural Sciences Campus as a control (Fig. 1)

Boreholes, hand-dug wells and stream water samples were collected from ten locations across the study area (Fig. 1, Table 1). The water samples were collected at various distances from the open dumpsites where groundwater contamination was suspected. The borehole water samples were collected at the wellhead before the water went through the tank or treatment units. The water samples were collected in 200ml clean polyethene bottles. The well was pumped for about two minutes before sample collection to ensure collection of representative samples. The surface water samples were collected below the surface. Prior to sampling, the plastic bottles were prewashed and rinsed with the water to be sampled and properly labelled. The samples for major anions and cations were acidified with a few drops of HNO_3 acid at a pH of 2 to avoid loss of ions. The samples were kept at a temperature of 4^0C for two days before transported for analysis.

Physical parameters such as temperature, pH, eH, EC, and TDS were measured in the field using the mercury-in-glass thermometer, digital mv redox pH meter, conductivity meter, WA 3000 and conductivity meter, respectively. The choice of plastic bottle containers was to minimize contamination that could alter water

Citation: Sikakwe et al.,2020. Municipal solid wastes disposal in non-engineered landfills release deleterious chemicals that degrade water quality in a developing city. Journal of Applied Sciences Research., 16(5): 7-21. DOI: 10.22587/jasr.2020.16.5.2

chemistry. The essence of acidifying the water samples for cation analysis was to homogenize and eschew absorption and adsorption of metals to the walls of the plastic containers. When water samples are acidified, it disallows most microbial growth and obstructs oxidation reactions and precipitation of cations [26]. A global positioning system (GPS) unit portable GARMIN Eltrex 76 was used for recording coordinates and elevations readings. The field sample collection was done in clement weather to avoid sample contamination.

Table 1 Sample locations and GPS coordinates

Location	Coordinates	Elevation (m)
1	6^0 19' 2.628"N 8^0 8' 7.037"E	27
2	6^0 19' 33.9"N 8^0 07' 47.3"E	57
3	6^0 19' 32.4"N 8^0 07' 48.8"E	73
4	6^0 19' 34.0"N 8^0 07' 12.9"E	60
5	6^0 18' 58.9"N 8^0 06' 04.4"E	51
6	6^0 18' 55.7"N 8^0 06' 18.1"E	65
7	6^0 18' 56.0"N 8^0 06 20.22"E	54
8	6^0 19' 5.1"N 8^0 06' 43.9"E	61
9	6^0 19' 11.44"N 8^0 06' 51.5"E	56
10	6^0 19' 21.31"N 8^0 06' 56.6"E	61

2.*2 Laboratory analysis*

The collected samples were transported to the laboratory for analysis. The samples were analyzed for anions (Cl, SO_4, HCO_3, NO_3, CO_3, COD, BOD and hardness using standard procedures. The cations (K, Na, Al, Mg, Ca, Fe and Mn) were analyzed variously using flame test, ion chromatography and atomic absorption chromatography (AAS).

2.3 Descriptive statistics

SPSS software was used for computing descriptive statistics of water chemical data for comparison with standard world bodies such as WHO, USEPA and NSDWQ.

2.4 Overview of the method of investigation

Geochemical data analysis is the best data for studying environmental pollution. The water sample collection for analysis is relatively simple compared to the geophysical investigation. Analysis of water samples using analytical techniques involves direct measurement of the concentrations of physicochemical parameters and heavy metals resulting from waste disposal at dumpsites. Indirect measurement of force fields using geophysical methods to deduce the level of pollution is not an accurate technique for assessing environmental pollution compared to geochemical data analysis.

3. RESULTS

3.1 *Water quality*

Detailed results of concentrations of physicochemical parameters, organics and inorganic ions /salts are presented in Table 2. Statistical summary of elements in the water samples, together with maximum allowable limits contained in Nigerian Standard for Drinking Water Quality [27], World Health Organization [28] and the United States Environmental Protection Agency [29] around the waste dumpsites are presented in Table 3.

Table 2 Detail results of physicochemical and heavy metals parameters in water samples

Parameters	Unit	BH 1	BH 2	BH 3	HDW 4	STR 5	HDW 6	BH 7	BH 8	HDW 9	BH 10
Temperature	^0C	29.3	27.6	29.2	29.3	29.3	29.3	29.3	29.4	27.7	29.5
pH	-	6.6	6.2	6.5	6.3	6.2	6.1	6.3	6.4	5.6	6.4
Turbidity	NTU	54.0	0.0	27.0	45.0	77.0	16.0	39.0	65.0	0.0	43.0
TDS	mg/L	3.40	20.0	0.2	0.3	0.1	0.2	1.9	0.4	6.2	0.3
Conductivity	ɥs/cm	507.0	10.7	395.0	798.0	789.0	558.0	1142.0	431.0	34.5	599.0
Total Hardness	mg/L	280.0	320.0	316.0	292.0	320.0	348.0	336.0	280.0	260.0	248.0
BOD	mg/L	276.0	640.0	60.0	206	192.0	42.0	46.0	64.0	460.0	4.8
COD	mg/L	672.0	328.0	528.0	560.0	640.0	432.0	528.0	640.0	348.0	400.0
CO_3^-	mg/L	225.0	220.0	150.0	350.0	130.0	200.0	250.0	280.0	260.0	290.0
HCO_3-	mg/L	75.0	92.5	50.0	65.0	65.0	80.0	50.0	75.0	25.0	60.0
NO_3^-	mg/L	2.4	4.6	3.5	3.3	3.8	3.2	5.1	3.1	4.23	2.6
SO_4^{2-}	mg/L	472.0	19.8	305.0	467.0	417.0	272.8	272.8	491.3	448.0	471.0
Cl^-	mg/L	164.0	56.0	130	180.0	530.0	350.0	900.0	242.0	78.0	200.0
Ca	mg/L	23.2	5.7	21.9	15.0	22.4	14.2	24.4	23.7	12.0	20.8
Na	mg/L	3.2	18.3	3.8	2.6	2.8	3.1	3.3	3.0	25.0	2.2
K	mg/L	8.9	0.0	6.6	6.2	4.9	1.3	7.4	4.8	0.0	5.2
Mg	mg/L	12.7	20.5	14.8	8.0	9.9	11.7	24.9	13.3	20.2	6.3
Fe	mg/L	0.0	0.1	0.2	0.2	0.0	0.2	0.0	0.3	0.1	0.2
Al	mg/L	0.02	0.2	0.04	0.1	0.1	0.1	0.1	0.1	0.2	0.1
Mn	mg/L	0.8	0.4	0.6	0.2	0.4	0.9	0.4	0.3	0.8	0.1

Table 3 Statistical summary of physicochemical parameters and heavy metals in water samples

Parameters	Unit	Mean	St.Dev.	Median	Minimum	Maximum	Mode	WHO,[28], USEPA, [29], NSDWQ,[27]
Temperature	^0C	29.0	0.7	29.3	27.6	29.5	29.3	-
pH		6.3	0.3	6.3	5.6	6.6	6.5	6.5-8.5
Turbidity	NTU	36.6	25.9	41.0	0.0	77.0	0.0	5.5
TDS	Mg/L	3.3	6.2	0.3	0.1	20.0	na	500.0
Conductivity	ɥs/cm	526.4	343.6	532.5	10.7	1142.0	na	1400.0
Total Hardness	mg/L	300.0	33.0	304.0	248.0	348.0	280.0	50.0
Carbonate(CO_3)	mg/L	235.5	65.8	237.5	130.0	350.0	na	-
Bicarbonate (HCO_3)	mg/L	63.7	19.0	65.0	25.0	92.5	75.0	-
Nitrate (NO_3)	mg/L	3.6	0.8	3.4	2.4	5.1	na	50.0
Sulphate (SO_4)	mg/L	363.8	148.5	433.0	19.7	491.3	272.8	250.0
Chloride (Cl)	mg/L	283.0	257.4	190.0	56.0	900.0	na	250.0
BOD	mg/L	199.0	208.6	128.0	4.8	640.0	na	6.0
COD	mg/L	507.6	125.0	528.0	328.0	672.0	528.0	100
K	mg/L	4.5	3.1	5.1	0.0	9.0	0.0	12.0
Na	mg/L	6.7	8.0	3.1	2.2	25.0	na	12.0
Mg	mg/L	14.2	6.0	13.0	6.3	24.9	na	150.0
Ca	mg/L	18.3	6.3	21.3	6.0	24.5	na	75.0
Fe	mg/L	0.1	0.1	0.1	0.0	0.3	0.0	0.2
Mn	mg/L	0.5	0.1	0.1	0.0	0.3	0.0	0.4
Al	mg/L	0.1	0.1	0.1	0.0	0.2	0.1	0.05-0.2

Citation: Sikakwe et al.,2020. Municipal solid wastes disposal in non-engineered landfills release deleterious chemicals that degrade water quality in a developing city. Journal of Applied Sciences Research., 16(5): 7-21. DOI: 10.22587/jasr.2020.16.5.2

Na -not available

4. DISCUSSION

4.1.1 *Physical Properties*

The temperature in the water samples displayed almost a constant value (Table 2). Temperature levels ranged from 27.6-29.5^{0}C with a mean and standard deviation of 29.0$\pm$0.7. The maximum temperature level was 29.5^{0}C, with a median of 29.3^{0}C and a mode of 29.3^{0}C. The temperature was generally high in locations proximate to dumpsites but lower in locations 2 and 9, which were sampled as control samples. The higher temperature in locations closer to the dumpsites can be attributed to effluents from the dumpsites. Temperature reflects air temperature when the water is surface water. Air temperature in surface water always differs from groundwater temperature, because groundwater temperature is due to the heat retained by aquiferous layers [30]. The concentration of pH ranged from 5.6-6.6 with a mean and standard deviation of 6.3$\pm$0.3 and possessing median and mode values of 6.33 and 6.4, respectively. The maximum value of pH (6.6) was obtained at location 3 (Ukwansi Street Junction borehole) and the least value recorded in location 9 (Onuiyi Street hand-dug well control point (Fig. 3). The tendency of acidic nature of most water sample locations may be due to leachates from waste dumps. The pH range of 5.6-6.6 recorded is not in agreement with the standard prescribed by WHO [28] and NSDWQ [27] of 6.5-8.5 for potable water. The pH level is an indicator of the rate of solubility in comparison to the release of excess carbon (iv) oxide gas from rocks [30]. Conductivity values ranged from 10.7-1142mg/L with a mean and standard deviation of 526.4$\pm$343.6 mg/L. Conductivity recorded a median value of 532.5Mg/L. The highest level of conductivity was obtained at location 7 (Uyamadu Street about 30m away from Salt Lake Hotel dumpsite). The high value of conductivity can be attributed to leachates from waste dumps into the borehole water. Conductivity values were within permissible standards of 1400mg/L for potable water set by WHO [28]. Low conductivity values reflect fresh water [31]. Kamboj and Choudhary [14] recorded conductivity range of 1220-2945ųs/cm in groundwater samples near dumpsites in Delhi, India. Conductivity is a valuable indicator of amount of material dissolved in water while total dissolved solids indicate the general nature of water quality and salinity [14]. The range of TDS in the study falls between 0.1-20.0mg/L. The highest value of TDS (20mg/L) was obtained at location 2 (CAS campus borehole near a dumpsite). Total disolved solids (TDS) values were noted to be generally low across the study area. Based on TDS classification by Rabinove et al. [32], the water is non-saline in the borehole. Adebara et al., [5] recorded total dissolved solids ranging from 144-212mg/L in borehole water samples around solid waste dumpsites in Osogbo and Ede Metropolis in Osun State Nigeria. In addition, TDS range from 232-286mg/L was obtained in Lagos metropolis from water samples around landfill leachate contaminated site by Kola-Olusanya, [8]. The TDS values obtained in this study were below USEPA [29] standard of 500mg/L for potable water.
Levels of turbidity in water samples of this study ranged from 0-77 NTU (Table 3), with a mean and standard deviation of 36.6$\pm$26, and a median value of 41 NTU. The highest level of turbidity was recorded at location 5, which is located at Inyiokwu River near a dumpsite by Hope High International School Abakaliki. The lowest value of 0NTU was obtained at Ebonyi State University Nursery/Primary School CAS Campus (Fig. 3).

It can be concluded that the borehole water at Ebonyi State University is non-saline and non-turbid. Turbidity values across the study were generally higher than WHO [28] standard of 5NTU for potable water. This can be traceable to solid waste dumpsites across the study area. Sohail and Siddiqui [9] established turbidity range of 0.8-10NTU in water samples around dumpsites in India. Turbidity above permissible levels causes visual disorders [33]. Analysis of physicochemical and bacteriological characteristics of groundwater was conducted by Okeke et al. [16] to assessed groundwater quality for drinking purpose in Abakaliki town.. The groundwater satisfied quality standards for most of the chemical parameters with exception of pH and hardness. The pH ranged below 6.5-8.5 and hardness was above 100mg/L. The authors concluded that groundwater from shallow aquifer in Abakaliki town is therefor generally polluted in terms of physical, chemical and turbidity parameters. They attributed the source of pollution to be partly geological and partly due to leachate from solid waste sites. Their findings are in agreement with this study.

4.2 *Chemical parameters*

4.2.1 Hardness

Hardness concentrations ranged from 248-348mg/L with a mean and standard deviation of 300±33.0. The median and mode of hardness levels were 304mg/L and 280mg/L respectively. The values of hardness were above USEPA [29] standard of 50mg/L for potable water. Hardness is a measure of the occurrence and abundance of divalent cations (Ca^{2+}, Mg^{2+}). Omofonmwan and Eseigbe [11] measured total hardness concentrations from 21.4-32.0mg/L in municipal solid wastes dumpsites around Benin Metropolis in Nigeria. Similarly, total hardness levels range of 280-5800mg/L were obtained by Vasanthi et al., [13] in water samples around municipal solid wastes disposal sites in Chennai. Soft water has less than 50mg/L hardness, moderately soft water 50-100mg/L, and hard water range from 100-200mg/L and very hard water is more than 200mg/L in hardness [34]. On this basis, water in the study area can be classified as very hard water. Hard water reacts with soap to form precipitates, thus reducing the cleansing action of soap. This is very common with borehole water in Abakaliki area.

The level of carbonate (CO_3^-) ranged from 130-350mg/L with a mean and standard deviation of 235.5±65.7 mg/L. Carbonate values recorded a median of 237.5mg/L. Carbonate levels and alkalinity of carbonate are both pointers to permanent hardness of water [35]. The concentration of bicarbonate (HCO_3^-) ranged from 25-92.5mg/L with a mean and standard deviation of 63.7±19.0 mg/L. The median and mode of bicarbonate values were 65mg/L and 75mg/L respectively. Nitrate recorded a mean and standard deviation of 3.6±0.8 mg/L and ranged from 2.4-5.1mg/L. The median value of nitrate was 3.4mg/L. The source of bicarbonate may be from high supply of CO_2 by rainwater [36]. The carbon iv oxide may be from waste dumpsites. Nagarajan et al., [15] obtained concentration range of 189-824mg/L from leachate and groundwater samples around municipal solid waste landfill sites in Tamil Nadu, India. The nitrate levels in this study were below WHO [28] standard of 50mg/L for potable water. Nitrate has proved to be a health hazard when it occurs in drinking water with concentrations in excess of allowable limits stipulated by WHO[28]. It is an indicator of pollution when it occurs in excess. Nitrate levels ranged from 9.5-81.00mg/L in groundwater samples collected in the proximity of selected solid waste disposal sites in a study conducted by Ali [37] in Kano, Nigeria. Nitrate levels in excess of 50mg/L in drinking water can result in health conditions often life-threatening, such as methemoglobinemia or blue baby syndrome.

Sulfate and Chloride levels ranged from 19.7-491.3mg/L and 56-900mg/L, respectively. Sulfate recorded a mean and standard deviation of 363.8±148.5 mg/L, while chloride obtained 283±257.4 mg/L. The mean values of sulphate and chloride exceeded WHO [28] and USEPA [29] permissible limits of 250mg/L for each parameter. Normally groundwater from igneous and metamorphic rocks contain lower concentrations of sulfate and chloride compared to groundwater from sedimentary rocks. In this case, the high levels of sulfate can be due to the presence of sedimentary rocks (shale, clays silts, etc.). At high concentrations in drinking water, sulfate may have an unpleasant taste, can cause laxative effects, and may be an indicator of contamination [37;38]. Chloride occurs in all-natural waters in varying proportions. Chloride is highly mobile and eventually reaches surface and groundwater aquifers from both natural and anthropogenic sources such as fertilizers, landfills, septic effluents [7]. Chloride can get into groundwater from solid wastes when it encounters rainwater then gains entrance into aquifers [11].

4.3 Chemical Oxygen Demand (COD) and Biological Oxygen Demand (BOD)

COD and BOD recorded ranges of 328-672mg/L and 4.8-640mg/L, respectively. The mean and standard deviation of COD was 507.6±125.0 mg/L, while that of BOD was 199.1±208.7 mg/L. Chemical oxygen demand had median and mode values of 528 mg/L and 528 mg/L, respectively. Biological oxygen demand recorded a median of 128mg/L. Both BOD and COD values in this study exceeded levels of 0.8-5.0mg/L and 10mg/L prescribed by WHO[28] and NSDWQ[27] for potable water [39]. Dhere et al., [40] posited that unscientific disposal of solid waste plays an enormous role in the degradation of physicochemical parameters in groundwater such as BOD, COD. High BOD and COD in water depict high organic strength in water samples [7]. Also high levels of BOD and COD are some of the biological parameters that characterize the degradation of water quality [41]. Chemical

Oxygen Demand is a measure of oxygen equivalent to the organic matter content of the water susceptible to oxidation by a strong chemical oxidant and thus is an index of organic pollution [7].

The average abundance of anions in the water samples was in the order: SO_4^{2-}>Cl_2^->CO_3^->HCO_3^->NO_3^-

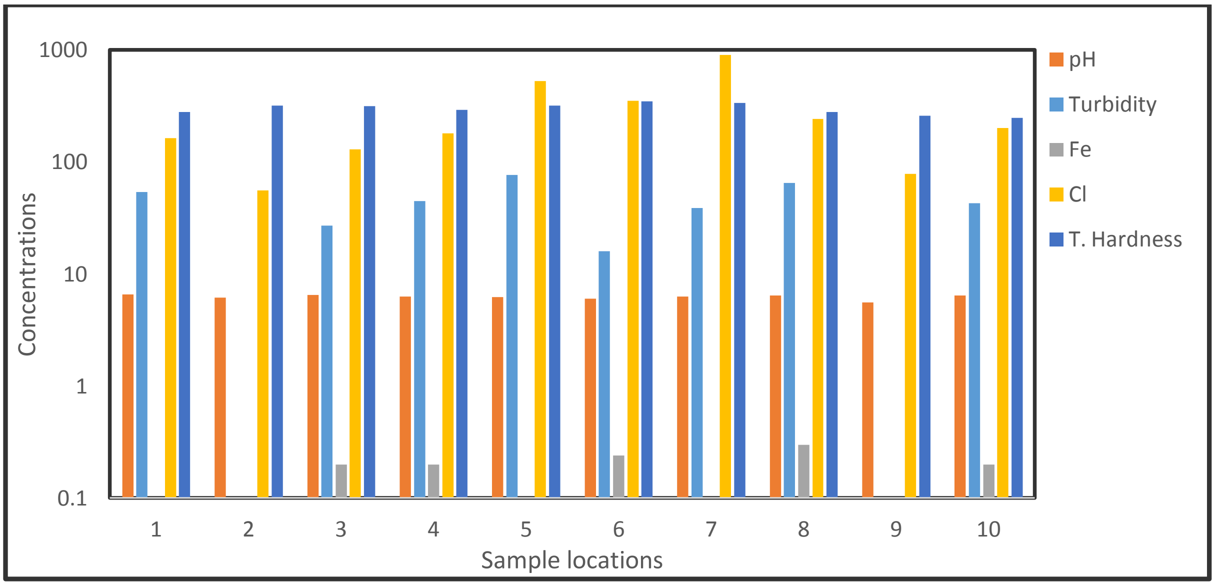

Fig 3 Spatial variation of selected parameters around the study area

4.4 Major cations

The concentrations of cations: K, Ca, Mg fall below allowable limits for potable water by WHO[28] and NSDWQ[27], with exception of Na that recorded levels that exceeded prescribed standards for potable water. The levels of potassium ranged from 0-8.9mg/L. Potassium recorded a mean and standard deviation of 4.5$\pm$3.11 with a median of 5.061mg/L. Sodium levels ranged from 2.2-25mg/L with a mean and standard deviation of 6.7$\pm$8.0 and a median value of 3.1mg/L. Magnesium attained a range of 6.3-25 mg/L with a mean and standard deviation of 14.2$\pm$6.0 and a median of 13.0mg/L. Calcium possessed a mean and standard deviation of18.3$\pm$6.3 mg/L and ranged from 5.7-24.488 mg/L. Calcium had a median value of 21.4mg/L. Levels of K were below allowable limits by WHO [28] for potable water in all the locations. Sodium concentrations exceeded WHO [28] and USEPA[29] standards for potable water in locations 2 and 10. Location 2 is in Ebonyi State University Nursery/ Primary School at CAS Campus, while location 10 is at No 5 Lagos Street off Meat Market. Potassium and sodium source is mostly from dissolution of feldspars in water [27; 42]. Magnesium levels were below permissible levels for potable water by NSDWQ[27]. Calcium and magnesium are responsible for temporary and permanent hardness in water. Concentration ranges of potassium (4-76 mg/L), sodium (0-437mg/L), magnesium (5-209mg/L) and calcium 28-188 mg/L) were obtained in groundwater samples near a municipal solid waste disposal site in Erode City by Ragkumar et al., [38]. Calcium level was below the permissible limit of 75 mg/L by recommended by WHO[28] for potable water in all the locations. Major cation average abundance was in the order: Ca^{2+}>Mg^{2+}>Na^+>K^+.

4.5 Heavy metal contamination

Groundwater samples were analyzed for potentially toxic elements such as aluminum (Al), iron (Fe) and manganese (Mn), which are characterized as undesirable metals in drinking water. Allowable limits of Al, Fe and Mn in drinking water by WHO[28] are 0.05-0.2, 0.2 and 0.4mg/L respectively. Iron exhibited levels above permissible levels for drinking water in location 8 (2 Nwankwo Street Vanco Junction). In some locations manganese exceeded the permissible level of 0.4mg/L for potable water stipulated by WHO [28]. Manganese concentration ranged from 0.1-0.9mg/L with a mean and standard deviation of 0.5$\pm$0.3 mg/L and a median of 0.4mg/L. Dissolved metals can be present in form of free ions or may form complexes with organic and inorganic ligands. The presence of heavy metal ions in leachate is not only affected by amounts of metals present in the waste mass but also the degradation processes within the disposal site. These are predominantly dependent on pH [43; 37]. Anaerobic groundwater may contain ferrous iron at concentrations up to several Mg/L without discoloration or turbidity in the water when directly pumped from a well. Iron also promotes growth of iron bacteria. At levels above 0.3mg/L, iron stains laundry and plumbing fixtures [37]. Manganese is not of health concern at all levels, but causing only acceptability problems of drinking water. At levels above 0.4mg/L manganese in water supply causes undesirable taste in beverage and stain sanitary wares and laundry. Even at a concentrations of 0.2mg/L, manganese will often form coatings in pipes, which may slough off as black precipitate [37]. Solid wastes, when dissolved usually contain abundant manganese [44]. Manganese is objectionable in water in the same way as iron. It occurs insoluble manganese bicarbonate, which changes to insoluble manganese hydroxide when it reacts with atmospheric oxygen. Stains caused by manganese are more objectionable and harder to remove than iron [11].

Aluminum concentrations in water samples in this study area ranged from 0.02-0.2mg/L. The mean and standard deviation of aluminum was 0.1±0.1mg/L with a median and mode of 0.1mg/L and 0.1mg/L, respectively. The level of aluminum fell within the standard of 0.05-0.02 mg/L prescribed by WHO[28] and NSDWQ[27]. Sohail and Siddiqui [9], identified Fe, and Mn range of 0.2-18.2mg/L and 0.1-1.1mg/L respectively in groundwater samples near open dumpsites in India. Excess manganese intake causes a neurological disorder. Ede and Paulinus [17] established Fe range of 0.01-0.04 mg/L in groundwater samples around Water Works road, Rice Mill and Mechanic Village areas in Abakaliki metropolis. No lasting effect could be attributed to known exposures from aluminum in drinking water [45]. The average abundance of heavy metals in water samples in this study is in the order: Mn>Fe>Al.

4.6 Spatial variation of physicochemical and heavy metal properties of water samples

The levels of pH reflects the acidic condition in almost all the locations and most cases outside the range of permissible levels or potable water recommended by WHO[28] and USEPA[29] standards. The pH range was from 5.6-6.6 contrary to standard levels of 6.5-8.5 recommended by WHO[28], USEPA [28] and NSDWQ [27] for drinking water (Table 2). The acidic condition may be due to solid waste effluents from dissolved metal coatings and garbage. Turbidity was nil at the control point (locations 2 and 9), but highest in location 5 (Near Oyiokwu stream dumpsite). Turbidity is a function of the presence of fine silt and clay in water, which imparts cloudiness. Bacteria may cling to these fine particles which makes it a water quality criterion [46]. All the sample locations recorded turbidity levels within the prescribed value by WHO[28] for potable water. Groundwater hardness is a common problem experienced by residents in Abakaliki area. This hardness of water in Abakaliki area can be partly explained by the geology of the terrain..

Sulfate had the lowest value of 19.7 Mg/L in location two, which is a control point. In addition, the highest value of 491.33 mg/L in location 10 (a borehole at No 5 Lagos Street). High sulphate level may be due to pyritization in the mine sites around Abakaliki area draining into the study area.

Chloride level had the highest concentration of 900 mg/L in location 7 (Uyammadu Street) and the lowest value of 56mg/L in location 2 (EBSU Nursery/Primary School). Chloride levels in locations 5, 6 and 9 (Table 1) exceeded recommended standard of 250 mg/L by NSDWQ[27] for potable water. Sources of chloride are NaCl and KCl. This is possible because groundwater sources in Abakaliki have a characteristic salty taste. Sources of chloride can also be from solid garbage and fertilizers in soils. Shebangarani [47] obtained a range of 519.84-53785.3 mg/L of chloride in groundwater near solid waste dumpsite in Asia. Biological oxygen demand (BOD) attained the lowest value of 4.8 mg/L in location 10 (number 5 Lagos Street borehole) and the highest value of 640 mg/L in location 2 (Fig.4). Apart from location 10, every other location achieved BOD value above WHO[28]and USEPA[29] standards for potable water. Chemical Oxygen Demand values were abnormally higher than the limit of 10mg/L prescribed by WHO[28] and USEPA [29] for potable water in all the locations. Therefore, groundwater pollution is suspected with respect to COD. Okpanechi [9] obtained COD values of 341mg/L and 420mg/L for borehole and hand dug wells close to solid waste open dumpsites in Samaria Zaria, Nigeria.

Citation: Sikakwe et al.,2020. Municipal solid wastes disposal in non-engineered landfills release deleterious chemicals that degrade water quality in a developing city. Journal of Applied Sciences Research., 16(5): 7-21. DOI: 10.22587/jasr.2020.16.5.2

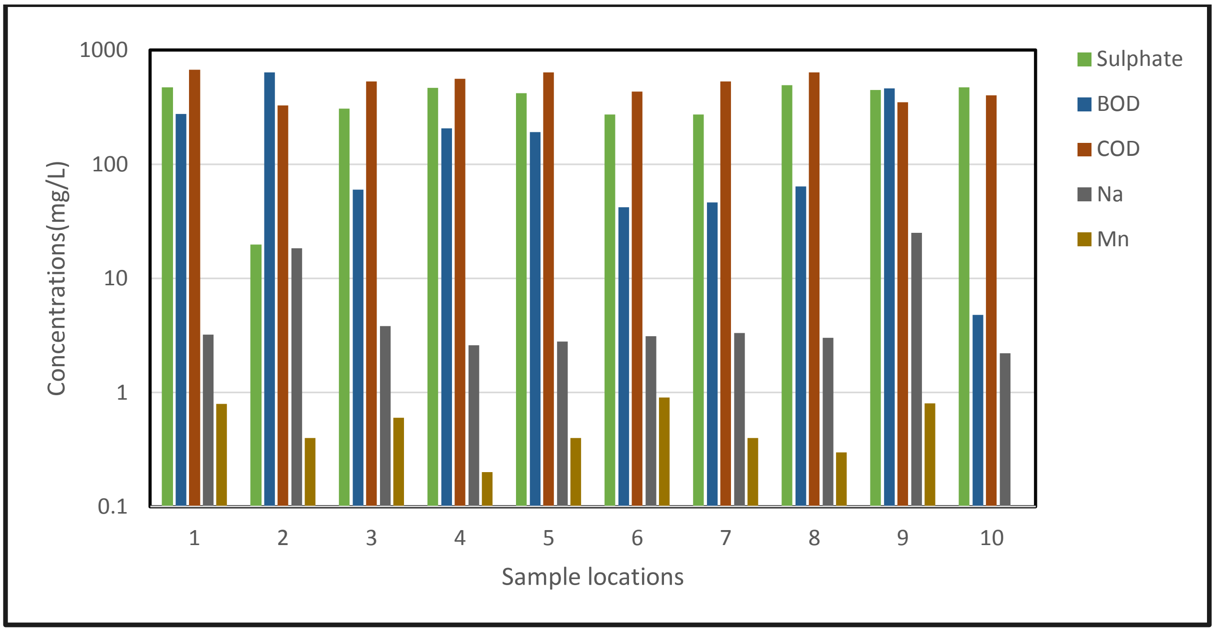

Figure 4. Spatial variation of selected parameters across the study area

Sodium levels in the study had the highest level of 24.99 mg/L in location 9 (Onuibuigi Street of Meat Market) and the least value of 2.183 mg/L in location 10 (Fig. 4). Sodium levels in location 2 and 10 obtained values more than 12 mg/L recommended by WHO [28] for potable water. Ali [37]) recorded sodium levels in a range of 635-1303 mg/L in water points near solid waste disposal points in Kano, Nigeria. Manganese levels were higher than 0.4mg/L recommended by WHO [28] in locations 1, 3, 6 and 9 while concentration of iron in only location 8 was above the value of 0.2mg/L recommended by WHO [28] for potable water. Ali [37] obtained ranges of 1.06-27.51mg/L and 0.00-13.20mg/L for Fe and Mn respectively in leachates from mine dumps in Kano, Nigeria.

In this study, there was detail analyses of chemical pollutants compared to previous work in this area which was not empirical. Unlike this study, analysis of hydrochemical parameterrs in Abakaliki area was not in relation to waste disposal sites but a general hydrochemical study for quality assessment. Previous work in the study area analyzed for inorganic pollutants while this study analyzed for both organic and inorganic pollutants.

4. Conclusion

Municipal solid waste disposal using non-engineered sites such as open dumpsites is a source of groundwater degradation. Groundwater degradation is prevalent in developing cities where standard waste disposal practices are not adopted. High levels of sulfate is a pointer to oxidation of sulphur in mine wastes commonly known as pyritization around mine sites which are common in Abakaliki area. The high concentration of biological oxygen demand (BOD) and chemical oxygen demand (COD) is evidence of high organic strength leading to degradation of water quality. Effluents from solid waste disposal sites increase acidity in groundwater. High chloride levels in water come from NaCl and KCl, which gives water a salty taste. Solid waste dumps effluents and fertilizers applications in soils are possible sources of chloride content in groundwater.

Concentrations of pH, Manganese, Na, Fe, BOD, COD, turbidity, total hardness, Cl, and SO_4 exhibited significantly high levels in most of the sampled water points. Manganese levels were above the WHO [28] specification for potable water in some locations. The levels of pH were acidic and were all outside acceptable limits for potable water recommended by NSDWQ [27]. The degree of total hardness was above limits recommended by WHO [28] for potable water. The water in this study can be described as very hard. That explains why it forms scales in kettles when boiled. The hardness is caused by calcium and manganese in the water. Sulphate levels in some locations were above levels stipulated by NSDWQ [27] for potable water. The BOD and COD parameters were above prescribed limits by WHO (2011) and NSDWQ [27] for potable water.

This can be attributed to effluents from open dumpsites in the study area. Chloride and sulphate anions recorded higher values in water samples than NO_3 and HCO_3. The water samples attained higher levels of turbidity than stipulated levels by USEPA[29], WHO[28], and NSDWQ [27] for potable water. Among the cations, levels of manganese, sodium and iron achieved values in some locations higher than levels prescribed by world standards [28; 29 and 27] for potable water. Levels of Al, Mg, K and Ca were below prescribed limits for potable water. Concentrations of nitrate bicarbonate and carbonate fell below the acceptable standard for potable water. Similarly, levels of physical parameters such as TDS and conductivity were below prescribed limits by WHO [28] for potable water.

From these findings, levels of physicochemical parameters and heavy metals recorded higher concentrations in water points proximate to solid waste dumpsites compared to the controlled point. In this light, it is evident that effluents from open dumpsites in the area made their ingress into groundwater, thereby polluting them. Groundwater in Abakaliki is hard with a salty taste. This water hardness, coupled with the effects from municipal solid wastes effluents has imparted an objectionable odour to water in the study area. These findings on groundwater quality are in agreement with the reality of the groundwater situation in Abakaliki area.

Acknowledgments

We deeply appreciate the efforts of the staff of water resources Abakaliki during field sample collection. We are grateful to Mr. Samuel Ojo for assistance during map preparation. We acknowledge the contributions of all the staff of springboard research laboratories by performing the analysis. We are thankful for all academic the staff of Geology programme at AE-FUNAI for their moral support during fieldwork. We appreciate Prof. Gabriel Egbe of the Department of English and Literary studies Veristas University Abuja for proofreading and editing the manuscript. We appreciate our families for their patience and understanding when our finances were diverted to fund this research at their expense.

Competing interest

There is no competing interest concerning this research

Ethics committee approval

This article is in line with publication ethics

Authors' contribution to the revised form

Gregory Sikakwe rephrased the title rewrote the abstract and modified the literature

God'swill Eyong corrected the table figures and stated a brief review of the method

Bridget Igwe Corrected the references and proofread the revised article

References

[1] Nigeria Institute of Safety Professional 2003 Contractor Employee HSE Training manual level 3. ECNEL Ltd PortHarcourt Nigeria

[2] Nwofe, P. A. 2017 Institutional waste management and disposal in Abakaliki metropolis, Ebonyi State, Nigeria,' AASCIT *Journal of Environment*, 2 (4),30-34, 2017

[3] Afolayan, O. S.,Ogundele, F. O.,&Odewumi,S. G. 2012 Hydrological implication of solid waste disposal on groundwater quality in Urbanised area of Lagos State Nigeria,'*International Journal of Applied Science and Technology,*2 (5),74-83,

[4] Adidebu, A. A.1982 Spatial pattern of solid waste generation in Ilorin. Paper presented at the Annual Conference of Nigerian Geographic Association Ibadan Nigeria

[5] Adebara, S. A., Afolayan, A., Omajali, D. L.,&Olatunji, A. A. 2016 Assessment of the effects of solid waste dumpsites on groundwater in Osogbo and Ede Metropolis Osun State Nigeria' *International Journal of Engineering Technologies and Management Research*,3(2), 1-21,

[6] Momodu, N.,Dimina, K. D.,&Dimina,J. E. 2011 Mitigating the impact of solid wastes in Urban Centers in Nigeria, *Journal of Hum. Ecology.* 34(2), 125-133

[7] Mor, S., Ravindra, K., Dahiya, R. P.,& Chandra, A. 2006'Leachate characterization and assessment of groundwater pollution near municipal solid waste landfill site,' *Environmental monitoring and assessment*, 118(1-3),435-456,

[8] Kola-Olusanya, A. 2017 Impact of municipal solid wastes on underground water sources in Nigeria, *European Scientific Journal,* 8 (2),1-19

[9] Ayub,S.& Siddiqui,S. 2015 Municipal solid waste dumping practice and its impact assessment,*European Journal of Science and Technology,*4(3): 33-54 Chapman, D. Water quality assessment. A guide for the use of biota, sediments and water in Environmental monitoring, University Press, Cambridge London, 1992

[10] Ejaz, N., Akhter, N.,NisarH& Ali Naem,U. 2010 Environmental impact of improper solid waste management in developing countries, A case study of Rawalpindi City, *Transactions on Ecology and the Environment*, 142,370-386

[11] Omofonwan, S. &Esiegbe, J. O. 2009 Effects of solid wastes on the quality of underground water in Benin Metropolis, Nigeria *J. Hum. Ecology*, 26 (2), 99-105

[12] Raman, N.,& Narayana, D. S. 2008 Impact of solid waste effect on groundwater and soil quality nearer to Pallavaran solid waste landfill site in Chennai: Rasayan, *Journal of Chemistry,*1(40), 828-836

[13] Vasanthi, P.,Kaliapan, S.,& Srinivasaraghan,R. 2008 Impact of poor solid waste management on groundwater, *Environmental monitoring and Assessment,* 143,227-238

[14] Kamboj,N.& Chaudhary,M. 2013 Impact of solid waste disposal on groundwater quality near Gazipur dumping site Delhi India, *Journal of Applied Natural Sciences,*5(2),306-312

[15] Nagarajan, R, Thirumalansamy, S.,&Lakshumanun, L. 2012 Impact of leachate on groundwater pollution due to non-engineered municipal solid waste landfill sites of Erode City, Tamil Nadu, India,Iranian *Journal of Environmental Health Sciences and Engineering*, 9(5),1-12, '

[16] Okeke, O. C., Dioha, E. C., Umeorizu, I. B.,Merole, M.C.N., Nwankwasi, J. T.,&Ekere, L. 2016 Physicochemical and bacteriological characteristics and quality assessment of groundwater from shallow aquifers in Abakaliki Town southeastern Nigeria,*' International Journal of Advanced Academia Research/ Science/ Tech. Engineering*, 2 (12),60-75

[17] Ede, C. O&Paulinus,N. N. 2015 Hydrogeochemical Evaluation of groundwater quality of Abakaliki and Environs, southeastern Nigeria, *International Journal of Innovation and Scientific Research,* 13 (2), 689-696

[18] Obasi, P. N.Nyankware, M. O.Akwundinobi, B. B. E. and M. O.Nwoke, 2015 Hydrochemicalinvestigation of water Resources at MkpunaEkwao mining District, Ebonyi state southeastern Nigeria, *African Journal of Geological Science Resource*, 3(3):1-7

[19] Murat, R. C. 1972 Stratigraphy and Paleogeography of the Cretaceous and Lower Tertiary in Southern Nigeria, African Geology Edited by T. F Dessauvagie and A. J Whiteman, Ibadan University of Ibadan press 25

[20] Orajaka, S. 1965 The geology of the Enyegbe and Ameke Lead-Zinc hides, Abakaliki division Hassan Nigeria, *A Reconnaissance Journal Nigeria Geological Meteorological Society,* 2(2),65-70

[21] Petters, S.W.1978 Stratigraphic Evolution of the Benue Trough and its implication for the Upper Cretaceous Paleogeography of West Africa, *Journal of Geology*, 86,311-322

[22] Reyment, R. A. 1963 Aspect of Geology Nigeria, Ibadan University Press 26

[23] Agumanu, A. I.1989 Abakaliki and the Ebonyi Formations: Subdivisions of the AlbianAsu River Group in the Southern Benue Trough Nigeria, *Journal of African Earth Sciences*, 9 (1),195-207

[24] Uzuakpunwa, A. B. 1974 The Abakalikipyroclastics. New age and tectonic implications,'Geological Magazine. 11, 65-70

[25] Orajaka, P.I.,&Umenwaliri,S. 1989 Diagnostic alteration of volcanoclastic rocks from AbakalikiArea, southeastern Nigeria, *Journal of Mining and Geology,* 25(185), 7-12

[26] Nwakwoala, H. O.,&Udom,G. J. 2011 Hydrochemicalfacies and ionic ratios of groundwater Port Harcourt southeastern Nigeria, *Research Journal of Chemical Sciences*, 30(1),3-8

[27] WHO 2011 World Health Organization Drinking water international standards 5thEdition United Nations Geneva Switzerland

[28] United States Environmental Protection Agency (USEPA) 2007 National Drinking Water Standards Washington, D. C office of water

[29] NSDWQ, 2007 Nigerian Standard for Drinking Water Quality Industrial Standard NIS 554, Standard Organization of Nigeria 30

[30] Edet, A., &Worden,R. H. 2009 Monitoring of physical parameters and evaluation of the chemical composition of river and ground water inCalabar Southeastern Nigeria,'*Environmental Monitoring and assessment,*157,243-250

[31] Chapman, D 1992 Water Quality Assessment. A guide of the use of biota, sediements and water in environmental monitoring University press Cambridge 585

[32] Rabinove, K.C, Ameena, C. J., Long Ford, R. H.,&BrookHari,J. W. 1958 Saline water resources of North Dakota US Geological Survey Water Supply Paper, 1428, 71

[33] Willock, D. B. 1993 Water Engineering. Hamshire:Evans Brothers

[34] Freeze, R. A, Cherry, J. A. 1979 *Groundwate*r Prentice Hall Eaglewood Cliff NJ,

[35] Nagaraju, A., Sureh, S., Killham, K.,&Hudson-Edwards,K. 2016 Hydrogeochemistry of waters of Magampeta Barite Mining area, Cuddapah Basin, Andhra Pradesh, India, Turkish. *Journal of Engineering and Environmental Science*, 30,203-219

[36] Matthess, G.&Harvey,J. C. 1982 'The properties of groundwater' Wiley New York

[37] Ali, A. F 2012 Groundwater pollution threats of solid wastes disposal in Urban Kano Nigeria. Evalauation and Protection strategies phD thesis University of Manchester

[38] Rajkurmar, N.,Submaramani, T.,&Elango, L.(2010) Groundwater contamination due to Municipal solid waste disposal –A GIS based study in Erode city, *International Journal of Environment Sciences,*1:39-55

[39] Okpanachi, A.S 2015 Masters degree Thesis Ahmado Bello University Zaria

[40] Dhere, M.A., Pawer, C.B., Pratapsingh, P.B.,&Patic, D. A. 2008 Municipal Solid waste disposal in pame city. An analysis of air and groundwater pollution, *Current Science,* 95(6),773-777

[41] Swer, S.,& Singh,O. P. 2004 Status of water quality in coal mining areas of Meghalaya, India. Proceedings on the National Seminar on Environmental Engineering with special emphasis on Mining and Environment (Eds) Indra, N. Seisha, Mrined, K . Ghoseand Gurdeep Singh 1-9

[42] Udom, G. E, Esu, E.O.,& Ekwere,S. J. 1996 Quality status of groundwater in Calabar Municipality Southeastern Nigeria, *Journal of Pure and Applied Sciences, .*2, 40-50

[43] Kjelsen, P. 1993 Groundwater Pollution source characterization of an old landfill, *Journal of Hydrology,*142,349-371

[44] Hughes, J. L.2004 Evaluation of groundwater degradation results from waste disposal to alluvium near Barstow California US Geological survey professional paper 878

[45] Clayton, D.B.1989 Water pollution at Lower moor, north Cornwall: report of the Lower moor Incident Health Advisory Committee Truro, Cornwall District Health Authority,

[46] Todd, T. L.1985 A grammer of Dimili WALS online edited by Dryer Mather & Haspelmath Martin is license under the a creative Commons Attribution 4.0 international License

[47] Shenbagarani, S (2013) Analysis of groundwater quality near solid waste dumping site . journal of Environmental Science, Toxicology and food Technology 4(2) 1-5