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Abbreviation

EC: Electrical Conductivity; TDS: Total Dissolved Solid; DO: Dissolved Oxygen; AAS: Atomic Absorption Spectroscopy; TH: Total Hardness; CF: Contamination Factor; CD: Contamination Degree; PLI: Pollution Load Index

Research Article

Physicochemical Properties and Heavy Metal Concentration in Borehole Water of Boko Haram Affected Areas of Madagali and Michika, Adamawa State, Nigeria

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Abstract

This study was carried out to assess the quality of borehole water in the Local Government Areas affected by Boko Haram insurgency. Madagali and Michika were two affected Local Government Areas in Adamawa state. This study was carried out in both the rainy and dry seasons. Physicochemical parameters and heavy metal level contaminations were used to assess the level of pollution. Physicochemical parameters that gave critical values of Pollution Index were temperature, Dissolved Oxygen and Chloride. While the heavy metals studied were Cd, Mn, Fe, Cu and Zn. High concentrations of Cd, Fe and Mn were recorded at some sites at levels beyond the recommended values by WHO (2011) and SON (2007). Higher concentrations of these metals were recorded during the rainy season. The pollution load indices (PLI) were found to be at a very high level, signifying a critical environmental condition which can cause health problems and even degrade the ecosystem. The activities of Boko Haram had greater effect on the water through the higher temperature, DO and Chloride concentrations. This could be due to explosive products that have the tendency of distorting the atmospheric conditions which invariably affected these parameters in the borehole water.

Introduction

Water is one of the prime necessities of life. We can hardly live for a few days without water. Still more than one billion people all over the world do not have ready access to adequate and safe water supply and more than 800 million of those with unsafe drinking water live in the rural areas [1]. Growing population, increase economic activities and industrialization has not only created an increase demand for drinking / potable water, but also resulted in severe misuse of this natural resource. Water all over the world is threatened not only by over exploitation and poor management, but also by ecological degradation [2]. Water quality refers to the chemical, physical, biological and radiological characteristics of water. It is a measure of the condition of water relative to the requirements of one or more biotic species and or to any human need or purpose [3]. Water is considered polluted when it's altered in composition or condition so that it becomes less suitable for any or all of the functions and purposes for which it would be suitable in its natural state [4]. Water pollution includes changes in the physical, chemical and biological properties of water. Various substances that pollute water include sediments, oxygen demand wastes, disease causing agents, plant materials, synthetic organic compounds, oil, radioactive materials, inorganic compounds and mineral substances [4]. Heavy metals in trace concentrations are some of the major sources of pollution. Water resources all over the world are threatened not only by over exploitation and poor management, but also by ecological degradation. The greatest public health concern about water is directed to its ever increasing number of toxic substances including inorganic and organic chemicals and pathogens [5]. Ground water from boreholes and shallow wells is a major source of drinking water in most rural areas of developing countries. The status and potential threats of ground water have been taken for granted and not been investigated on a large scale in most of the developing countries [6]. Drinking water in most rural communities of developing countries comes from sources such as rivers, streams, lakes, boreholes and wells, and they are likely to be polluted with domestic, agricultural or industrial waste [7]. Pollution of ground water is a major threat posed by leachate which is formed by anaerobic decomposition of waste and may infiltrate the aquifer. Ground water contamination has become a great problem due to rapid growth rate of population, industrialization and urbanization in the metropolitan city all over the world [8]. The activities of Boko Haram that range from killing, bombing, burning of houses are some sources of environmental hazards as a result of guerilla warfare which pollutes not only the water, but releases toxic dust into the atmosphere, causing air pollution, degradation of the landscape, and damage to natural habitat [9]. Drinking water quality standards describes the quality parameters set for drinking water, these parameters change duly due to various types of pollution and seasonal variation [8]. In this case where anthropological activities is one of the major causes of pollution, the agencies mandated to enforce compliance of drinking water quality standard should look into the areas affected by Boko Haram, to ascertain that drinking water adheres to standard to save them from diseases, so that they can enjoy healthy living and development. Heavy metals are natural constituents of the earth's crust and biologically important at trace level [10]. The level of contamination of water by heavy metals in the environment internationally is very high thereby affecting the biosphere, including aquatic lives present in fresh waters [11]. More attention should be given to heavy metals in water because of bioaccumulation and bio-magnification potential and their persistence in the environment [12]. Heavy metals are persistent in soil, therefore they are transferred to aquifer via soil and plant roots [13]. This work examines the quality of drinking water (borehole) with seasonal variation in two of the local government areas of Adamawa State, affected by Boko Haram; Madagali and Michika.

Materials and Methods

All sample for AAS Analysis (digested) water samples were filtered and analyzed using Atomic Absorption Spectrophotometer Buck Scientific BLC 10/11 under standard operation condition. In order to provide greater data confidence from analytical procedure regarding bias and variability, appropriate quality assurance and quality control on water samples were ensured.

Study Area

Madagali and Michika are bounded to Borno State to the north and east, Cameroon Republic to the West and Mubi North to the South. They lay within latitude 13° 30' and 13° 45' north of the equator and longitude 11° 00' and 10° 30' east of Greenwich meridian [14].

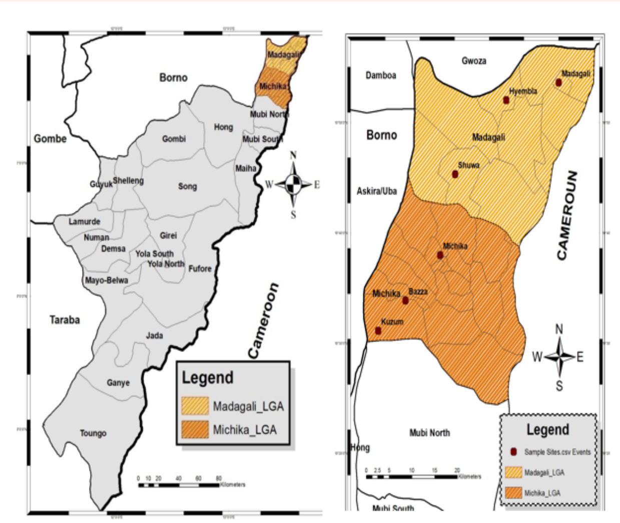

Figure 1: Map showing Adamawa State and study area.

Sample Locations

Borehole water was collected from three locations in each Local Government Area hereby labelled as Md_1 (Madagali), Md_2 (Hyembla), Md_3 (Shuwa) in Madagali LGA, and Mc_1 (Michika), Mc_2 (Bazza), Mc_3 (Kuzzum) in Michika LGA. Numan Local Government, Numan town, far off from the polluted areas was used as control. The water samples were collected manually using 1.0 L bottles (plastic) and treated with 10.mL of conc. HNO_3 to maintain the state of the cations in solution and slow biological changes before taking to the laboratory for physico-chemical analysis as recommended by Maitera. Water samples were then stored in the refrigerator at 5°C.

Sample Analysis

The pH, Electrical Conductivity (EC), Total Dissolved Solid (TDS) and Temperature were determined by a combined water pH/EC/TDS/T portable water model MI805 Martini instrument. Dissolved Oxygen (DO), determined using DO meter while Total Hardness was determined by EDTA titration, Chloride was determined by Mohr's titrimetric method. Cadmium, iron, zinc copper and manganese by Atomic Absorption Spectroscopy (AAS). All methods according to APHA (2005).

Pollution Index

Pollution Index of Madagali and Michika borehole water were determined using pollution quality of water as developed by [15] and adopted by [4]. This uses multiple items of water qualities expressed as Ci and permissible levels of respective items expressed as Lij. The relative value of Ci/Lij is the expression of Pollution Index. A value greater than 1.0 indicates that the water requires some special treatment before use for specific purpose. The Pollution Index of the water therefore is expressed as (Pij).

$$pij = \sqrt{\frac{(mn * ci / lij)^2 + (mean \frac{ci}{lij})^2}{2}}$$

Results and Discussions

Table 1: Madagali Borehole water.

	Dry Season Ci	Rainy Season Ci	WHO Permissible (Li) level	Dry Season Ci/Lij	Rainy Season Ci/ Lij
T	31.17	30.98	25	1.247	1.239
pH	6.07	6.92	6.5	0.934	1.065
EC	453.44	425.77	1400	0.324	0.304
TDS	222.97	212.11	1000	0.223	0.212
DO	6.44	6.36	5	1.288	1.272
TH	226.44	205.77	500	0.453	0.412
Cl-	399	401.22	250	1.596	1.605
$\sum_{Lij} Li$	-	-	-	6.029	6.109
	-	-	-	0.861	0.873
Pij	-	-	-	4.31	4.41

Key: T= Turbidity, EC=Electric Conductivity, TDS= Total Dissolved Solute, DO= Dissolved Oxygen, TH= Total hardness, Cl- = Chloride ion

Table 2: Michika Borehole.

	Dry Season Ci	Rainy Season Ci	WHO Permissible (Li) level	Dry Season Ci/Li	Rainy Season Ci/Li
T	28.43	27.6	25	1.137	1.104
pH	6.15	6.83	6.5	0.946	1.05
EC	250	271.75	1400	0.179	0.194
TDS	125.33	143.58	1000	0.125	0.144
DO	6.69	6.5	5	1.115	1.3
TH	317.16	166.5	500	0.634	0.333
Cl-	344.08	333.83	250	1.376	1.335
$\sum(\frac{C_i}{L_{ij}})$	-	-	-	5.512	5.46
$\sum(\frac{C_i}{L_{ij}})n$	-	-	-	0.787	0.78
Pij	-	-	-	3.937	3.939

Pollution Load Index of Water

Table 3: Mean concentration of heavy metals in Borehole waters of Michika and Madagali L.G.A in dry season.

	Cd	Zn	Fe	Mn	Cu
Mc_1	0.13 ± 0.01	0.30 ± 0.05	0.64 ± 0.08	0.12 ± 0.001	ND
Mc_2	0.13 ± 0.01	1.61 ± 0.02	13.35 ± 0.03	0.17 ±0.0001	ND
Mc_3	0.16 ± 0.02	0.10 ± 0.01	0.68 ± 0.01	0.25 ± 0.03	ND
Md_1	0.11 ± 0.01	0.27 ± 0.03	0.72 ± 0.06	0.05 ± 0.001	0.04 ± 0.01
Md_2	0.10 ± 0.01	0.43 ± 0.02	4.83 ± 0.02	0.31 ± 0.09	ND
Md_3	0.04 ± 0.01	0.52 ± 0.02	1.90 ± 0.04	0.15 ± 0.07	0.22 ± 0.08
WHO (2011)	0.003 mg/L	3.0 mg/L	0.3 mg/L	_	2.0 mg/L
SON (2007)	0.01 mg/L	5.0 mg/L	0.3 mg/L	0.2 mg/L	1.0 mg/L

Table 4: Mean concentration of heavy metals in Borehole waters of Michika and Madagali LGA in Rainy Season.

	Cd	Zn	Fe	Mn	Cu
Mc_1	0.05 ± 0.001	0.24 ± 0.01	1.69 ± 0.04	0.07 ± 0.003	3.00 ± 0.03
Mc_2	0.03 ± 0.001	0.47 ± 0.02	1.91 ± 0.02	0.26 ± 0.01	ND
Mc_3	0.02 ±0.0003	0.30 ± 0.02	4.24 ± 0.01	0.35 ± 0.01	ND
Md_1	0.05 ± 0.008	0.17 ± 0.001	2.16 ± 0.03	0.05 ± 0.001	0.13 ± 0.01
Md_2	0.05 ± 0.004	0.26 ± 0.02	10.89 ± 0.01	1.06 ± 0.02	0.22 ±0.3
Md_3	0.02 ± 0.001	0.59 ± 0.03	1.91 ± 0.05	0.17 ± 0.01	0.20 ± 0.01
WHO (2011)	0.003 mg/L	3.0 mg/L	0.3 mg/L	_	2.0 mg/L
SON (2007)	0.01 mg/L	5.0 mg/L	0.3 mg/L	0.2 mg/L	1.0 mg/L

Cd was above recommended limit by WHO (2011) and SON (2007) in both seasons in all locations. But higher values of Cd were obtained in the dry season ranging from 0.04 ± 0.01 – 0.16 ± 0.02 mg/L, then in the rainy season ranges from 0.02 ± 0.003 to 0.50 ± 0.001. Mc_3 has the highest with 0.16 ± 0.02 mg/L (dry season) while it has the least value during the rainy season. Cd is widely distributed in the earth's crust. Human activities such as mining, metal production and combustion of fossils fuels can result in elevated Cd concentrations in the environment. From this data the possible anthropogenic activity was the use of fossil fuels; for burning houses, fueling their vehicles, motor cycles which the Boko Haram used, this might have caused such Cd high concentration in borehole water in these locations. Zn concentration was all within the acceptable limits as it was within 3.0 mg/L and 5.0 mg/L as stipulated by WHO and SON respectively. There seems to be no activities to warrant a high value of Zn in these localities. Fe is a common occurring metallic element. The value of Fe recorded during the dry and the rainy seasons at all locations of these Local Government Areas exceeded the maximum limits set by WHO and SON. Fe has the highest concentration of the metals in all locations and recorded the highest level in the dry season at Mc_2 (13.35 ± 0.03 mg/L) and Md_2 with (10.89 ± 0.01 mg/L) in the rainy season. Except for Mc_2, all the values of Fe were higher during the rainy season tah the dry season. The basement rock of these locations according to Adebayo (2004), are rich in iron. Mn values ranged from 0.05 ± 0.001-0.31 ± 0.09 mg/L during the dry season, while the rainy season has a range of 0.07 ± 0.003 to 0.35 ± 0.01 mg/L. This indicates a rise in concentration of Mn during the rainy season. Mn content of Mc_3 (0.25 ± 0.03 mg/L) and Md_2 (0.31 ± 0.09 mg/L) in the dry season were above the permissible limits of 0.2 mg/L (SON 2007), while at the other locations, where within the limits. In the rainy season Mc_1 (0.07 ± 0.003 mg/ L), Md_1 (0.05 ± 0.001 mg/L) and Md_3 (0.17 ± 0.01 mg/L) were within limits. Cu was below detectable limits in some of the locations during the dry season except in Md_1 (0.04 ± 0.01 mg/L) and Md_3 (0.22 ± 0.08 mg/L) which fall within the permissible limits of WHO (2.0 mg/L) and SON (1.0 mg/L). In the rainy season Cu was below detectable limits in Mc_2 and Mc_3. Cu concentration in Mc_1 (3.00 ± 0.03 mg/L) exceeded the recommended limits of WHO and SON, whereas the other location were within limits. Most of the heavy metals have higher concentrations during the rainy season than the dry season. This showed that rain is a medium of transfer of heavy metals from different location to the leachate and eventually borehole water reported that heavy rain may improve the water quality by diluting and washing away pollutant and may also lower the water quality by flushing in pollutants such as fertilizers and suspended or dissolved solutes. We can conclude that the rainy season has significant effect on the concentrations of heavy metals in borehole water.

Table 5: CF, CD, PLI of borehole water of Madagali LGA in the Rainy Season.

	Sample sites				Contamination Factor (CF)		
	Md1	Md2	Md3	Conc of Bn	CF_1	CF_2	CF_3
Cd	0.05±0.008	0.05±0.004	0.02±0.001	0.3	$1.67*10^{-1}$	$1.67*10^{-1}$	$6.67*10^{-2}$
Zn	0.17±0.001	0.26±0.02	0.59±0.03	95	$1.79*10^{-3}$	$2.74*10^{-3}$	$6.21*10^{-3}$
Fe	2.16±0.03	10.89±0.01	1.91±0.05	46, 000	$4.70*10^{-5}$	$2.37*10^{-4}$	$4.15*10^{-5}$
Cu	0.13±0.01	0.22±0.31	0.20±0.01	45	$2.89*10^{-3}$	$4.89*10^{-3}$	$4.44*10^{-3}$
Mn	0.05±0.001	1.06±0.02	0.17±0.01	850	$5.88*10^{-5}$	$1.25*10^{-3}$	$2.0*10^{-4}$
CD	_	_	_	_	0.17	0.18	0.08
PLI	_	_	_	_	4.738	5.811	4.332

Bn: Background shale concentration

Table 6: CF, CD, PLI of borehole water of Madagali LGA in the Dry Season.

	Sample sites				Contamination Factor (CF)		
	Md1	Md2	Md3	Conc of Bn	CF1	CF2	CF3
Cd	0.11±0.01	0.10±0.01	0.04±0.01	0.3	$3.67*10^{-1}$	$3.33*10^{-1}$	$1.33*10^{-1}$
Zn	0.27±0.03	0.43±0.02	0.52±0.02	95	$2.84*10^{-3}$	$4.53*10^{-3}$	$5.47*10^{-3}$
Fe	0.72±0.06	4.83±0.02	1.90±0.04	46, 000	$1.56*10^{-5}$	$1.105*10^{-4}$	$4.13*10^{-5}$
Cu	0.04±0.01	ND	0.22±0.08	45	$8.89*10^{-4}$	_	$4.89*10^{-3}$
Mn	0.05±0.001	0.31±0.09	0.15±0.07	850	$5.88*10^{-5}$	$3.65*10^{-4}$	$1.76*10^{-4}$
CD	_	_	_	_	0.37	0.33	0.14
PLI	_	_	_	_	6.108	8.823	4.814

Bn: Background shale concentration

Table 7: CF, CD, PLI of borehole water of Michika LGA in the Rainy Season.

Sample sites					Contamination Factor (CF)		
	Mc1	Mc2	Mc3	Conc of Bn	CF_1	CF_2	CF_3
Cd	0.05±0.001	0.03±0.001	0.02±0.003	0.3	$1.67*10^{-1}$	0.1	$6.67*10^{-2}$
Zn	0.24±0.01	0.47±0.02	0.30±0.02	95	$2.53*10^{-3}$	$4.95*10^{-3}$	$3.16*10^{-3}$
Fe	1.69±0.04	1.91±0.02	4.24±0.01	46, 000	$3.67*10^{-5}$	$4.15*10^{-5}$	$9.22*10^{-5}$
Cu	3.00±0.03	ND	ND	45	$6.67*10^{-2}$	-	-
Mn	0.07±0.003	0.26±0.01	0.35±0.1	850	$8.24*10^{-5}$	$3.06*10^{-4}$	$4.11*10^{-4}$
CD	_	_	_	_	0.24	0.11	0.7
PLI	_	_	_	_	6.111	8.904	9.454

Table 8: CF, CD, PLI of borehole water of Michika LGA in the Dry Season.

Sample sites				Contamination Factor (CF)			
	Mc1	Mc2	Mc3	Conc. of Bn	CF_1	CF_2	CF_3
Cd	0.13±0.01	0.13±0.01	0.16±0.02	0.3	$4.33*10_{-1}$	$4.33*10_{-1}$	$5.33*10_{-1}$
Zn	0.30±0.05	1.61±0.02	0.10±0.01	95	$3.16*10_{-3}$	$1.69*10-_{2}$	$1.05*10_{-3}$
Fe	0.64±0.08	13.35±0.03	0.68±0.01	46, 000	$1.39*10_{-5}$	$2.90*10_{-4}$	$1.48*10_{-5}$
Cu	ND	ND	ND	45	_	_	_
Mn	0.12±0.001	0.17±0.001	0.25±0.03	850	$1.41*10_{-4}$	$2.0*10_{-4}$	$2.94*10_{-4}$
CD	_	_	_	_	0.44	0.45	0.53
PLI	_	_	_	_	7.196	8.071	7.025

Bn: Background shale concentration

The result of the Pollution Index of Borehole water using the physicochemical parameters of Temperature (T), pH, Electrical Conductivity (EC), Total Dissolved Solid (TDS), Dissolved Oxygen (DO), Total Hardness (TH) and Chloride (Cl-); Table I and II from Madagali and Michika have rainy season values 4.41 and 3.94. While in the dry season 4.31 and 3.94 respectively. This signifies high pollution. A value of 1.0 is the critical value for pollution index. A value greater than 1.0 indicates that the water requires some special treatment before use for specific purpose (Egereonu et al. 2012). The season variation of the pollution index in both Local Governments are not significantly different. As can be seen from Table I and II, the relative pollution of DO, Cl- and Temperature in both rainy and dry season of Madagali and Michika were critical as they were above 1.0.

The Contamination Factor (CF) for each metal, Contamination Degree (CD) and Pollution Load Index (PLI) of all the sites indicated high values. The PLI indicates progressive deterioration, because it was greater than 1 in all the sites and in both seasons. Hakason (1980) classified contamination factor less than 1 as low, Andy and Khaled (2009) likewise classified contamination degree (CD) as any value less than 6 indicates low CD. While PLI indicates the severity of pollution in the site. PLI is classified into perfect PLI when the value is less than 1, when PLI is equal to 1, this indicates only baseline levels of pollutants present, while PLI greater than 1 indicates progressing deterioration (Thomilson et al. 1980).

The highest value of CD in the study area was obtained in Michika LGA during the two seasons, which are 0.70 and 0.53 in rainy and dry season respectively. The least was in Madagali 0.08 in the rainy season. The highest pollution index was obtained in Michika during the rainy season (9.454) and the least was in Madagali during the rainy season (4.332). The PLI were higher in Michika in both seasons than in Madagali in both seasons as well. There is no significant difference in the sites for both seasons.

The result of the Pollution Index of Borehole water using the physicochemical parameters of Temperature (T), pH, Electrical Conductivity (EC), Total Dissolved Solid (TDS), Dissolved Oxygen (DO), Total Hardness (TH) and Chloride (Cl-); Table I and II from Madagali and Michika have rainy season values 4.41 and 3.94. While in the dry season 4.31 and 3.94 respectively. This signifies high pollution. A value of 1.0 is the critical value for pollution index. A value greater than 1.0 indicates that the water requires some special treatment before use for specific purpose (Egereonu et al. 2012). The season variation of the pollution index in both Local Governments are not significantly different. As can be seen from Table I and II, the relative pollution of DO, Cl- and Temperature in both rainy and dry season of Madagali and Michika were critical as they were above 1.0.

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Conclusion

From the general analysis some concentrations did not meet the WHO and SON standard, while others met the standards. However the study indicated higher concentrations of heavy metals in the rainy seasons and this agrees with findings by Eseyi et al. (2018) and Andrew (1972).

It was found out that the critical pollutants in physicochemical parameters are Temperature, Dissolved Oxygen (DO) and Chloride (Cl-) in all the sites and in both seasons. This indicating some product of explosive materials finding their way into the water body, distorting the temperature and Dissolved Oxygen balance and elevating the Chloride level.

The high values of PLI should be of great concern and the heavy metal content in water should be checked from time to time to monitor it because of bioaccumulation and to prevent progressive deterioration of the sites.

Recommendation

TDS, DO, Chloride, temperature and heavy metal content in water should be checked from time to time to monitor it, because of bioaccumulation and to prevent progressive deterioration of the sites.

Conflict of Interest

All the authors declare that there is no conflict of interest

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