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Physicochemical Quality of Groundwater Samples around Federal College of Animal Health and Production Technology, Ibadan Students' Residential Areas

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Abstract

Groundwater is a major source of water for students at the Federal College of Animal Health and Production Technology, Ibadan students' residential areas. This study investigated the physicochemical profile of groundwater samples of the study area by standard analytical procedure. A total of ten water samples from five sampling points within the study area were collected. Elevation and coordinates of the locations were taken using a global positioning system. Results of the physical parameters showed: pH (7.08 -7.29), Temperature (25.00 - **45.90**)℃, Total dissolved solid (82.00 - 484.50) mg/L, Electrical conductivity (154.50 - 949.00) **µ**/cm, Turbidity (12.81 - 82.65) NTU, Total alkalinity (2.91- 38.16) mg/L and Total hardness (2.20 - 202.85) mg/L; values were lower than WHO safe limit except for turbidity. Results of the chemical parameters showed (mg/L): cations - Ca^{2+} (0.71 -190.96), K^{+}(1.52 - 10.01), Mg^{2+}(1.49 - 15.87) and Na^{+} (7.37 - 88.30); anions -PO^{-}_{4} (BDL - 1.77), SO^{2-}_{4} (1.34 - 32.95), NO^{-}_{3} (30.36 - 722.07), NO^{-}_{2} (12.72 - 354.05), Cl^{-} (16.08 - 127.79) and F^{-} (0.14 - 0.88); metal - Fe (BDL - 9.85), Cu (0.35 - 6.40), Zn (2.50 - 6.10) and Mn (0.38 - 2.95); values obtained were within the safe limits set by WHO except for NO_3^- and NO_2^-. High nitrate and nitrite levels indicate sewage pollution. Thus, the groundwater samples may not be safe for consumption and domestic use unless it is treated. Mean contents of the heavy metals (except Cu) are above the WHO limits. This may suggest that the environment is not free of heavy metal contamination and hence there could be a risk associated with the ingestion of the metals. The potential health risk due to heavy metal contamination in the groundwater samples should be evaluated in order to reveal health implications of the water when ingested. However, this study could serve as a baseline for further research in the future.

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Keywords: Groundwater, Cations, Anions, Heavy metals

1. Introduction

Groundwater is one of the most significant natural water resources readily available in many countries and has considerably been utilized for drinking and irrigation purposes (Amadi *et al*., 2013; Selvakumar *et al*., 2017). Groundwater quality is important to human health, agriculture, aquaculture, and industry, domestic and drinking usages (Vanloon and Duffy, 2005). Groundwater resource has become the primary source of domestic water supply in the world at large because it looks clean (Hynds *et al*., 2014; Raimi and Sabinus, 2017). Groundwater quality depends not only on natural factors such as aquifer lithology, groundwater velocity, quality of recharge waters and interaction with other types of water or aquifers but also on human activities and the environment. The environment plays an important role in health and human development, and the adverse health effects from exposure to environmental contaminants are linked to specific environmental hazards, such as benzene and leukemia (Ojekunle et *al*., 2020).

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Over the last few years, groundwater resources are among the most important environmental issues due to heavy metals contamination and human industrial activities (Öztürk *et al*., 2009; Khodabakhshi *et al*., 2011; Ghasemi *et al*., 2011). The physical and chemical characteristics of groundwater are being contaminated and deteriorated due to different human activities such as agriculture, domestic and industrial activities (Azizullah *et al*., 2011). Municipal and industrial wastes, chemical fertilizers, herbicides and pesticides have entered the soil, infiltrated some aquifers and degraded the ground-water quality. Other pollution problems include sewer leakage, faulty septic-tank operation and landfill leachates (Madugundu *et al*., 2014). Overpopulation and unintended urbanization, unhindered exploration guidelines, and improper dumping of solid and liquid wastes enhance the infiltration of harmful substances into the under-ground water resources (Ganiyu *et al*., 2020).

The degradation of groundwater quality in a geological area is a function of both physical and chemical parameters that are greatly influenced by geological formations and anthropogenic activities (Subramani *et al*., 2005). Groundwater contamination has become a huge problem to environmental scientists due to rapid growth of population, industrialization and urbanization rate in the metropolitan cities all over the world (Kumar, 2014; Cozzarelli *et al*., 2011 and Satyana-rayanan *et al*., 2016). The quality of groundwater is usually characterized by different physicochemical parameters levels. These parameters change widely due to diverse types of pollution, seasonal variation and groundwater extraction (Rama-Krishnaiah *et al*., 2009). Assessment of physicochemical characteristics in groundwater sources is necessary in order to understand the quality *viz-a-viz* the sources, fate and potential risks. Hence, the study was designed to assess the physicochemical properties in groundwater sources around Federal College of Animal Health and Production Technology (FCAH & PT), Moor Plantation, Ibadan student's residential areas.

2. Materials and Methods

2.1. Study Area

The study was conducted at the students' residential areas of the Federal College of Animal Health and Production Technology (FCAH & PT), Moor Plantation, Ibadan. These areas included Adabeji, Odo Ona, Gbekuba, Main hostel and Bora hostel. Elevation and coordinate values were taken for each sample location with the aid of global positioning system (GPS) Garmin channel eTrex10 and map of the sampling points was drawn using a Geographical information system (GIS) and are presented in Figure 1.

2.2. Sample Collection

Groundwater samples were collected from borehole and hand dug wells used by students of the FCAH & PT, Ibadan as source for drinking, cooking and bathing purposes. A total of ten groundwater samples (five boreholes and five wells) were randomly collected from the locations within the study area.

Samples from the wells were collected by lowering a clean plastic container tied to a synthetic rope down the well. Samples from borehole water were collected by first opening the tap to flow out for about two minutes, before putting the containers to collect.

Prior to sampling, the bottles were washed with detergent and rinsed with the groundwater to be sampled. Groundwater samples were then collected in 2-L polyvinyl chloride bottles to prevent unpredictable changes in characteristics. After collecting the water samples, each sampling bottle's cap was tightly screwed to prevent leakage (Odukoya and Abimbola, 2010; Ganiyu *et al.*, 2020). The collected samples were treated with few drops of nitric acid (to keep metals in solution) and kept in an ice-crested cooler to prevent any kind of chemical or biological reaction prior to chemical analysis (Ukah *et al.*, 2019). All the water samples were well labeled and transported in black polyethylene bags to the laboratory for relevant chemical analysis within 24 hours from the time of sample collection. The analysis was conducted at the Multipurpose Laboratory of Federal College of Animal Health and Production Technology, Ibadan.

2.3. Sample Analysis

Analysis was carried out for various water quality parameters (physical and chemical parameters) in groundwater samples of the study by standard methods.

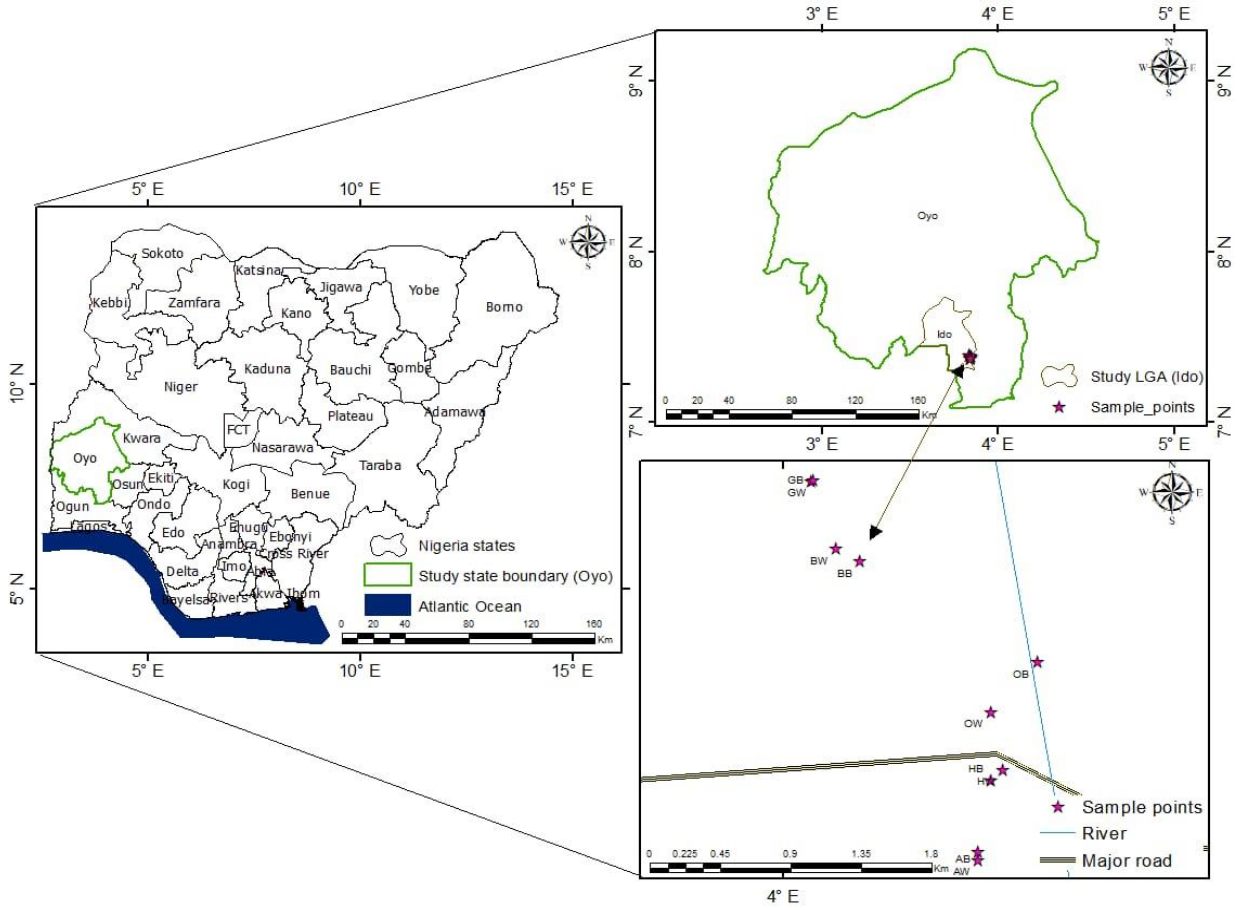


Figure 1: Map of the Study Area showing the sampling points

2.3.1. Physical Parameters

Physical parameters such as pH, total alkalinity, electrical conductivity (EC), temperature, turbidity, total dissolved solids (TDS) and total hardness in groundwater samples of the study were investigated using standard methods.

The temperature of the samples was taken in-situ using mercury in glass thermometer so as to document the true condition when collected. Hydrogen ion concentration (pH), electrical conductivity and total dissolved solids were measured in-situ using portable hand-held multimeter.

Total alkalinity was determined according to the method described by Okoro *et al*., (2012). One hundred millilitres of the water samples were measured into conical flasks. Phenolphthalein was prepared by weighing 0.5 g in 50 ml of 95% ethanol and 50 ml distilled water with constant stirring. Two to three drops of phenolphthalein was added to the water samples in the conical flasks. Each water sample was titrated with 0.01 M HCl until the pink colour disappeared. This end point represents phenolphthalein alkalinity. A few drops of methyl orange indicator were added to the samples in conical flasks (samples already treated with phenolphthalein indicator). The sample turned yellow immediately on addition of methyl orange. The solution was titrated with 0.01 N HCl until the colour change (greenish blue) was observed which represents the total alkalinity.

The turbidity of the water samples were determined by the use of turbidity meter. The water sample was poured in the sample bottle to the mark. The blank sample was placed in the cell holders on the meter; the blank sample was the distilled water in the sample bottle. The water sample in the sample bottle was placed in the cell holder after removing the blank sample and read. The turbidity of the water samples were then displayed in NTU.

Total hardness was determined according to a method described by Okoro *et al*. (2012). Fifty millilitres of each water samples were measured into the conical flasks. Two millitres of buffer solution were added to each sample, the colour remained unchanged. A small amount of eriochrome black indicator (1.0 g of erichrome dissolved in 100 ml ethanol) was added to each sample, a pink colouration was observed. The samples were then titrated up to the observance of blue colouration. The titre value of each water sample was multiplied with (44.892) as the approved conversion factor (Ukah

et al., 2019), where the hardness of the water samples is expressed in mg/L.

2.3.2. Chemical Parameters

Prior to heavy metal analysis, water samples were digested. Two millitres of each of the test substances was transferred to a pre-washed 100-mL beaker containing analytical grade, 25 mL of aqua regia mixture (70% HNO_3 and HCl ratio: 3:1). The mixture was digested in a digestion vessel at the temperature of 80 °C until obtaining a homogenous solution. Afterward, the solution was cooled, filtered through a Whatman No.42 filter paper into a 50-mL volumetric flask, and diluted to the mark with deionized water. The filtrate was subjected to atomic absorption spectroscopy using a Perkin Elmer Atomic Absorption Spectrophotometer at the FCAH&PT Multipurpose Laboratory, Moor Plantation, Apata, Ibadan with suitable hollow cathode lamps. The samples were also analyzed for major cations (Na^+, Mg^{2+}, Ca^{2+} and K^+) and anions (sulphate, phosphate, nitrate, nitrite, chloride and fluoride). The chemical analysis was carried out using the standard methods according to a method described by Adebayo *et al*. (2021).

Sulphate (SO_4^{2-}) concentration in the groundwater samples was determined using the turbimetric method. The method is based on the principle of formation of barium sulphate in the presence of (acidified HCl) barium chloride. The process is enhanced in the presence of glycerol and other organic compound. The absorbance of the colloidal solution was measured against a standard on a UV visible Spectrophotometer. Sodium (Na^+) and Potassium (K^+) contents were determined using Flame Photometry. Sodium and potassium standard solutions were prepared by diluting a 1000 mg/L stock solution with distilled water to obtain final concentrations of 1 mg/L, 5 mg/L, 10 mg/L, 20 mg/L, and 50 mg/L. Groundwater samples were then filtered to remove particulate matter. For samples with expected high concentrations, appropriate dilutions were made using distilled water. The flame photometer was calibrated using the prepared sodium and potassium standards. A blank (distilled water) was used to zero the instrument. 10 mL of each groundwater sample was aspirated into the flame photometer, and the emission intensities for sodium and potassium were recorded.

Calcium (Ca^{2+}) and Magnesium (Mg^{2+}) contents were determined using Atomic Absorption Spectrometry (AAS). Calcium and magnesium standard solutions were prepared by diluting a 1000 mg/L stock solution with distilled water to obtain final concentrations of 1 mg/L, 2 mg/L, 5 mg/L, 10 mg/L, and 20 mg/L. Groundwater samples were filtered to remove particulate matters. Samples were diluted with distilled water. The AAS was then calibrated using the prepared calcium and magnesium standards. A blank (distilled water) was used to zero the instrument. 10 mL of each groundwater sample was aspirated into the AAS, and the absorbance values for calcium and magnesium were recorded at their respective wavelengths. Chloride (Cl^-) contents were determined using Titration Method. Silver nitrate solution (0.1 M), Potassium chromate indicator solution (5% w/v), Chloride standard solution (100 mg/L) were the reagents used. Groundwater samples were filtered to remove particulate matter. For samples with expected high chloride concentrations, appropriate dilutions were made using distilled water. Fifty millilitres of each groundwater sample was placed in a conical flask. Two drops of potassium chromate indicator were added, turning the solution yellow. The sample was titrated with 0.1 M silver nitrate until a persistent red-brown color appeared, indicating the endpoint.

Phosphate (PO_4^{3-}) contents were determined using the Molybdate Blue Method. Phosphate standard solutions were prepared by diluting a 100 mg/L phosphate stock solution with distilled water to obtain final concentrations of 0.5 mg/L, 1 mg/L, 2 mg/L, 5 mg/L, and 10 mg/L. Ammonium molybdate solution (10% w/v), Sulfuric acid solution (1:1 diluted with water), Ascorbic acid solution (0.1 M), Potassium antimonyl tartrate solution (0.5% w/v) were the reagents used. Groundwater samples were filtered to remove particulate matter. To 20 mL of each groundwater sample, 10 mL of the molybdate reagent mixture (ammonium molybdate, sulfuric acid, ascorbic acid, and potassium antimonyl tartrate) was added, and the mixture was diluted to 50 mL with distilled water. The color was allowed to develop for 15-30 minutes, and the absorbance was measured at 880 nm using a spectrophotometer.

Nitrite (NO_2^-) and Nitrate (NO_3^-) contents were determined using Spectrophotometry. Nitrite and nitrate standard solutions were prepared by diluting 100 mg/L stock solutions with distilled water to obtain final concentrations suitable for analysis. Sulfanilamide solution (4% w/v), N-(1-Naphthyl)ethylenediamine dihydrochloride (NED) solution (0.2% w/v), Cadmium reduction column (for nitrate reduction), Phosphate buffer solution (pH 7.5) were the reagents used. Groundwater samples were then filtered to remove particulate matter. For samples with expected high nitrite or nitrate concentrations, appropriate dilutions were made using distilled water.

For Nitrite Determination, 10 mL of each groundwater sample, 1 mL of sulfanilamide solution was added, followed by 1 mL of NED solution. The mixture was allowed to stand for 10 minutes for color development. The absorbance was measured at 540 nm using a spectrophotometer. For Nitrate Determination, Groundwater samples were passed through a cadmium reduction column to reduce nitrate to nitrite. The reduced samples were then treated as described for nitrite determination, and the absorbance was measured at 540 nm.

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3. Results and Discussion

3.1. Results of the Physicochemical Parameters of the Groundwater Samples

Analysis was carried out for various water quality parameters (physical parameters - pH, electrical conductivity, total dissolved solids, turbidity, total alkalinity and total hardness; common cations - Na^+, Mg^{2+}, Ca^{2+} and K^+; common anions - sulphate, phosphate, nitrate, nitrite, chloride and fluoride and some heavy metals - Mn, Fe, Cu and Zn) in the groundwater samples using standard analytical methods and are presented in Tables 1 - 3. Results are compared with permissible limit recommended by the World Health Organization (WHO). In the study, the temperature varied from 25.00°C (Gbekuba Borehole) and 45.90°C (Adabeji Well) with an average value of 37.51°C. A significant difference of ($p < 0.05$) was observed in all the samples. The ground water in these sampled areas is good for domestic purposes since it falls within the WHO limit.

pH governs the behaviour of several other important parameters of water quality such as ammonia toxicity, chlorine disinfection efficiency and the solubility of metal ions (Chindo *et al.*, 2013).. In this study, pH ranges between 7.08 (Adabeji Borehole) and 7.39 (Main Hostel Borehole) with an average value of 7.20. All samples are were weakly alkaline. No significant difference ($p > 0.05$) was observed in most of the samples of the study. According to WHO guidelines, a suitable pH range of 6.5 – 8.5 is recommended (WHO, 2017). Hence, all the groundwater samples of the study areas are found to be within the permissible limits as prescribed.

TDS values depend on climate, the host rock, and the residence time of the groundwater in the geological matrix (Behailu *et al*., 2017). The TDS was found to range between 82.00 mg/L (Bora Hostel Borehole) to 484.50 mg/L (Main Hostel Borehole) with an average of 301.65 mg/L. A significant difference ($p < 0.05$) was observed among all the groundwater samples of the study. All the TDS values were found to be below the acceptable limit of 1000 mg/L set by the WHO (2017). Hence, the groundwater samples in all the locations were of good quality for drinking (Sampath *et al*., 2011; Wickramasinghe *et al*., 2021).

EC is a measure of the ability of an aqueous solution to carry an electric current that depends on the presence and total concentration of ions, their mobility and valance and on the temperature (Behailu *et al*., 2017). It ranged between 154.50 µS/cm and 949.00 µS/cm at Bora Hostel borehole and Main Hostel respectively with an average value of 533.45µS/cm. The WHO permissible limit is 1500 µS/cm; values obtained in th*e* study were below the WHO limit.

Turbidity in water arises from the presence of very finely divided solids which are not filterable by routine methods (Behailu *et al*., 2017). It varied from 12.81 NTU (Bora hostel borehole) to 82.65 NTU (Main hostel borehole) with an average concentration of 51.99 NTU. All the samples have a high turbidity value greater than 5.00 NTU that is recommended by WHO; this indicates that it is necessary to treat water from the sampling locations before use. A significant difference ($p < 0.05$) was observed among all the groundwater samples of the study.

Total alkalinity is a measure of the ability of water to neutralize acids (Behailu *et al*., 2017). The values in groundwater samples of the study were observed to vary from 2.91 mg/L to 38.16 mg/L at Bora Hostel Borehole and Main Hostel Borehole respectively with an average value of 19.31 mg/L. A significant difference ($p < 0.05$) was observed among all the groundwater samples of the study. All the values of the groundwater samples of the study were found to be below the permissible limit of 120 mg/L recommended by WHO (2017).

Total hardness is the property of water which prevents the lather formation with soap and increases the boiling points of water (Patil and Patil, 2010). It ranged from 2.20 mg/L (Bora Hostel Borehole) to 202.85 mg/L (Main Hostel Borehole) with an average value of 60.22 mg/L. Values obtained in the study are lower than the permissible limit of 300 mg/L prescribed by the WHO. According to some classifications, water having hardness up to 75 mg/L is classified as soft, 76 - 150 mg/L as moderately soft, 151 - 300 mg/L as hard and more than 300 mg/L as very hard (Saravanakumar and Ranjith-Kumar, 2011). On this basis, the results show that Borehole of Adabeji, Bora Hostel and well water of Adabeji, Bora Hostel, Gbekuba and Odo Ona samples are soft while Gbekuba borehole, Main Hostel borehole, Odo Ona borehole and Main Hostel well water samples are moderately soft.

Table 1: Physical parameters of the groundwater samples of the study

Sample	Temp (°C)	pH	TDS (mg/L)	EC (µS/cm)	TB (NTU)	TA (mg/L)	TH (mg/L)
Borehole							
AB	43.50a	7.08f	168.50h	327.50g	21.23i	3.85h	4.56hi
BB	26.00f	7.11e	82.00j	154.50j	12.81j	2.91i	2.22i
GB	25.00f	7.23c	398.00d	777.50c	68.08d	23.66d	76.23d

HB	41.20b	7.39a	484.50a	949.00a	82.65a	38.16a	202.85a
OB	42.15b	7.34b	422.50b	320.50h	79.91b	33.59b	87.14c
Well							
AW	45.90a	7.25c	317.00f	614.00e	55.94f	18.49f	10.67g
BW	36.50e	7.17d	95.50i	175.00i	25.35h	3.10i	8.12gh
GW	38.00d	7.23c	252.50g	489.50f	39.36g	14.94g	45.84f
HW	39.10c	7.16d	380.00e	731.50d	62.83e	21.77e	97.70b
OW	26.25f	7.19d	416.00c	795.50b	71.74c	32.64c	66.90e
Average	**37.51**	**7.20**	**301.65**	**533.45**	**51.99**	**19.31**	**60.22**
PL	**25 – 50**	**7.0 – 8.5**	**1000**	**1500**	**5.0**	**120**	**300**

PL = Permissible Limits (WHO, 2017)
Means with same letter (s) in a column are not significantly different at 5 % level of probability by Duncan Multiple Range Test (DMRT)
Key:
Temp = Temperature
EC = Electrical conductivity
TH = Total hardness
G = Gbekuba
pH = Hydrogen ion concentration
TB = Turbidity
A = Adabeji
H = Main Hostel
TDS = Total dissolved solid
TA = Total alkalinity
B = Bora Hostel
O = Odo Ona

Table 2 gives the concentrations of some cations (Na^+, Mg^{2+}, Ca^{2+} and K^+) and common anions (sulphate, phosphate, nitrate, nitrite, chloride and fluoride) in the groundwater samples around the residential areas of the students of FCAH & PT, Ibadan using standard methods.

Calcium is directly related to hardness (Murhekar, 2011). It ranged between 0.71 mg/L (Bora Hostel borehole) and 190.96 mg/L (Main Hostel borehole) with an average of 51.38 mg/L. All the values of the study were found to be below the permissible limit of 100 mg/L recommended by the WHO (2017) except for Main Hostel borehole. A significant difference ($p < 0.05$) was observed among all the groundwater samples of the study.

Magnesium is directly related to hardness (Murhekar, 2011). Magnesium content in the investigated water samples ranged from 1.49 mg/L at Bora Hostel well to 15.87 mg/L at Gbekuba borehole with an average value of 8.84 mg/L; all values of the study were found to be below the recommended WHO limit of 150 mg/L. No significant difference ($p > 0.05$) was observed among Adabeji and Bora Hostel borehole and well water samples.

Sodium concentrations were found to be from 7.37 mg/L to 88.30 mg/L at Bora Hostel well and Odo Ona well respectively with the average value as 43.70 mg/L. Na^+ concentration of the study were below the WHO limit of 200 mg/L. A significant difference ($p < 0.05$) was observed among all the groundwater samples of the study. Similarly, K^+contents in the groundwater samples varied from 1.52 mg/L (Bora Hostel borehole) to 10.01 mg/L (Main Hostel well) with an average value of 6.92 mg/L. No significant difference ($p > 0.05$) was observed in most of the samples. Values of K^+ in all the groundwater samples of the study were below 90 mg/L, the limit prescribed by WHO (2017).

Phosphate may occur in groundwater as a result of domestic sewage, detergents, and agricultural effluents with fertilizers (Murhekar, 2011). The phosphate levels ranged between 0.00 mg/L and 1.77 mg/L with water samples from Adabeji Borehole and Gbekuba with the least value and Bora Hostel borehole the highest. The average value of 0.71 mg/L was recorded. A significant difference ($p < 0.05$) was observed among all the groundwater samples of the study except between Adabeji Borehole and Gbekuba well.

Sulphate occurs naturally in water as a result of leaching from gypsum and other common minerals (Manivaskam, 2005). The sulphate content has the highest (32.95 mg/L) and least concentrations (1.34 mg/L) at Odo Ona borehole and Adabeji borehole respectively with an average of 15.08 mg/L which falls within the prescribed limit of 250 mg/L (WHO, 2012). A significant difference ($p < 0.05$) was observed among most of the samples.

Nitrates in groundwater sources may be from soluble nitrate compounds or from run-off from inorganic fertilizers that may leach into the groundwater sources (Manivaskam, 2005). The most common source of nitrate concentration is attributed to animals and human waste disposal practices and the use of agricultural fertilizer (Ediagbonya *et al.*, 2015; Behailu *et al*., 2017). Nitrate concentrations of the study ranged between 30.36 mg/L (Adabeji borehole) and 722.07 mg/L (Main Hostel borehole) with an average concentration of 364.58 mg/L. A significant difference ($p < 0.05$) was observed among all the groundwater samples of the study. All the values of this study are more than the recommended value of 50 mg/L as expressed by WHO (2012) except for Adabeji borehole. High nitrate levels in waters above 50 mg/L for drinking purposes will render them hazardous to infants as they induce the "blue

baby" syndrome (methaemoglobinaemia) (Chindo *et al.*, 2013).

Nitrite is an intermediate in the oxidation of ammonia to nitrate, such oxidation can proceed in soil, and because sewage is a rich source of ammonia, waters which show any appreciable amounts of nitrite are regarded as being of highly questionable quality (Chindo *et al.*, 2013). It varied from 12.72 mg/L (Bora Hostel borehole) to 354.05 mg/L (Main Hostel borehole) with an average of 156.72 mg/L. A significant difference ($p < 0.05$) was observed among all the groundwater samples of the study. All the nitrite contents in groundwater samples of the study are above the prescribed limit of 0.2 mg/L set by WHO (2012); values greater than the prescribed limit indicates sewage pollution. Thus the source may not be safe for consumption and domestic use unless it is treated.

Chloride and fluoride are very common in water systems as they are added to drinking water for various health and sanitary purposes (Behailu *et al*., 2017). However, chloride and fluoride levels can be increased by contamination of fertilizers, road salt, and industrial pollution as well as human and animal waste (Behailu *et al*., 2017). Chloride concentration in the groundwater samples of the study was found to vary from 16.08 mg/L in Gbekuba borehole to 127.79 mg/L in Main Hostel borehole with an average concentration of 86.74 mg/L. The values are below the WHO (2017) limit of 250 mg/L which could indicate that the groundwater samples may be safe for consumption. The fluoride contents varied from 0.14 mg/L to 0.88 mg/L with an average of 0.52 mg/L. The highest content was observed at Main Hostel Borehole. All the groundwater samples of the study have low or acceptable concentrations of fluoride (< 1.5 mg/L) according to the WHO (2012) recommendation.

Table 2: Chemical parameters of the groundwater sources of the study (mg/L)

Sample	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	PO_4^{-}	SO_4^{2-}	NO_3^{-}	NO_2^{-}	Cl^{-}	Fl^{-}
Borehole										
AB	2.99hi	1.57d	29.08h	2.66e	0.00e	1.34e	136.13h	71.34h	75.84e	0.48f
BB	0.71i	1.50d	12.24i	1.52e	1.77a	7.97d	30.36j	12.72j	38.03g	0.14h
GB	60.36d	15.87a	75.05b	6.87c	0.22cde	5.07de	378.89f	121.18f	16.08h	0.63c
HB	190.96a	11.90c	42.00f	2.44e	1.01abcd	12.99c	722.07a	354.05a	127.79a	0.88a
OB	72.68c	14.47b	40.72g	6.27cd	0.15de	32.95a	579.74b	264.87b	120.43b	0.72b
Well										
AW	8.92g	1.75d	49.81c	2.38e	1.09abc	22.89b	461.27d	231.31d	108.68c	0.56e
BW	6.63gh	1.49d	7.37j	4.00de	0.83bcde	2.16e	51.34i	21.99i	48.16f	0.14h
GW	33.95f	11.89c	47.92d	3.55e	0.00e	22.63b	396.51e	135.15e	102.03d	0.39g
HW	83.61b	14.09b	44.43e	10.01b	1.39ab	16.14c	328.87g	113.59g	109.72c	0.60d
OW	53.01e	13.89b	88.39a	29.60a	0.64bcde	26.64b	560.60c	240.99c	120.61b	0.70b
Mean	**51.38**	**8.84**	**43.70**	**6.92**	**0.71**	**15.08**	**364.58**	**156.72**	**86.74**	**0.52**
PL	**100**	**150**	**200**	**90**	**5.00**	**100**	**50**	**0.2**	**250**	**1.5**

PL = Permissible Limits (WHO, 2012; 2017)

Means with same letter (s) in a column are not significantly different at 5 % level of probability by Duncan Multiple Range Test (DMRT)

Key:

Ca^{2+} = Calcium Mg^{2+} = Magnesium K^{+} = Potassium Na^{+} = Sodium PO_4^{-} = Phosphate SO_4^{2-} = Sulphate
NO_3^{-} = Nitrate NO_2^{-} = Nitrite Fl^{-} = Fluoride Cl^{-} = Chloride A = Adabeji B = Bora Hostel
G = Gbekuba H = Main Hostel O = Odo Ona

Table 3 gives the concentrations of the metals analyzed in the groundwater samples around the residential areas of the students of FCAH & PT, Ibadan using standard methods.

Iron is an essential element for dietary requirement for most of organisms, and it is central atom in haemoglobin and helpful to transport the oxygen in to various organs through the blood (Tadiboyina and Rao, 2016). In this study, it varied from BDL – 9.85 mg/L with an average value of 3.73 mg/L. All the values obtained are above the WHO (2017) limit of 0.3 mg/L which could indicate that the groundwater sample is contaminated with iron metal. Chronic consumption *o*f water with iron overload may results in fatigue, weight loss, joint pains and ultimately heart disease, liver problems and diabetes (US-CDC 2011).

Copper is a trace essential heavy metal found in the environment and spread through the natural phenomenon which enters into groundwater through industrial wastes, agriculture pesticides and corrosion of copper pipes (Tadiboyina and Rao, 2016). It varied from 0.35 mg/L (Hostel well) to 6.40 mg/L (Gbekuba Borehole) with a mean concentration of 1.89 mg/L. Values of Cu obtained in the study are below the WHO (2017) limit of 2.0 mg/L except for Adabeji well, Gbekuba Borehole and Bora Hostel Borehole. Cu exposure could lead to gastrointestinal disorders and

liver damage (Taylor *et al*., 2020).

Zinc is an essential trace metal that enters into water through industrial wastewaters, galvanic industries, battery production, zinc leaks from zinc pipes and rain pipes etc. (Tadiboyina and Rao, 2016). In the study, it ranged from 2.50 mg/L (Gbekuba Well) to 6.10 mg/L (Odo Ona Borehole) with an average concentration of 4.58 mg/L. The values of Zn of the study are above the WHO (2017) limit of 3.0 mg/L (except at Gbekuba Well). Zinc exposure has been shown to promote apoptosis in the brain (Plum *et al.,* 2010). Long term ingestion of zinc in water has been known to cause vomiting, anaemia, and stomach cramps (Singh *et al*., 2018).

Manganese is one of the common essential trace elements that enter into atmosphere via suspended particulates resulting from industrial emissions, soil erosion, volcanic emissions and the burning human activities are also responsible for much of the manganese contamination in water in some areas (Tadiboyina and Rao, 2016). It ranged from 0.38 mg/L to 2.95 mg/L with the least value obtained at Bora Hostel Borehole and the highest value at Gbekuba Borehole. The average value of 0.96 mg/L was obtained in the study. All the values of the study are above the safe limits of 0.5 mg/L (except in Main Hostel Borehole and Bora Hostel Borehole) set by WHO (2017). Excessive Mn intake via drinking water can lead to a neurological disorder, including a reduction in intellectual capacity and DNA damage (WHO, 2011; Annaduzzaman *et al*., 2018).

Table 3: Some metals of the groundwater samples of the study (mg/L)

Samples	Zn	Mn	Fe	Cu
Borehole				
AB	4.65bcd	0.65d	9.85a	1.08f
HB	4.70bcd	0.40d	8.93b	1.65d
OB	6.10a	0.65d	3.98d	0.98f
GB	5.45ab	2.95a	2.85e	6.40a
BB	4.63bcd	0.38d	2.05f	3.28b
Well				
AW	5.28abc	0.60d	7.65c	2.73c
HW	3.85d	2.00b	BDL	0.35h
OW	4.48cd	0.55d	0.78h	0.58g
GW	2.50e	1.05c	BDL	1.43e
BW	4.18d	0.35d	1.2g	0.45h
Average	**4.58**	**0.96**	**3.73**	**1.89**
PL	**3.00**	**0.50**	**0.30**	**2.00**

PL = Permissible Limits (WHO, 2017)
Means with same letter (s) in a column are not significantly different at 5% level of probability by Duncan Multiple Range Test (DMRT)
BDL = ≤ 0.005mg/L

4.0. Conclusion and Recommendations

This study investigated physicochemical quality of groundwater samples around the Federal College of Animal and Health Production, Ibadan students' residential areas using standard analytical procedures and the following conclusions were inferred from the study:

1. All the physical parameters analyzed in the study except turbidity have values within the safe limits indicated by WHO. A high turbidity indicates that it is necessary to treat water from the sampling locations before use.
2. The average values for all the cations (Ca^{2+}, Mg^{2+}, K^{+} and Na^{+}) are within the safe limits set by WHO.
3. The mean contents for the anions (PO_4^{-}, SO_4^{2-}, NO_3^{-}, NO_2^{-}, Fl^{-} and Cl^{-}) are within the safe limits set by WHO except for NO_3^{-} and NO_2^{-}. High nitrate and nitrite levels indicate sewage pollution. Thus the groundwater samples may not be safe for consumption and domestic use unless it is treated.

Based on the study carried out, the following recommendations are hereby suggested:
Routine monitoring of the water samples should be encouraged. The potential health risk due to heavy metal contamination in the groundwater samples should also be evaluated in order to reveal health implications of the water when ingested. However, this study could serve as a baseline for further researches on the subject matter in future.

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