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Comparative Assessment of Well and Borehole Water Quality Index in Sokoto Metropolis

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The study focuses on the comparative assessment on the levels of some physicochemical parameters of well and borehole water collected from five locations in Sokoto metropolis to ascertain their quality index. Samples were collected randomly and analyzed using standard method of analysis. The physicochemical parameters analyzed include; pH, Turbidity, Total Dissolved Solids (TDS), Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Chlorides (Cl^-), Fluorides (F^-) Sulphates (SO_4^{2-}) and Nitrate (NO_3^-). The result of the study was subjected to Descriptive statistics and water quality index. The descriptive statistics results revealed that physicochemical parameters like pH, TDS, SO_4^{2-} , and turbidity are within the WHO limit of drinking water while parameters like Ca^{2+} , Mg^{2+} and Cl^- were within and not within the WHO limit in some sampling locations whereas parameters like F^- and NO_3^- were found not within the WHO limit in all the sampling locations. The result shows that both water sources were found within excellent and very good water quality index respectively which indicates that both water sources (well and borehole water) consumed within Sokoto metropolis are safe and suitable for drinking as it meets the minimum requirements of WHO standard of drinking water quality.

Keywords: Physicochemical, Index number, Correlation, metropolis, Quality index.

1. Introduction

Water is a major constituent of the human body necessary for physicochemical processes and thus crucial for human health and livelihood in general (Sobsey, 2012). This benefit of water is however assured if the water is safe for consumption and other uses. According to Meybeck *et al.* (2016), portable water is that which is odourless, colourless, tasteless, free from any form of contaminants and safe for consumption. In Nigeria, well and borehole water are among the significant sources of drinking water. However, these sources are not always safe for drinking because of the presence of impurities that affect the quality of water. (Amaechi, 2016). The water supply in State is inadequate to meet the needs of the population (Wright *et al.*, 2016). In Nigeria, despite the involvement of the World Bank, African Development Bank, and United Nations Children's Educational Fund (UNICEF) to improve the quality of water for drinking, yet the assessment of safe water is still a challenge (Ajayi *et al.*, 2008). Regardless of its source, drinking water is usually subjected to safety and quality tests. Ishaku *et al.* (2011) stated that the water supply in rural areas in Nigeria

is a public quality dilemma as over 70% of the households do not have access to clean drinking water. Gregory and Victor, (2018) confirmed this by reporting the need to examine issues arises from the increase in wells and boreholes dug in Nigeria and concerns regarding groundwater contamination. Oyediji *et al.* (2009) reported violations of international water quality standards for the recommended aquifers for boreholes and wells dug. Borehole and well water are among the major alternative source of drinking water for the average Nigerian. However, reports indicated that most of these sources might not meet acceptable water quality for drinking purposes (Amaechi, 2016). As a result, the WHO, Food and Agricultural Organisation (FAO) and United States Environmental Protection Agency (USEPA) has set up standard for physicochemical and heavy metals contamination to ensure the quality and safety of potable water (USEPA, 2014; WHO, 2017; FAO, 2017). These standards are based on the physicochemical, heavy metals and microbiological constituents in water and defined with tolerable limits. Therefore, this study seeks to examine the quality index of physicochemical profile of

potable (well and borehole water) across state metropolises.

2. Materials and Methods

2.1 Study Area

Sokoto metropolis is located between latitude 13°2'45.6"N and longitude 5°14'20.4"E. The metropolis has an estimated population of about 503,256 people as of 2015 with 95.9 person per square kilometer and 3 percent growth rate annually based on 2016 population census (NPC, 2006). The Metropolis covers 16 km radius away from the reference points which comprises 4 local governments such as Sokoto south, Sokoto North, Wamakko and part of Kware local governments of Sokoto State, Nigeria with Local inhabitants mostly Hausa, Fulani and other groups such as, Yoruba, Igbo and other migrants. The predominant language is Hausa. Occupations of city dwellers include trading, commerce, domestication of animals with a reasonable proportion of the population working in private and public sectors. Population of farmers is on the decline (Jagaba *et al.*, 2018).

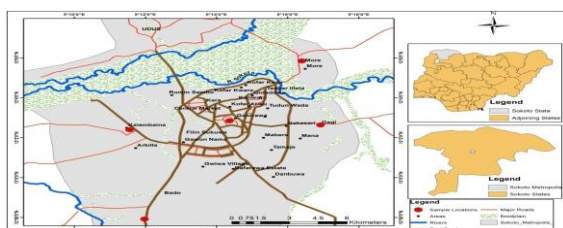


Figure 1: Map showing the study area

2.2 Sampling

Five sampling locations with longitude and latitude are designated as Moreh (5.273°E and 13.098°N), Gagi (5.282°E and 13.045°N), Kalambaina (5.192°E and 13.041°N), Kanwuri (5.198°E and 12.966°N) and UDUS Permanent site (5.239°E and 13.048°N). A total number of 45 water samples from wells and boreholes were collected for the analysis in the month of January, 2022. Three samples of each borehole and well water were collected 3 times in a day (morning, afternoon and evening) from fifteen (15) sampling locations. All the samples were collected in pre rinsed plastic containers to maintain the constant pH and minimize loss of sample and contamination. The pH, Temperature and conductivity were determined immediately at the point of collection and the samples were stored at a room temperature. (APHA, 2005)

2.3 Analysis Technique

The water quality parameters measured in the field were pH using pH meter, turbidity using turbidimeter, Total Dissolved Solids (TDS) and Sulphates was determined by gravimetry method, Chlorides and Nitrates by agentometry

method, However, element such as Fluorides, Calcium and Magnesium were determined using Atomic Absorption Spectroscopy (AAS).

2.4 Total Dissolved Solid (TDS)

A clean platinum evaporating dish was placed in an oven set at 100 °C for one hour. Then it was placed in a desiccator to cool and it was weighed. It was then transferred into a hot plate; thoroughly mixed with 100 cm³ of the water sample and was transferred by a means of measuring cylinder. The cylinder was rinsed several times with distilled water to make sure that all suspended materials transferred to the dish. After the sample was evaporated the dish and the residue was dried in an oven set at 103 °C for one hour, cooled in the desiccator and then reweighed (APHA, 2005).

2.5 Sulphate

100 cm³ of the sample was dispensed in a 250 cm³ capacity Erlenmeyer flask, 5ml conditioning reagent was added and mixed using a magnetic stirrer. A spoonful of barium chloride crystals was added while the solution was still being stirred, the turbidity was measured at 30 seconds after stirring at interval of 4minutes. A blank was prepared with no barium chloride added and the sulphate concentration was calculated using the formula:

$$\frac{mg}{L} SO_4 = \frac{mg SO_4 \times 1000}{Vol. of sample}$$

2.6 Chlorides

20 ml of the water samples were pipetted in a conical flask. 1 ml of freshly prepared potassium chromate solution is added as an indicator and titrated against standard AgNO₃ solution taken in the burette. The end point was reached when the colour change was observed from yellow to reddish brown colour.

2.7 Nitrate

This was carried out by the method described by APHA (2005). The sample was neutralized at pH 7. 100 cm³ of the sample was placed in a beaker and allow to evaporate to dryness on a water bath. The residue was dissolved using a glass rod with 2 cm³ disulphuric acid reagent and then transferred to Nessler's tube. 6 cm³ of ammonium hydroxide (NH₄OH) and EDTA was added drop-wise till the residue dissolved. A blank will also be prepared in the same way using distilled water instead of the sample. The colour development was read at 410 nm with a light path of 1 cm. The nitrate concentration was calculated using the formula below:

$$\frac{mg}{L} nitrate = \frac{mg nitrate \times 1000}{Vol. of sample}$$

2.8 Analysis of Metals Using AAS

Atomic absorption spectroscopy (AAS) was adopted for the analysis (Umar, 2010). The principle of the method is based on nebulising the solution of the sample into an air-acetylene flame where it vaporised. Ions of elements were atomised. The atoms formed absorb radiation of certain characteristics wavelength from their respective hollow cathode lamp. The measured absorbance is proportional to the amount of analyte in the sample solution. The concentrations of the elements: F⁻, Ca²⁺ and Mg²⁺ were measured using an atomic absorption spectrophotometer (AAAnalyst 400 by Perkin Elmer, USA).

2.9 Calibration of Atomic Absorption Spectrometry (AAS)

The characteristic concentration check value is the concentration of element (in mg/l) that produces a signal of approximately 0.2 absorbance units under optimum conditions at the wavelength listed. By using the characteristic concentration check, the operator determined whether instrumental parameters are optimized and whether the instrument is performing up to specifications. Calibration of AAS was carried out by using an external calibration curve. The external calibration curve was prepared from solution of known concentrations of the sample element, which is also known as stock solution. High purity metal salts dissolved in high purity acids were used to make the stock solution. Working standards were diluted from the stock standard. From the selected sampling locations, three samples of each borehole and well water were collected.

2.10 Water Quality Index (WQI)

The water quality index is a simple method used for the analysis of general quality of water. The method was proposed by Horton (1965) and Brown *et al.* (1970). To calculate this index, Horton (1965) proposed the first formula which takes into account all the parameters necessary to determine the quality of surface water and which reflects the composite influence of various important parameters for the assessment and management of the water quality. This index has been used for the first time to highlight the physio-chemical changes likely to occur and their impact on the quality of the water supply. The WQI is determined by comparing nine (9) water quality parameters measured in this study, namely; pH, Turbidity, Total Dissolved Solids (TDS), Calcium (Ca²⁺), Magnesium (Mg²⁺), Chlorides (Cl⁻), Fluorides (F⁻) Sulphates (SO₄) and Nitrate (NO₃⁻). The WQI is calculated by using the weighted arithmetic index method. This method consists of classifying water quality according to the degree of purity by using the

most commonly measured water quality variables. The water quality index for the study was calculated using the formula in equation 1:

$$qi = 100 [(Vi-Vid)/(Si-Vid)] \text{-----}1$$

Vi is the measured value of the *i*th parameter at a given sampling point

Si is the acceptable value of the *i*th parameter;
Vid is the ideal value of the *i*th parameter in pure water; it is equal to zero for all water parameters, except fluoride, dissolved oxygen and pH which are respectively 1.0mg / l; 14.6mg / l and 7.

The weighting (*Wi*) of the various water quality parameters is inversely proportional to the recommended standards for the corresponding parameters.

$$Wi = K / Si$$

With

Wi is the weight of the *i*th parameter;
Si is the acceptable value of the *i*th parameter;
K is a constant of proportionality given by the relation [Kalavathy *et al.*, 2011]

$$K = 1 / [1 / S1 + 1 / S2 + \dots + 1 / Sn] \text{-----}2$$

The IQE is determined from the relationship

$$IQE = \sum_{i=1}^n qi Wi / \sum Wi \text{-----}3$$

The acceptable limit values used are taken from the values recommended by the WHO. They are given in Table 1 with the weightings of each parameter considered in the calculation of the WQI.

Five quality classes can be identified according to the values of the IQE water quality index.

Table 1.0: WQI Classification range

Water Quality assessment Grid	Class
0-25	Excellent quality water
26-50	Good quality water
51-75	Low quality water
76-100	Very low-quality water
>100	Not potable water

3. Results and Discussion

Concentration of the selected physicochemical parameters and index value of the selected sampling locations were presented in Figures 2 to 13.

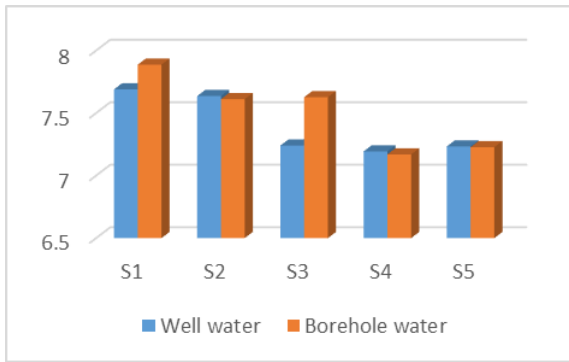


Figure 2: pH of well and Borehole water

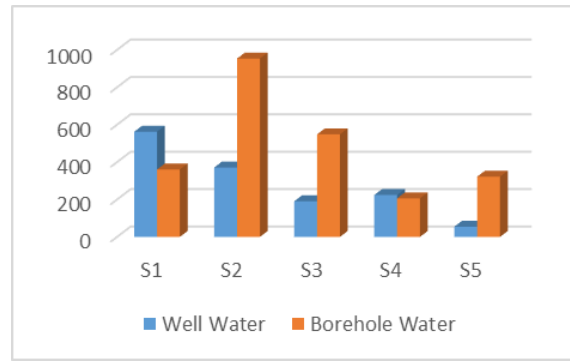


Figure 6: Magnesium concentration of well and Borehole water

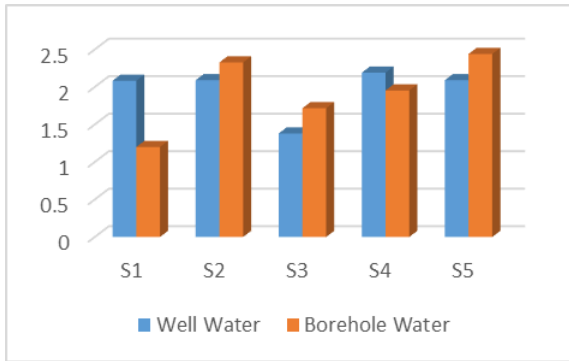


Figure 3: Turbidity of well and Borehole water

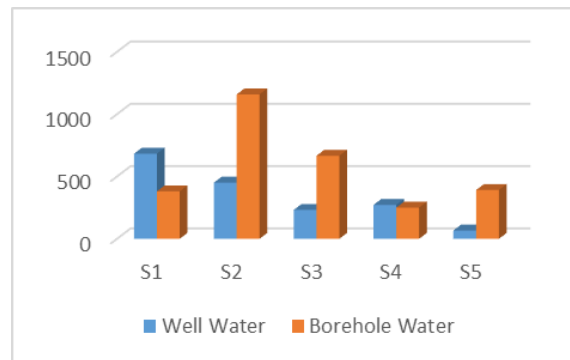


Figure 7: Chloride concentration of well and borehole water

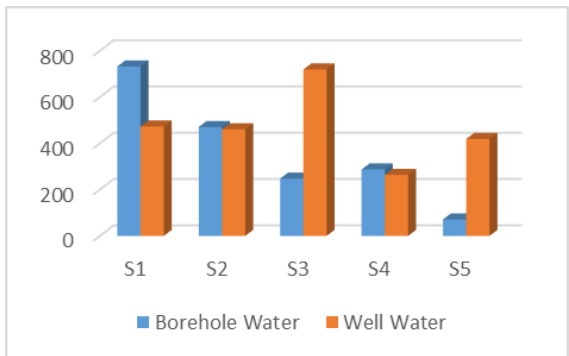


Figure 4: TDS of well and Borehole water

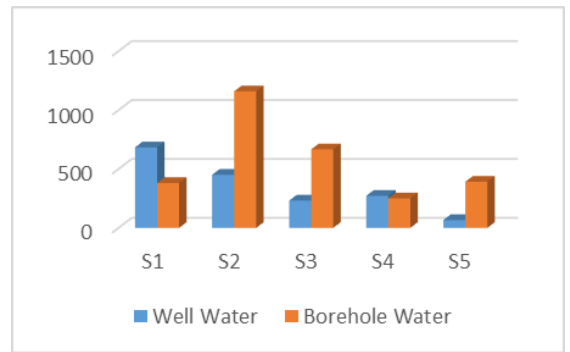


Figure 8: Fluoride concentration of well and Borehole water

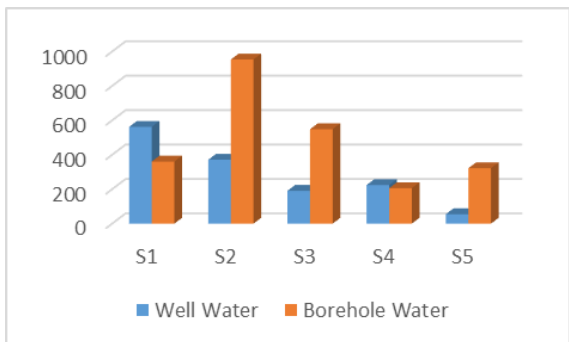


Figure 5: Calcium Concentration of well and Borehole water

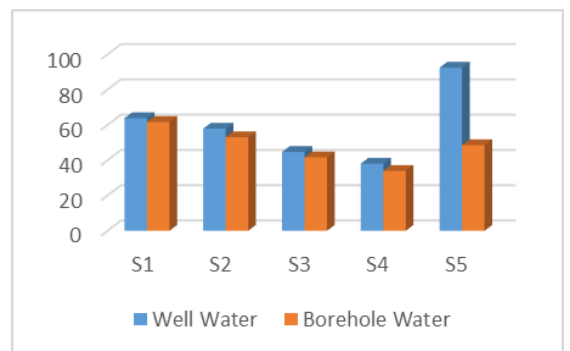


Figure 9: Sulphate concentration of well and Borehole water

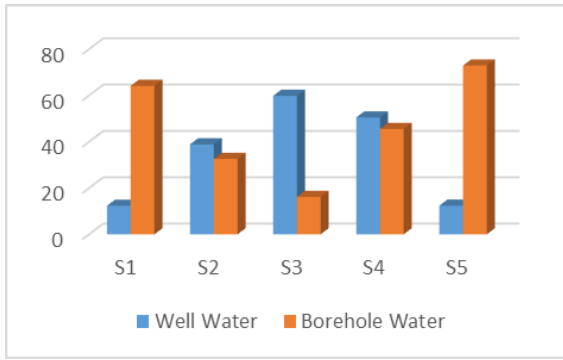


Figure 10: Nitrate concentration of well and Borehole water

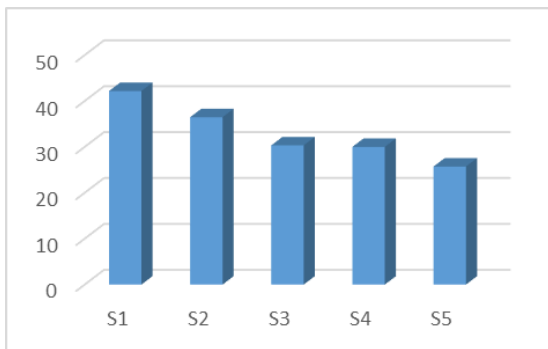


Figure 11: Well water Index result

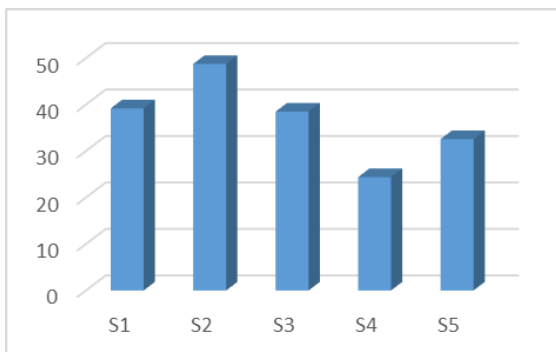


Figure 12: Borehole water Index result

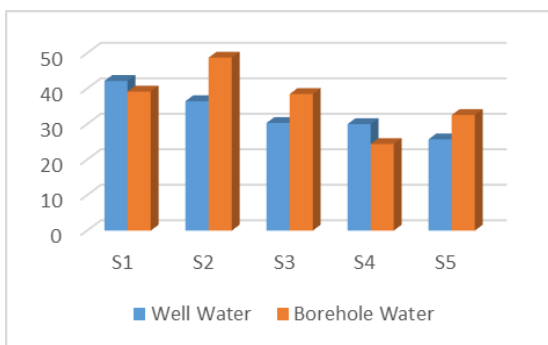


Figure 13: Well and Borehole water index result

The average pH values range from (7.19 ± 0.35) to (7.69 ± 0.13) and from (6.169 ± 0.806) to

(7.877 ± 0.180) for well and borehole water respectively. Hence, the pH values recorded in both water samples are within the WHO standard range for drinking water of 6.5-8.5. The values obtained in this study are compared with that of (Zacchaeus *et al.*, 2020) who reported a pH range of 4.35 to 9.42 for groundwater in Sagamu and Ota areas of Ogun State, Nigeria. Generally, the pH of the samples tended to be slightly alkaline in all the five sampling locations. Although pH does not have a direct health implication on human beings but its indirect effects cannot be ignored (Adekunle *et al.*, 2004).

The average Turbidity in well and borehole water samples ranged from $(1.38 \pm 0.20$ NTU) to $(2.19 \pm 0.17$ NTU) and from $(1.200 \pm 0.000$ NTU) to $(2.440 \pm 0.496$ NTU) which was below the WHO standard value of 5 NTU. This indicates that the turbidity of well and borehole water are within the recommended range and safe for consumption as it does not have much health impact. The level of turbidity obtained in this study is similar to 3.94 ± 1.52 NTU obtained by Michael *et al.* (2015) and disagrees with Reuben *et al.* (2018) who reports high turbidity level of 20.89 ± 6.23 in the analysis of river water collected from Nasarawa State.

Total Dissolve Solids (TDS) ranged from $(71.31 \pm 1.26$ mg/l) to $(732.56 \pm 76.06$ mg/l) concentration of TDS was observed from S₅ and S₁ sampling locations and from $(263.444 \pm 98.420$ mg/l) to $(719.433 \pm 526.316$ mg/l) from S₄ and S₃ sampling locations from well and borehole water respectively. Therefore, the level of TDS recorded in all the sampling locations are within the WHO standard limit of 500-1500 mg/l, This support the findings of (Iroha *et al.*, 2020) who reports the highest TDS level of $(750.00 \pm 1.80$ ppm) and lowest TDS level of $(89.11 \pm 0.50$ ppm) in borehole and river water samples from Ikwo. Reuben *et al.* (2018) in their study reported TDS level of 38.38 ± 8.240 mg/l. TDS also affect the taste and acceptability of drinking water if present at levels beyond recommended limits. Accordingly, the total dissolved solid values recorded in this study could be considered tolerable.

Concentration of Calcium (Ca^{2+}) Concentration ranged from 54.75 to 562.31 mg/l from S₅ and S₁ and from 206.192 to 953.700 mg/l from S₄ and S₂ sampling locations from well and borehole water respectively whereas WHO recommended safe range for Ca^{2+} in drinking water is 75-200 mg/l which indicates that only one sampling location was found within the recommended range of drinking water. The result of the study is not line with the findings of Oparochao *et al.* (2010) with calcium concentrations in the water samples ranging from 0.72 to 2.80 mg/l. The high level of

calcium in the water samples could be attributed to the coming in contact with certain rocks and minerals especially limestone and gypsum when these minerals dissolved, they release calcium and magnesium.

Magnesium (Mg^{2+}) ranged from ($37.26 \pm .15$ mg/l) to (382.63 ± 39.15 mg/l) values were reported from S_5 and S_1 sampling locations and from (140.343 ± 48.098 mg/l) to (649.296 ± 833.965 mg/l) from S_4 and S_2 sampling locations for well and borehole water respectively. The recommended permissible range for Mg^{2+} in drinking water is 30-150 mg/l which implies that very few among the sampling locations are found within the recommended range. The result of the study is not in line with Oparochao *et al.* (2010) who reported Mg^{2+} concentration of 0.24mg/l to 1.50 mg/l which is quiet below the maximum allowable concentration (MAC).

The mean average concentration of Chloride (Cl^-) varied from (66.52 ± 0.54 mg/l) to (683.18 ± 70.05 mg/l) from S_5 and S_1 sampling location and from (250.520 ± 85.857 mg/l) to (1158.834 ± 1488810 mg/l) from S_4 and S_2 sampling locations for well and borehole water respectively. This indicates that the chlorides (Cl^-) level in some of the sampling locations are high whereas in other sampling locations are within the recommended range of 200-600 mg/l by WHO. High levels of Cl^- are typically associated with having high total dissolved solids. Also presence of high level of Cl^- is a common cause of well water pollution and also gives salty taste to water. This disproportionate the findings of Oparochao *et al.* (2010) with a mean of 10.86 ± 8.10 ppm chloride concentration which was low compared to the findings of the study.

Fluoride (F^-) concentration varied from (2.17 ± 0.16 ppm) to ($2.81 \pm .47$ ppm) from S_5 and S_1 sampling locations from (1.686 ± 0.889 ppm) to (3.025 ± 0.252 ppm) from S_4 and S_1 sampling locations for well and borehole water respectively. Therefore, the fluoride (F^-) concentration in all the sampling locations on both water sources exceeds the WHO recommended range of 1-1.5 mg/l. A study conducted by Jdh *et al.* (2013) revealed the occurrence of fluoride in groundwater is due to weathering and leaching of fluoride-bearing minerals from rocks and sediments. Fluoride when digested in small quantities (<0.5ppm) is beneficial in promoting dental health by reducing dental caries, whereas higher concentrations (>1.5 ppm) may cause fluorosis.

Sulphate (SO_4^{2-}) concentration varied from (38.07 ± 3.45 mg/l) to (92.43 ± 0.78 mg/l) from S_4 and S_5 sampling locations and from (33.919 ± 12.712 mg/l) to (61.671 ± 0.922 mg/l) from S_4 and S_1 sampling locations for well and borehole water respectively. The SO_4^{2-} level in all of the sampling

locations on both water sources are within the recommended range of 400 mg/l by WHO. The result of the study is above the findings of Elijah *et al.* (2021) with SO_4^{2-} level ranging from 1.20 ppm to 6.90 ppm.

Average concentration of Nitrates (NO_3^-) was found to vary from 10.32mg/l (S_1) to 86.08mg/l (S_3) and from 16.184 mg/l (S_3) to 72.886 mg/l (S_5) while the standard concentration for NO_3^- issued by WHO is 10 mg/l. This indicates that the concentration of NO_3^- in both water sources of all the five sampling locations are higher than the WHO permissible limit for drinking water. This is similar to Elijah *et al.* (2021) with recorded Nitrate level ranging from 3.40 ppm to 18.90 ppm.

4. Conclusion

The water quality index (WQI) results reveals that the water samples from all the sampling locations were within the Excellent to very good water quality according to water quality index rating scale. For well water samples, four sampling locations: S_1 to S_4 was within the range of good water quality of 26-50 while one sampling location: S_5 were found within the range of excellent water quality of 0-25 while for borehole water four sampling locations: S_1 , S_2 , S_3 and S_5 were found within the value of 26-50 (Good water quality) while one sampling location: S_4 were found within the index value of 0-25 (Excellent water quality). Hence the quality of well and borehole water of Sokoto metropolis in terms of these physiochemical properties is safe for drinking and other purpose.

Conflict of interest

The authors declare no conflict of interest.

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