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Comparative Assessment of the Quality of Groundwater and Surface Water in a University Locality in South-Eastern Nigeria

Glory J. Okore [1], Chibuike U. Nwachukwu [2], Mary Joan O. Ngumah [3], C. Ejiogu [4], Victor N. Nwugha [5], Bonaventure O. Eke[6] & Mary N. Fidelis [7],

[1]. Department of Chemistry, Alvan Ikoku Federal University of Education, Owerri, Imo State, Nigeria.
[2]. Department of Biology, Alvan Ikoku Federal University of Education, Owerri, Imo State, Nigeria.
[3]. Department of Biology, Alvan Ikoku Federal University of Education, Owerri, Imo State, Nigeria.
[4]. Department of Physics, Alvan Ikoku Federal University of Education, Owerri, Imo State, Nigeria.
[5]. Department of Physics, Alvan Ikoku Federal University of Education, Owerri, Imo State, Nigeria.
[6]. Department of Integrated Science, Alvan Ikoku Federal University of Education, Owerri, Imo State, Nigeria.
[7]. Department of Health Education, Alvan Ikoku Federal University of Education, Owerri, Imo State, Nigeria.

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Abstract: *This study evaluated the quality of borehole and surface water in a University community in Owerri, Imo State, Nigeria, with reference to WHO permissible limit for drinking water. Eight borehole water samples were collected strategically from various points within the university community and its environs. Besides, three water samples were collected upstream, midstream and downstream of the surface water. Thirteen physicochemical parameters including Total dissolved solids, conductivity, pH, among others, were tested for the eleven water samples. The concentration of selected heavy metals such as arsenic, lead, cadmium, mercury etc.,were also tested to check their compliance to WHO permissible limits for portable water. Standard analytical procedures for testing the quality of water samples were employed for the study. The findings from the result show that only five out of the thirteen tested physicochemical parameters were within permissible limit with WHO standards for drinking water, which include TDS, sulphate, nitrate, fluoride and dissolved oxygen. The result of the hypothesis test showed that there is no significant difference between the physicochemical parameter values except for the BOD at p:0.0241<0.05 ; there is significant difference in the concentration of arsenic at p: 0.0248<0.05 for the ground water and surface water samples. It is therefore recommended that borehole and surface water in the university community should be properly treated before consumption. Also, government and other stakeholders should provide alternative treated borehole or pipe-borne water for the University community.*

Keywords: Assessment, water quality, surface water, ground water, physicochemical parameters

INTRODUCTION

Water has been provided naturally, and is used for industry, agriculture and drinking. There are two forms of water found in nature, namely surface and ground water. Surface water occurs as rivers, while ground water is obtained underneath the earth, and man can have access to it using boreholes. It is very necessary to maintain good quality for water, through continuous monitoring. Besides, the impact of portable water to human health cannot be over-emphasized. Industrial and agricultural activities, coupled with indiscriminate dumping of wastes can lead to a degradation of water quality. The staff and students of the university rely so much on water for their daily activities. It is therefore necessary to assess the suitability of ground and surface water within the community to ensure health safety.

Abolli et al. [1] used electrometric, titrimetric and spectrophotometric methods to investigate physicochemical parameters and water quality index of 40 water samples collected from 13 borehole sites. The findings from the results showed that water collected from two sites did not have acceptable quality. The study of Masoud et al. [2] on alluvial aquifer of Makkah Al-Mukarramah province of Saudi Arabia using irrigation water quality index gives a picture of the quality and suitability of ground water to be used for irrigation in agricultural practice. Alqarawy et al. [3] examined 173 water samples from Makkah Al-Mukkaramah province of Saudi Arabia with the aim of determining the water quality index using physicochemical parameters, and found 30 % of the ground water samples unfit for drinking. Masood et al. [4] assessed the irrigation and drinking water quality index of over 1100 samples of ground water from upper and central Pujang, by determining some physicochemical parameters. The results showed heavy metal pollution in Lahore and widespread microbiological contaminations across all the studied areas owing to poor treatment of industrial effluent and poor sewage management system. Adimalla [5] evaluated the entropy weighted water quality index and pollution index of groundwater samples from Semi-arid regions of India with physicochemical parameter determinations, and the findings of the study revealed that only 60 % of the water samples studied were found fit for drinking, at the boarder level, while the remaining 40% were declared unfit for drinking. Saalidong et al. [6] predicted the quality of ground water based on the interactions of the physicochemical parameters with each other. Osta et al. [7] assessed the water quality index of Makkah-Al Mukarramah province of Saudi Arabia, and found out that 95% of the water was unfit for drinking while 45.5% were unfit for irrigation purposes. Mohammed et al. [8] evaluated the suitability of aquifer from Al-Jawf basin for irrigation purposes and discovered that calcium, magnesium, sodium ions, among others were in abundance.

Gaagai et al. [9] evaluated the suitability of water from Sahara aquifer in Algeria for irrigation purposes using irrigation water quality index, from physicochemical parameter determinations, and found out that 65% were to be used for that purpose without restrictions. Yousfi et al. [10] determined the irrigation and water quality index of Ghiss-Nekkor aquifer of Morocco, using physicochemical parameters and statistical analysis, and obtained values ranging from 90.93-337.28, showing poor water quality and unsuitability of the assessed water samples for drinking. Dippong et al. [11] evaluated the water quality index of water samples collected from 17 wells in Seini region of North West Romania, and discovered that most of the water samples were suitable for drinking and did not contain risk levels of carcinogenic contaminants.

The thoroughly reviewed literature does not show evidence of research on borehole and surface water quality within the location of study. Hence the present research work is set to determine the quality indices of ground and surface water, using selected physicochemical parameters and comparing them with World Health Organization standards, to ascertain the suitability of these water sources for human consumption, agricultural and industrial activities.

Specific Objectives

1. To evaluate selected physicochemical parameters and compare their levels in the surface and ground water, with WHO safety guidelines for drinking water;
2. To determine the contamination factor and geoaccumulation factor, and use their values to find out the extent of pollution of surface and ground water.
3. To find out if there is significant difference between surface water and ground water in the university community

MATERIALS AND METHODS

Sample Collection and preservation

A total of eleven (11) samples of water were collected, eight (9) from different borehole points in the main campus and Shell camp extension, and three (3) from the surface water. Samples from borehole were collected directly from the pump after allowing it to run for five minutes to flush the system and ensure that the water collected was fresh. Samples from the surface water were collected at three points, upstream, midstream and downstream, with the aid of a long-handled sampler. Polythene bottles, properly labeled, were used for the collection of water samples. These bottles were sterilized with ethanol and rinsed several times with the water, before collecting the one for analysis, to avoid contamination. The collected water samples were stored in ice coolers, so as to maintain a temperature of 4°C while transporting them to the analytical laboratory. Physicochemical analysis was carried out on the water samples within 24 hours after collection, to ensure that there is no change in the parameters.

Analytical Methods for Physicochemical Parameters

Determination of pH

The pH was measured using Laboratory pH Meter Hanna model HI991300 (APHA; 2005). The electrodes of the pH meter were first rinsed with distilled water, dried, and then rinsed with a small portion of the water sample to be analysed. This was followed by the immersion of the pH electrodes in a small beaker containing the water sample filled up to 2 cm., and ensured that the electrodes were at least 1 cm away from the sides and bottom of the beaker. The temperature measurement was taken, and the pH meter was turned on to take the measurement which was recorded as well.

Turbidity

Turbidity is a measure of the clarity of a liquid. It is caused by the presence of clay, silt, micro-organism and suspended organic matter in the water sample. It is measured in the unit of NTU, meaning Nephelometric Turbidity Units, measured with turbidimeter or nephelometer. The turbidimeter is first calibrated with standard solutions of formazin, to obtain a calibration curve. The measurement is carried out at room temperature. The sample vial is first rinsed with the sample to be analysed, before fill it to the calibration line with the sample. The outside of the vial is wiped with a clean cloth to remove fingerprints or excess liquid. The sample vial is then placed in the turbidimeter chamber, which is closed, and the instrument is allowed to stabilize, the measure key is pressed, and the reading is taken in triplicate measurement, and the average calculated.

Determination of electrical conductivity

The electrical conductivity was determined using APHA 2510 B guideline Model DDS-307 (APHA; 1998). The digital electrical conductivity was calibrated before use. This was achieved by warming up, rinsing with deionized water, then immersing the electrical conductivity cell in standard KCl solution, and allowing the system to auto-calibrate until it reaches a value of 1413 µS/cm at 25°C. The cell was rinsed again with distilled water and a portion of the water sample to be analysed. The electrical conductivity cell was then immersed in the water sample, stirred with a magnetic stirrer to ensure uniformity, and the reading was taken as soon as there was a stable reading on the meter. The temperature at which the measurement was taken, was also recorded.

Determination of total dissolved solids

The measurement of Total dissolved solid was done using APHA 2510 A TDS 139 tester (APHA; 1998). A known volume of filtered water sample of 250 ml was placed in the pre weighed evaporating dish, and placed in the oven at 105°C and the water was evaporated completely after 6 hours. The dish was cooled in a desiccator to room temperature, and then re-weighed with the residue on it. The calculation of the Total Dissolved Solids was done using the equation below.

$$\text{TDS} = \frac{(\text{A-B}) \times 10^3 \text{mg/l}}{\text{Sample volume in ml}} \qquad (1)$$

Where A = weight of dish + solids (mg)
B = weight of dish before use (mg)

Nitrate Determination

Nitrate in the water sample was determined using PD303 UV Spectrophotometer (APHA; 1998). A total volume of 50 ml of the water sample was put in a porcelain dish using pipette and evaporation was carried out on a hot water bath. Addition of 2 ml phenol disulphonic acid was done, constantly stirring with a glass rod, so as to dissolve the residual mass. The solution was made alkaline by the addition of NaOH and distilled water. This was followed by filtration into a Nessler's tube, making it up to 50 ml with distilled water, and allowing it to stand for 10 minutes to develop the colour. The absorbance was measured at 410nm using a spectrophotometer. The concentration of the nitrate was determined by extrapolating from already prepared calibration curve, and expressed in mg/L.

Phosphate determination

The concentration of phosphate ion in the water sample was determined by using colorimetric method. First, a calibration curve was obtained with standard stock solutions of anhydrous KH_2PO_4 in the range of 0-1.0 mg/L, which was mixed with 8 mg/L of combined reagent so as to obtain a coloured complex. The mixture was allowed to stand for at least 10 minutes for colour development, then absorbance was measured at 880 nm and distilled water was used as the blank. This was followed by the mixing of the water sample for analysis with combined reagent, which was left to stand for 10 minutes for the coloured complex to form, after which the absorbance was determined at 880 nm. The concentration of phosphate in the water sample was obtained by extrapolation with the standard curve and expressed in mg PO_4^{2-} at 25° C.

Sulphate determination

The determination of sulphate in the water sample was carried out by turbidimetric method of reacting the sulphate ion with barium chloride to form a precipitate of barium sulphate, which was measured spectrophotometrically. The preparation of calibration curve was initially carried out by dissolving 1.479 g of anhydrous sodium sulphate in 1 litre of distilled water to form a standard solution, which was later used to prepare working standards of between 0-50 mg/L by serial dilution. This was followed by the addition of 1 ml of conditioning agent, stirring the solution for 30 seconds, and adding 0.2 g of freshly prepared barium chloride to form a precipitate of barium sulphate. The turbidity was measured at 420-440 nm. The calibration curve is a plot of absorbance (turbidity) against sulphate ion concentration. The sample analysis was carried out by measuring the absorbance of 50 mg of water sample mixed with 1 ml of conditioning agent and barium chloride, and extrapolating on the calibration curve to obtain the required sulphate ion concentration in the water sample, which is expressed in mg/L.

Acidity

Acidity is a measure of water to neutralize bases. It is an indication of the amount of dissolved carbon (IV) oxide, mineral acids and acid salts. It is carried out by titrating of the water sample with sodium hydroxide using phenolphthalein as an indicator. The 50 ml burette was rinsed with distilled water, then severally with 0.025 N NaOH. A measure of 100 ml of the water sample was placed in a 250 ml Erlenmeyer flask with the aid of pipette. The titration was done to a purple end point. The acidity is expressed in milligrams of calcium carbonate as follows.

$$\text{Acidity} = \frac{(\text{ml NaOH titrant}) \times \text{normality of NaOH} \times (50\,000)}{(\text{ml of water sample})} \qquad (2)$$

Biological Oxygen Demand Determination

BOD is calculated as the difference between the oxygen at day 0 and dissolved oxygen at day 5
The general equation for the determination of a BOD value is:

$$\text{BOD (mg/l)} = D_1 - D_2 \qquad (3)$$

Where D_1 = initial DO of the sample, D_2 = final DO of the sample after 5 days, and P = decimal volumetric fraction of sample used.

If 100 ml of sample are diluted to 300ml, then P= 0.33. Notice that if no dilution was necessary, P = 1.0 and the BOD is determined by $D_1 - D_2$.

Dissolved Oxygen in Water determination

The dissolved oxygen in the water sample was determined with the addition of 1cm^3 manganese (I) sulphate solution followed by 1cm^3 alkaline – iodide –azide solution, below the liquid surface. The stopper was replaced immediately after each addition with gentle inversion severally for mixing, to produce a brownish precipitate of $MnO(OH)_2$ which is allowed to settle halfway to produce clear supernatant water. This is followed by addition of 1cm^3 concentrated sulphuric acid, also below the water surface, to produce a yellow iodine solution. A measure of 100 cm^3 of this solution was pipetted into a 250 cm^3 conical flask, and titrated against 0.0125 mol/dm^3 of sodium thiosulphate solution, with the aid of starch solution indicator.

$$\text{DO (mg/L)} = V \times 0.2 \qquad (4)$$

where V = volume (ml) of 0.025 N sodium thiosulphate used for titration of 100 ml sample.

Total Alkalinity

Two drops of mixed indicator were added to 100 ml of sample, in which phenolphthalein alkalinity were determined, followed by titration with 0.02 M standard HCl to, at pH 4.6, to a colour change from yellow to pink for mixed indicator or a change from yellow colour to orange for methyl orange indicator. The conversion obtained tallies with the equation below.

$HCO_3^- + H^+ = H_2CO_3 = H_2O + CO_2$

$$\text{Total alkalinity as Mg/l CaCO}_3 = \frac{V \times M \times 100,000}{\text{Volume of sample used in ml}} \qquad (5)$$

where V is volume of acid used in ml, M is the molarity of acid, which is 0.02 M.

$OH^- + CO_3^{2-} + HCO_3^- + 4H^+ = 3H_2O + 2CO_2$

Bicarbonate of Water Sample.

Bicarbonate in water sample was determined titrating 100 ml of the water sample in a clean flask with 0.02 M HCl solution, using two (2) drops of phenolphthalein as indicator. There was previous precipitation of the carbonate in the water sample with excess barium chloride solution, which does not in any way affect the concentration of the bicarbonate in the water sample. The concentration of bicarbonate in the water sample was thus calculated with the formula given below.

$$\text{Bicarbonate (mg/L)} = \frac{V \times M \times 100,000}{\text{ml of sample used}} \qquad (6)$$

Where V is the volume of acid used in ml, and M is the molarity of acid used, in this case 0.02 M HCl

Fluoride Ion Concentration

Fluoride ion in water sample is determined by reacting it with Zirconium-dye lake, also known as SPADNS reagent, to form a colourless complex, which causes a decrease in the intensity of colour, of which is measured spectrophotometrically and is proportional to the concentration of the fluoride ion. Standard chloride solution was prepared with 2.21g of sodium fluoride and diluted to solutions ranging between 0-2 mg/L, which were reacted with zirconyl-SPADNS reagent, and absorbances recorded at 570 nm, and used to construct a calibration curve. The sample analysis was carried out by adding 10 ml of zirconyl-SPADNS reagent to 50 ml of the sample of water in a clean beaker, and carrying out the absorbance measurement at 570 nm, after standing the mixture for one minute. The fluoride ion concentration was obtained by extrapolation from the calibration curve.

RESULTS AND DISCUSSION

The result of the test for the physicochemical parameters are presented in Tables 1 and 2 and Figures 1 to 26 below.

Table 1: Physicochemical result of ground water.

Sample	Conduct ivity µs/cm	TDS mg/l	pH	Turbid ity NTU	Phosphate mg/l	Alkalinity mg/l	BOD mg/l	Acidity mg/l	SO_4^{2-} mg/l	NO_3^- mg/l	DO mg/l	Bicarbonate mg/l	F^- mg/l
WHO permissible Limit	1000	1000	6.5-8.5	5	5	120	6	30	250	50	5	500	1.5
D Hostel	269	134.6	6.29	1	9.555	18	84.10	8	73.278	6.333	7.8	115	0.043
B Hostel	169.5	83.7	6.18	17	6.009	12	79..20	4	64.338	4.964	7.4	127.5	0.034
English/1000 Capacity	135.9	67.9	6.25	15	3.948	4	81.30	6	74.333	7.357	7.5	97.5	0.010
Agric. Dept	152.7	76.4	6.18	0	5.759	30	86.50	4	54.389	3.679	6.9	107.5	0.044
Alvan Nursery	106	53	6.56	2	6.584	24	83.20	18	55.222	3.417	7.3	105	0.019
Future Hope Shell Camp	153.7	76.8	6.31	5	6.334	14	92.10	6	71.556	4.738	7.7	97.5	0.009
0.065NAS/Biology Laboratory	162.4	81.2	6.12	5	10.466	10	96.30	8	68.167	6.583	7.5	87.5	0.065
Safari Club Shell Camp	363	181.3	5.12	9	8.341	26	81.20	10	75.00	3.429	6.1	80	0.054

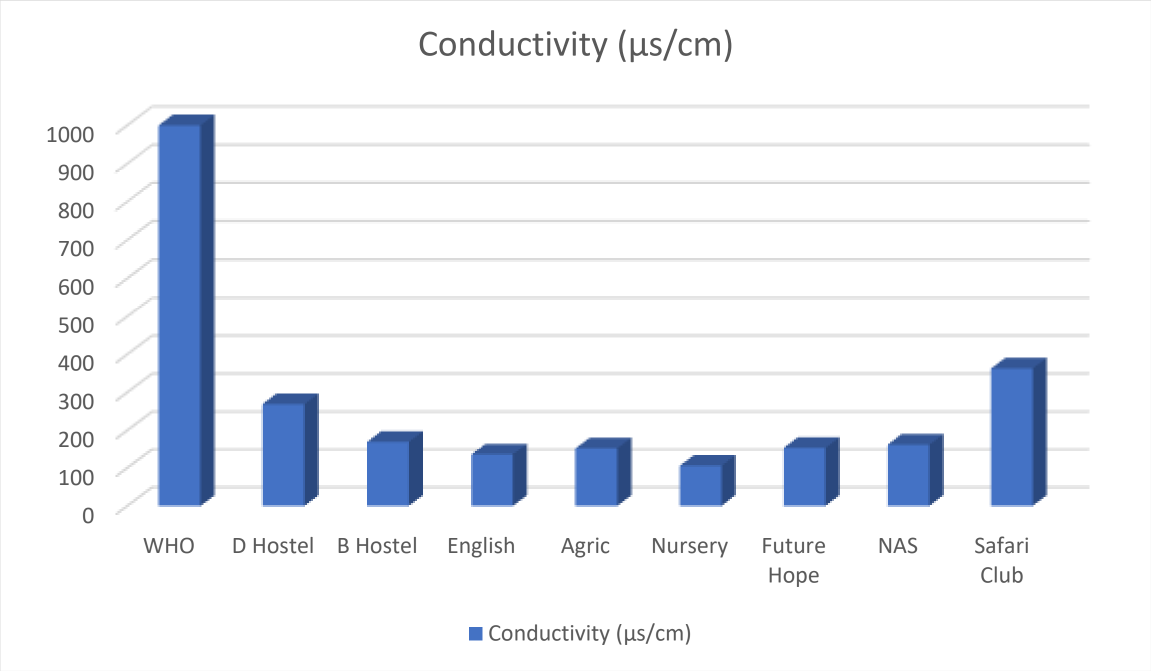

Figure 1: Conductivity results for ground water

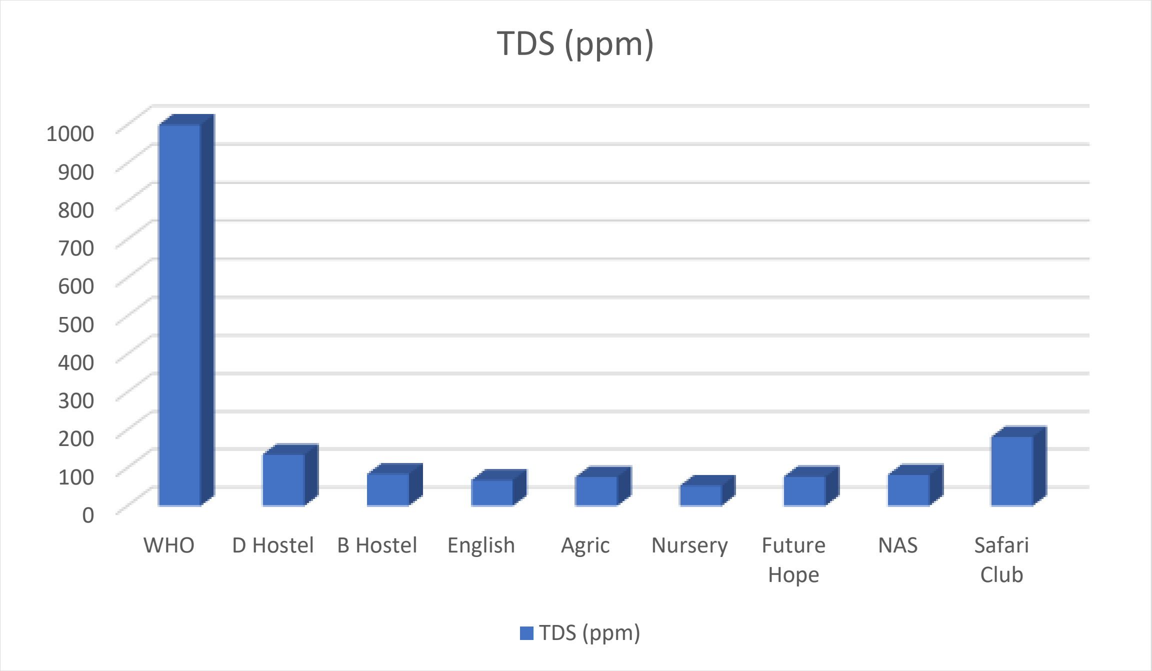

Figure 2: Total Dissolved Solids results for ground water

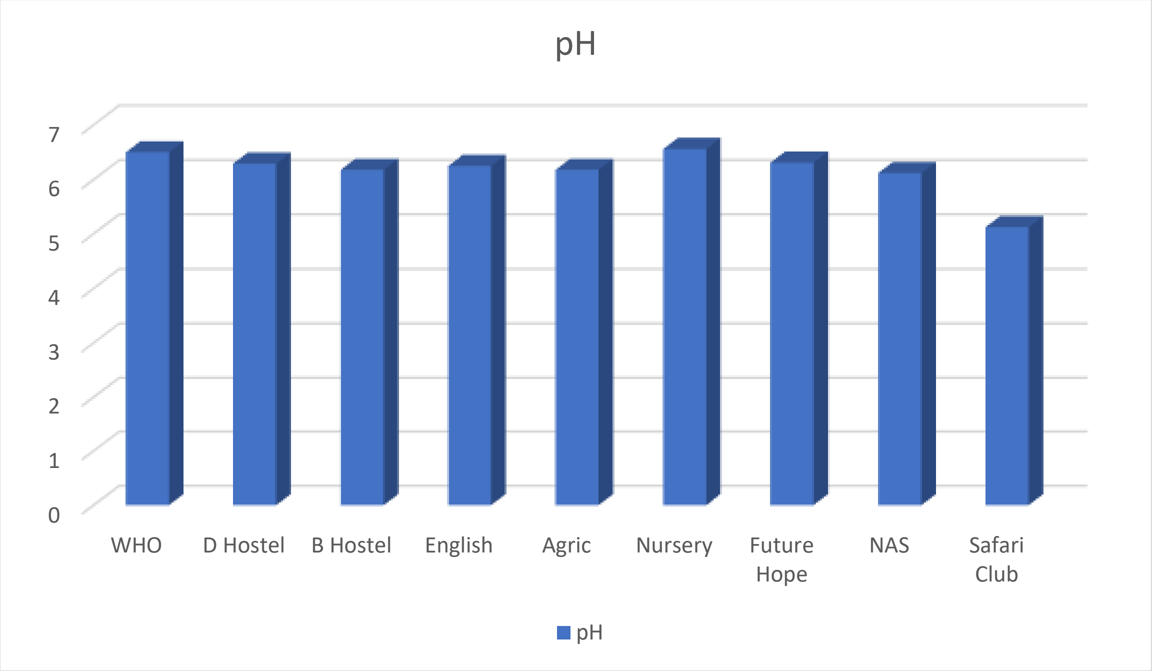

Figure 3: pH results for ground water

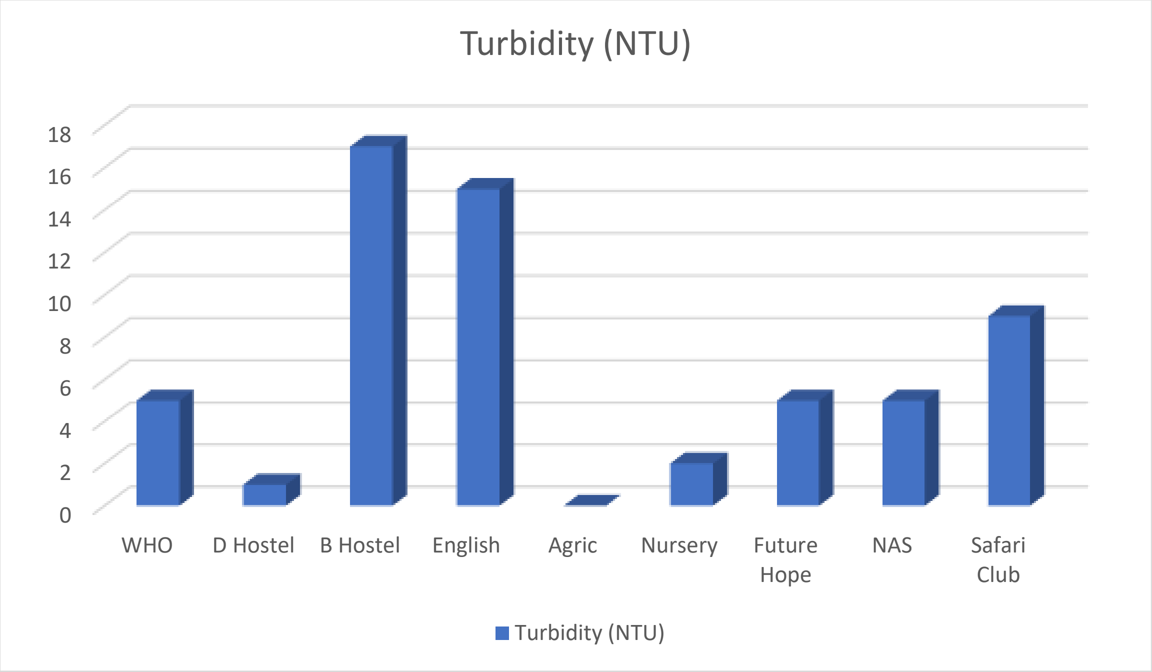

Figure 4: Turbidity results for ground water

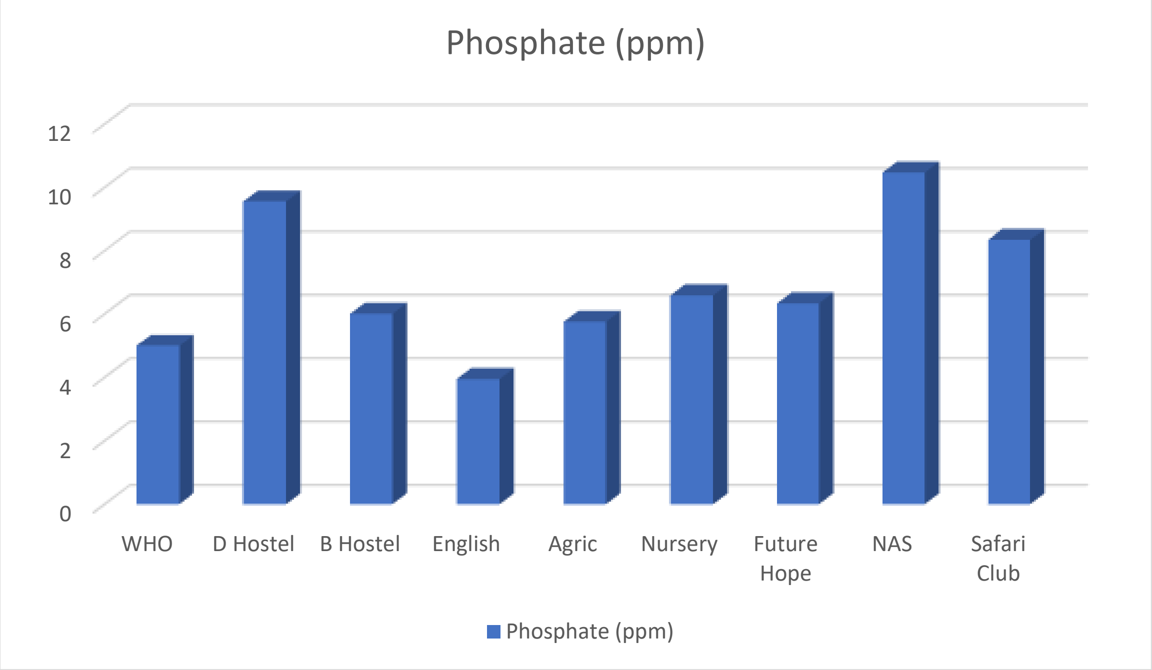

Figure 5: Phosphate results for ground water

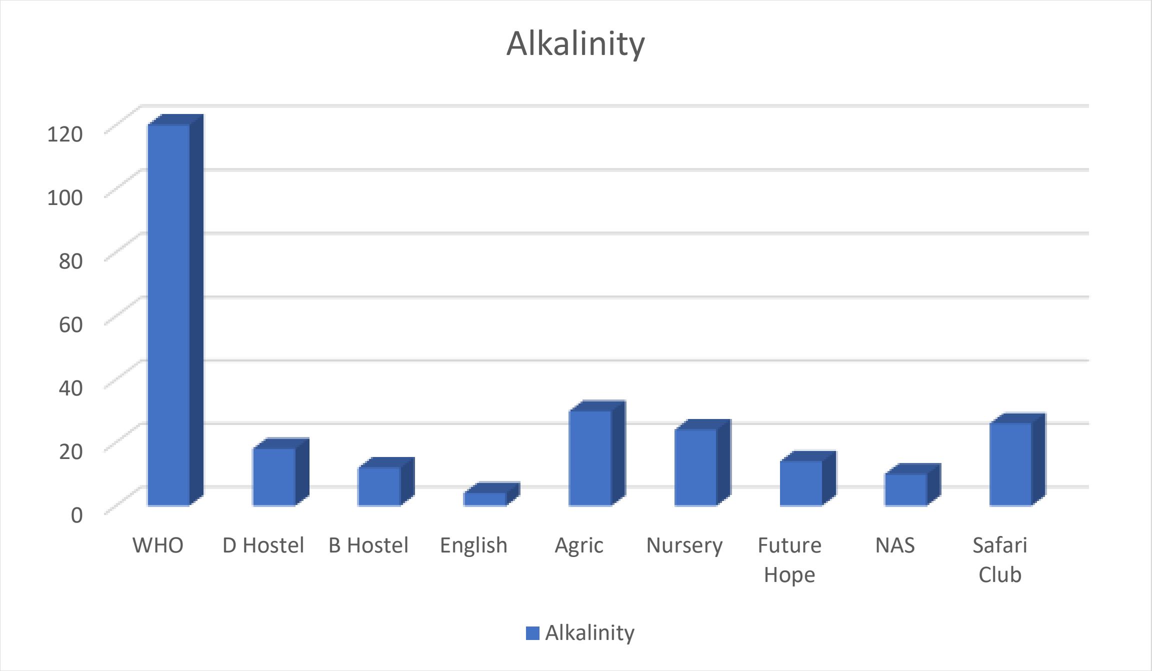

Figure 6: Alkalinity results for ground water

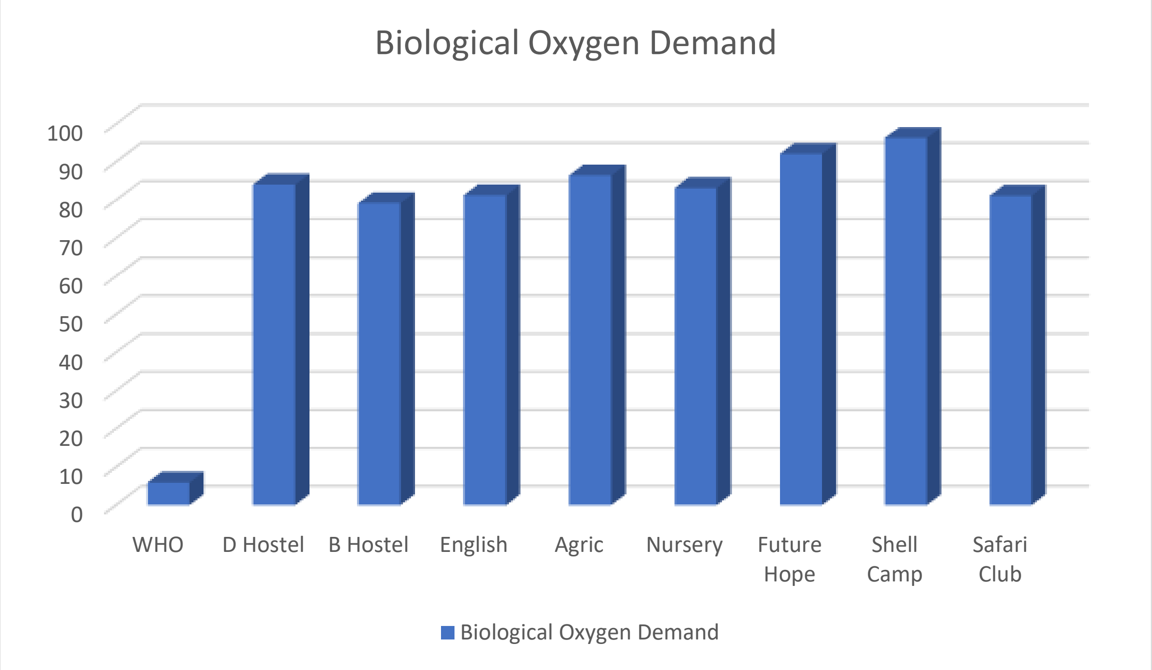

Figure 7: Biological Oxygen Demand for ground water

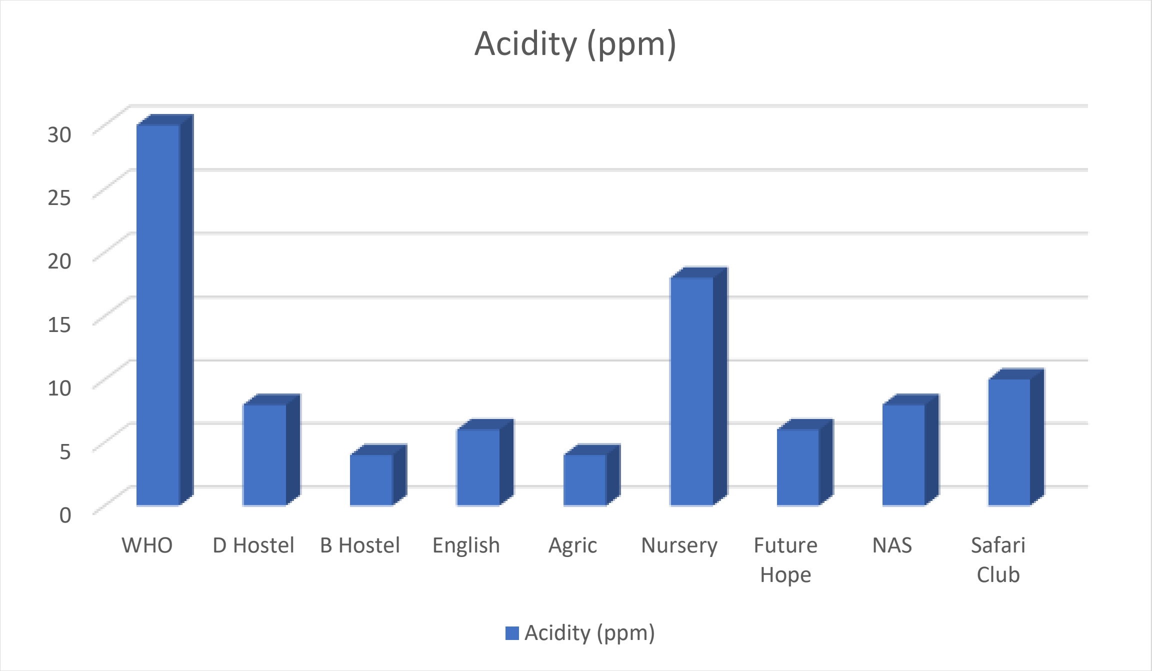

Figure 8: Acidity results for ground water

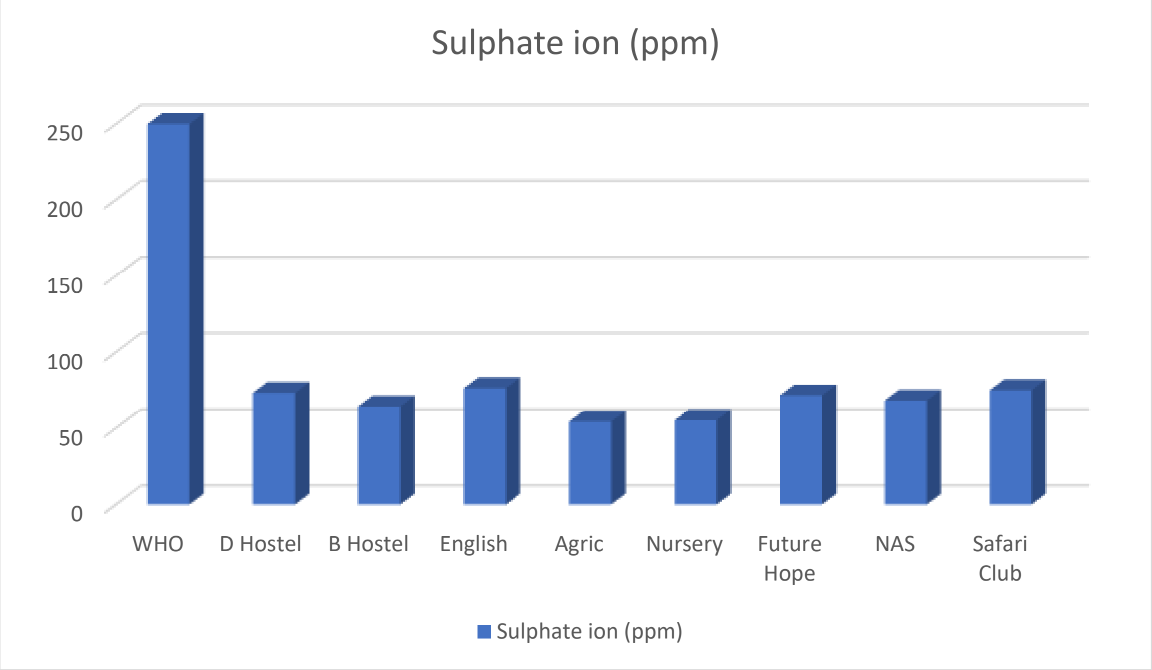

Figure 9: Sulphate results for ground water

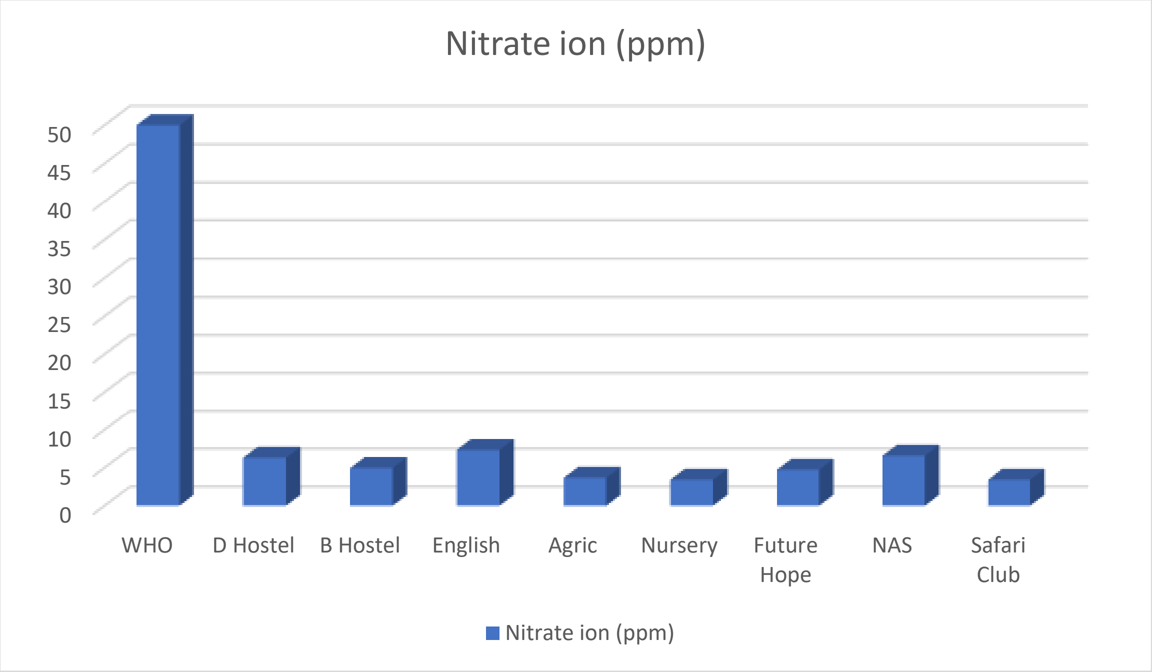

Figure 10: Nitrate results for ground water

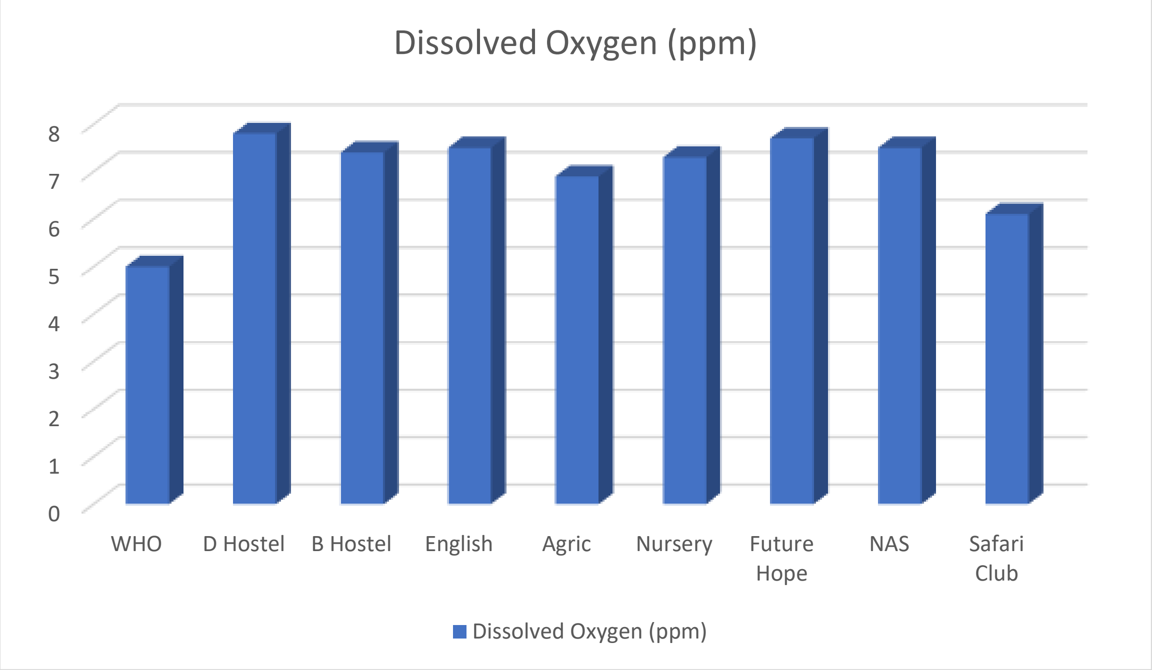

Figure 11: Dissolved oxygen results for ground water

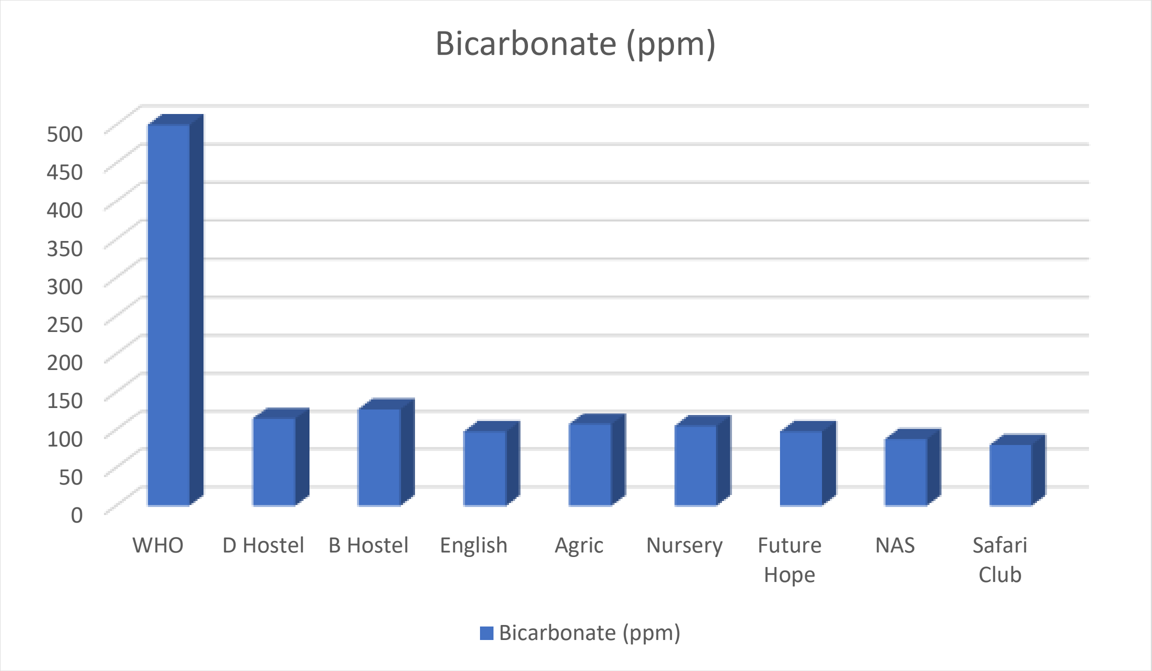

Figure 12: Bicarbonate results for ground water

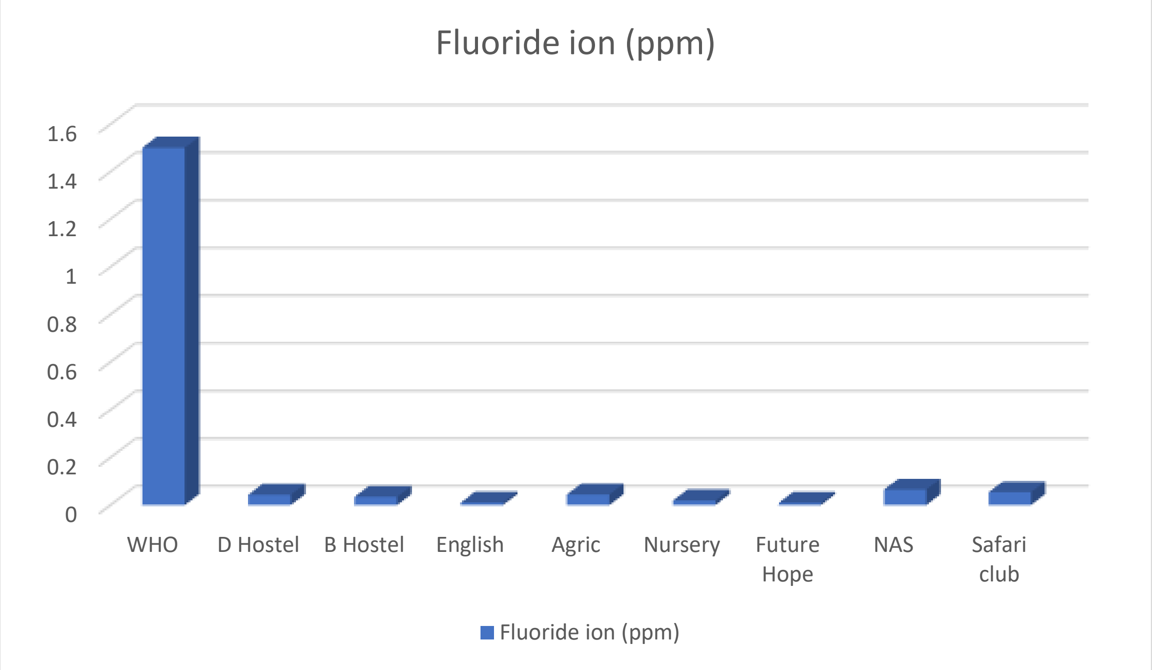

Figure 13: Fluoride results for ground water

Table 2: Physicochemical result of surface water.

Sample	Conductivity µs/cm	TDS mg/l	pH	Turbidity NTU	Phosphate mg/l	Alkalinity mg/l	BOD mg/l	Acidity mg/l	SO_4^{2-} mg/l	NO_3^- mg/l	DO mg/l	Bicarbonate mg/l	F^- mg/l
WHO permissible limit	1000	1000	6.5-8.5	5	5	120	6	30	250	50	5	500	1.5
Nworie Midstream	26	13	6.36	25	6.019	56	78.20	8	71.667	4.155	9.8	130	0.021
Nworie Downstream	144.9	72.5	5.32	5	10.423	32	68.40	6	73.333	3.488	7.2	92.5	0.019
Nworie Upstream	80	40.0	4.38	9	4.208	16	74.10	4	75.778	3.988	8.3	115	0.023

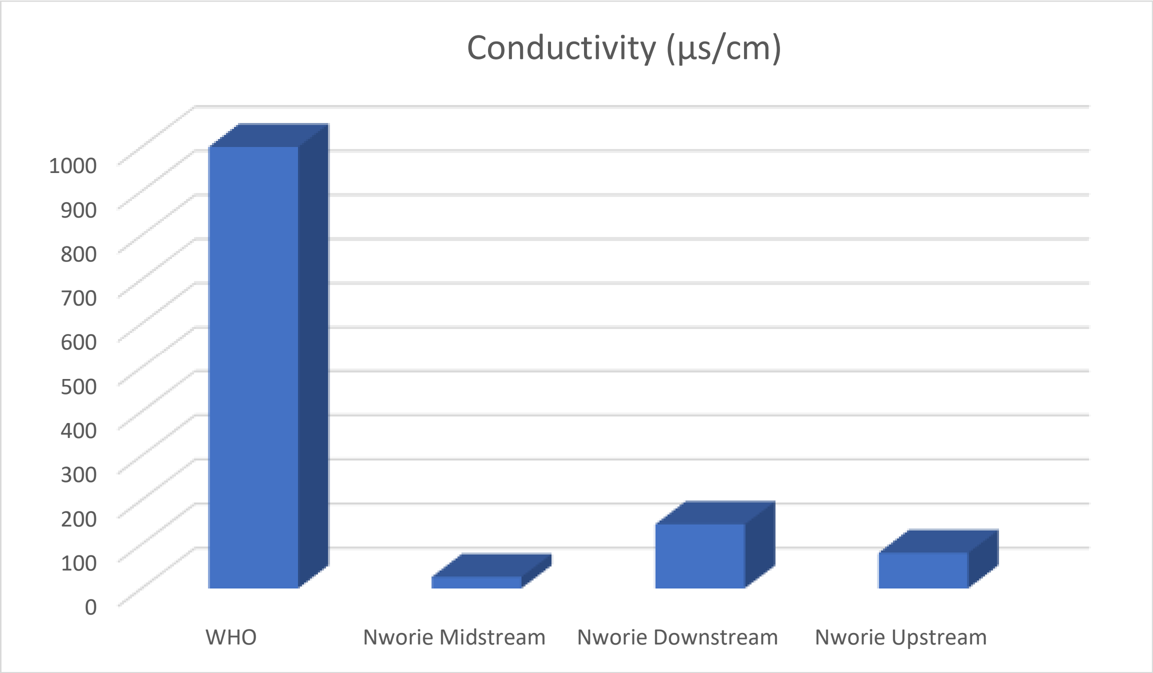

Figure 14: Conductivity results for surface water

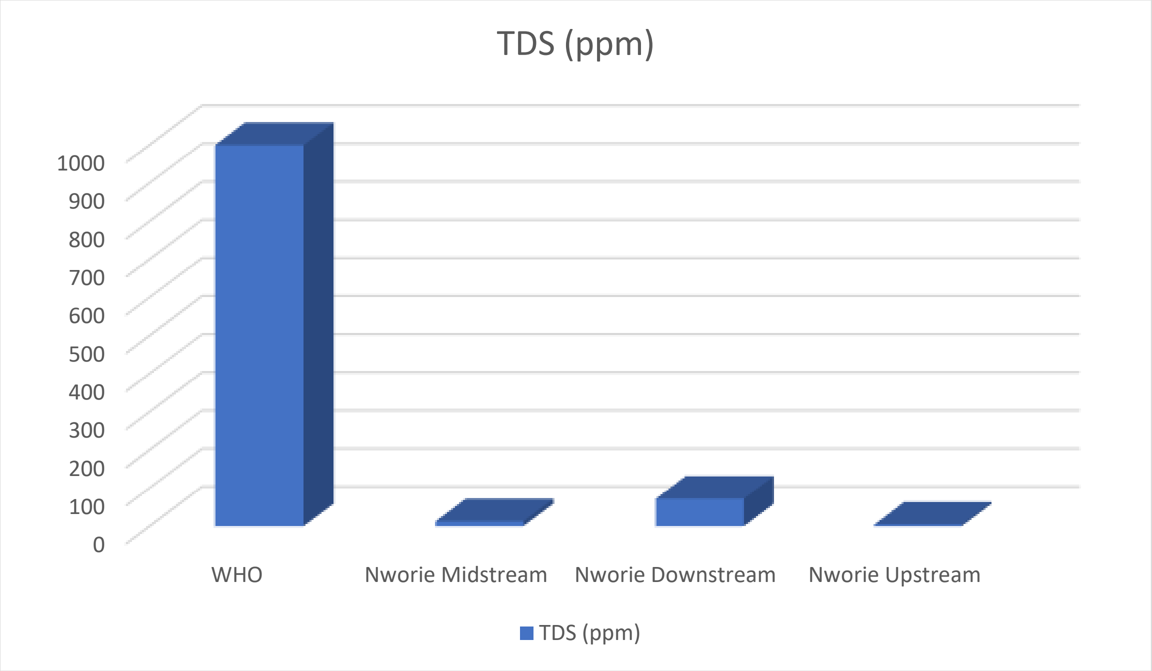

Figure 15: Total Dissolved Solids results for surface water

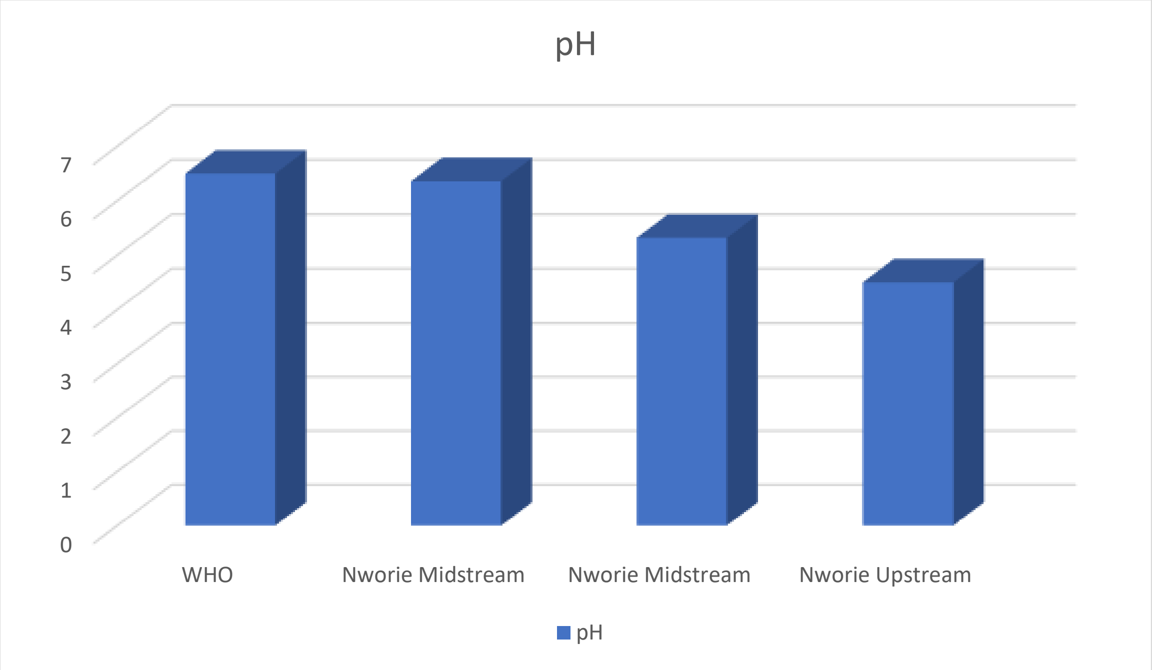

Figure 16: pH results for surface water

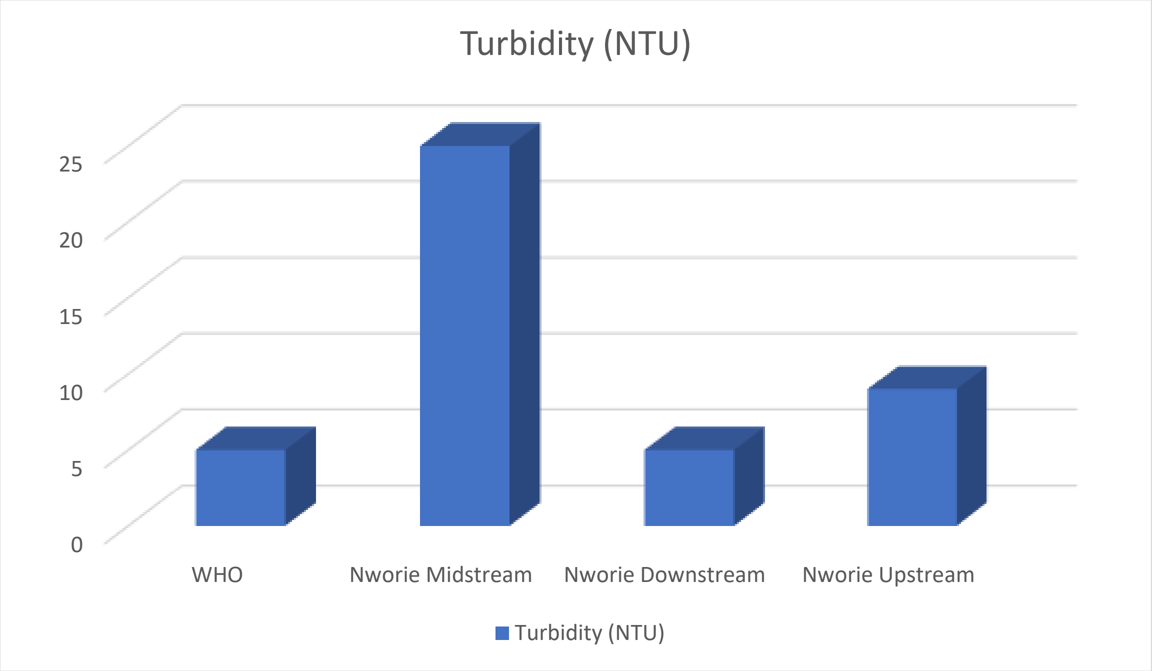

Figure 17: Turbidity results for surface water

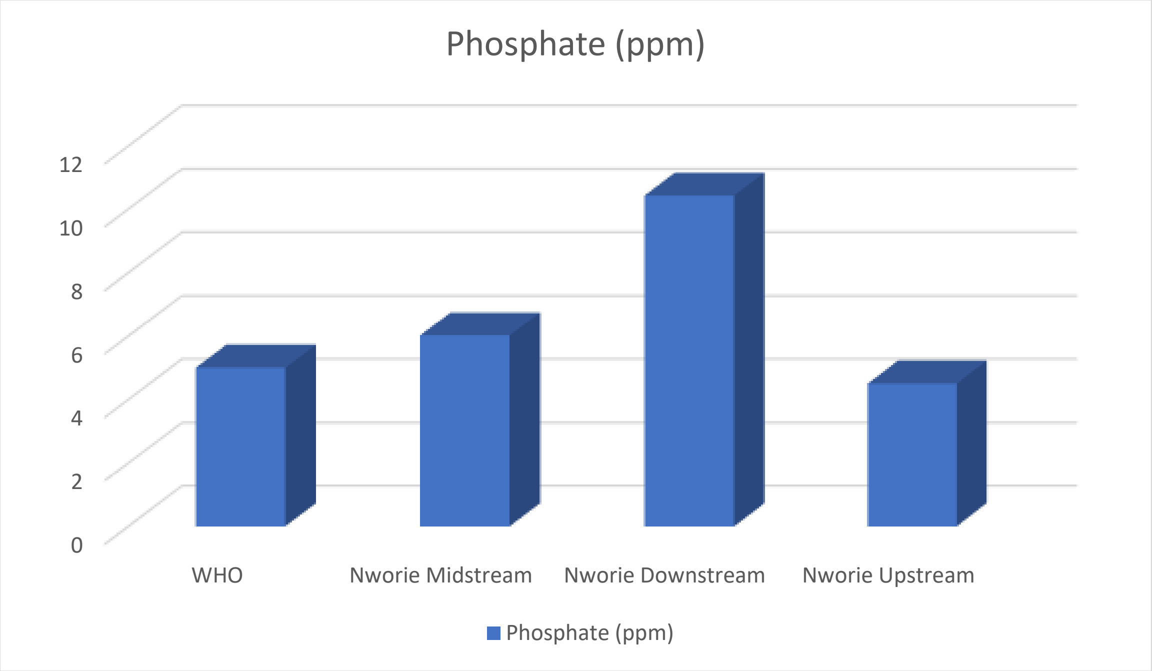

Figure 18: Phosphate results for surface water

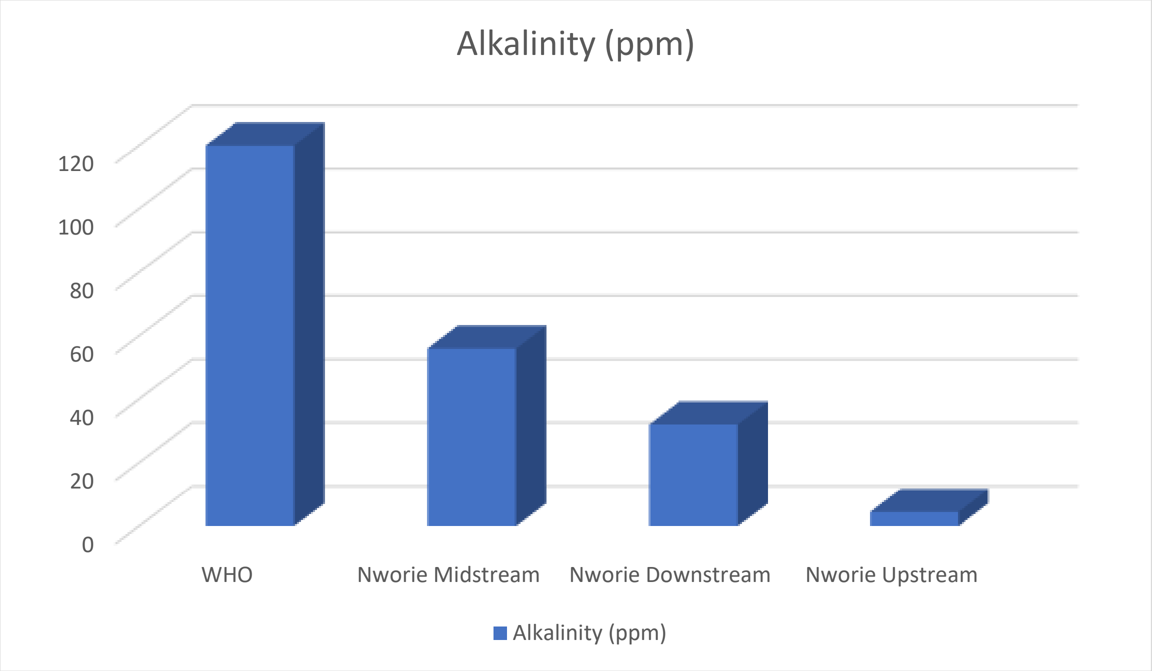

Figure 19: Alkalinity results for surface water

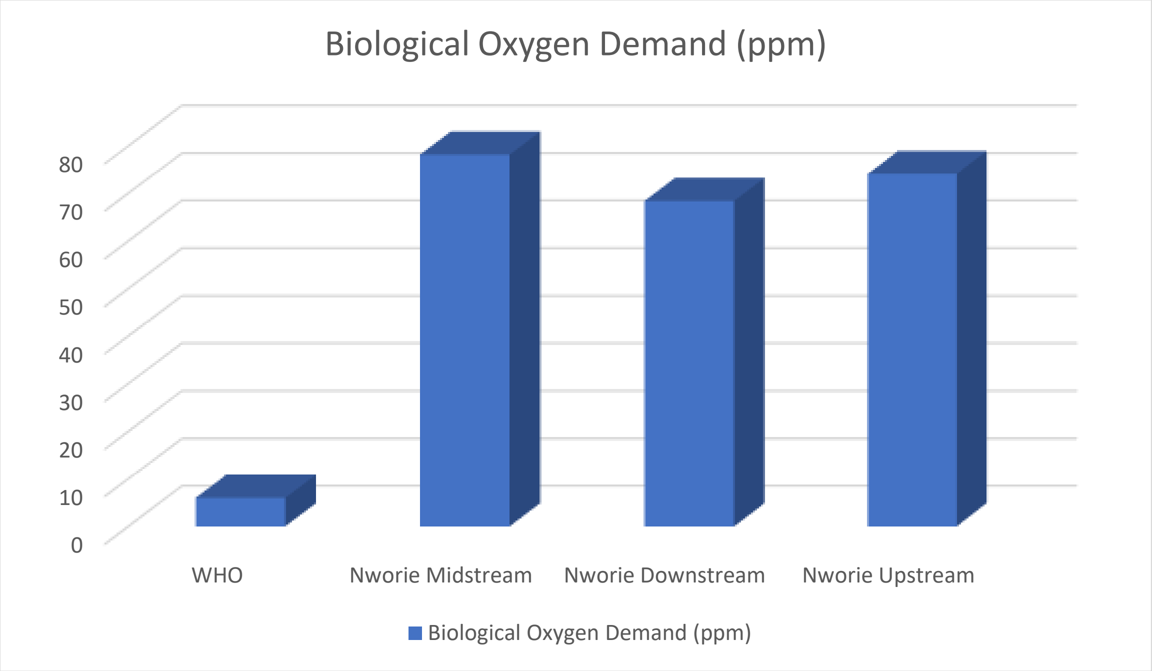

Figure 20: Biological Oxygen Demand results for surface water

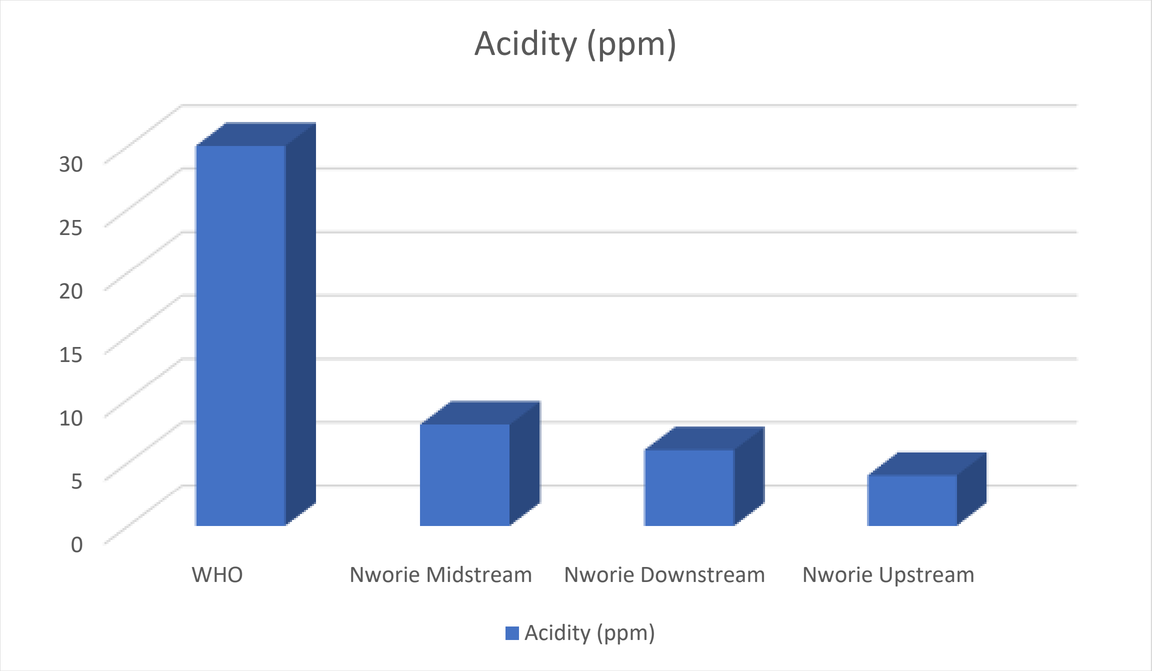

Figure 21: Acidity results for surface water

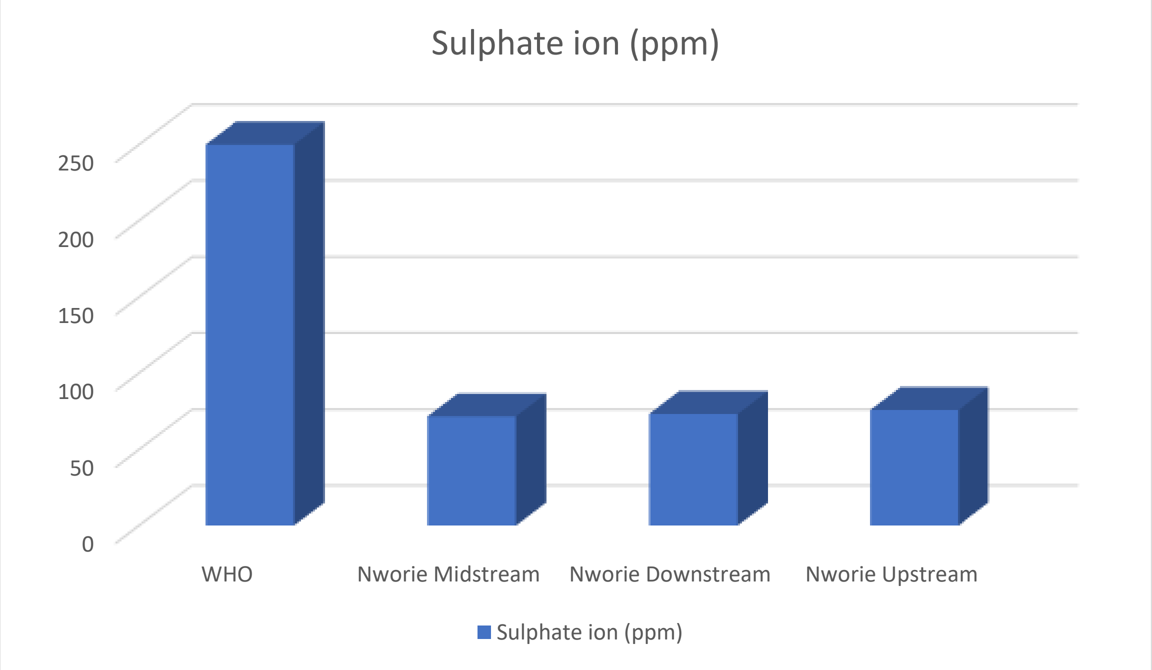

Figure 22: Sulphate results for surface water

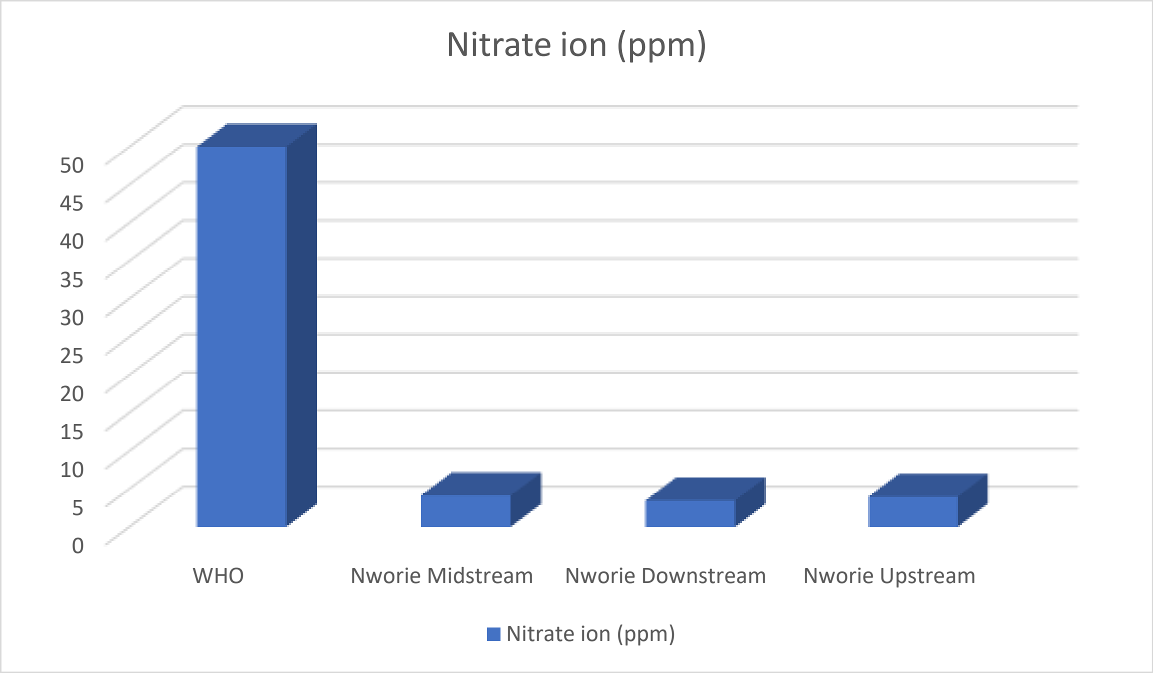

Figure 23: Nitrate results for surface water

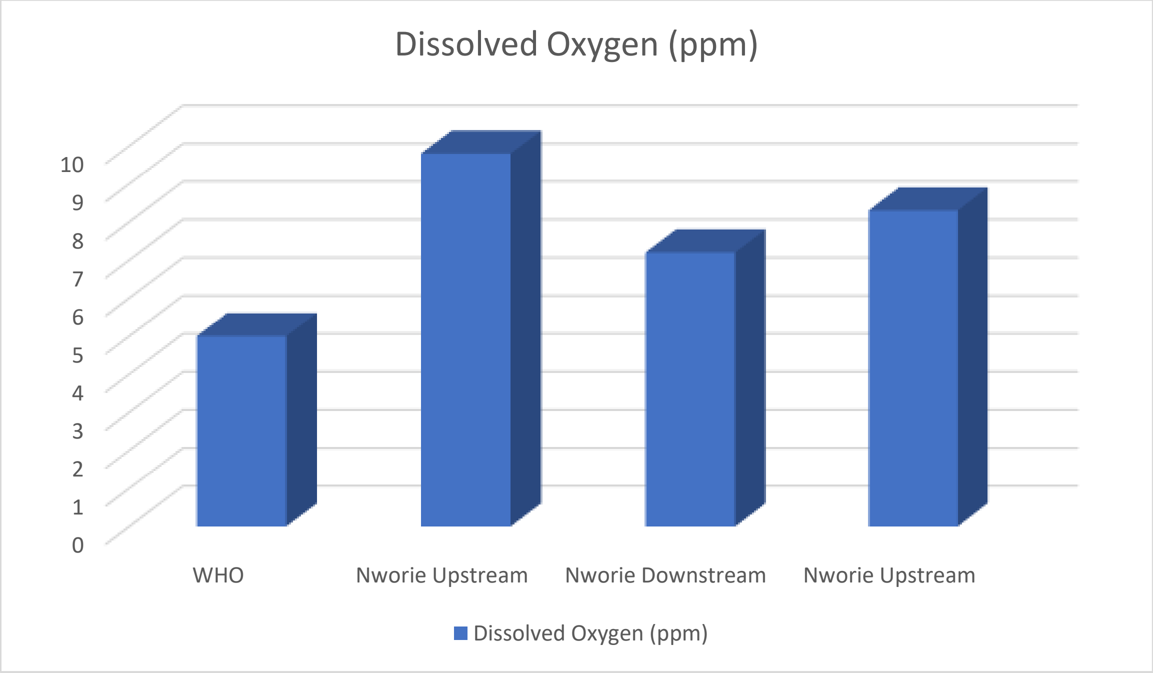

Figure 24: Dissolved Oxygen results for surface water

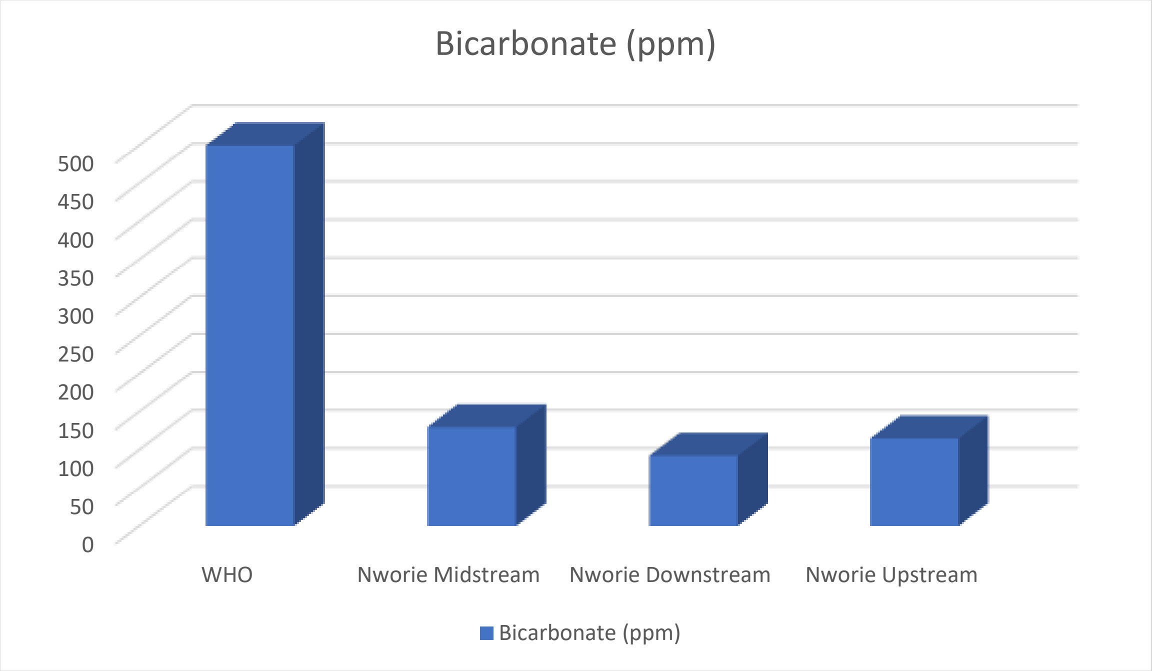

Figure 25: Bicarbonate results for surface water

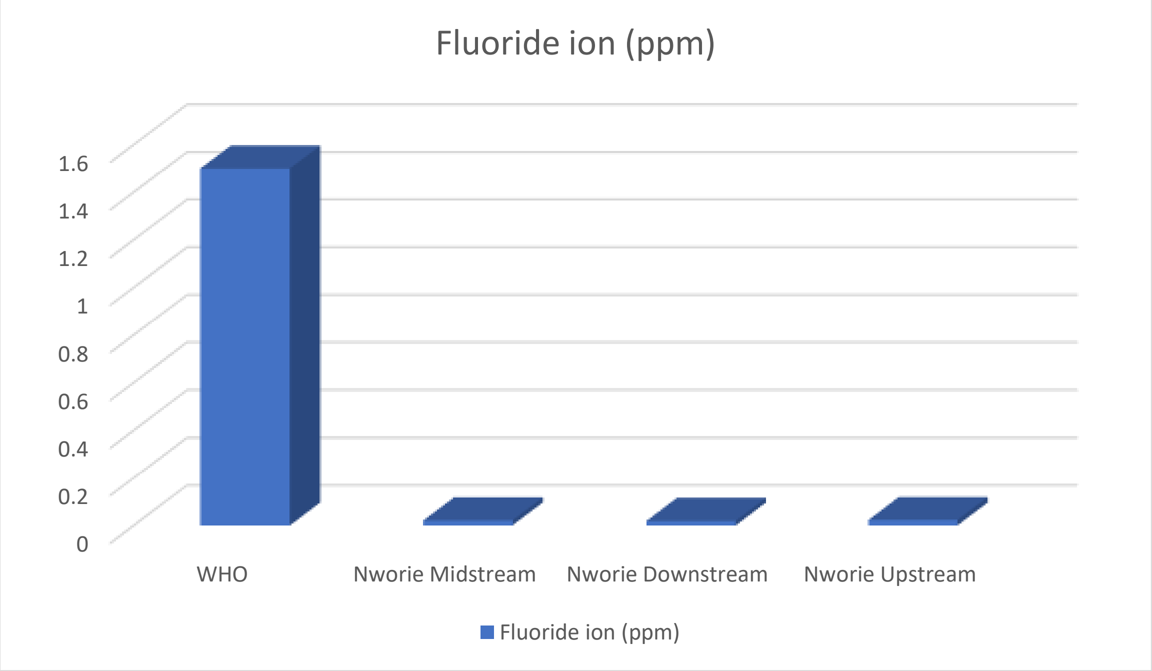

Figure 26: Fluoride results for surface water

Pollution models like contamination factor and geoaccumulation factor of surface and ground water were calculated using the formulae below and the outcomes were presented in Tables 3. 4, 5 and 6 as follows.

Contamination Factor, $C_f = \frac{C_{sample}}{C_{background}}$ 7

Whereby C_{sample} = Concentration of the parameter in the sample

$C_{background}$ = the baseline concentration, in this case, it is taken as the WHO permissible limits for drinking water

Geoaccumulation Index, Igeo = $log_2 \left(\frac{C_{sample}}{1.5 \times C_{background}}\right)$ 8

Where C_{sample} is the measured concentration of the sample, $C_{background}$ is WHO permissible limit and 1.5 is the correction factor for natural variability.

Table 3: **Contamination Factor for Surface Water Samples**

Sample	Cond.	TDS	pH	Turbidity	Phosphate	Alkainity	BOD	Acidity	SO_4^{2-}	NO_3^-	DO	HCO_3^-	F^-
Nworie Midstream	0.03	0.01	0.98	5.00	1.20	0.47	13.03	0.27	0.29	0.08	1.96	0.26	0.01
Nworie Downstream	0.14	0.07	0.82	1.00	2.08	0.27	11.40	0.20	0.29	0.07	1.44	0.19	0.01
Nworie Upstream	0.08	0.04	0.67	1.80	0.84	0.13	12.35	0.13	0.30	0.08	1.66	0.23	0.02

Table 4: Contamination Factor for Groundwater Sample

Sample	**Cond.**	**TDS**	**pH**	**Turbidity**	**Phosphate**	**Alkalinity**	**BOD**	**Acidity**	**SO_4^{2-}**	**NO_3^-**	**DO**	**HCO_3^-**	**F^-**
D Hostel	0.27	0.13	0.97	0.20	1.91	0.15	14.02	0.27	0.29	0.13	1.56	0.23	0.03
B Hostel	0.17	0.08	0.95	3.40	1.20	0.10	13.20	0.13	0.26	0.10	1.48	0.26	0.02
English/ 1000 Capacity	0..14	0.07	0.96	3.00	0.79	0.03	13.55	0.20	0.30	0.15	1.50	0.20	0.01
Agric Dept	0.15	0.08	0.95	0.00	1.15	0.25	14.42	0.13	0.22	0.07	1.38	0.22	0.03
Alvan Nursery	0.11	0.05	1.01	0.40	1.32	0.20	13.87	0.60	0.22	0.07	1.46	0.21	0.01
Future Hope/Shell Camp	0.15	0.08	0.97	1.00	1.27	0.12	15.35	0.20	0.29	0.09	1.54	0.20	0.01
NAS/Bio Lab	0.16	0.08	0.94	1.00	2.09	0.08	16.05	0.27	0.27	0.13	1.50	0.18	0.04
Safari Club	0.36	0.08	0.79	1.80	1.67	0.22	13.53	0.33	0.30	0.07	1.22	0.16	0.04

Table 5: Geoaccumulation Index (I-geo) of Surface Water Samples

Sample	**Turbidity**	**Phosphate**	**BOD**	**Acidity**	**SO_4^{2-}**	**NO_3^-**	**F^-**
Nworie Midstream	1.74	0.17	3.11	-0.91	-1.78	-2.27	-6.16
Nworie Downstream	-0.58	0.48	2.99	-1.32	-1.78	-2.44	-6.29
Nworie Upstream	0.26	-0.12	3.05	-1.91	-1.77	-2.30	-6.05

Table 6: Geoaccumulation Index (I-geo) of Ground Water Samples

Sample	**Turbidity**	**Phosphate**	**BOD**	**Acidity**	**SO_4^{2-}**	**NO_3^-**	**F^-**
D Hostel	-2.58	0.35	3.15	-0.91	-1.77	-2.31	-5.12
B Hostel	1.85	-0.32	3.06	-1.91	-1.95	-2.76	-5.63
Eng/1000 Capacity	1.66	-0.92	3.09	-1.32	-1.74	-2.35	-8.23
Agric. Dept.	0	-0.46	3.18	-1.91	-2.13	-2.94	-5.10
Alvan Nursery	-1.91	-0.18	3.14	-0.73	-2.11	-3.12	-6.31
Future Hope	-0.58	-0.25	3.28	-1.32	-1.82	-2.81	-6.87
NAS/Biology	-0.58	0.48	3.41	-0.91	-1.89	-2.26	-4.54
Safari Club	0.26	0.15	3.03	-0.58	-1.74	-3.12	-4.80

From Table 1 and 2 and Figures 1 to 26, all tested samples, apart from Nworie upstream, had appreciably high conductivity values, with Safari Club and D hostel samples exceeding the WHO permissible limit of 250 **µS/cm** for portable water, at 363 **µS/cm** and 269 **µS/cm** respectively, which implies that they may contain more ions and minerals. However, TDS values were within acceptable values according to WHO. The pH values for all the tasted water sample are below 6.5 except Alvan nursery sample, with a pH of 6.56. The acceptable WHO range is 6.5-8.5. This shows that the tested samples are slightly acidic, a situation that may lead to corrosion of pipes, leaching of metals and the water needs to be treated before using in agriculture. Apart from the samples obtained from D hostel, Agricultural department, and Alvan nursery, with turbidity values of 1 NTU, 0 NTU and 2 NTU respectively, all other tested samples were either at the threshold level of 5.0 NTU, or in excess, thus implying that those affected samples contained suspended solids, clay or micro-organism, and should be treated before use as drinking water. The WHO permissible limit for phosphate in portable water is 0.3 mg/l. However, the phosphate levels for all the tested water samples far exceeded this threshold value, with values as 10.466, 10.423 and 9.555 for NAS/Biology laboratory, Nworie downstream and D hostel respectively. This may be caused by untreated industrial and domestic effluent, agricultural run-off, thus leading to enrichment of the water body with phosphorus nutrients, and promotion of algae growth and other aquatic plants. This may consequentially lead to oxygen depletion, death of aquatic animals, foul odour , and poor water quality. The BOD values for all the water samples outrageously exceeded the WHO permissible limit of 3.0 mg/l, with values as high as 96.3 mg/l, 92.1 mg/l and 86.5 mg/l for NAS/Biology laboratory, Future Hope school and Agricultural department respectively. This reduces available oxygen for aquatic organisms, and also makes the water unsafe for drinking because of the presence of organic pollutants. Although there is no set limit by WHO for acidity, but high concentration levels of 18 mg/l, 10 mg/l, and 8 mg/l for samples from Alvan nursery, Safari club and NAS/Biology laboratory, and low pH values recorded, suggest acidic pollution and carbonic acid build-up. Sulphate and nitrate, dissolved oxygen and fluoride levels for all the tested water samples were within the WHO acceptable limits for portable water. Bicarbonate levels for portable water should not exceed 120 mg/l. Samples from Nworie midstream and

B hostel exceeded this value at 130 mg/l and 127.5 mg/l respectively. High bicarbonate levels in water does not have any health implication.

Abolli et al. [11] studied groundwater quality with physicochemical parameters such as TDS, electrical conductivity, total hardness using electrometric, titration and spectrophotometric methods of analysis. The present study attempted to compare the quality of groundwater and surface water with classical analytical and spectrophotometric methods. Besides, only five physicochemical parameters in the present research were within the WHO permissible limit for drinking water, only the mean of magnesium ion was within the WHO limit in the work of Abolli et al. Rao et al. [12] in a similar test for quality of groundwater samples in Odisha, India discovered that above ninety percent of water in the study region were unfit for drinking as a result of high concentrations of magnesium, sodium, chloride, sulphate and nitrate ions. The work of Rao et al. [13] indicates that the ground water studied was from a rural part of Telangana, India while the present work is from a university community in South Eastern Nigeria. The study also showed that only an insignificant part of water from the studied zone had parameters below the drinking water limit. Egbueri and Agbasi [14] employed physicochemical parameters to study ground water samples in Ojoto, Southeastern Nigeria, about 25% of the water samples studied were unfit for drinking; researchers for the present work studied ground water quality from Owerri, South East Nigeria. Mahammad et al. [15] studied the quality of water from Damoda fan Delta in India for irrigation purpose using physicochemical parameter analysis and discovered that that 25% of well water were contaminated with heavy metals, whereas the present work studied the suitability of ground water in a university community in southeastern Nigeria for drinking purpose, and discovered heavy metal pollution in most of the studied samples. Alogayell et al. [16] also assessed water samples from the central region of Saudi Arabia. and found all of them suitable for irrigation purpose. Vig et al. [17] also assessed groundwater quality near the industrial zone of Rupnagar, Punjab and found them marginally suitable for drinking and irrigation purposes. Shuaibu et al. [18] evaluated the quality of groundwater in the Komadugu-Yobe basin in Nigeria and found only 27% suitable for drinking. The present work assessed the comparison in the quality of groundwater and surface water in a university community in Owerri, Nigeria. Muntaz et al. [19] determined the suitability of water in seven districts in Pakistan for drinking and found out that water samples from three districts out of the seven studied districts were of poor quality due to excess of electrical conductivity and total dissolved solids, as was also obtainable in the present research. Physicochemical parameters were used by Parihar et al. [20] to assess the quality of groundwater from Rajasthan India, and discovered that most of the parameters were below the WHO permissible limit for portable water, unlike the case in the present study.

Tables 3 and 4 show the calculated contamination factors for surface and ground water samples. Contamination values lower than indicates that there is low contamination, values greater than 1 and less than 3 show moderate contamination, above 3 and below 6 shows considerable contamination. The sample is considered to be very highly contaminated, if the contamination factor is above 6. Taking a closer look at Table 3, the contamination factor for turbidity shows considerable contamination for midstream sample at 5.00, and moderate contamination for downstream and upstream samples at 1.00 and 1.80 respectively; phosphate values show moderate contamination for midstream and downstream at 1.02 and 2.08; BOD values show very high contamination for midstream, downstream and upstream samples at 13.03, 1.40 and 12.35, which reflects heavy organic pollution. Moderately high contamination factor for dissolved oxygen (DO) for all samples shows good oxygenation, and does not produce pollution concerns. All other parameters indicate low contamination at C_f less than 1 for all the tested samples. From Table 4, the contamination factor for turbidity for B hostel and English/1000 capacity is considerably high at 3.40 and 3.00 respectively, whereas Future Hope shows moderate contamination at $C_f = 1$. With the exception of English/1000 capacity location, C_f values for phosphate for all other sampled sites show moderate contamination at C_f greater than 1. Very high contamination factors (> 13) for BOD for all samples indicate strong organic pollution, $C_f > 1$ for dissolved oxygen (DO) for all samples indicate good oxygenation, and is not a pollution threat. Contamination factors of less than 1 for pH for all samples (except Alvan nursery) show low contamination, but physicochemical values of pH values less than 6.5 depict slight acidity. All other samples have C_f less than 1, showing low contamination.

The geoaccumulation index, I_{geo} values in Table 5 for acidity, sulphate, nitrate and fluoride ions for all the tested samples shows practical non-contamination, BOD values depict moderate to heavy contamination at I_{geo} 3.11, 2.99 and 3.05 for midstream, downstream and upstream samples, phosphate result shows low contamination for midstream and downstream samples at I_{geo} values of 0.17 and 0.48 respectively. Turbidity values for midstream reflect moderate contamination at I_{geo} value of 1.74. Taking a look at Table 6, the BOD value of $I_{geo} > 3$ for all the locations signify moderate to heavy contamination, reflecting strong organic pollution load. The geoaccumulation index of 1.85 and 1.66 for turbidity for B Hostel and English/1000 capacity shows moderate contamination; phosphate values for D hostel and NAS building are slightly high at 0.35 and 0.48 respectively, thus reflecting low contamination. All other values of I_{geo} for the tested parameters at the sampled locations show practical non-contamination.

The reviewed work of Akakuru et al. [21] reveal extreme pollution through the geoaccumulation index calculation This work differs from the present work in geographical content, also heavy metals were the focus of the reviewed work, whereas the present work focused on physicochemical parameters. The reviewed work of Akakuru et al. [22] show low contamination for most of the tested parameters, with contamination factor less than one, while geoaccumulation index revealed that most of the samples were extremely pollution. The present work and the reviewed work differ both in content and geographical scope. Dasari et al. [23] through the determination of water quality index showed that seventy-six percent of the water assessed, were not suitable for drinking. The work of Desai et al. differ from the present research in geographical and content assessment. The work of Osisanya et al. [24] reveal that the water that was examined had poor quality and could only be used for irrigation. Whereas the reviewed work utilized water quality index, contamination factor, pollution load index among others to determine water quality, the present work used geoaccumulation factor and contamination factor to determine water quality. The work of Al-Sabah and Aldhahi [25] through the determination of the contamination factor and metal pollution index showed low contamination, whereas the reviewed work examined water on the soil of Iraq, the present study was on a geographical location in Southeast Nigeria. Egbueri et al. [26] determinations of pollution indices parameters showed that eight to twelve percent of the wells were slightly contaminated. Both works differ in geographical and content scope. Nisar et al. [27] also obtained similar results from assessment of drinking water quality of ground and surface water in Moti village, Northen Pakistan, but the present work is in a university community, Southeastern Nigeria. Contaminant concentrations exceeded the threshold levels for portable water. Similarly, Rao et al [28] discovered through the overall water quality index that 95.93% of groundwater sources in a part of Odisha were unfit for drinking. Besides, Samal and Tarai [29] evaluated samples of water collected from industry, market, institutions, construction sites of Bhubaneswar, and the overall water quality index shows that the water is not in the poor and very poor range. Rakotondrabe et al. [30] sought to determine the influence of gold mining on drinking water quality in the Mari catchment of a community, East Cameroon, using selected physicochemical parameters and heavy metal pollution index., and discovered that the major elements were within the WHO guidelines for portable water, although some of the trace elements exceeded the required concentration, thus making the water unfit for drinking.

Test of Hypothesis

Null hypothesis (H_0): There no significant difference between the physicochemical parameter values of ground water and surface water in the university community.

Alternate hypothesis (H_1): There is significant difference between the physicochemical parameter values for ground water and surface water in the university community.

Table showing the summary of the mean and standard deviations for ground and surface water used for the study

Table 7: Mean and standard deviations for ground and surface water with regards to physicochemical parameters

Parameter	Mean for ground water	Standard deviation for ground water	Mean for surface water	Standard deviation for surface water	t-value	p-value
Conductivity (µs/cm)	189.03	84.55	83.63	59.53	-2.31	0.656
TDS (mg/l)	94.36	42.27	41.83	29.79	-2.31	0.0664
pH	6.13	0.43	5.35	0.99	-1.31	0.3072
Turbidity (NTU)	6.75	6.39	13.00	10.58	0.96	0.4187
PO_4^{2-} (mg/l)	7.12	2.16	6.88	3.20	-0.12	0.9122
Alkalinity (mg/l)	17.25	8.88	34.67	20.13	1.45	0.2694
BOD (mg/l)	85.49	5.91	73.57	4.92	-3.38	0.0241
Acidity (mg/l)	8.00	4.54	6.00	2.00	-1.01	0.3400
SO_4^{2-} (mg/l)	67.04	8.32	73.59	2.07	2.07	0.0699
NO_3^- (mg/l)	5.06	1.54	3.88	0.35	-2.04	0.0733
DO (mg/l)	7.28	0.55	8.43	1.31	1.49	0.2606
Bicarbonate (mg/l)	102.19	15.09	112.50	18.87	0.85	0.4573
F^-(mg/l)	0.0348	0.0206	0.0210	0.0020	-1.87	0.1022

From Table 7, the t-values and p-values show that there is no significant difference between the ground water and surface water values for all the physicochemical parameters tested, except BOD (at p: 0.0241<0.05). This implies that the groundwater and surface water under study are formed by the same environmental and geochemical parameters. The test for hypothesis presents a worrisome scenario, where eight out of thirteen physicochemical parameters tested exceeded the threshold values of WHO standards for portable water, which indicates that water from both sources are not fit for drinking except adequate and proper treatments are carried out on them. The statistically significant difference obtained for BOD (at $p<0.05$) and the higher physicochemical values of BOD for ground water more than surface water suggest that the ground water sources of water within the studied area are receiving more organic wastes than the surface water. This could be caused by infiltration of effluents from septic tanks, and organic pollutants into the underground water., thus posing potential health concerns as most communities rely on groundwater sources for drinking and other domestic activities.

CONCLUSION

Although some of the tested parameters were within safety limits, approximately sixty- two percent of them exceeded the WHO threshold levels for drinking water.

The calculated contamination factor (Cf) and geoaccumulation index (Igeo) also validated high pollution for both the surface and ground water, hence stressing the susceptibility of the water resources within the university community to human generated activities, which rendered the water sources unfit for drinking.

This necessitates the critical need for proper waste disposal, controlling human and industrial activities through enactment of environmental protection laws, and application of water treatment measures to ensure that drinking water within the university environment is safe for human health.

The result of the hypothesis test showed that there is no significant difference between the physicochemical parameter values for ground water and surface water, with the exception of BOD.

Recommendations

There should be educational campaigns through radio, community and school meetings, to create awareness on the potential health hazards posed by drinking untreated borehole and surface water from the University. Besides, government and all the stakeholders should endeavour to provide safe alternative source of water for the University community, such as treated pipe-borne water, or safer alternative bore-hole water. There should also be the enactment and enforcement of laws by Environmental protection to restrict discharge of domestic, agricultural and industrial effluent into the river. Urban and town planning authorities should closely monitor land activities around water bodies that could lead to their pollution, such as chemical-intensive farming, indiscriminate dumping of refuse among others. Health assessment studies should be carried out to find out both short-term and long-term risks associated with exposure to these contaminants in both children and adult persons.

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