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Groundwater Quality Assessment and its Suitability for Drinking Purposes in Nasarawa Area, Kano State, Nigeria

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ABSTRACT

Groundwater serves as a source of freshwater for different purposes including drinking, domestic, agricultural and industrial. The quality and suitability of groundwater of some selected boreholes for drinking purposes in Nasarawa local government area Kano state was assessed. Five sample locations were considered in this study. These are Badawa, Wurro Bagga, Kawon maigari, Ring road bye pass and Bakin tasha yankaba. Water samples were collected in a clean plastic bottles. Descriptive statistics of minimum, maximum, mean and standard deviation were used. The result obtained revealed that all studied parameters pH, EC, T, TDS, Cl⁻, TH, Zn, Cu, Fe and Mn concentration found to be within the maximum permissible limit recommended by WHO 2011, with mean value of 7.06±0.18, 778.60±191.75, 27.3±0.30, 402.20±97.86, 151.57±59.69, 120.8±35.56, 0.108±0.056, 0.254±0.119, 0.215±0.103 and 0.12±0.06 found within the permissible limit recommended by WHO 2008 and NSDWQ 2007 for drinking water except Pb, Cd, Cr and Mg exceeded the stipulated limit for drinking water set by WHO 2011 with the mean value of 0.113±0.066, 0.125±0.050, 0.275±0.163 and 1.04±0.38 respectively. DWQI result indicated that the quality of groundwater sampled is poor. It is concluded that the water required further treatment before consumption. It is further recommended that domestic waste, industrial effluents, landfill leachates and septic tanks that contribute to the contamination of groundwater should be properly control and manage in order to safeguard the quality of groundwater for human consumption.

Keywords: Physico-chemical, Heavy metals, Suitability assessment, DWQI, Nasarawa area, Kano state.

1.0 INTRODUCTION

Groundwater is the main sources of drinking water in many countries, particularly in arid and semi-arid regions where limited rainfall was received annually with insufficient surface water. Groundwater quality has become a major concern today (Li *et al.*, 2014; Shuaibu, *et al.*, 2017). However, global climate change, anthropogenic activities, and poor groundwater management have resulted in decreased groundwater quantity and degraded groundwater quality (Giri and Singh 2015; He *et al.*, 2016). Shuaibu, *et al.*, (2020) reported that groundwater source can potentially contain several naturally occurring chemical elements, many of which are not tested routinely as indices of water quality. The natural chemical quality of groundwater is generally good, but excess concentration of various chemical constituents such as arsenic, manganese, iron, and other toxic elements contaminate groundwater (Hasan and Ali, 2010; Wu and Sun 2016).

Over the years, the importance and use of groundwater has increased significantly in many urban centers of developing nations. The quality of groundwater has gained serious attention due to rapid urbanization, unplanned land-use practices, industrialization, population increase and intensive agricultural activities pose an increased risk of contamination in groundwater resources (Liu *et al.*, 2016; Etikala *et al.*, 2019). However, availability of quality water in sufficient quantities for human consumption, agricultural and industrial activities is key to the development of many nations. Most of the developing countries of the world today is challenged with the problem of providing adequate quality water to meet the demand of its populace. WHO, (2008). Taiwo *et al.*, (2011) documented that, large portions of the populace in developing countries die annually as a result of water borne diseases such as cholera, typhoid, hepatitis, diarrhea, etc. In Africa, the World Health Organization (WHO) estimated that the health sector would save more than US\$11 billion in

treatment cost if access to basic water and sanitation services were improved. People would gain 5.5 billion productive days each year due to reduced diarrhoeal disease (Aladejana and Talabi, 2013).

Therefore, the assessment of the suitability of groundwater for a number of purposes such as domestic, drinking, irrigation and industrial activities is not only essential but is frequently undertaken all over the world to determine the concentrations of some important parameters using appropriate WHO and national agencies guidelines (Srinivasarmoothy *et al.*, 2009; Shemishere, *et al.*, 2019). This is because evaluation of water quality prior to its use will help in freeing from water borne diseases and other attendant problems associated with impaired water (Obeta and Ocheje, 2013). The world health organization reported that the single major factor adversely influencing the general health and life expectancy of a population of many developing countries is ready access to portable drinking water. Report from UNDP 2006 also indicated that, about 1.2 billion people lack access to safe drinking water globally (Ajewole, 2005; Oyekale and Ogunsanya, 2012). Oyekale and Ogunsanya, (2012) also documented that Nigeria ranks amongst the countries with the lowest level of portable water supply in the world despite being signatory to the International Water Decade (1981-1990). While Dada and Ntukekpo (1997) documented that, 80% of all diseases and 30% of death are related to drinking water in most developing countries of the world.

As a result of unavailability or inadequate quality of surface water, demand for groundwater resources has increased over the years for drinking purposes particularly in many urban centers including Kano metropolis. It is therefore imperative to assess the quality of groundwater in order to ascertain its suitability for drinking

purposes and recommend remediation if necessary for sustainable management. With the above literature, this study is aim at assessing the level of groundwater quality and its suitability for drinking purposes in some part of Nasarawa local government area of Kano state Nigeria.

2.0 MATERIALS AND METHODS

2.1 Description of study area

Nasarawa local government area of Kano state is the study area. It is found within Kano metropolis. It lies between 11°58'37''N to 8°33'45''E and 11°97'69''N to 8°56'25''E (Fig.1), covering a geographical area of about 34 Sq. Km. This area is characterized by wet and dry climatic type with dry season relatively longer than the wet season, with a mean annual temperature of 28°C. The warmest period of the year is from April to June, when the maximum temperature recorded is 38-39°C. December and January are usually recorded as the month of cooler period. Rainfall in the study area is characterized by irregularities in time and space and does not exceed 600 mm/year and the highest rainfall period was recorded in the month of July, August and September (Olofin, 2014). The relative humidity is higher during the wet season to about 80% and lower during the dry season about 20% (Mustapha and Aris 2012a).

Geologically, the study area is underlain by a crystalline basement complex of pre-Cambrian origin which loses its identity by disappearing into the Chad Formation. The basement complex consists of granite rocks, which are generally gneissic and commonly developed in a mixture of pegmatite of schist granite, gneiss, and irregular masses of pegmatite. Aeolian sand derived from wind deposits covers most part of the area (Tasi'u, 2019). The area is covered by Sudan savannah vegetation type. The natural vegetation in this area has been modified as a result of several centuries of human activities such as urban construction.

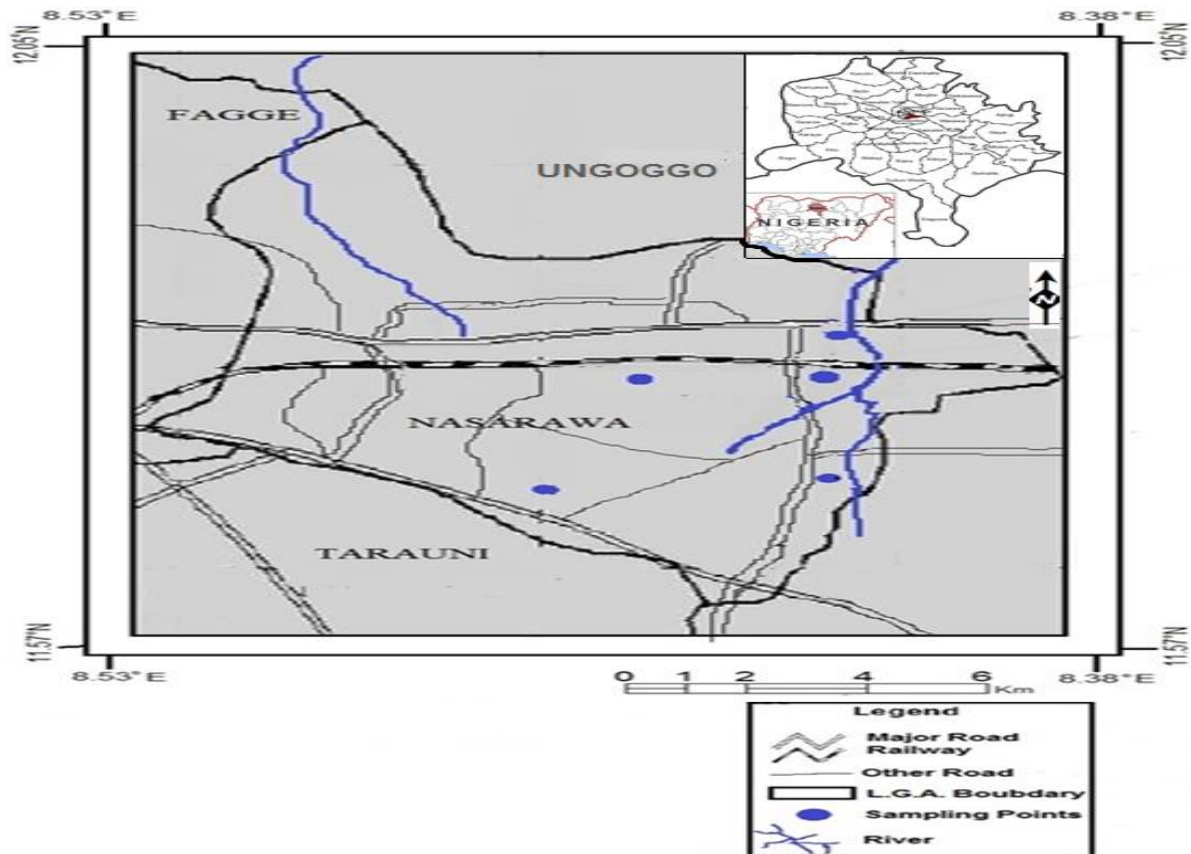


Fig. 1: Map of Nasarawa local government showing study area

2.2 Groundwater Samples collection and laboratory analysis

Water samples were taken from five (5) functional boreholes of drinking water supply system in the study area (Table 1). All samples were collected in two litre polyethylene containers. The bottles were rinsed with distilled water and nitric acid prior to sample collection. Along with sampling, the water was allowed to flow for two to three minutes and then sampling bottles were slowly filled. The water samples were analyzed for various physicochemical and heavy metals parameters using standards method recommended by APHA (2012) including, pH, electrical conductivity,

temperature, total dissolve solids, chloride, total hardness, zinc, cadmium, chromium, manganese, lead, magnesium, iron and copper. The samples were labeled, stored and transported to laboratory. pH and electrical conductivity (EC) were measured by using pH and EC meter (pH 3505 and EC 4510 Janway), temperature were measured using glass thermometer, total dissolved solids (TDS) was calculated using equation: $TDS = 0.55 \text{ } \rho + 0.75 \text{ } (EC)$. Chloride and total hardness was analyzed using titrimetric method. Heavy metal concentrations were analyzed using atomic absorption spectrophotometer AAS BRAND MODEL:BUCK SCIENTIFIC/VGP210

Table 1: The coordinates of sampling stations.

Stations	Location/Area	Latitude	Longitude
BH1	Wurro Bagga	11°59'57.19N	08°35'28.21E
BH2	Badawa	12°00'05.19N	08°34'34.28E
BH3	Kawon maigari	11°58'53.65N	08°34'16.61E
BH4	Ring road bypass	12°00'18.91N	08°35'13.36E
BH5	Bakin tashar 'yankaba	12°00'37.47N	08°35'31.52E

2.3 Drinking Water Quality Index (DWQI)

DWQI has widely been used by several researchers to evaluate the groundwater quality for drinking

purposes in various regions of the world (Ramakrishnaiah *et al.*, 2009). The under listed steps were followed to estimate the DWQI:

Step 1: Each parameters was assigned with a weight (w_i) according to its relative impact on the overall quality of water for drinking purpose. The maximum weight of 5 was assigned to Iron and manganese due to its toxicity to human health and its importance in water quality assessment. The least weight of 1 was given to Hardness, as it has less harmful effect to human health (WHO, 2017). *Step 2:* Weight of each parameter (w_i) was divided by the sum of weight of n parameters to compute the relative weights (W_i) through the equation

$$W_i = \frac{w_i}{\sum_{i=1}^n w_i} \quad (1)$$

where “ W_i ” is the relative weight, “ w_i ” is the weight of each parameter and “ n ” is the number of parameters (Table 2).

Step 3: Quality rating scale (Q_i) for each parameter is derived by its concentration in each water samples by its respective standard according to the

WHO guidelines and then multiplied by 100. The equation of Q_i is given below as:

$$Q_i = \frac{C_i}{S_i} \times 100 \quad (2)$$

where C_i is the concentration of each groundwater quality parameter, Q_i is the quality rating, S_i is the recommended guideline value for each chemical parameter.

Step 4: Sub-index (S_{li}), and DWQI: sub-index (S_{li}) and DWQI were computed by the following equations:

$$S_{li} = W_i \times Q_i \quad (3)$$

$$DWQI = \sum S_{li} \quad (4)$$

According to Ramakrishnaiah *et al.*, (2009) DWQI values were categorized into five classes: excellent (<50), good (50–100), poor (101–200), very poor (201–300) and unsuitable (>300) for drinking purpose.

Table 2: Relative weights of groundwater quality parameters, used for computation of drinking water quality index (DWQI).

Parameters	Units	NSDWQ	Weight (w_i)	Relative weight (W_i) = $w_i / \sum_{i=1}^n w_i$
pH	/	7.0-8.5	3	0.073
TDS	mg/l	1500	5	0.122
Cl	mg/l	600	3	0.073
TH	mg/l	500	2	0.048
Pb	mg/l	0.1	4	0.098
Zn	mg/l	3	3	0.073
Cd	mg/l	0.03	4	0.098
Cr	mg/l	0.05	4	0.098
Mg	mg/l	0.5-50	3	0.073
Cu	mg/l	1.0	3	0.073
Fe	mg/l	0.5	3	0.073
Mn	mg/l	0.2	4	0.098
			$\sum w_i = 41$	$\sum W_i = 1$

2.4 Statistical Analyses

The data were statistically analyzed using mean, standard deviation, statistical package SPSS 20.0 were used in the analysis. Furthermore, results were compared with the drinking water standards established by regulatory bodies such as World Health Organization (WHO, 2011) and Nigeria Standard for Drinking Water Quality (NSDWQ, 2007) to understand the suitability for drinking purpose in the study area.

3.0 RESULTS AND DISCUSSION

3.1 Physicochemical Characteristics of Groundwater

The physicochemical parameters are very important because they have a significant effect on the quality of water. Some of the physico-chemical parameters of groundwater samples were analyzed and its descriptive statistics (minimum, maximum, mean and standard deviation) are shown in Table 3.

3.1.2 pH, EC and T⁰

pH is a term widely used to express the intensity of the acid or alkaline condition of a solution. The pH values of groundwater samples vary from 6.8 to 7.3 with a mean of 7.06 mg/l, indicating a neutral to alkaline water. As per the drinking water standards (NSDWQ 2007 & WHO, 2017), the maximum permissible limit for pH concentration in water is

8.50. Therefore among all groundwater samples, it indicate pH concentration are within the permissible limit (Table 3). This study is coincide with the findings of Abdalbaki, *et al.*, (2014). EC denotes the conducting capacity of water. EC is a measure of total dissolved solids (TDS) i.e., it depends upon the ionic strength of the solution. Increase in the concentration of dissolved solids increases the ionic strength of the solution. EC values range from 476 to 945 mg/l with the mean of 778.6 mg/l. The increase in TDS and EC increases the corrosive nature of water. Unusual taste, odour and feel problems usually due to total dissolved solids and higher EC indicate the presence of dissolved minerals (WHO 2011). The EC value is found below the permissible limits set by NSDWQ (2007) and WHO (2017). This is in line with the findings of Nahannu, *et al.*, (2017). T⁰ range from 26.8⁰ to 27.6⁰ with mean value of 27.3⁰. T⁰ also fall within acceptable limit set by the NSDWQ (2007) and WHO (2017). Shawai, *et al.*, (2019) reported a similar result in Kumbotso area Kano metropolis.

3.1.1 Chloride, TDS & TH

Chloride in groundwater is generally considered as index of pollution particularly when the concentration is high. It is usually makes the water

taste salty (Marghade *et al.*, 2012; Adimalla and Taloor, 2020). The Cl⁻ concentration in groundwater samples ranges from 74.55 to 221.8 mg/l with the mean value of 151.57mg/l. However, the mean concentration of Cl⁻ is below the maximum permissible limit set by NSDWQ (2007) and WHO (2017). This result collaborate with the finding of Shawai, *et al.*, (2019). TDS is an important parameter in drinking water. In the study area, TDS values varied from 265 mg/l to 498 mg/l with a mean value of 402.20 mg/l which is within the acceptable limit recommended by NSDWQ (2007) and WHO (2017). This is in line with the findings of Nahannu, *et al.*, (2017). Total hardness of groundwater is caused by compounds of calcium and magnesium, and by a variety of other metals (Alaya *et al.*, 2014). Intake of higher concentration of total hardness may lead to health hazards such as kidney problems and the formation of kidney stones. Therefore, determining the TH content in the drinking water is most important which can help to ascertain its suitability for drinking purposes, In this study, the concentration of TH is in the range of 73 mg/l to 157 mg/L with a mean of 120.8 mg/l. This value of TH is found within the standard permissible limit for drinking water. This is contrary to the findings of Sa'eed and Mahmud, (2014).

Table 3: Descriptive statistics of some physico-chemical parameters of groundwater samples in the study area alongside with WHO 2017 & NSDWQ 2007 approved standards for drinking water.

Samples	PH	EC (μS/cm)	TEMP (°C)	TDS (mg/l)	CL (mg/l)	TH (mg/l)
BHI	6.8	476	26.8	265	177.5	142
BH2	7.1	826	27.4	498	177.5	94
BH3	7.0	719	27.3	339	221.8	157
BH4	7.1	927	27.6	434	106.5	138
BH5	7.3	945	27.3	475	74.55	73
Min	6.8	476	26.8	265	74.6	73
Max	7.3	945	27.6	498	221.8	157
Mean	7.06	778.60	27.3	402.20	151.57	120.8
St. Dev	0.18	191.75	0.30	97.86	59.69	35.56
NSDWQ	6.5-8.5	1000	-	500	250	200
WHO	7.0-8.5	1500	30-35°C	1500	600	500

St. Dev = Standard deviation, NSDWQ = Nigerian Standard for Drinking Water Quality, WHO = World Health Organization.

3.2 Heavy Metals Concentration In Groundwater

The analytical results of heavy metals of groundwater samples were compared with the drinking water standards recommended by (NSDWQ 2007, & WHO 2006). The summary

statistics of the heavy metals of the collected samples are presented in Table 4. From the result (Table 4), it was observed that the Zn, Cu, Fe and Mn concentration fall within the maximum permissible limit recommended by WHO 2011, with mean value of 0.108±0.056, 0.254±0.119,

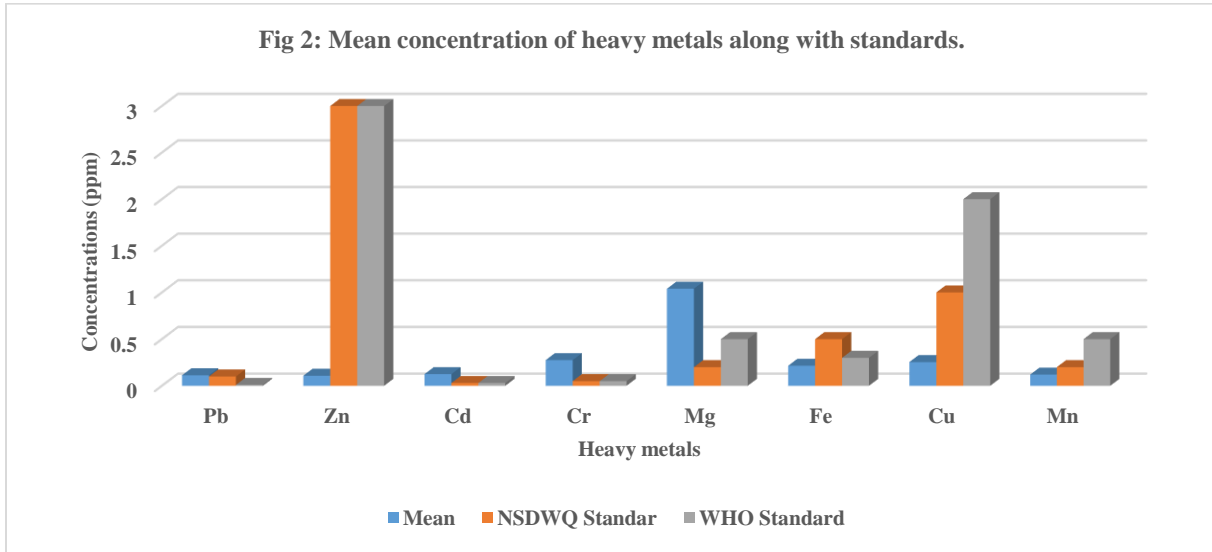
0.215±0.103 and 0.12±0.06. Based on this results, the groundwater sample is suitable for drinking purpose. The low values of these parameters therefore indicate that the high water table in the study area (0.5 to 5 m) is within the zone of aeration where these elements are insoluble. The low level of concentration of heavy metals in groundwater correlates well with its acidic to alkaline nature. Under such condition, metals are insoluble and tend to deposit in the solid phase. This is particularly true of Fe and Mn which are deposited as hydrous ferric and manganese oxides respectively. These oxides have large adsorption capacity for metal ions thereby decreasing the mobility of heavy metals and enhancing their concentration in the soil. (Tse and Adamu, 2012 cited in Hems, 1985). This result is in line with the similar findings of Kantoma, *et al.*, (2017).

On the other hand, Pb, Cd, Cr and Mg exceeded the stipulated limit for drinking water set by WHO 2011 with the mean value of 0.113±0.066, 0.125±0.050, 0.275±0.163 and 1.04±0.38 respectively. The high concentration of Pb, Cd, Cr and Mg in the groundwater samples could be attributed to the anthropogenic sources within the area such as domestic and Bampai industrial effluents, landfill leachates, and septic tank discharge. Therefore, based on these results, the water is unfit for drinking. Presence of these heavy metals in groundwater can cause a serious negative effect on human health such as anemia, blood pressure, headaches, nerve damage, abdominal pain, kidney disease, obstructive lung diseases, bone defects (ostemalacia or osteoporosis), convulsions, dermatitis and diathasis. This is in contrary with the findings of Tukura, *et al.*, (2014).

Table 4: Summary statistics of heavy metals concentration in groundwater samples.

Sample location	Parameters (ppm)							
	Pb	Zn	Cd	Cr	Mg	Fe	Cu	Mn
BH1	0.043	0.129	0.1	0.375	1.0	0.185	0.272	0.1
BH2	0.174	0.065	0.1	0.25	0.6	0.111	0.181	0.05
BH3	0.174	0.097	0.2	0.125	1.2	0.148	0.363	0.15
BH4	0.043	0.055	ND	0.125	0.8	0.370	0.090	0.1
BH5	0.130	0.194	0.1	0.5	1.6	0.259	0.363	0.2
Min	0.043	0.055	0.1	0.13	0.6	0.111	0.090	0.05
Max	0.174	0.194	0.2	0.50	1.6	0.370	0.363	0.2
Mean	0.113	0.108	0.125	0.275	1.04	0.215	0.254	0.12
St. Dev	0.066	0.056	0.050	0.163	0.38	0.103	0.119	0.06
NSDWQ	0.1	3.0	0.03	0.05	0.2	0.5-50	1.0	0.20
WHO	0.01	3.0	0.03	0.05	0.5	0.3	2.0	0.5

BH = Borehole, St. Dev = Standard deviation, NSDWQ = Nigerian Standard for Drinking Water Quality, WHO = World Health Organization.



3.3 Groundwater Suitability for Drinking Purpose

To assess the suitability of groundwater for drinking purpose, the analytical results (Table 3 & 4) have been compared with standard guideline values recommended by the Nigerian standard for drinking water quality (NSDWQ 2007) and World health organization (WHO, 2006). Water for drinking purposes should be colorless, odorless, clear and free from excessive dissolved solids as well as harmful organism. It has high standards of physical, chemical and microbiological purity. Generally, water for potable uses should have good quality. But chemicals in drinking water which toxic may cause a severe effect on human health (Atta, *et al.*, 2018). By comparing the analyzed

groundwater samples with recommended values for drinking water set by WHO 2006, pH, EC, temperature, total dissolved solids and total hardness mean values are all fall within stipulated limit recommended by WHO 2006 (Table 3). Based on these results, the groundwater samples in this study is suitable for drinking purpose.

However, the concentration of heavy metals such as Zn, Cu, Fe and Mn are found within permissible limits set by WHO 2011. Therefore, the water can be used for human consumption. While Pb, Cd, Cr and Mg concentrations are found above the permissible limits for drinking water established by WHO 2011 (Table 4). Therefore, these excess concentration of elements should be remove before used for drinking.

Table 5: Calculated drinking water quality index for the study area

Parameters	Observed value (Mi)	Standard value (Si)	Relative weight (Wi)	Sub-index (Qi)	Sli
pH	7.06	7.0-8.5	0.073	100.86	7.36
EC	778.60	1500	0.122	51.91	6.33
TDS	402.20	1500	0.073	26.81	1.96
Cl ⁻	151.57	600	0.048	25.26	1.21
TH	120.8	500	0.098	24.16	2.37
Pb	0.113	0.05	0.073	1130	16.50
Zn	0.108	3.0	0.098	3.6	0.35
Cd	0.125	0.05	0.098	416.7	39.59
Cr	0.275	0.5-5.0	0.073	550	39.05
Mg	1.04	1.0	0.073	5.2	0.37
Fe	0.215	0.5	0.073	43	3.05
Cu	0.254	0.2	0.098	25.4	2.41
Mn	0.12	6.5-8.5	0.073	60	4.26
$\sum Sli = 124.81$					

CONCLUSION

From the result obtained, it can be concluded that all studied parameters were found within the limit for drinking water set by the national and international standards except Pb, Cd, Cr and Mg concentrations which were found above the permissible limit set by NSDWQ, 2007 and WHO, 2017 guidelines for drinking water. Based on the DWQI assessment, the quality of water is poor. The groundwater sampled from the study site is therefore slightly contaminated. It is recommended that further treatment of groundwater in the area should undertake before use. Proper control and management of domestic and industrial effluents, landfill leachates and septic tanks are highly important in order to maintain low levels of these parameters.

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