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Original paper

Assessment of change pattern for physicochemical parameters in groundwater within Kaura- Namoda and its environs, Zamfara State, Nigeria

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ABSTRACT: Demand for quality and adequate per capital daily need of water had encouraged high percentage of the World population to explore groundwater sources. The quality of the water however cannot be guarantee until necessary standardized tests and monitoring is carried out. This study investigated the quality of water from bore holes in 6 locations within Kaura Namoda and its environs. 13 quality parameters were determined in laboratories in 2006, 2012, 2018 and 2022. Twelve of the parameters determined for the years were found to be within the acceptable W.H.O and N.S.D.W.Q standards, however only Magnesium value range of 3.0mg/l – 35.0mg/l was found to be above the 0.2mg/l recommended limit for drinking-water. We also discovered that the trend of increase concentration of Magnesium and Nitrate is detected. The quality of groundwater is generally good but water hardness is prevalent.

Keywords: Groundwater, water quality, trend of change, physicochemical characteristics

INTRODUCTION

Water is an essential ingredient of life but good and potable water cannot be said to be available from its sources (Surface water, Groundwater and even harvested rain water), the reason been that water is a universal solvent that virtually dissolve materials in contact with it. Assessment of water quality is also an essential activity in order to provide the water that will satisfy the requirement for its intended uses, for example the quality demand for potable water cannot be said to be the same for irrigation purposes, hence the establishment of quality standards (for example WHO and NSDWQ standards) for different specific and particular uses. Change in water quality is inevitable because "Change" has been referred to as the only issue of life that remain constant, because any issue of life is bound to experience change no matter how minute it may be, hence monitoring becomes imperative especially in issue of water quality that human activities (Ahmed et al., 2016), and environmental factors can easily affect from time to time, also the interaction of water with geological materials during movement also serve as major determinant of its chemical characteristics (Campana,1996). Human health is negatively affected when low-quality groundwater is sourced for drinking (Jibrin, 2019), and contaminated surface water for irrigation also impact negatively on plant growth and its yield (Saadu et al., 2022; Panaskar et al., 2016). Inadequate water supply and per capital demand for potable water in semi-urban and rural communities especially in semi-arid northern areas of Nigeria had led to exploitation of shallow and deep groundwater (Saadu et al, 2019). The dependence on groundwater exploitation as source of water supply continue to increase as a result of Malthusian trends and environmental changes (Khair et al.,2019; Minderhoud et al., 2017; Urfels et al., 2020). According to United State

Environmental Protection Agency report of 2008, about one-third of the population of the world depends on groundwater supplies and an estimated 44 percent of population in sub-Saharan Africa depends on groundwater resources (MacDonald, 2000). Monitoring and managing groundwater is imperative in view of the world population that solely depends on it. The knowledge based on water quality and its variability as revealed through literatures and the undivided suggestions that the physical and chemical compositions in water meant for drinking must be known and understood underscores the importance of adequate monitoring. The groundwater quality from rural Kebbi State was investigated by Saadu et al. (2022), and was found to be good, whereas the quality of groundwater of some villages within the Federal Capital territory of Nigeria was found to fall short of the permissible standard levels for drinking-water set by WHO and NSDWQ (Jibrin, 2019). Studies had also shown that water quality parameters do vary from season to season and also over long period of time (Adebola et al., 2023; Saadu et al., 2022; Saadu et al., 2019), therefore the essence of investigation of pattern of groundwater quality change in Kaura Namoda and its environs. Therefore the aim of this work is to determine the trend of concentration of physicochemical and heavy metals in water within the space of sixteen years with specific objectives of determining the groundwater quality with reference to World Health Organization (WHO) standards and Nigerian Standards for Drinking-Water Quality (NSDWQ),to detect any physicochemical and heavy metals in water that may pose a threat to health, and finally to determine specific quality parameters that exhibits increasing trend in concentration within the period of 2006 to 2022.

Statement of problem

Kaura-Namoda town is expanding in size and population following the trend of projected population growth in the World and Nigeria in particular. This growth in size and population lead to continuous demand for increase potable water supply of which the water treatment plant in the town is unable to cater for, also the neighbourhood villages and communities could not access the quantity supply to the metropolis hence necessitating the need to seek water from open dug wells on the stream bed and also the available sunk bore holes in their vicinity. The need to augments shortage of water from the Water Board with groundwater had prompted the State Government to sink several numbers of motorized and hand pumped bore holes in village and towns in Kaura-Namoda Local Government Area, likewise individual householders and organizations have constructed their own bore holes (Adebola et al., 2023). The awareness through several studies (Adebola,2001; Alan et al.,2005; Gary, 2005; Yusuf, 2007; Ohwo, 2011; Adebola and Magaji, 2014; Enejo et al., 2016), that all groundwater does not essentially satisfy the quality standards for drinking-water, demand that every bore hole sunk in any place must be subjected to quality tests before usage and regular monitoring of quality level of the water sources so that changes in quality levels can be detected early and where the changes are adversely negative to the well-being of the users appropriate measures can be employed to safe guard the health and well-being of the people using the water.

MATERIALS AND METHODS

Study area

Kaura Namoda Town is the Headquarter of Kaura Namoda Local Government Area of Zamfara State. Zamfara State is located in the North Western region of Nigeria and covers an area of about 38,418 km^2 and is located between latitudes 11^0 8' 00'' N and 13^0 22' 00'' N, longitude 4^0 52' 00'' E and 7^0 20' 00'' E and Gusau is the State Headquarter. Zamfara State is bordered in the North by Niger Republic, to the South by Kaduna State, in the East by Katsina State and to the West by Sokoto and Niger States. It has a population of 3,278,873 and consists of fourteen local government areas including Kaura Namoda, the core study area (National Population Census, 2006). The population of farmers in Zamfara State is 95% of the total population of the state and is a reflection of the population of those engaged in farming activities in the communities within Kaura Namoda Local Government Area (Chukwuji et al, 2018). Kaura Namoda Town is located in the Northeastern part of Zamfara State between latitude 12^0 33' 49'' N and latitude 12^0 39' 00'' N, longitude 6^0 33' 13'' E and longitude 6^0 37' 12'' E. The distance of the town is 56.5km East of Gusau town and is accessible through a network of both tarred and untarred roads. It has an area of 868 km^2 and a population of 281,367 (National Population Census, 2006) Borehole water samples were collected from different locations within Kaura Namoda town in the years 2006, 2012, 2018 and 2022. In the year 2006, the numbers of identified boreholes was 8 out of which 3 numbers were selected and samples collected for investigation. Also in the year 2012, the numbers of identified bore holes was 35 in number, with 8 numbers being motorized and with overhead storage tank while the remaining 27 were hand pump type, out of these numbers, 6 of the sited locations were chosen and samples collected from them. In 2018 and 2022 the numbers of bore holes had increased and many of them could not be identified because many individuals' families and private organizations had sunk their own, hence the researchers decided to continue to collect samples from the same 6 locations selected in the year 2012. The samples collection were carried out for dry season only (January - February), this was done bearing in mind that the ground water flow at this period will be stable and the dissolved constituents will not be unstable like the period of raining season when we have heavy surface flow and the infiltration is high. Marked 1.5L sterile plastic bottles (Nitric acid was used for sterilization) were used to collect the water samples directly from the mouth of the boreholes. The sterilized bottles were completely filled to exclude any air bubbles before they were tightly covered then transported in cold plastic container, with ice blocks that chilled the samples during transportation to the laboratories.

On-site parameters determination includes the pH (electronic digital pH meter), Temperature (Digital thermometer), and Electrical conductivity (NORLYAB LM8 meter and when the water samples were taken to the laboratory, data was confirm with electrolytic method: DDS307 conductivity meter). The physicochemical parameters were carried out in the laboratory according to prescribed standard of testing according to the individual methods applied in determination of the parameters. Turbidity Nephelometric method was used to determine turbidity (turbidity meter: HACH 2100P) and for Sulphate, barium chloride was used as precipitating agent to convert Sulphate to Barium Sulphate precipitate in a colloidal form. The absorbance of the barium Sulphate solution was measured by turbidimeter. The concentration of Sulphate measured was compared to a standard curve to arrive at the value obtained in each samples. Total Hardness (T.H), Calcium (Ca^{2+}) and Magnesium (Mg^{2+}) were determined by EDTA titrimetric method. Chloride (Cl^-) was determined using the Mohr titrimetric method. Nitrate (NO_3^-) concentration was obtained by UV spectrophotometric method and Acid titration method was used for Alkalinity. The WHO and NSDWQ standards were used as reference bench mark for the purpose of comparing the values obtained for the parameters if results are within acceptable standards.

RESULTS AND DISCUSSION

The characteristic contents in a water source will depend upon the properties of the soil and the materials it came in contact with along the flow path, and these contents in the body of water would influence the quality of the water by altering its actual or original state. Laboratory analysis and on-site monitoring provide evidence of the well-being of the water; hence this research study demonstrated the importance of investigating the quality of water from the source before acceptability for community general usage. Analysis of water samples was carried out for 3 locations in 2006, with the results presented in (Table 1), while 6 locations were repeatedly tested for in 2012, 2018 and 2022, and their results presented in (Tables 2, 3 and 4) respectively. The analysis of water samples taken in 2006 and 2012 were carried out in a standard-equipped laboratory in Federal Polytechnic Kaura Namoda and the samples collected in 2018 and 2022 were analyzed in Ahmadu Bello University (ABU), Zaria. Thirteen physicochemical quality parameters were tested and determined in this study. The characteristic variations in concentration for 4 quality parameters of the 13 parameters analyzed were considered for trend analysis. The selected parameters (Alkalinity, Nitrate, Magnesium and Sulphate) indicated a trend of increase and decrease concentration values between 2006 and 2022. The concentration value for the remaining 9 quality parameters fluctuate and had no changing pattern. Year 2006 indicated higher concentration values than other years. This outcome is probably connected to the age of when the bore holes were sunk, because the analysis carried out in 2006 (January-February) in the 3 sites selected were constructed in December 2005, and at the time of sampling, the extraction of water in the holes had not remove the original stored water in the unconfined aquifer and because of the years of gradual addition of constituents parameters to the aquifer stored water before the holes were constructed, so the test values in 2006 is higher while year's 2012,2018 and 2022 shows appreciable decrease of concentration since daily extraction of water is carried out. This is reflected in the steepness of the slope of (Figures 1, 2, 3 and 4).The pH values of all the samples in this work falls within the 6.5-8.5 recommended by WHO and NSDWQ. The general trend of Total Alkalinity in (Figure 1) shows that there is yearly decrease in concentration; this could be as results of daily water extraction from the bore holes resulting in re-adjustments of aquifer soil grains that permit free and easy movement of water within the aquifer. The study by Minderhoud et al. (2017) also indicated that overall, groundwater extraction indeed induce subsidence showing that movement of soils grains do occur within the aquifer (Table 5).

The Nitrate values as shown in (Figure 2), from 2006 continue to increase, however the range of its concentration during the years under consideration is 3.0 to 35.0mg/l for the dry season. The study by Ahmed et al (2016) indicated that nitrate values measured during raining season (July- September) were higher than dry season and that this may not be unconnected with nitrogenous fertilizer application by farmers during the growing period. However the nitrate concentration for dry season in this study is lower than the 50mg/l World Health Organization (WHO) for drinking-water. The concentration values of Magnesium as shown in (Figure 3) indicated that from 2012 to 2022, for all the sample locations it continue to maintain increase concentration. This may not be unconnected with natural occurrence of *magnesium tetraoxosulphate (VI)*, known as *Kieserite*, $MgSO_4.H_2O$ and on crystallization it's known as *Epson Salt*, MgSO4.7H2O (Osei, 2016), and Epson salt is commonly use in the community for different purposes. Sulphate concentration for LS, ST and FP in (Figure 4) shows decreasing trend but NL indicated increasing concentration from 2012 to 2022, while the rest sites

Table 1: Physicochemical parameters for 2006

Sampling site	Turbidity (NUT)	Temperature (°C)	pH	Total Dissolved Solids(mg/l)	Total Alkalinity (mg/l)	Total Hardness (mg/l)	Chlorides (mg/l)	Electrical Conductivity	Nitrate (mg/l)	Calcium (mg/l)	Magnesium (mg/l)	Iron (mg/l)	Sulphate (mg/l)
Low-cost	35	26	6.6	76	6.5	225	10.7	695	3.1	18.9	14.3	3.0	17.0
SohoTasha	30	27	7.7	52	7.5	60	10.0	650	3.5	10.8	9.5	0.2	8.0
FPT-Site	25	25	7.0	62	6.9	62	7.0	500	3.0	12.6	12.,6	0.02	13.0
Average	30	26	7.1	63.3	7.0	116	9.2	615	3.2	14.1	12.1	1.07	12.7

Table 2: Physicochemical parameters for 2012

Sampling site	Turbidity (NUT)	Temperature (°C)	pH	Total Dissolved Solids(mg/l)	Total Alkalinity (mg/l)	Total Hardness (mg/l)	Chlorides (mg/l)	Electrical Conductivity	Nitrate (mg/l)	Calcium (mg/l)	Magnesium (mg/l)	Iron (mg/l)	Sulphate (mg/l)
Low-cost	34	25	6.6	10.3	5.2	28.7	15.67	520	18.0	11.5	0.073	0.35	5.35
SohoTasha	25	31	6.7	2.33	4.5	25.3	15.67	630	23.5	8.6	1.06	0.05	4.80
FPT-Site	12	27	7.4	2.3	3.5	21.7	3.3	450	32.3	10.3	1.01	0.02	6.35
SabonGari Rd	16	26	7.3	10.3	5.4	31.7	15.67	515	20.0	7.5	0.133	0.03	3.65
NYSC Lodge	24	26	6.2	9.0	5.2	23.7	1.0	425	15.5	9.5	1.103	0.05	2.40
Behind M/Park	21	22	7.1	2.7	5.1	22.7	3.3	460	12.3	12.3	1.06	0.03	3.50
Average	22	26	6.9	6.2	4.82	25.6	9.1	500	20.3	10.0	0.74	0.09	4.34

Table 3: Physicochemical parameters for 2018

Sampling site	Turbidity (NUT)	Temperature (°C)	pH	Total Dissolved Solids(mg/l)	Total Alkalinity (mg/l)	Total Hardness (mg/l)	Chlorides (mg/l)	Electrical Conductivity	Nitrate (mg/l)	Calcium (mg/l)	Magnesium (mg/l)	Iron (mg/l)	Sulphate (mg/l)
Low-cost	3.4	28	7.3	3.2	3.5	26.5	16.3	447	33.0	16.5	2.40	0.07	4.55
SohoTasha	4.6	27	7.4	2.5	3.30	28.2	13.3	525	25.2	10.5	1.25	0.05	3.80
FPT-Site	12.2	26	6.8	2.8	3.5	30.5	5.3	430	31.5	13.4	0.55	0.03	3.48
SabonGari Rd	27.6	25	6.8	8.6	5.3	25.0	10.8	560	23.0	8.4	1.50	0.02	2.68
NYSC Lodge	22.0	26	7.4	7.2	4.6	23.6	2.5	400	18.1	9.5	1.60	0.03	3.20
Behind M/Park	20	26	7.1	3.2	5.4	23.2	3.2	435	15.3	8.6	1.26	0.02	3.30
Average	15.0	26	7.1	4.6	4.3	26.2	8.6	466	24.4	11.2	1.43	0.04	3.50

show irregular values. The concentration of parameters in samples of water analyzed shows that some parameters show did not have a definite decreasing or increasing trend throughout the periods under consideration. The Turbidity, Total Dissolve Solids (TDS), Total Alkalinity (TA), Total Hardness (TH), Chloride (Cl^-), Electrical Conductivity (EC), Iron (Fe) and Sulphate (SO_4^-) shows decreasing concentration from 2006 to 2022 and is reflected in the range of concentration values for the years. The concentration of TDS (2.3 – 76mg/l), in all the wells was less than 500mg/l allowable standard in drinking-water. The mean concentration values for TH (25.5 – 116mg/l) fall within the standard permissible value of 150mg/l. Chloride concentration mean values (8.2 – 9.2mgl/), for all the boreholes is lower than the maximum allowable standard of 250mg/L. The mean values range

Table 4: Physicochemical parameters for 2022

Sampling site	Turbidity (NUT)	Temperature (°C)	pH	Total Dissolved Solids(mg/l)	Total Alkalinity (mg/l)	Total Hardness (mg/l)	Chlorides (mg/l)	Electrical Conductivity	Nitrate (mg/l)	Calcium (mg/l)	Magnesium (mg/l)	Iron (mg/l)	Sulphate (mg/l)
Low-cost	3.20	28	7.3	5.2	2.40	28.0	16.0	330	35.0	10.5	2.68	0.05	4.0
SohoTasha	4.5	27	6.8	2.5	2.10	31.2	12.5	500	25.5	13.5	2.3	0.03	3.50
FPT-Site	10.3	25	7.5	3.0	2.5	26.1	5.0	420	30.0	12.3	1.65	0.04	2.60
SabonGari Rd	28.2	28	7.4	6.2	6.3	22.3	10.0	520	26.5	7.4	1.82	0.02	3.20
NYSC Lodge	22.0	26	6.8	7.1	3.8	22.6	3.0	420	20.2	8.4	1.26	0.03	3.50
Behind M/Park	21.0	25	6.8	3.1	2.6	23.0	2.8	430	16.0	10.3	1.55	0.02	3.50
Average	14.9	26.5	7.1	4.5	3.3	25.5	8.2	437	25.5	10.4	1.88	0.03	3.4

Table 5: Sampling sites and coding.

Sampling site	Low cost	SohoTasha	Federal Polytechnic	SabonGari Road	NYSC lodge	Behind Motor Park
Code	LS	ST	FP	SG	NL	BM

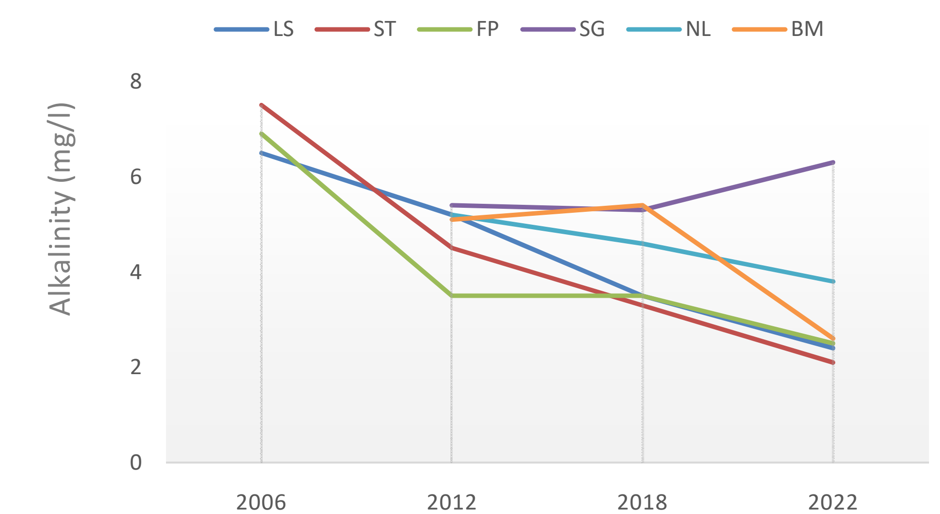

Figure 1: Alkalinity of Water Samples

of 437 – 615µS/cm for electrical conductivity is less than acceptable value of 1149µS/cm, likewise Sulphate concentration mean values of 3.4 – 12.7mg/l falls below maximum permissible level of 250mg/l. The pH values for all the wells during the periods of analysis are within the acceptable value range of 6.5 – 8.5. Calcium concentration value of 10.0mg/l – 14.1mg/l is less than 250mg/l allowable standard and does not show any increasing or decreasing trend between year 2006 and year 2022. Nitrate (NO_3^-) concentration shows increasing trend in value from year 2006 to year 2022. The increasing concentration of Nitrate in sample of groundwater from 2006 to 2022 is most likely connected with the increase access to and usage of Nitrate Fertilizer by farmers from year to years. Nitrate is one of the chemicals from agricultural activities that are of health significance in drinking-water at maximum level of 50mg/L for short term exposure (WHO, 2011) ; however the range of values of Nitrate, 3.0mg/l – 35.0mg/l is below the maximum permissible of 50mg/l. The presence of Nitrate in groundwater could be as a consequence of excess inorganic or organic fertilizer applied in farming that plants did not consume, also it may come as a result of nitrate release from decomposing plants, and then the excess is dissolve by rain water and infiltrate into the aquifer and is yearly added to the groundwater.

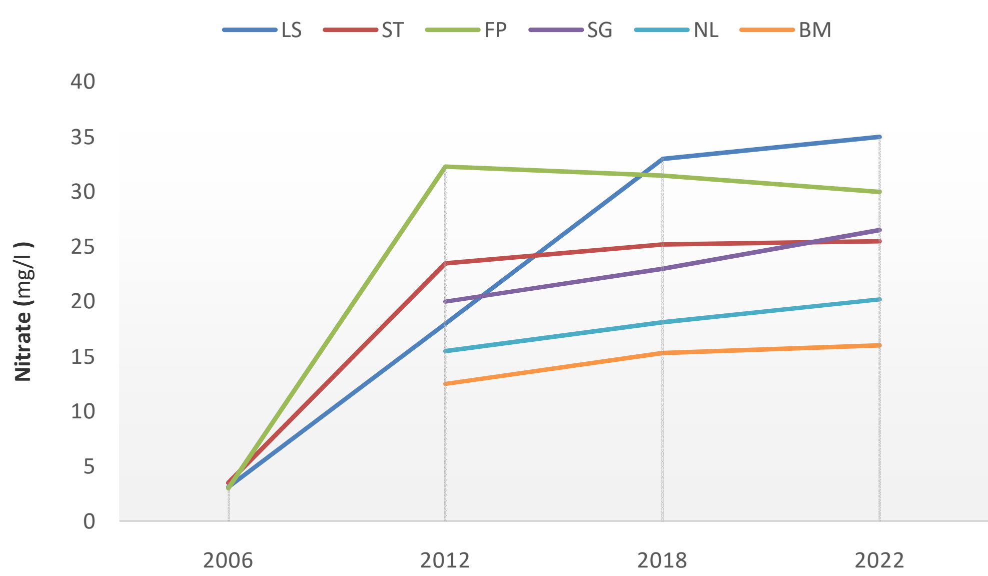

Figure 2 : Nitrate Concentration in Water samples

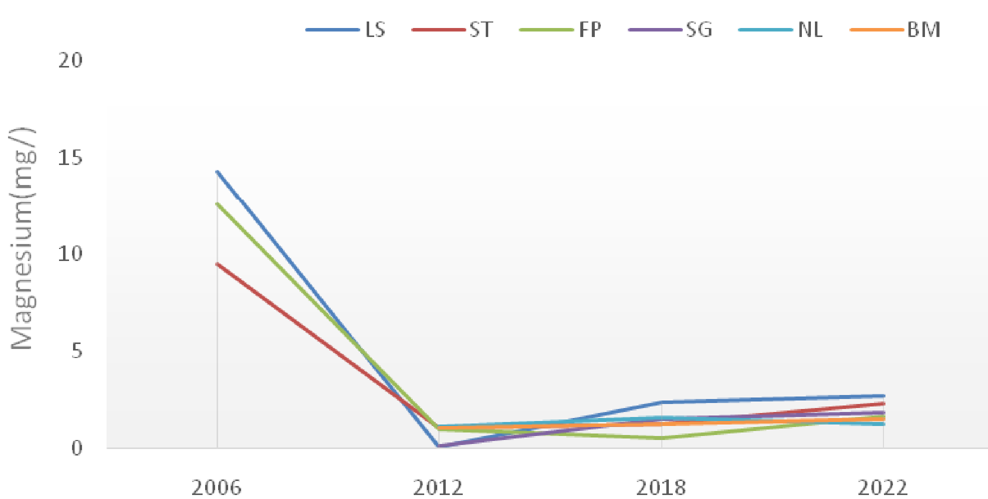

Figure 3 : Magnesium concentration in Water Samples

Magnesium concentration values in all the wells (0.55 – 14.3mg/l), for all the years in consideration is greater than 0.2mg/L acceptable level. Magnesium concentration shows consistent yearly increment from 2012 to 2022 and the only quality parameter out of the 13 parameters determined that is found to remain higher than the allowable standard level. The presence of Magnesium and Calcium cations had been noted to cause hardness in any particular sample of water (WHO, 2011). Traditionally measurement of hardness is the capacity of water to react with soap. Hard water required considerable more soap to produce a latter. The degree of hardness in drinking-water is important for aesthetic acceptability by consumers. The calcium ion taste threshold recommended by WHO is in the range of 100 – 300mg/l, depending on the associated anions (WHO, 2011).No health based guideline value had been proposed for hardness in drinking-water, however hard water is usually indicated by precipitation of soap scum and the need for excess of soap to achieve cleaning.

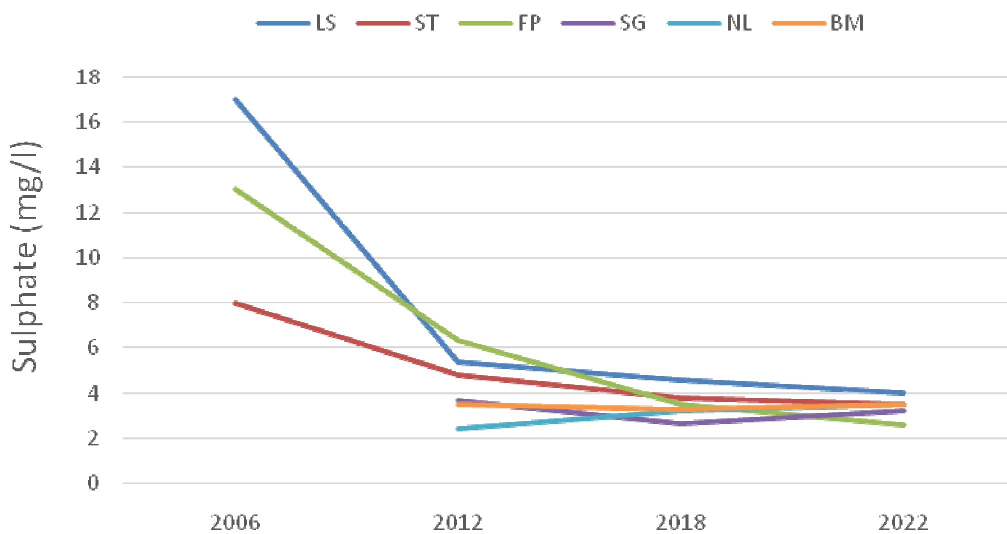

Figure 4 : Sulphate concentration in Water Samples

The water of borehole in Soho-Tasha was found to be significantly hard in 2006, this condition limited the people in the neighbourhood to its usage and eventually it was abandon and the State Government sunk another borehole in 2011 in the area that people around there were comfortable to access and used. In 2012 samples of water were collected from the new sunk borehole and quality analysis of hardness was discovered to be 25.3 mg/l and subsequent years of 2018 and 2022 hardness level was found to be 13.3mg/l and 12.5mg/l respectively. As the year runs-by and water continues to be drawn from Soho-Tasha borehole, the total hardness level continues to reduce.

Conclusion

The groundwater quality determination from 2006 to 2022 (spanning 16 years) shows that nitrate concentration continue to increase from 3.0 to 35.0mg/l within Kaura Namoda town and its environs. This outcome calls for intensive investigation of groundwater in the local government area and a study of the level of nitrogenous fertilizers that are yearly applied. The concentration of magnesium in the sampled waters indicated that between years 2006 to 2022 the quality is above the WHO and NSDWQ recommended permissible level of 0.2mg/l, there is therefore the need to carry out research on how and why magnesium values in bore holes water continue to increase. The remaining 11 investigated quality parameters are within the acceptable recommended standard and do not show any particular pattern of increment or decreasing trend. This work focuses on the dry season period bearing in mind that fluctuation in concentration values will be more stable than during the wet season period when high rate of infiltration and dilution of chemical constituents is expected to be high. The results of this study satisfy the aim and objectives of the research.

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