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Assessment of Some Physicochemical Parameters in Borehole Water Samples Drilled Near Public Conveniences in Kano Metropolis, Nigeria

[1*]Abubakar, A. U. and [2]Sa'id, M. D.

[1]*Department of Soil Science, Faculty of Agriculture, Bayero University, P.M.B. 3011 BUK, Kano, Nigeria
[2]Department of Pure and Industrial Chemistry, Faculty of Physical Sciences, Bayero University, P.M.B. 3011 BUK, Kano, Nigeria
***Correspondence Email:** auabubakar.ssc@buk.edu.ng

ABSTRACT

This research was carried out to assess some physicochemical parameters in boreholes water samples drilled near public conveniences in Kano metropolis, Nigeria. A total of 31 samples were randomly collected and analysed from different sampling sites for some physicochemical parameters. The results for physicochemical parameters ranged as follows: pH (5.600±0.200-8.300±0.100), Electrical conductivity (93.333±5.774-2756.670±30.551µS/cm), colour (0.000-403.667±3.055 pt. co unit), Turbidity (0.000-74.667 NTU), taste was detected in 57% of the water samples from the sampling sites, Odour was detected in about 40% of the sampling sites. Total alkalinity (16.267±1.761-681.167±15.873 mg/l), Chloride (23.667±4.099-641.367±20.496 mg/l), Total hardness (51.200±3.200-609.467±11.085 mg/l), Sulphate (1.333±0.289-15.000±1.000 mg/l), Nitrate (0.013±0.006-23.233±3.493 mg/l), phosphates (0.013±0.006-1.967±0.115 mg/l). Sulphate, Phosphate, Nitrate, Total Hardness, Total alkalinity were found to be within the maximum permissible limit set by W.H.O. The pH, EC, colour, taste, odour, Turbidity, chloride, contents were found to exceed maximum permissible limit set by W.H.O. in most of the samples analysed. Analysis of variance shows that there is a significant difference at ($P<0.05$) in all of the parameters analysed. It can be concluded that most of the physicochemical parameters analysed fall below the maximum permissible limit set by W.H.O.

Keywords: Boreholes, Kano, Physicochemical-Parameters, Public Convenience

INTRODUCTION

Water is one of the basic necessities for the sustenance of life, and it impacts nearly all areas of life. Water quality and the risk to water-borne diseases are critical public health concerns in many developing countries. It has been reported that about billion people mostly living in the developing world does not have access to safe and adequate water (UNICEF/W.H.O., 2012).

Contamination of water bodies has increasingly become an issue of serious environmental concern. Clean water is a priceless and limited resource that man has begun to treasure only recently after decades of pollution and waste (Silberberg, 2003). Potable water is an essential ingredient for good health and the socio-economic development of man but it is lacking in many societies (Udom *et al.*, 2002).

All Natural waters contain many dissolved substances. Contaminants such as bacteria, viruses, heavy metals, nitrates and salt have polluted water supplies as a result of inadequate treatment and disposal of waste from humans and livestock, industrial discharges and over-use of limited water resources (Singh and Mosley, 2003).

To avoid groundwater pollution from effluent leachate, the community water and sanitation Agency (CWSA) recommends that pit latrines should be constructed at least 100 feet (30m) downhill of boreholes (CWSA, 2003). In addition, W.H.O., (2006a) asserted that a minimum of 50 feet (15m) between a pollution source and downstream water abstraction point will be satisfactory.

Water must be assessed before it is used for drinking, domestic, agricultural or industrial purposes. This is mostly done with different physicochemical parameters, which mostly depend on the purpose of the water and the extent to which the quality and purity is required (Umar *et al.*, 2003). Water has different types of physical, chemical and biological impurities. These require different tests to determine the level of these contaminants in the water. To obtain water of good quality, it should be tested for trace metals, heavy metals, organic materials and biological contaminants. For water to be considered as good for drinking then it should pass all these tests and it should also contain required amount of mineral level (Umar, 2006). Previous studies on boreholes water from Kano, (Saeed and Mahmoud, 2014) had reported that, most of the physicochemical parameters analysed were within the maximum permissible limit set by W.H.O. (2020). This work

was set to explore a wider scope of various local Governments within the Kano metropolis.

Materials and Methods

In the preparation of reagents, chemicals of analytical grade purity were used. All glassware involved were cleaned with chromic acid and finally rinsed with de-ionized water.

Study Area

Kano is located on latitude 12°02'N and longitude 08°30'E is the largest and most populous city in Northern Nigeria. There are several public conveniences located at different places in the state particularly in the metropolitan zone. GPS (EFREX 10 of Garmin Product) was used in taking the coordinates. The borehole water samples were collected from thirty- one different locations and their distance proximities to public conveniences are presented in Table.1 as well as their coordinates shown in Fig.1.

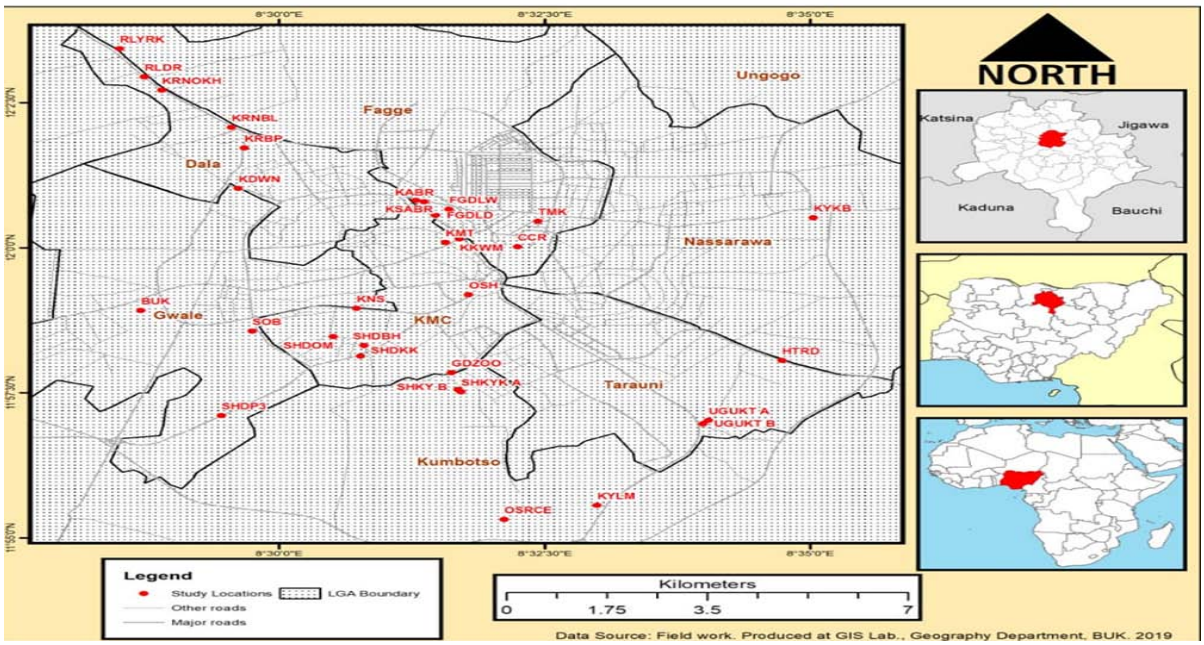

Fig.1: Map of Kano metropolitan Showing the sampling areas

Table 1: Distance between Soak-aways and Boreholes

S/NO.	Sampling Sites	Distance (Metre)
1.	SHKYK A	13.0
2.	SHKYK B	13.8
3.	GDZOO	4.5
4.	OSH	18.3
5.	KNS	15.5
6.	SHDOM	9.5
7.	SHDBH	15.7
8.	SHDKK	15.3
9.	SHDP3	22.5
10.	SOB	4.0
11.	KYLM	12.3
12.	OSRCE	14.8
13.	UGUKT A	10.8
14.	UGUKT B	14.7
15.	HTRD	15.5
16.	KKWM	18.8
17.	KMT	34.0
18.	FGDLD	31.4
19.	FGDLW	14.3
20.	KABR	21.3
21.	KSABR	32.5
22.	KRNBL	18.0

23. RLDR	18.0
24. RLYRK	12.3
25. KRNOKH	16.1
26. KRBP	19.9
27. KDWN	33.3
28. KYKB	29.5
29. CCR	6.0
30. TMK	18.5
31. BUK	22.6
W.H.O. (2006a)	**≥ 15**

Key: SHKYK A&B (ShekaYarKasuwa), GDZOO (Gidan Zoo), OSH (Opposite School of Hygiene), KNS (Kofar Na'isa), SHDOM (Sharada Opposite Masallacin Juma'a), SHDBH (Sharada Behind Hospital), SHDKK (Sharada Kwanar Kasuwa), SHDP3 (Sharada Phase 3), SOB (Salanta Opposite B.U.K), KYLM (Kasuwaryanlemo), OSRCE (Opposite Sa'adatu Rimi College of Education), UGUKT A&B (Unguwa Uku Tasha), HTRD (Hotoro Depot), KKWM (Kasuwar Kantin Kwari), KMT(Kofar Mata), FGDLD (Fagge D Layin Dabinai), FGDLW (Fagge D Layin Wapa), KABR (Kwanar Abattoir), KSABR (Karar Shanu Abattoir), KRNBL (Kurna Babban Layi), RLDR (Rijiyar Lemo Dan Rimi), RLYRK (Rijiyar Lemo Yan Rake), KRNOKH (Kurna Opposite Kunya Hospital), KRBP (Kofar Ruwa bye-pass), KDWN (Kofar Dawanau), KYKB (Kasuwar Yan Kaba), CCR (Civic Centre Road), TMK (Tashar Malam Kato), BUK (Bayero University, Kano), W.H.O. (World Health Organisation).

MATERIALS AND METHODS

Sample Collection

The water samples were collected in 1.0 L cleaned and dried plastic containers. During sampling, sample bottles were rinsed with water samples three times and then filled. Discrete sampling method was adopted in each of the thirty-one designed sampling points. The samples were collected in triplicate and mixed to make a representative samples. The samples were labelled and then taken to the laboratory where they were stored in a refrigerator at temperature of about 4℃ in order to lower the microbial and chemical activities prior to analysis (USEPA, 2016).

Determination of Physicochemical Parameters

Measurement of pH

The pH of the samples was determined in *situ* using a pH meter (Hanna Model NO. ASIN B0855 HLXMZ). The meter, was first calibrated with two sets of buffers (buffer of pH 4 and 7). After calibration, the electrode was immersed into the beaker containing 50 cm^3 of the water samples and the readings were recorded in triplicates for each sample (APHA, 2005).

Determination of Electrical Conductivity (EC)

The EC of the samples was determined at the sampling point using an EC meter (Hanna Model NO. ASIN B0855HLXMZ). The conductivity meter was standardized by dipping the electrode into a 0.01 M potassium chloride (KCl) solution, the standardized electrode was then immersed into the samples and the readings were recorded in triplicates for each sample (APHA, 2005).

Determination of Colour

The colour of the samples was determined using portable data logging spectrophotometer (HACH DR/ 2010). The sample was filled into 50 cm^3 capacity cell and the colour was determined at 455 nm. Separate cell was used for blank. The values obtained were recorded in triplicates for each sample with their units as pt.co unit (APHA, 2005).

Determination of Turbidity

The sample cell was filled with the sample. The turbidity of the samples was determined at 860 nm with NTU as unit, using portable data logging spectrophotometer (HACH DR/ 2010). Blank sample was used to zero the machine after each sample analysed. The values obtained were recorded in triplicates for each sample (APHA, 2005).

Determination of Odour

About 250 cm^3 water was measured into 500 cm^3 wide-mouthed, stoppered flask followed by the addition of little portion of KOH. The flask was heated over a water bath to the temperature of 60 ℃. The flask was then shaken, the stopper was then removed and the nose promptly applied to the aperture of the flask. If no odour is perceptible the water is regarded as odourless. The results obtained were recorded in triplicates for each sample (W.H.O., 2005).

Determination of Taste

Water samples were warmed to room temperature. Exactly 30 cm^3 of the samples was transferred into the beaker (50 cm^3 capacity). Samples were then tasted on both tip and back of tongue. The results obtained were recorded in triplicates for each sample (W.H.O., 2005).

Determination of Alkalinity

About 50 cm^3 of water samples was transferred into 100 cm^3 conical flask, 3 drops of

phenolphthalein indicator was added. Colour change was not observed which indicates that, CO_3^{2-} is not present. To the colourless solution, 2 drops of methyl orange indicator was added and titrated with 0.025 M H_2SO_4 to the methyl orange end-point. The titre values obtained were recorded in triplicates for each sample. Blank was also used in the same manner (APHA, 2005; AOAC, 2010).

Calculation

$$\text{Bicarbonate } (HCO_3^-)mg/l = \frac{AxMx61x1000}{ml\ of\ sample}$$

$$A = \text{Titre value of } H_2SO_4 \text{ used}$$

$$M = \text{Molarity of } H_2SO_4 \text{ (Titrant)}$$

Determination of Chloride (Mohrs's Method)

About 50 cm^3 of water samples was transferred into a 100 cm^3 conical flask, 3 drops of K_2CrO_4 indicator was added and titrated with 0.1 M $AgNO_3$ solution to the red precipitate of AgCl. The titre values obtained were recorded in triplicates for each sample. Blank was also used in the same manner (APHA, 2005; AOAC, 2010).

Calculation

$$Chloride\ (mg/l) = \frac{AxMx35.5x1000}{ml\ of\ sample\ used}$$

A= Titre value of $AgNO_3$ used
M=Molarity of $AgNO_3$ (Titrant)

Equation of the reaction:

$$Ag^+_{(aq)} + Cl-_{(aq)} \rightarrow \quad AgCl \rightarrow 2Ag^+ + CrO_4{}^{2-} \rightarrow Ag_2\ CrO_4$$

at the end point reddish brown (APHA,1998)

Determination of Total Hardness

About 50 cm^3 of distilled water was poured into 250 cm^3 capacity beaker, 25 cm^3 of conc. Ammonia solution and 20 cm^3 of the water samples were added. About 5 drops of Eriochrome T black indicator was added followed by addition of 1 ml of 2% NaCN. The solution was titrated with 0.02 N EDTA to a bright blue end-point. The values obtained were recorded in triplicates for each sample. This titration is a measure of the total Ca and Mg in the sample aliquote used. Blank sample was used in the same manner (AOAC, 2010).

Calculation

$$Hardness\ CaCO_3\ (mg/l) = \frac{(A-B)\ x\ Mx1000}{ml\ of\ sample\ used}$$

A=Volume of EDTA used for sample
B=Volume of EDTA used for blank
M= Molarity of EDTA
Equation of the reaction: $Na_2EDTA_{(aq)} + M^{2+(aq)} \rightarrow MEDTA_{(aq)} + 2Na(s)$

Determination of Nitrate

Exactly, 25 cm^3 of water sample from each sample was pipetted into the sample cell. The content of one sachet of the reagent powder pillow (nitraVer 5 nitrate) was added to the cell and the cell was stoppered and vigorously shaken for a minute to dissolve the powder. The sample concentration was recorded at 500 nm, using portable data logging spectrophotometer (HACH DR/2010). The values obtained were recorded in triplicates for each sample. Blank sample was treated in the same manner (APHA, 2005).

Determination of Phosphate

Exactly, 25 cm^3 of water sample from each sample was pipetted into the sample cell. 1.0 cm^3 of molybdovanadate reagent was added and this was swirled to mix. The mixture was allowed to stay for 3 minutes. The sample concentration was then recorded at 430 nm, using portable data logging spectrophotometer. The values obtained were recorded in triplicates for each sample. Blank sample was treated in the same manner (APHA, 2005).

Determination of Sulphate

Exactly, 25 cm^3 of water sample from each sample was pipetted into the sample cell. The content of one sachet of the reagent powder pillow (SulfaVer 4 reagent) was added to the cell and the cell was stoppered and vigorously shaken for 5 minutes to dissolve the powder. The sample concentration was recorded at 450 nm, using portable data logging spectrophotometer (HACH DR/2010). The values obtained were recorded in triplicates for each sample. Blank sample was treated in the same manner (APHA, 2005).

RESULTS AND DISCUSSION

The Results of physicochemical parameters are presented below.

pH

From Fig. 2, it can be seen that, the mean pH values for the samples analysed ranged from 5.600±0.200 to 8.300±0.100. The highest pH value was obtained at RLDR sampling site (8.300±0.100) while the lowest pH was obtained at KKWM sampling site (5.600±0.200), (Figure 2). This low pH may be attributed to the presence of organic acids, hydrolysing salts such as iron (II) sulphate and aluminium sulphate (W.H.O., 2007). A similar result was obtained by Mbugua (2014). Analysis of variance (ANOVA), (F pr. < 0.001) shows that P <0.05, this means that there is a significant difference in pH values among the boreholes water samples. About 85 % of the samples analysed fall within the acceptable limit (6.500-8.500) set by W.H.O. (2020). The Control sample was analysed as (6.367±0.058).

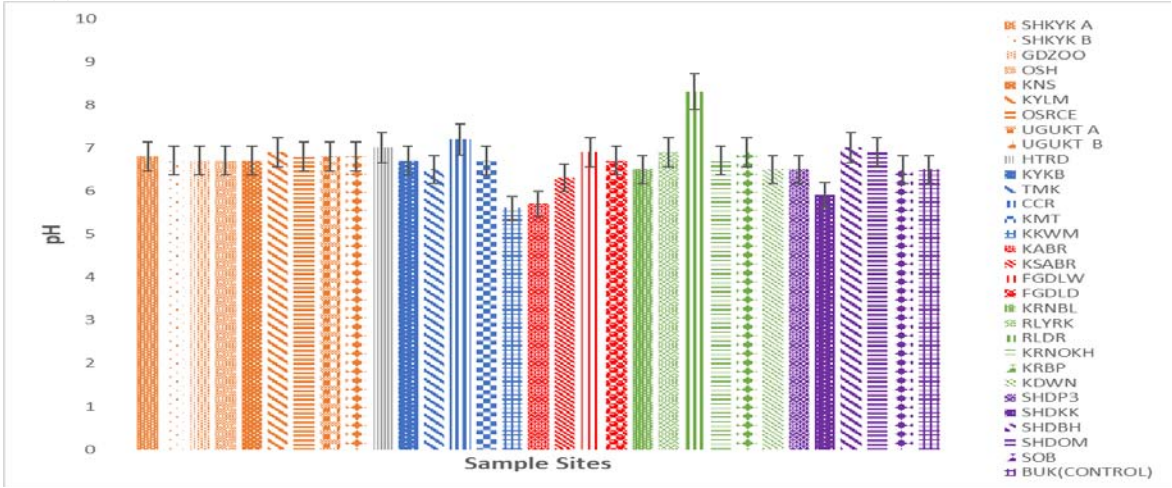

Fig. 2: pH Level

Electrical Conductivity

The mean values of electrical conductivity for the samples analysed ranged from 93.333±5.774-2756.67±30.551 µS/cm as presented in Fig. 3. The highest EC was obtained at KRNBL sampling site (2756.67±30.551 µS/cm). The high EC values may be attributed to the high content of dissolved inorganic salts which may cause water to taste salty (Hach, 2000). Harison, (1992) attributed high EC to the high level of sewage materials as well as leaching of organic contaminants. The highest EC may also be due to the high level of chloride as well as taste and odour detected in the sample. The lowest EC was obtained at KNS sampling site (93.333±5.774) µS/cm. A similar result was obtained by Abdul and Thabit (2016). Analysis of variance (ANOVA),(F pr. < 0.001) shows that P< 0.05, this means that there is a significant difference in EC values among the boreholes water samples. About 60 % of the samples analysed fall within the acceptable limit.

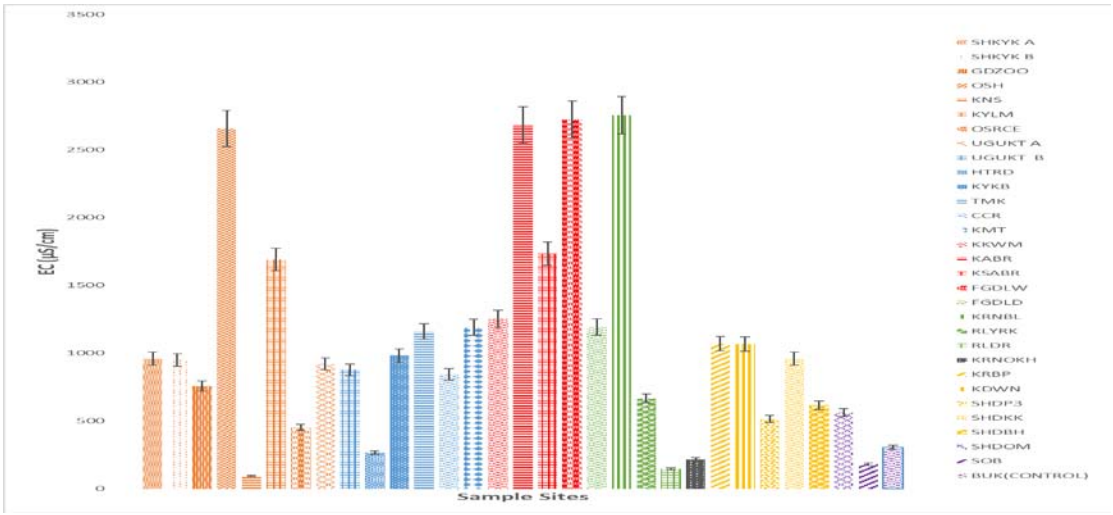

Fig. 3: Electrical Conductivity

Colour

The mean values of colour for the samples analysed ranged from (0-403.667±3.055 pt.co unit) as shown in Fig. 4. The highest colour was obtained at KNS sampling site (403.667±3.055 pt.co unit). This may be attributed to the presence of coloured organic matter associated with the humus fraction of soil (W.H.O. , 2009), may also be due to the high levels of iron as well as turbidity as the sampling site is close to the dumpsite which may lead to the leaching of the contaminants to the water. A similar result was obtained by Mgbemena *et al.,* (2014). Analysis of variance (ANOVA), (F pr. < 0.001) shows that P<0.05, this means that there is a significant difference in Colour values among the boreholes water samples. About 75 % of the samples analysed fall within the acceptable limit (0-15 pt.co) unit set by W.H.O., (2020). The control sample is also within the acceptable limit.

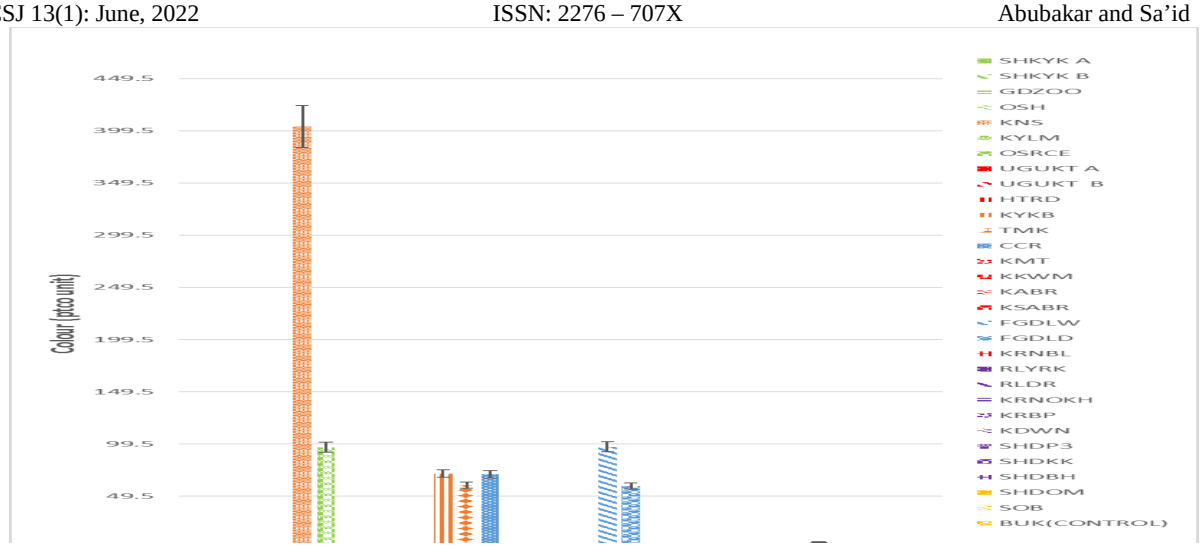

Fig. 4: Colour Intensity

Turbidity

The mean values of Turbidity for the samples analysed ranged from (0- 74.667 NTU) as shown in Fig. 5. The highest turbidity was obtained at KNS sampling site (74.667± 1.528 NTU). A similar result was obtained by Abdul and Thabit (2016). Analysis of Variance (ANOVA),(F pr. < 0.001) shows that P<0.05, thi s means that there is a significant difference in Turbidity values among the boreholes water samples. About 95 % of the samples analysed fall within the acceptable limit (5 NTU) set by W.H.O., (2020). Duncan (1996) explains that high turbidity may be caused when light is blocked by large amounts of silt and microorganisms in water, may also be due to the presence of inorganic particulate matter and non-soluble metal oxides as stated by (Dagim *et al.*, 2016). Turbidity can indicate that, water may be contaminated with pathogens presenting human health concerns (Olson, 2004).

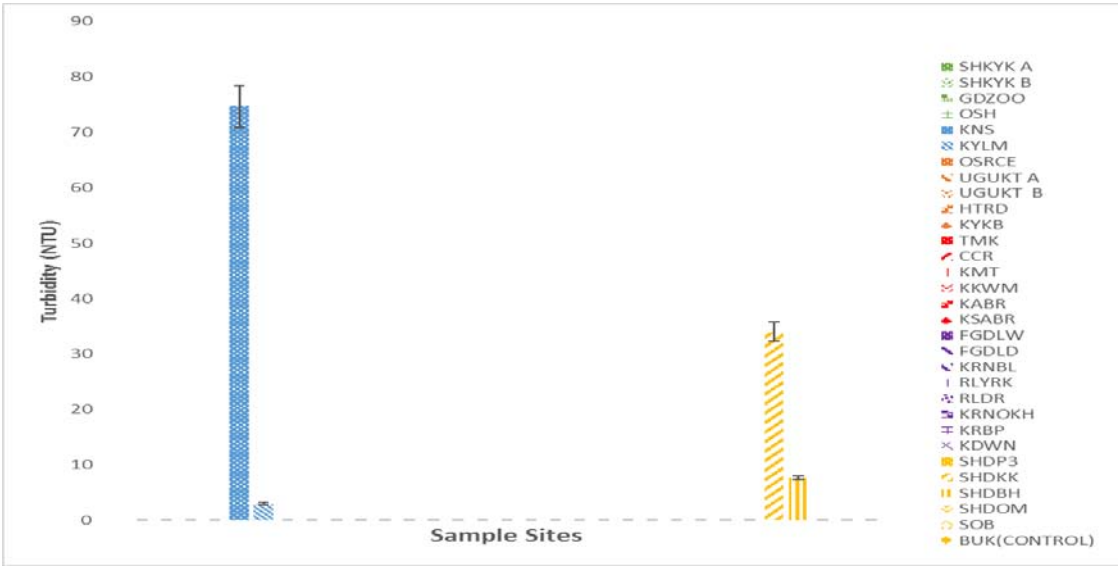

Fig. 5: Turbidity

Odour

Odour was detected in about 40 % of the sampling sites. This may be attributed to the high level of chloride content and decayed organic matter as stated by (Rowland *et al.*, 2008). About 60% of the sampling site analysed fall within the acceptable limit (Unobjectionable) set by W.H.O. (2020). Control sample was analysed as Unobjectionable.

Taste

Taste was detected in about 57 % of the sampling sites. This may be attributed to the high values obtained from their electrical conductivities values as well as the presence of some metals. About 43 % of the sampling site analysed fall within the acceptable limit (tasteless) set by W.H.O. (2020). Control sample was analysed as tasteless.

Table 2: Results for Taste and Odour

Sample Site	Taste	Odour
SHKYK A	Tasteless	Unobjectionable
SHKYK B	Tasteless	Unobjectionable
GD ZOO	Tasteless	Unobjectionable
OSH	Taste Detected	Objectionable
KNS	Tasteless	Unobjectionable
KYLM	Taste Detected	Unobjectionable
OSRCE	Tasteless	Unobjectionable
UGUKT A	Taste Detected	Objectionable
UGUKT B	Taste Detected	Unobjectionable
HTRD	Tasteless	Unobjectionable
KYKB	Taste Detected	Objectionable
TMKT	Taste Detected	Unobjectionable
CCR	Taste Detected	Objectionable
FGDLW	Taste Detected	Unobjectionable
FGDLD	Taste Detected	Unobjectionable
KMT	Taste Detected	Unobjectionable
KKWM	Taste Detected	Unobjectionable
KABR	Taste Detected	Objectionable
KSABR	Taste Detected	Objectionable
KRNBL	Taste Detected	Objectionable
RLDR	Taste Detected	Objectionable
RLYRK	Tasteless	Unobjectionable
KRNOKH	Tasteless	Unobjectionable
KRBP	Taste Detected	Unobjectionable
KDWN	Taste Detected	Objectionable
SHDP 3	Tasteless	Objectionable
SHDKK	Tasteless	Objectionable
SHDOM	Taste Detected	Objectionable
SHDBH	Taste Detected	Objectionable
SOB	Tasteless	Unobjectionable
BUK (control)	Tasteless	Unobjectionable
W.H.O. (2020)	**Tasteless**	**Unobjectionable**

Total Alkalinity

The mean concentration of total alkalinity for the samples analysed ranged from 16.267±1.761-681.167±15.873 mg/l as shown in Fig. 6. The highest result was obtained at KRNBL sampling site (681.167±15.873 mg/l). The high content may be attributed to the excessive amount of sodium hydroxide, potassium hydroxide and other hydroxide containing compounds as stated by (Bernard and Ayeni, 2012). This high content made it to be unpalatable and also not suitable for irrigation purposes (W.H.O., 2005). The main species that contribute to the alkalinity includes; bicarbonates, hydroxides, phosphates and borates (USGS, 1998). Excessive alkalinity may cause stomach upset and encrustation of utensils, pipes and water heaters. High levels can also give a 'flat' taste to the water and cause "itchy" skin when bathing (APHA, 1998). There are no serious adverse health effects from drinking water with alkalinity above or below the suggested levels (Scheel *et al.*, 2011). The lowest result was obtained at KNS sampling site (16.267±1.761) mg/l. The result obtained was not in agreement with the result obtained by Mbugua (2014) and Olanipekun (2013), but somehow close to what was obtained by Ilori *et al.*, (2018). Analysis of variance (ANOVA), (F pr. < 0.001) shows that P <0.05, this means that, there is a significant difference in total alkalinity values among the boreholes water samples. About 97 % of the samples analysed fall within the acceptable limit (≤500 mg/l) set by W.H.O. (2020). The control sample was analysed as (124.542±4.402 mg/l).

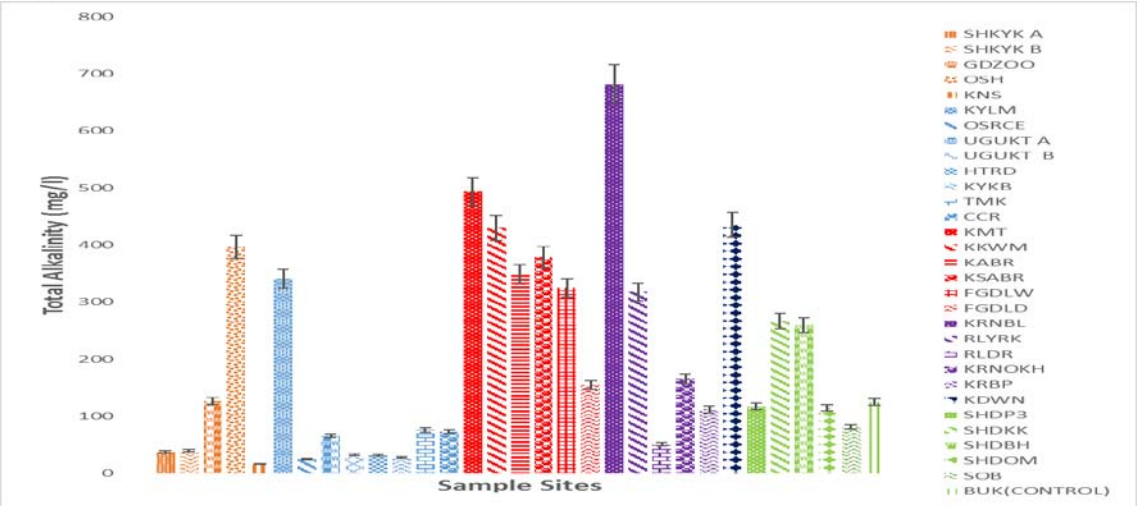

Fig. 6: Mean Concentration of Total Alkalinity

Chloride

The mean concentration of chloride for the sampling site analysed ranged from(23.667±4.099-641.367±20.496 mg/l) as shown in Fig. 7. The highest result was obtained at KABR sampling site (641.367±20.496 mg/l). The high level content may be attributed to the high EC values and taste detected in most samples and no health based guidelines was proposed (W.H.O., 2009). The lowest result was obtained at KNS sampling site (23.667±4.099 mg/l). A similar result was obtained by Abdul and Thabit (2016). Analysis of variance (ANOVA), (F pr. < 0.001) shows that P<0.05, this means that there is a significant difference in chloride values among the boreholes water samples. About 80 % of the samples analysed fall within the acceptable limit (≤ 250 mg/l) set by W.H.O. (2020). The control sample was analysed as (54.433±4.099 mg/l).

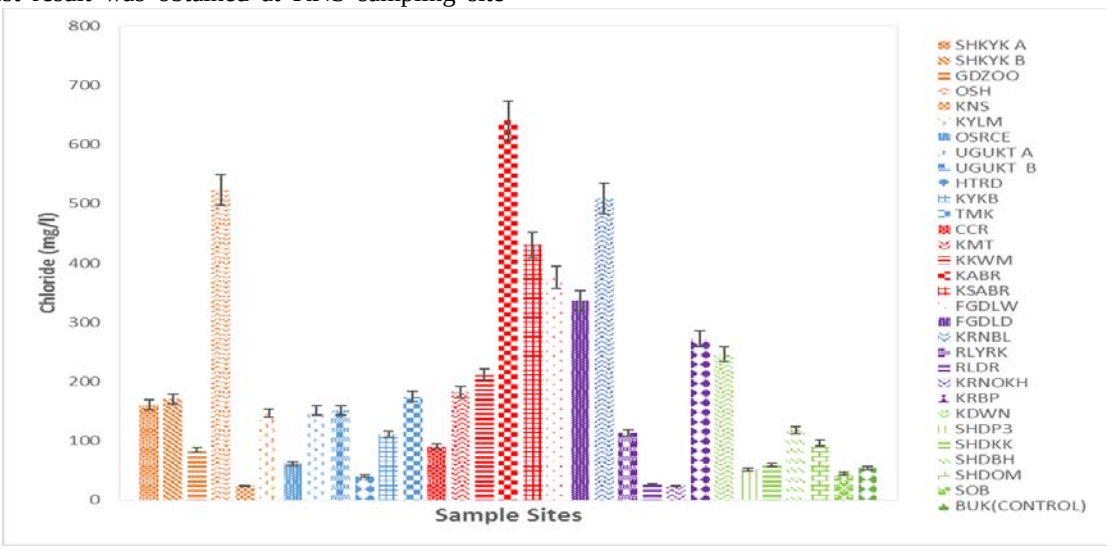

Fig. 7: Mean Concentration of Chloride

Total Hardness

The mean concentration of total hardness for the samples analysed ranged from (51.200±3.2000-609.467±11.085 mg/l) as shown in Fig. 8. The highest result was obtained at KRBP sampling site (609±11.085 mg/l). This high content may be as a result of the presence of excess amounts of insoluble metals and salts which rendered it to be not suitable for other purposes such as washing. The lowest result was obtained at KNS sampling site (51.200±3.200 mg/l). A similar result was obtained by Olanipekun (2013). Analysis of variance (ANOVA), (F pr. < 0.001) shows that P<0.05, this means that there is a significant difference in total hardness values among the boreholes water samples analysed. About 97 % of the samples analysed fall within the acceptable limit (≤ 500 mg /l) set by W.H.O. (2020). The control sample was analysed as (107.733±9.238 mg/l).

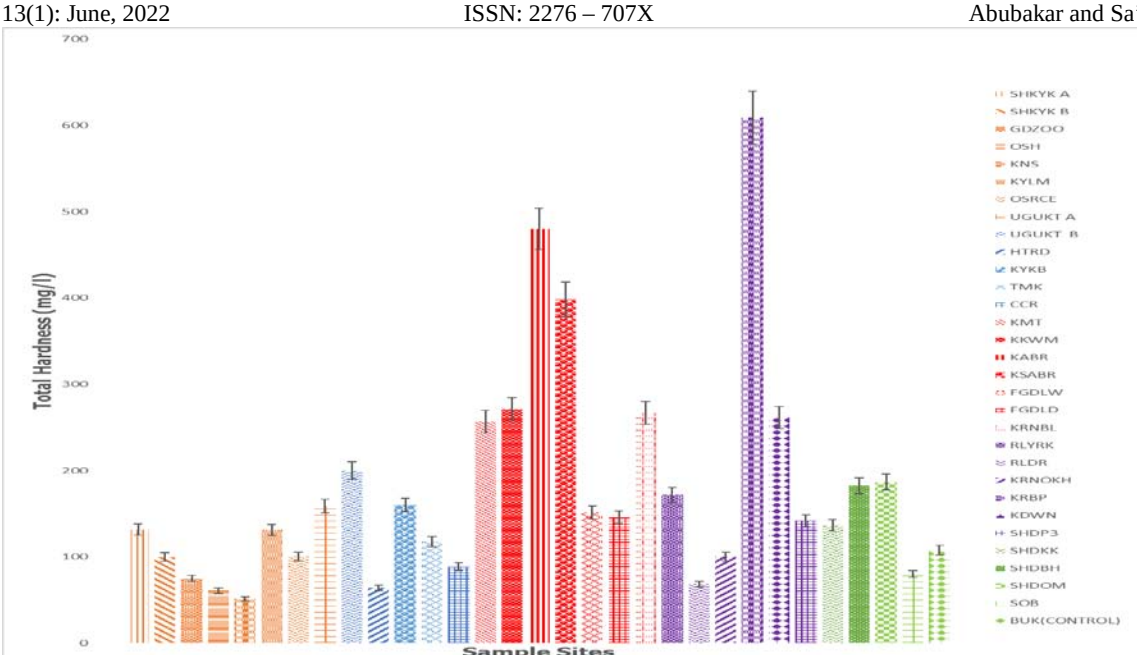

Fig. 8: Mean Concentration of Total Hardness

Nitrate

The mean concentration of Nitrate for the samples analysed ranged from (0.013±0.006-23.233±3.493 mg/l) as shown in Fig. 9. The highest Nitrate was obtained at KRNBL sampling site (23.233±3.493 mg/l). The lowest result was obtained at RLYRK, FGDLD and CCR sampling sites (0.013±0.006 mg/l). A similar result was obtained by Benedict (2015). Analysis of variance (ANOVA), (F pr. < 0.001) shows that P<0.05, this means that there is a significant difference in Nitrate values among the Boreholes water samples. All the samples analysed fall within the acceptable limit (≤ 50 mg/l) set by W.H.O. (2020). The control sample was analysed as (1.267±0.289 mg/l). Suthar *et al.* (2009) had strongly suggested intensive agriculture and heavy use of N-fertilizer to be major enrichments of nitrate in ground water. This low contents were found to be in agreement with W.H.O., (2003) drinking water quality report which concluded that, the nitrate concentration in ground water and surface water is normally low but can reach higher levels as a result of leaching or run-off from agricultural land or contamination from human or animal waste as a consequence of the oxidation of ammonia and similar sources.

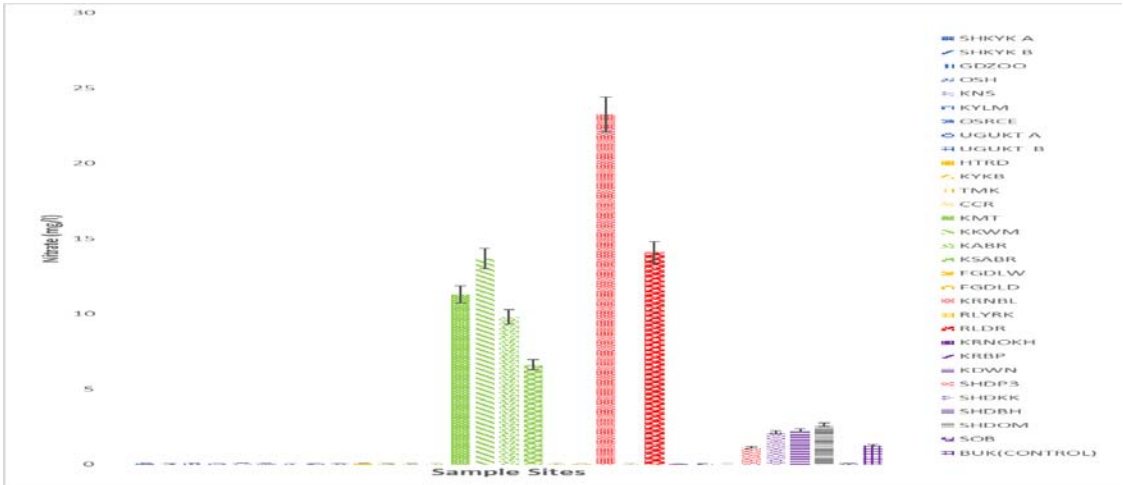

Fig. 9: Mean Concentration of Nitrate

Sulphate

The mean concentration of sulphates for the samples analysed ranged from (1.333±0.289-15.000±1.000 mg/l) as shown in Fig.10.The highest sulphate was obtained at SHDP3 sampling site (15.000±1.000 mg/l). This may be due to the discharge of industrial wastes and domestic sewages as stated by W.H.O. (1999), Oxidation of sulphides from sulphurous gases discharged to the atmosphere which often result in acid rain water containing detectable levels of sulphate at industrial areas may also lead to the high sulphates

content (Fashola and Nwankoala, 2013). The lowest result was obtained at KDWN sampling site (1.333±0.289 mg/l). A similar result was obtained by Benedict (2015), and Ebri *et al*. (2016). Analysis of variance (ANOVA), (F pr. < 0.001) shows that P<0.05, th is means that there is a significant difference in Sulphate values among the Boreholes water samples. All the results for the samples analysed fall within the acceptable limit (≤ 250 mg/l) set by W.H.O. (2020). The control sample was analysed as (7.333±0.577 mg/l).

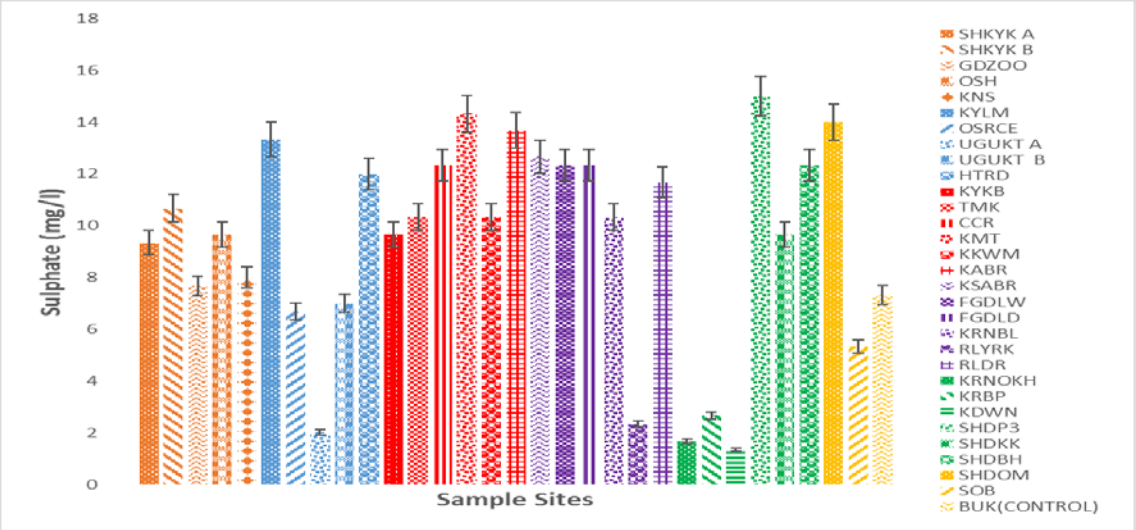

Fig.10: Mean Concentration of Sulphate

Phosphate

The mean concentration of phosphate for the samples analysed ranged from (0.013±0.006-1.967±0.115 mg/l) as shown in Fig. 11. The highest Phosphate was obtained at SHDKK sampling site (1.967±0.115 mg/l). The lowest Phosphate was obtained at TMK and FGDLW sampling site (0.013±0.006 mg/l) respectively. A similar result was obtained by Abdul and Thabit (2016), Ebri *et al.,* (2016). Analysis of variance (ANOVA), (F pr. < 0.001) shows that P<0.05, this means that there is a significant difference in phosphates values among the borehole water samples. All the values obtained from the samples analysed fall within the acceptable limit (≤ 3 mg/l) set by W.H.O. (2006b). The control sample was analysed as (1.500±0.100 mg/l). Phosphates constitutes a very important pollution problem whenever it is found in significant amount. It promotes algal growth and/ or microphytes, leading to the cyclic problem of eutrophication (Thriodore, 2004). It was established that, high phosphorous concentration has no health implication except for its role in causing eutrophication of water bodies (W.H.O., 2004).

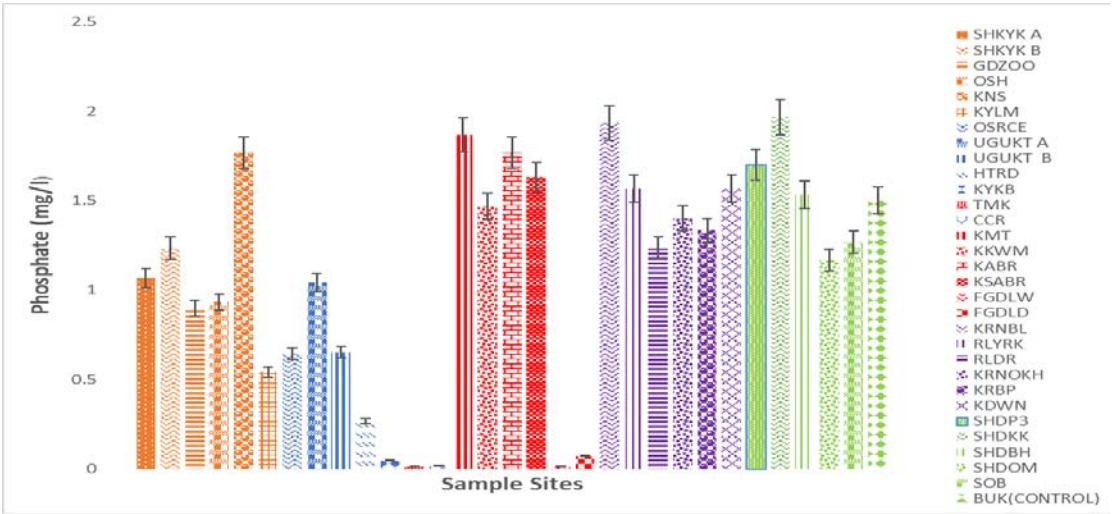

Fig. 11: Mean Concentration of Phosphate

Table 3 provides the summary of all the analysed parameters as per their maximum permissible limits.

Table 3: Summary of the Sampling Sites According to the Maximum Permissible Limits (MPL)

Parameters	Within MPL (%)	Above MPL (%)
pH	85	15
Electrical Conductivity(µS/cm)	60	40
Colour (pt.co. unit)	75	15
Turbidity (NTU)	95	5
Odour	60	40
Taste	43	57
Total Alkalinity(mg/l)	97	3
Total Hardness(mg/l)	97	3
Chloride(mg/l)	80	20
Nitrate(mg/l)	100	0
Sulphate(mg/l)	100	0
Phosphate(mg/l)	100	0

CONCLUSION

This study has shown that some physicochemical parameters such as; sulphate, nitrate, phosphate, total hardness, total alkalinity, were found to be within the W.H.O., (2020) permissible limits for almost all the samples analysed. Parameters such as; pH, EC, Taste, odour, colour, turbidity and chlorides were found to exceed the W.H.O. (2020) permissible limits in some samples. The low values obtained in sulphate, nitrate and phosphates indicated that, there is no contamination from the nearby soak-aways, pit-latrines as well as septic tanks to the boreholes. Thus, it can be concluded that most of the parameters analysed in the boreholes water samples indicated that the water samples were safe for consumption and other domestic purposes.

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