SPATIO-TEMPORAL GROUNDWATER VARIABILITY OF PHYSICOCHEMICAL PARAMETERS OF MINNA AND ENVIRONS, NIGER STATE, NIGERIA

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Abstract

Spatio-temporal groundwater variability of physicochemical parameters was investigated in Minna and Environs. The Study analysed selected physicochemical parameters of hand dug well water. Mixed methods approach of quantitative and qualitative research methods were adopted. A total of twenty four water samples were collected from twelve wells for both rainy (October, 2018) and dry (March, 2019) seasons from four locations and taken to the laboratory for the physicochemical analysis in order to determine the level of chemical concentration and the results were compared with NSDWQ (2007) and WHO (2011) standards. The physicochemical: colour, odour, pH, Turbidity, electrical Conductivity, Total Dissolved Solid, Chloride^{-}, sulphate, Nitrate, Alkalinity, Total Hardness and Total Suspended Solid were determined using standard laboratory testing methods. Statistical analyses was conducted using one way ANOVA and Duncan PostHoc via SPSS package version 23. The results indicates that all the physicochemical parameters analysed were within the NSDWQ and WHO recommended standards for both rainy and dry seasons excepts colour, odour Cl^- and TH which exceeded the permissible limits. Just one sample and four samples during the rainy and dry seasons were recorded brown and slightly brownish respectively. Odour was detected in two samples only in the rainy season. The TH was significantly ($p<0.05$) highest in MK (626.67±174.58 mg/l) and MT (540.00±255.02) during dry season than the rainy season exceeding the NSDWQ (2007) and WHO (2011) limits of 150 mg/l and 500 mg/l respectively. While Cl^- were significantly highest in MK (389.95±48.39 mg/l) and MR (291.88±49.35 mg/l) exceeding the permissible limit of 250 mg/l given by NSDWQ and WHO respectively. The study therefore reveals that the physicochemical parameters of the well water samples in MK, MR, CH and MT are generally suitable for drinking and for domestic purposes. The hardness of the water should be soften for domestic purposes through the use of Soda and simple home white vinegar to neutralise excess calcium.

***Keywords**: Hand dug wells; Spatio-temporal; Groundwater Variability; Minna and environs; Physicochemical*

Introduction

Before the existence of boreholes and hand-dug wells, rainfall, streams, ponds, and rivers were the major sources of drinking water to the people of Nigeria. In contemporary Nigeria, such boreholes and pipe born water can be access in some areas as a result of development. Lack of rapid development, economic capabilities and high population rate, the boreholes and pipe born water is either not adequate or not affordable to common man. Therefore, the common man had to resort to digging wells as the only alternative source of water for drinking and for daily domestic and commercial purposes (Bremer and Harter, 2012). However, 52% of Nigerians cannot access improved water supply for drinking (Orebiyi *et al*., 2010). Groundwater is seen as the most essential and valuable natural resources, expected to be free from contamination. However, this water resource is often contaminated by numerous ways (Ponniah, Chandrasekar and Saravanan, 2012). Groundwater gets contaminated with various contaminants produced from diverse sources such as agriculture, industrial and domestic. The abundance of this significant natural resource has been taken for granted increased use of ground water and contaminate generated has crossed the limits of sustainability in many parts, due to rapid change in land use form. Population growth has led to marvellous increase in demand for fresh water due to extreme agricultural activities. With rapid growth in population and industry, quality of groundwater become vulnerable by disposal of municipal and industrial solid waste (Raju, Shukla, and Ram, 2011). However, the suitability of water for various uses depends on the biological, physico-chemical and radiological properties of water (Ondor and Addo, 2013).

Groundwater pollution take place when wastewater is reverted to the hydrological cycle. Severe application of fertilizers, agrochemicals, sewage/drain water and mining activities on major lineaments are observed to be a serious threat to groundwater quality (Azadeh and Basavarajappa, 2009). Related water diseases are accountable for 80% of different sickness in the developing countries and eradicate more than 5 million persons every year (United Nations Educational Scientific and Cultural Organization (UNESCO, 2007). The major drinking water sources, principally in African countries are from pipe borne, boreholes, deep and shallow wells, dug outs, streams and rivers which are mostly of poor quality. Water quality is an increasing concern all over the developing world and this has both public health and socio-economic consequences (United Nations International Children's Emergency Fund (UNICEF, 2013).

Groundwater susceptibility to contamination is the tendency and possibility for all form of contaminants to get to the water table after introduction at the ground surface (Sniffer, 2004). The groundwater generated by a well or the one confined within an aquifer of any geographical area has some susceptibility to contamination from anthropogenic activities. Accessing good quality drinking water in Minna and other parts of Niger State is one of the biggest challenges to many households which have, for years, depended on other sources of water to augment the erratic supply made by the government (Ndamitso *et al*., 2013). Hence the need to know the Contamination status of groundwater from the study area. This study aim at investigating the spatio-temporal Groundwater variability of physicochemical parameters of Minna and environs and to analyse the physicochemical properties of the sampled hand dug well waters.

Materials and Methods

Study Area

The Study areas are Maitumbi (MB), Maikunkele (MK), Chanchaga (CH) and Morris (MR) found in Bosso and Chanchaga Local Government areas located in Niger state. The state lies between Longitude 3˚30' and 7˚20'E and Latitude 8˚22' and 11˚30'N of Guinea Savanna vegetation zone in the north central part of Nigeria which also fall within the middle belt of Nigeria (Ayinde, Ojehomon, Daramola and Falaki, 2013).

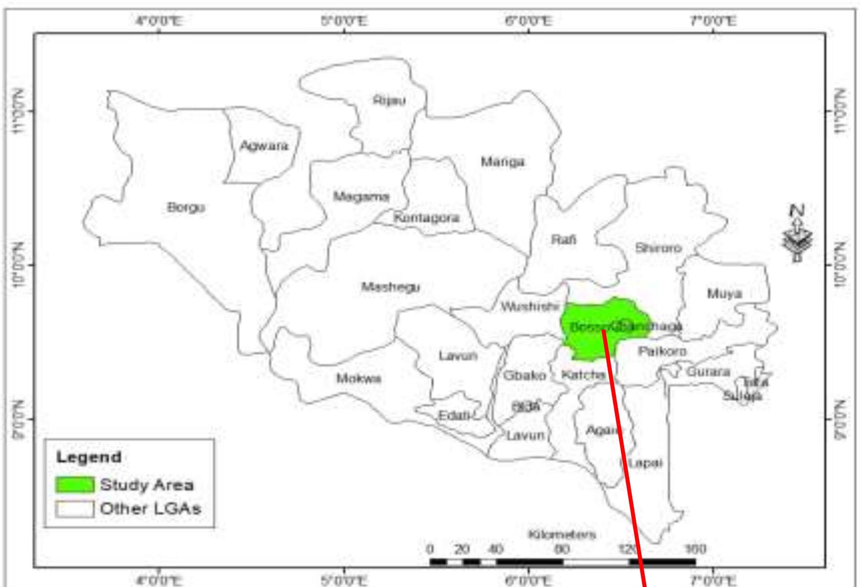

Figure 1. Map of the study Area

Figure 2. Sample collection points

Source: Remote Sensing and GIS Laboratory, FUTminna, 2019.

The study area is characterised by distinct rainy and dry seasons with annual rainfall ranging from 1,100mm in the northern parts to 1,600mm in the southern parts. The maximum temperature recorded is usually not more than 94^{o}C between March and June, while the minimum is normally between December and January. The rainy seasons last for about one hundred and twenty (120) days in the southern parts to about one hundred and fifty (150) days in the northern parts of the State.

Sample Collection

Fresh samples of groundwater were collected from the randomly selected wells that are not less than 100m apart, using passive sampling (zero purge) method. The Garmin GPS 76Xc model were used to locate the wells on the study area Map by taking the latitude and longitude position of each well that was chosen. The samples were collected in October 2018 for rainy season and March 2019 at the peak of the dry season when most of the wells were at their lowest levels. All the sampling containers were washed with distilled water and then washed again with the target water before sampling. The fresh samples of groundwater were collected manually in a clean 1 L plastic container from Maitumbi (MB), Maikunkele (MK), Chanchaga (CH) and Morris (MR). Transparent polythene were placed on each of the containers with a tight fitting lid to make them air tight. Three (3) samples were randomly collected from each of the selected study areas making it 12 samples during the rainy season and 12 samples during the dry season. Therefore, a total of 24 samples were collected from the selected study areas. The containers were labelled accordingly and stored in the plastic coolers (Ice chest) filled with Ice cubes and transported immediately for physicochemical laboratory analyses and the results compared with Nigerian Standard for Drinking Water Quality (NSDWQ, 2007) and World Health Organization (WHO, 2011).

Physicochemical Analysis

The twenty four water samples collected from twelve hand dug well water were analysed for fourteen physicochemical parameters: colour, odour, pH, Temperature, Turbidity, Electrical Conductivity (EC), Total Dissolved Solid (TDS), Chloride (Cl^-), Sulphate (SO_4), Nitrate (NO_3), Acidity, Alkalinity, Total Hardness (TH) and Total Suspended Solids (TSS). Parameters that changes rapidly were measured in situ using standard field equipment. These parameters included pH, Temperature, Turbidity, EC, TDS. The instruments used for the physicochemical analysis include HANNA pH/^{0}C meter - HI 2211; HANNA instrument EC/TDS Meter - HI8033; Turbidity using HANNA instruments portable Turbidity meter - HI93703; JENWAY 6305 Spectrophotometer was used to determine NO^3 and Titration was used to determine Chloride and total hardness.

Statistical Analysis

The physicochemical results from the laboratory were generated in triplicates and analysed statistically using Statistical Package for Social Scientist (SPSS) Version 23 and Microsoft Excel 2013. One way analysis of variance (ANOVA) with Duncan POSTHOC analysis was used to show the level of significant difference between variables at ($p<0.05$) and independent t-test was used to analyse and compare the difference between rainy and dry seasons. Results of the study were represented using table

Result and Discussion

The mean values of the physicochemical parameters of hand dug well for dry and rainy seasons and their comparison with NSDWQ (2007) and WHO (2011) standards for drinking water are presented in Table 1 which showed the seasonal changes of the physicochemical parameters of water samples within each location of MK, MR, CH and MT.

According to the result obtained from the laboratory, none of the samples had any objectionable colour or odour during the rainy seasons except one (8.3%) of samples collected from MR during the rainy season were brownish in appearance and two (16.6%) of samples collected from (MK and MR) and (MK and MT) during the dry season were brownish and slightly brownish respectively, this indicates that there was higher percentage of colouration obtained during the dry season than the rainy season. These might be due to the existence of coloured organic matter (primarily humic and fulvic acids) combined with the humus fraction of soil in the sampled locations. The colouration could also strongly be caused by the presence of iron and other metals, either as natural impurities or as corrosion products (Amadi et al., 2012). Health-based guideline value is not given for colour in drinking-water. (WHO, 2011).

Odour was detected in two (16.6%) of water samples collected from MR and CH during the rainy season and no odour was detected during the dry season. The odour presence in drinking water should be unobjectionable according to NSDWQ and WHO drinking water standard. The odour in the said water sample might be due to the presence of organic substance or increased microbial activity in the well water. Usually, the taste buds in the oral cavity senses the inorganic compounds of metals (magnesium, calcium, sodium, copper, iron, and zinc). Water is expected to be free of objectionable odour, hence, it should not be offensive to the common consumers (WHO, 2011).

From the result in Table 1, the pH from MK, MR, and CH well water samples were observed to be significantly ($p>0.05$) indifferent for both rainy and dry seasons respectively except for MT which is significantly ($p<0.05$) higher in the dry season with a mean value of 7.29±0.17 compared to its rainy season with the value of 6.52±0.09.

The pH mean values all fall within the NSDWQ and WHO recommended permissible values of 6.5-8.5 and 6.5-8.5 respectively. The pH values of the present study consequently does not lead to the dissolution of heavy metals in the study area. This studies is in agreement with the findings of Amadi et al. (2015) who evaluated Groundwater Quality in Shallow Aquifers in Minna, Nigeria. The authors observed that pH mean values was 7.8 and is within the WHO (2006) acceptable values of 6.5-8.5. pH is an important parameter in drinking water as it helps in determining the corrosivity of water (WHO, 2007). It is an important parameter in evaluating the acid–base balance of water and also an indicator of acidic or alkaline state of water status. (Meride and Ayenew 2016). The pH values found in water samples does not have any health implication (NSDWQ, 2007).

Table 1 Seasonal Variability of Physicochemical Parameters of Minna and Environs

WHO LIMIT		**6.5-8.5**	**-**	**5 NTU**	**750 µS/cm**	**1000 mg/l**	**250mg/l**	**250 mg/l**	**50mg/l**	**-**	**300mg/l**	**500mg/l**	**-**
NSDWQ MAXIMUM LIMIT		6.5-8.5	Ambient	<5 NTU	1000µS/cm	<500mg/l	<250mg/l	<100 mg/l	<50 mg/l	-	-	<150mg/l	<500 mg/l
MT	DRY	7.29±0.17^{b}	25±2.05^{a}	2.10±2.10^{a}	336.67±112.60^{a}	227.80±74.61^{a}	206.79±15.63^{b}	15.66±5.17^{a}	2.62±1.50^{a}	92.82±15.88^{a}	211.19±25.73^{a}	540.00±255.02^{a}	1.50±0.58^{a}
	RAINY	6.52±0.09^{a}	21.70±2.35^{a}	0.70±0.70^{a}	236.67±29.63^{a}	158.57±19.85^{a}	80.11±10.77^{a}	9.99±0.31^{a}	11.54±0.45^{b}	95.00±22.91^{a}	202.07±11.52^{a}	280.98±106.81^{a}	2.57±1.22^{a}
CH	DRY	6.98±0.30^{a}	25.47±0.44^{a}	0.00±0.00a	133.33±23.33^{a}	89.33±15.63^{a}	115.81±38.42^{a}	8.60±2.31^{a}	28.83±7.14^{a}	78.15±17.44^{a}	187.00±77.89^{a}	156.67±47.02^{a}	2.70±0.40^{b}

	RAINY	6.90±0.14^a	13.20±4.05^a	0.00±0.00^a	230.00±43.59^a	154.10±29.20^a	42.13±3.27^a	0.64±0.08^a	7.99±0.21^a	46.67±10.93^a	183.67±75.27^a	87.13±14.12^a	0.83±0.44^a
MR	DRY	7.40±0.10^a	22.73±1.37^a	3.65±3.15^a	386.67±74.24^a	259.07±49.74^a	291.88±49.35^a	16.02±1.31^a	26.12±4.58^a	104.27±36.71^a	149.76±63.03^a	360.00±98.25^a	2.96±1.51^a
	RAINY	6.64±0.0.54^a	15.77±5.38^a	1.30±1.30^a	496.67±201.69^a	332.77±135.13^a	154.10±21.80^a	12.59±0.70^a	7.33±0.70^a	63.07±29.69^a	75.13±12.59^a	355.70±98.25^a	3.53±1.51^a
MK	Dry	7.67±0.18^a	22.87±1.27^a	2.31±1.65^a	533.67±13.33^a	359.57±8.93^a	389.95±48.39^a	3.28±0.82^a	18.8±2.32^a	81.89±21.22^a	249.25±19.13^a	626.67±174.58^a	2.37±0.62^a
	Rainy	7.13±0.23^a	14.2±4.97^a	0.00±0.00^a	366.67±24.04^b	245.67±16.10^b	87.37±19.25^b	6.21±0.13^a	6.39±0.10^a	80±21.79^a	241.25±35.20^a	71.77±18.57^b	3.67±2.19^a
PARAMETERS		pH	Temperature	Turbidity	E. conductivity	TDS	Cl^-	SO^4	NO_3	Acidity	Alkalinity	TH	TSS

Values are represented as mean± SEM of triplicate determinations. Values with different superscript between two seasons for each location are significantly different (p>0.05) while superscript that are similar across the row shows no significant difference at (p>0.05). Where MK= Maikunkele, MR= Morris, CH= Chanchaga, MT= Maitumbi, NSDWQ= Nigerian Standard for Drinking Water Quality, WHO= World Health Organization

Source: Author's Field Compilation (2018/2019)

The Temperature values obtained from the four locations had no significant difference during both rainy and dry seasons (Table 1) and where found to be within the ambient range in temperature giving by NSDWQ and WHO (2011) temperature limit was not given. These findings does not agree with the results of Ojutiku, Ibrahim and Raymond (2014) who Assessed water quality parameters and trace metal contents of drinking water sources in Minna Metropolis, reported that there were variation in the mean values of the temperatures obtained in various areas but were significantly different in temperatures and associated it to the weather of the study areas at that specific period. The variation of the present study may be that the seasons probably did not have any profound effect on temperature regardless of different timing in sample collection. Temperature is useful in assessing the quality of drinking water as it influences the overall quality of water (physicochemical and biological characteristics) including the rate of chemical reactions in the water body, decrease in the solubility of gases and improving the tastes and colours of water (Palamuleni and Akoth, 2015).

Turbidity values obtained from the study areas had no significant ($p>0.05$) difference between the two seasons of rainy and dry seasons. However the highest mean value of 3.65±3.15 NTU was recorded during the dry season for MR and was found below the recommended NSDWQ and WHO limits of 5 NTU (Table 1). Turbidity should ideally be lower than 5 NTU, since the appearance of drinking water with a turbidity of less than this value is normally acceptable to consumers. Turbidity may be seen as the level of transparency in water. It does not have a health based guideline (WHO, 2011). Amadi et al. (2015) who evaluated groundwater quality in shallow aquifers in Minna, reported a mean value of 3.8 NTU and added that turbidity values in some area were recorded higher than the recommended values of 5.0 NTU. The author's finding is not in agreement with the present studies. However, the low values in NTU in the study may be due to some of these wells had fairly well head cover thereby prevented suspended particles and other contaminants to enter into the wells from the surface or through leaching as observed (Mishra, Mudgal, Khan, Padmakaran and Chakradhar 2009).

EC is the ability of water to let electric current pass through it. It is written as micro mhos per centimeter (μ mhos/cm) (Srinivas, Pradeep, Srinivasa and Hemalatha, 2011). When water is clean it does not conduct electricity and therefore conductivity of water is a function of ionic elements existing in that particular water (Amadi, *et al.*, 2013).

EC were not significantly ($p>0.05$) different between the two seasons of rainy and dry seasons for all sampled locations. However, it is significantly higher with the mean values of 533.67±13.33 μS/cm during the dry season than the rainy season in well water samples collected from MK as indicated in Table 1. This value is found below the recommended standards of 1000 and 750 μS/cm giving by NSDWQ and WHO respectively. However, these studies is in disagreement with the findings of Amadi et al. (2015) who evaluated Groundwater Quality in Shallow Aquifers in Minna, North-Central Nigeria. The authors observed that the EC ranged between 126 μS/cm to 600 μS/cm with a mean value of 169.4 μS/cm. The variation observed in this present study may be due to different water sampled analysed or increased in the amount of dissolved solids in water samples obtained during the dry seasons in MK which could determine the increase in EC in the study area in Table 4.1, as the TDS increases during the dry season. These results however indicates clearly that well water in the study area was not considerably ionized and has the lower level of ionic concentration activity due to small dissolve solids.

The TDS were significantly ($p>0.05$) not different between the two seasons of rainy and dry seasons for all sampled locations. However, TDS is significantly higher having 359.57±8.93 mg/l during the dry season than the rainy season in MK (Table 1). The values where found below the standard limit of 500 and 1000 mg/l set by both NSDWQ (2007) and WHO (2011) respectively. These result is similar to the findings of Nazir et al. (2016) who classified drinking water quality index and identification of significant factors in lower Quartile (Q1) of Bhakkar district. The authors observed that TDS value was 370 mg/l and were within the WHO recommended limit of 1000 mg/l. Water has the ability to dissolve a wide range of inorganic and some organic minerals or salts such as potassium, calcium, sodium, bicarbonates, chlorides, magnesium, sulphates etc. These minerals produced unwanted taste and diluted color in appearance of water. This is an important parameter for the use of water. The water with high TDS value indicates that water is highly mineralized (Meride, and Ayenew, 2016).

The concentrations of Cl^- obtained from the sampled well water in MK and MT is significantly ($p<0.05$) higher with a mean value of 389.95±48.39 mg/l and 206.79±15.63 mg/l during the dry season than the rainy season respectively. The Cl^- values were below the NSDWQ and WHO standard limit respectively except the Concentration of well water sample in MK and MR which exceeded the NSDWQ and WHO permissible limit of 250 mg/l during the dry season (Table 1). These studies differs from Paul and Salifu (2015) who analysed some anions in well water in Minna Metropolis, Niger State, Nigeria. The authors observed that the mean results of samples of MK and MT were 65.4 and 137.12 mg/l respectively.

These differences in the present studies could be due to the differences in well water samples collected. Where Cl^- concentrations are observed to be high in the environment, it is normally associated with high significant human activities (Frassetto, Sellmeyer and Sebastian (2008). Cl^- is mainly obtained from the dissolution of salts of hydrochloric acid as table salt (NaCl), NaCO2 and added through industrial waste, sewage. C^{l-} is significant in metabolising the human body and other major physiological processes. The significance of Cl^- in drinking water cannot be overstated. It provides a measure of protection against any contamination which may occur (Yisa, Gana, Jimoh and Yisa 2012). Excess Cl^- concentration may damage metallic pipelines and structure, as well as growing floras. (Meride and Ayenew, 2016). This parameter is however, not of health significant (NSDWQ, 2007; WHO, 2011).

Nevertheless, according to Elaine (2017) and Frassetto et al. (2008) stated that excess Cl^- level in the human system causes hyperchloremia, a situation evolving from electrolyte imbalance. Even though Cl^- is an essential electrolyte in the human system, it may become imbalance due to changes in the electrolyte levels in the blood stream of human resulting in dehydration and excessive function of the kidney which is the organ regulating this balance. This can lead to further problems such as vomiting, kidney failure, diarrhea, and even seizures and convulsions.

The results of SO_4 where significantly ($p<0.05$) not different between the two seasons of rainy and dry seasons for each location. However, MR had the highest mean of 16.02±1.31 mg/l during the dry season. The result exhibit that the concentration of SO_4 was far below the recommended limit of 100 mg/l and 250 mg/l as set by both authorities (Table 1). Paul and Salifu (2015) also reported a conflicting SO_4 mean value of 84.5 mg/l which was obtained in Minna Central in their analysed study of some anions in well water in Minna Metropolis, Niger State, Nigeria. The variation in the present study might be due to poor dissolution of salts of sulfuric acid which are found abundantly in almost every water bodies and no major negative impact of SO_4 on human health is reported (Meride, and Ayenew 2016).

The NO_3 value obtained were not significantly ($p>0.05$) different between the two seasons of rainy and dry seasons for each location of MK, MR CH and MT. Nevertheless, MT had the highest value of 11.54±0.45 mg/l during the rainy season than the dry season. The values were below the NSDWQ and WHO permissible limit in drinking water of 50 mg/l. This studies is not in agreement with the findings of Paul and salihu (2015) and Amadi et al. (2015). The authors reported that the NO_3 value of 61.94 mg/l was recorded for MT and 33.2 mg/l was recorded for Minna, North Central respectively. The variation in the present studies could be due to temporal differences in well water samples collected and or very slow bedrock dissolution due to groundwater migration or may be due to pollution from fertilizer blending plant in part of the study area, which could serve as point source pollution to the ground water sources in part of the study area. The NO_3 are among the primary nutrients that are mainly responsible for the stimulation of the growth of macrophytes (aquatic plants) and phytoplankton (algae) (Paul and Salifu 2015). Higher level of NO_3 in drinking water result to methaemoglobinaemia (blue baby

syndrome), goiter, birth malformation, hypertension and gastric cancer (Annapoorna and Janardhana 2015; Dan-Hassan *et al.*, 2012).
Acidity and Alkalinity results of the samples recorded from the study area were not significantly different for both seasons. Acidity permissible limit and health guideline value was not given. Alkalinity results of the samples recorded from the study area were not significantly different between seasons. The values were found lower than the WHO permissible limit of 300 mg/l (Table 1). These study is not in consonant with the findings of Amadi, Ameh, Ezeagu, Angwa, and Omanayin (2014), who analysed physicochemical parameters of well water, reported that the Alkalinity mean value of 94.90 mg/l recorded in Edati Village, Niger State. The variation in the present study could be principally from carbonate minerals found in limestone dissolving in the aquifer of the study area. Alkalinity is a measure of water's ability to neutralize acids, and so alkalinity and acid are as well related to pH (Mechenich and Andrews, n.d.) It is likely for water to become corrosive when the alkalinity level is lower. Alkalinity in water equal to or greater than 150 mg/L might contribute to scale (lime) formation in plumbing (Mechenich and Andrews, n.d.).
TH showed no significant ($p>0.05$) difference in the well water samples for both rainy and dry seasons of location (MR, CH and MT) except the samples from MK where TH value was significantly higher with a mean value of 626.67±174.58 mg/l during dry season than the rainy season. However, the mean values of TH recorded in the study area between seasons have exceeded the NSDWQ except the TH mean values obtained during the rainy season from well water samples in MK and CH, while MK and MT exceeded the limits of 500 mg/l set by WHO (Table 1).
These studies is in agreement with Khwaja and Aggarwal (2014) who Analysed groundwater quality using statistical techniques in a case Study of Aligarh city of India reported that the TH of the water samples ranges between 197 to 608 mg/l. Most of the samples were found above the standard limit of (200 mg/l) set by BIS. TH is a measure of the capacity of water to the concentration of calcium and magnesium in water and is usually expressed as the equivalent of CaCo3 concentration. The degree Hardness of the water in MK and MT could be attributed to the concentration of Calcium and magnesium being the major constituents responsible for water hardness which results in dissolution of carbonate minerals such as calcite and dolomite (Basavarajappa and Manjunatha 2015). Hard water is a nuisance because of mineral buildup on fixtures and poor soap/detergent performance and high level of TH do not pose a health risk (WHO 2011). However, in some instances, where dissolved calcium and magnesium are high, water could

be a major contributor of calcium and magnesium to the diet. Hard water is useful in the growth of children, if within the permissible limit (Khwaja and Aggarwal 2014).

TSS concentration was significantly ($p>0.05$) not difference between the two seasons of location (MK, MR and MT) except for the well water sample of CH which was significantly ($p>0.05$) higher with 2.70±0.40 mg/l in the dry season than the rainy season.

The values in all locations for both seasons are by far below the NSDWQ recommended maximum permissible limit of 500 mg/l. No permissible standard for TSS established by WHO. A conflicting mean value of TSS up to 22 ± 26 mg/L was observed during the dry season at the urban site by Taiwo, Towolawi, Olanigan, Olujimi and Arowolo (2015) in their Comparative Assessment of Groundwater Quality in Rural and Urban Areas of Nigeria. The authors were unable to compare the value with standard limit since it was not given by WHO (2008). The variation in this present studies could be due to very insignificant presence of variety of material including inorganic matter (silt and sediment) and organic matter such as decaying plant, animal matter and waste from sewage (Murphy 2007). TSS are solids in water that can be retained by filter.

Conclusion and Recommendations

The study conducted on groundwater variability of Minna and Environs during rainy and dry seasons in October 2018 and March 2019 revealed that the physicochemical parameters of the hand dug well are generally suitable for drinking and all parameters where within the recommended standard limits during both seasons, except TH and Cl– found to exceed the recommended permissible limits of NSDQW (2007) and WHO (2011) during both rainy and dry seasons. Seasonal variations indicated higher concentration of Total Hardness, Chloride (Cl–), Electrical conductivity (μS/cm), and nitrate (NO3) during the dry season than the rainy season. Nitrate is seen to be rapidly increasing during the dry season than the rainy season in Morris (MR) which could be pollution arising from Morris blending fertilizer plant. Relevant authorities such as the state Ministry of Urban and regional planning should ensure with might that the facility is moved and relocated to appropriate location (industrial layout) to curtail and avoid any future pollution which might occur, since this facility is situated within the residential area of Morris Phase II developmental area and also ensure the facility is adopting best environmental practices to manage the waste appropriately to sustain the environment. As for the hardness, the hard water should be boiled on a high level this will remedy the unpleasant taste resulting from high calcium concentration. Allow to cool, the white sediments (insoluble minerals) will settle on the bottom of the pot then filter the water using cloth filter to remove sediment by the respective well owners.

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