

Assessing the Physicochemical Parameters of Water Sources in the Fiapre Vicinity, a Suburb of Sunyani in the Brong Ahafo Region of Ghana

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ABSTRACT

This study was carried out to assess the water quality of all the available sources of water – stream (Attadie Stream), wells, boreholes and potable pipe-borne water supplied by the Ghana Water Company by treatment of water from the Tano River in the Fiapre vicinity for a period of three months, from February to April, 2018. Results from the survey were compared with the World Health Organization (WHO) standards to ascertain whether these waters are safe for drinking or not. A total of 11 samples were taken from all the sources of water in Fiapre. These samples were taken from 4 boreholes, 4 wells, and 1 sample each of upstream and downstream with 1 sample taken from water supplied by the Ghana Water Company. These samples were analyzed for their physicochemical parameters comprising pH, temperature, conductivity, total alkalinity, total dissolved solids, total hardness, calcium, magnesium, chloride, biological oxygen demand and chemical oxygen demand. From the study it was observed that the pH, electrical conductivity, total dissolved solids, chloride and total hardness of all the samples were within the World Health Organization standards. The samples, W 2 and GWC had their other parameters within the WHO standards while the rest had one or more of the other parameters way above the WHO standards.

Key words: *Physicochemical parameters, Alternative sources, Water quality, Fiapre.*

1. INTRODUCTION

Water resource is a very vital unit of all living things and also contributes to domestic activities in diverse ways. Its accessibility and availability is key to sustainable development in crop production, industrial production and domestic purposes. The availability of water should not be of concern as the planet is 70 % water. However, of this vast amount of water, 97 % is in oceans and seas and is unsafe to drink unless it is treated, which is very expensive and 2 % is locked up in the polar icecaps and ice sheets. The last 1 % is located across the globe in lakes, rivers and in aquifers [1]. This 1 % faces contamination from waste created by humans as well as from the radioactive decay of uranium in rocks. The globe is therefore left with less than 1 % of the 70 % water as potable for consumption.

The inability of many people across the world to access treated water whose purity is guaranteed has resulted in the reliance on alternative sources of water such as rainwater, untreated surface water sources and groundwater for domestic and other uses. Ghana faces no different fate from the rest of the world in terms of good quality drinking water.

The Ghana Water Company Limited (GWCL) which was established on 1st July, 1999 is responsible for the constant supply of potable water for the whole of Ghana. The Brong Ahafo Region has a population of 2,310,983 (2010 census) and a population

growth rate of 2.2% [2]. The current population for the areas being served by GWCL is 915,972 (2010 census) and the water coverage is estimated to be 52% [2].

The daily demand for water is 54,970 m³ as against current installed daily production capacity of 20,749 m³ out of which the current average daily production target is 14,678 m³ leaving a huge demand gap of 40,292 m³ per day representing 26.7% adverse difference [3]. This statistic gives a clear indication why there is a limited supply of water by GWCL to every part of the region. Consequently, communities in Sunyani such as Fiapre, resort to using water from streams and dug-out wells. Some of these water points appear visibly clean sources of water but may be unsafe for drinking [4].

Surface water is the water found in streams, rivers, lakes and wetlands. Surface water may be readily accessible and easily abstracted but is naturally contaminated [5]. In some frugally populated areas, streams, lakes, and ponds are subject to considerable faecal pollution due to poor sewage discarding [6]. Also the water running across the surface of the ground picks up numerous constituents such as microbes, organic matter and mineral deposits as it flows. It becomes rich in nutrients and therefore, become a perfect medium for the growth of all types of micro-organisms [7]. Maintaining good quality surface water is essential in ensuring the multiple uses of it. In Ghana, raw water has been under increasing threat of pollution in recent years due to rapid demographic changes. This has coincided with the establishment of human settlements lacking appropriate sanitary infrastructure. Many settlements have been developed with no proper water supply and sanitation services. People living in these areas, as well as downstream users, often utilize the contaminated surface water for drinking, recreation and irrigation. This creates a situation that poses a serious health risk to the people [8].

Water contained in the pores of soil or in aquifers is called groundwater[9]. In several parts of the world groundwater sources are the single most imperative supply for the production of drinking-water. Groundwater has been found to have a more stable quality and better bacteriological quality than surface waters [10]. According to Appelo and Postma [9], groundwater is less vulnerable to bacterial pollution than surface water because the soil and rocks through which ground water flows screen out most of the bacteria. Additionally aquifers are often well protected by layers of soil and sediment. This efficiently filters rainwater as it permeates through them, thus eradicating particles, pathogenic microorganisms and many chemical elements. Many invisible dissolved mineral and organic constituents are present in ground water in various concentrations. Most are harmless or even beneficial but others are detrimental, and a few may be highly poisonous.

Water quality refers to the chemical, physical, biological and radiological characteristics of water. It is a measure of the condition of water relative to the requirements of one or more biotic species and/or to any human need [11]. Water quality parameters include the physicochemical, biological and radiological characteristics of water. Physicochemical parameters are the physical and chemical parameters associated with water which have an influence on its quality and also affect the biological constituents of the water [12]. The physical parameters of water include temperature, turbidity, odour, colour, suspended solids, conductivity and total dissolved solids. These can affect the aesthetics and taste of the water and may also complicate the removal of microbial pathogens during water treatment [13]. The chemical parameters include pH, biochemical oxygen demand (BOD), chemical oxygen demand (COD), alkalinity, hardness, anions such as sulphates, phosphates, nitrates, nitrites, chlorides, fluorides as well as heavy metals. Some of these parameters tend to pose more chronic health risks while others can have a more instantaneous impact on consumers[14].

The aim of this work is to determine the quality of all the available water sources in Fiapre to evaluate its suitability for domestic use.

2.0 MATERIALS AND METHODS

2.1 Study Area

Ghana is positioned between latitude 4°44'N and 11°11'N and 3°11'W and 1°11'E, about 750 Km north of the equator at the western coast of Africa. Ghana shares borders with Burkina Faso to the North, Togo to the East, La Cote d'Ivoire to the West and the Gulf of Guinea at the South [15]. The country is divided into ten regions (Figure 1).

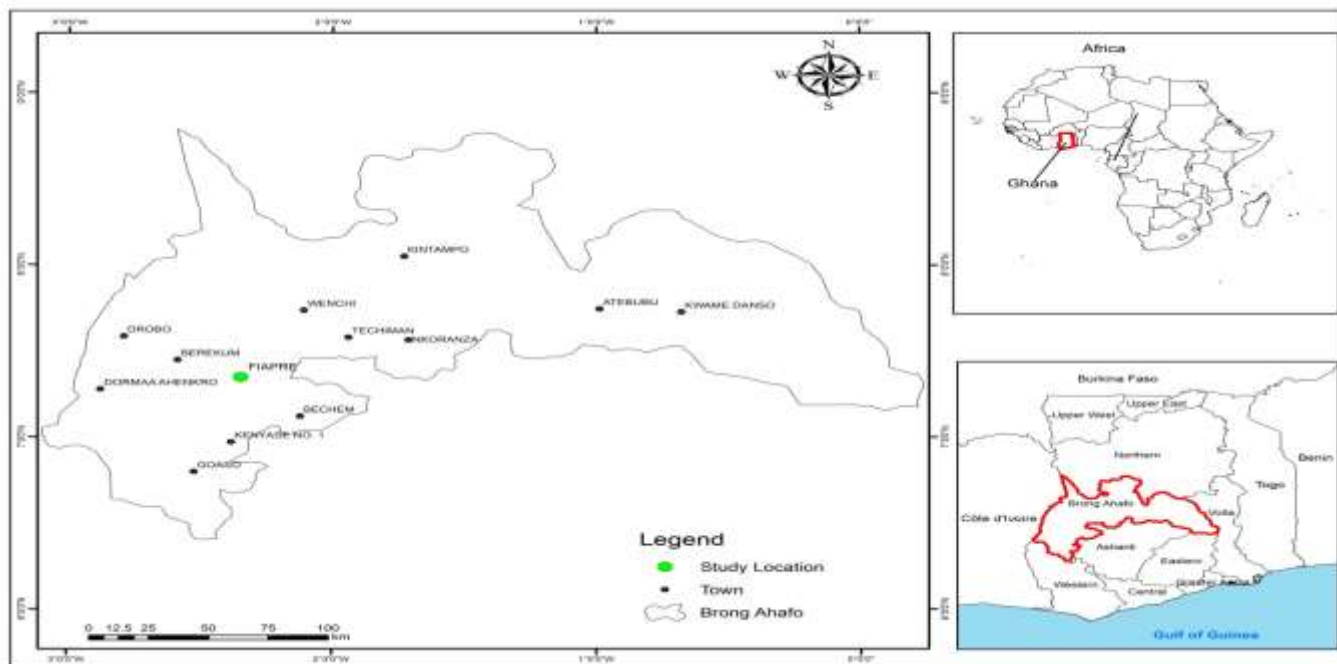


Figure1. Map of Africa, Ghana and Fiapre the sampling location

The Brong Ahafo region is located in the middle part of Ghana and is bordered to the north by the Black Volta River and to the east by Lake Volta, and to the south by Ashanti region, eastern and western regions and to the west by the southeastern border of Ivory Coast [3]. The region has a tropical climate with high temperature between 23°C and 39°C. It enjoys a maximum rainfall of 1000 mm in the northern part and 1400 mm in the southern part of the region [16].

2.2 Sample collection

Water was sampled from selected boreholes, wells and a stream in Fiapre located in the Brong Ahafo region from February to April, 2018. Samples were taken from 4 different wells, 4 boreholes, a stream and water supplied by Ghana Water Company, over a period of three months.

The water samples were collected into 1.5 L pre-washed and screw-capped bottles. The bottles were washed with sulphate free soap, rinsed with distilled water, air dried and sterilized at 100°C to avoid any contamination. The boreholes were labelled BH 1 to BH 4, wells were assigned W1 to W4, the sample collected from the stream was assigned SU and SD for upstream and downstream respectively and water supplied by Ghana Water Company labeled GWC.

2.3 Determination of Physicochemical Parameters

2.3.1 Temperature

The temperature was measured with a thermometer with penetration probe. The probe was rinsed with distilled water before dipping it into the water sample to about 3 cm to 4 cm and reading was allowed to stabilize and recorded

2.3.2 pH

The pH was measured with a pH meter. The probe on the pH meter was first tested with distilled water and calibrated to pH 7. It was then tested against a buffer of pH 9 at a temperature of 25°C. The probe was then immersed in the sample which was stirred gently, allowed to stand for 1-2 minutes for a stable reading to be obtained and recorded.

2.3.3 Electrical Conductivity

The conductivity was determined by means of a Bante 901 Benchtop Multimeter. The conductivity cells and beaker were rinsed with a portion of the sample. 100 mL beaker was filled with the sample. The cell was then inserted into the sample in the beaker. The temperature control was adjusted to that of the sample which has already been determined and the probe was then inserted into the vessel and the conductance recorded.

2.3.4 Total dissolved Solids (TDS)

The TDS was determined using the Bante 901 Benchtop Multimetric. The cells of the multimetric were rinsed with a portion of the sample. It was then inserted into the beaker containing 100 mL of the sample and the TDS recorded.

2.3.5 Chloride

The total amount of chloride was determined by Argentometric titration. 50 mL of sample was taken and 1 mL of K_2CrO_4 indicator solution was added. This was then titrated against standard $AgNO_3$ to a pinkish yellow end point. Reagent blank value was established by titrating 50 mL of distilled water with 1 mL of K_2CrO_4 as indicator, against the standard $AgNO_3$ solution.

2.3.6 Total Alkalinity

A 50 mL sample was measured into a conical flask. Two drops of mixed indicator were added and the resulting mixture was titrated against a standard 0.100M $HCl_{(aq)}$ to the first permanent pink colour at pH 4.5 [17].

2.3.7 Total Hardness

50 mL of sample was pipetted into a conical flask and 1 mL of a buffer solution (pH 14) was added till pH 10. 1.00g of Eriochrome Black T indicator was then added to the mixture. It was then mixed constantly and titrated against a standard 0.01M EDTA until the last trace of purple disappeared and the colour turned bright blue.

2.3.8 Calcium

The amount of calcium was determined by EDTA titration method. 2.0 mL of 1M NaOH was added to 50 mL of sample. The mixture was stirred and 4.0 mL of the Eriochrome Black T indicator was added to it. Titration was done immediately after the addition of the indicator as 0.01M EDTA titrant was slowly added with continuous stirring until the colour changed from red through purple to a pure blue with no trace of reddish or purple tint.

2.3.9 Magnesium

Calcium and total hardness were determined by EDTA titration method. Magnesium hardness was calculated from the difference between the total hardness and the calcium hardness which is expressed in mg/L.

2.3.10 Biological Oxygen Demand (BOD)

BOD was determined by the dilution method. Dilution water was prepared by adding 1 mg/L each of phosphate buffer, magnesium sulphate solution, calcium chloride solution and ferric chloride solution to a 1 L aerated distilled water. A 2.5 mL of the sample was made up to 1 L with the dilution water. Careful mixing was done to avoid the formation of bubbles. The mixed dilution was syphoned into two BOD (300 mL) bottles excluding air bubbles. One of the BOD bottles was corked and incubated for five days at 20 °C. To the other BOD bottle were added 2 mL of Manganese (II) sulphate ($MnSO_4$), followed by 2 mL of alkaline-iodide azide and bottle corked carefully to exclude air bubbles. The content was mixed thoroughly by shaking and inverting several times and the precipitate allowed to settle at the bottom of the sample. After the precipitate had settled, 2 mL concentrated sulphuric acid (H_2SO_4) was added, corked and the bottle inverted several times to dissolve the precipitate resulting in the formation of an intense yellow coloured solution. 100 mL of the solution was taken and titrated with 0.0125M sodium thiosulphate to a pale yellow colour. 1 mL starch indicator was added and the titration was continued until the first disappearance of the blue colour. The above procedure was followed for the incubated samples at the end of the 5 days to determine the difference in dissolved oxygen (DO) for the computation of BOD.

2.3.11 Chemical Oxygen Demand (COD)

COD was determined by the closed tube reflux method. The digestion tubes and caps were washed with concentrated sulphuric acid first to prevent contamination. 10 mL of the sample was transferred into a labelled culture tube and a 10 mL solution containing potassium dichromate, mercuric sulphate and sulphuric acid was added to the sample. 30 mL of concentrated sulphuric acid was then added to the solution. The tube was tightly capped, shaken and inverted several times to mix completely. The tubes were then placed in a digester at 150°C and refluxed for two hours, and then cooled to room temperature. 1-2 drops of ferroin indicator were added and titrated against standard Ferrous Ammonium Sulphate (FAS) solution until the colour changes from blue-green to reddish brown or wine (endpoint). The procedure was repeated for a blank sample containing the reagents and a volume of deionized water equal to that of the sample.

3.0 RESULTS AND DISCUSSIONS

Water is considered palatable if its TDS level does not exceed 600 mg/L and poor if the level ranges from 900 to 1200 mg/L [18]. The water is considered unacceptable for drinking if TDS level exceeds 1200 mg/L (Table 1).

Table 1: Palatability of drinking water in relation to its TDS level [18]

TDS category	Concentration of TDS [mg/L]
Excellent	less than 300
Good/ fresh	300 to 600
Fair	600 to 900
Poor	900 to 1200
Unpalatable / unacceptable	above 1200

3.1 Total Dissolved Solids (TDS) (mg/L): GWC sample had the lowest TDS value followed by boreholes (BH) and then the wells (W) (Table 2). 134 mg/L and 147 mg/L were recorded for upstream and downstream respectively and these were higher compared with the other samples. These high figures may be due to dissolved mineral content from various rock formations. Notwithstanding these, all the values recorded for TDS were below the recommended level indicated by the WHO [19] for drinking water which is supposed to be below 1000 mg/l. Table 1 gives categorization of palatable water in respect to TDS concentration. From the table it can deduced that all the samples were excellent in terms of palatability since the TDS recorded for all the samples were below 300 mg/L. However, water with extremely low concentrations of TDS may also be unacceptable because of its flat, insipid taste.

3.2 Temperature (°C): Temperature affects the activities of microorganisms in water bodies. High water temperature increases the growth of microorganisms and may increase complications related to taste, odour, colour and corrosion [20]. The temperatures recorded for all the samples were slightly above room temperature of 25°C and can be attributed to the daily maximum temperature of 35°C [16].

3.3 pH: WHO recommends the pH for drinking water to be in the range of 6.50 – 8.50 (Table 2). From the study the lowest pH recorded was 6.78 for Well 3 and the highest was 7.50 for Upstream. All the samples had their pH within the WHO standards and can therefore be declared as safe for drinking in terms of pH. Acidic water has the tendency to corrode the metallic pipes through which they flow. On the other hand, basic water above pH 8 in the same range will resist disinfectants used in the water. Therefore, the sources and their respective pH as shown on the table are not basic and are open to being disinfected by chlorination.

3.4 Conductivity (µS/cm): The WHO does not have a health-based guideline for conductivity, but does recommend water to be less than 1400 µS/cm which is relative to 1000 mg/l TDS. The conductivity of water is affected by the suspended impurities and also depends upon the number of ions in the water. From the study it was observed that the lowest TDS of 42.00 mg/L was recorded for GWC and its conductivity of 102.50 µS/cm was also the lowest of all the samples (Figure 2, Table 2). In the same way the highest TDS of 147 mg/L for Upstream also recorded the highest conductivity 292 µS/cm buttressing the point that Conductivity is affected by TDS.

Table 2: TDS, PH, Conductivity and Temperature of samples analysed

WATER SAMPLE SOURCE	PHYSICOCHEMICAL PARAMETERS			
	TDS [mg/L]	pH	Conductivity [μ S/cm]	Temperature [$^{\circ}$ C]
BH 1	63.00	7.15	156.00	29.00
BH 2	69.00	7.12	142.00	30.00
BH 3	83.00	6.90	164.00	30.00
BH 4	64.00	6.94	128.00	30.00
W 1	108.00	7.38	214.00	29.00
W 2	108.00	7.09	216.00	29.00
W 3	106.00	6.78	212.00	30.00
W 4	108.00	6.81	216.00	29.00
SU	134.00	7.50	282.00	30.00
SD	147.00	7.15	292.00	29.00
GWC	42.00	6.90	102.50	28.00
WHO Standards	<1000.00	6.50-8.50	<1400.00	Not specified

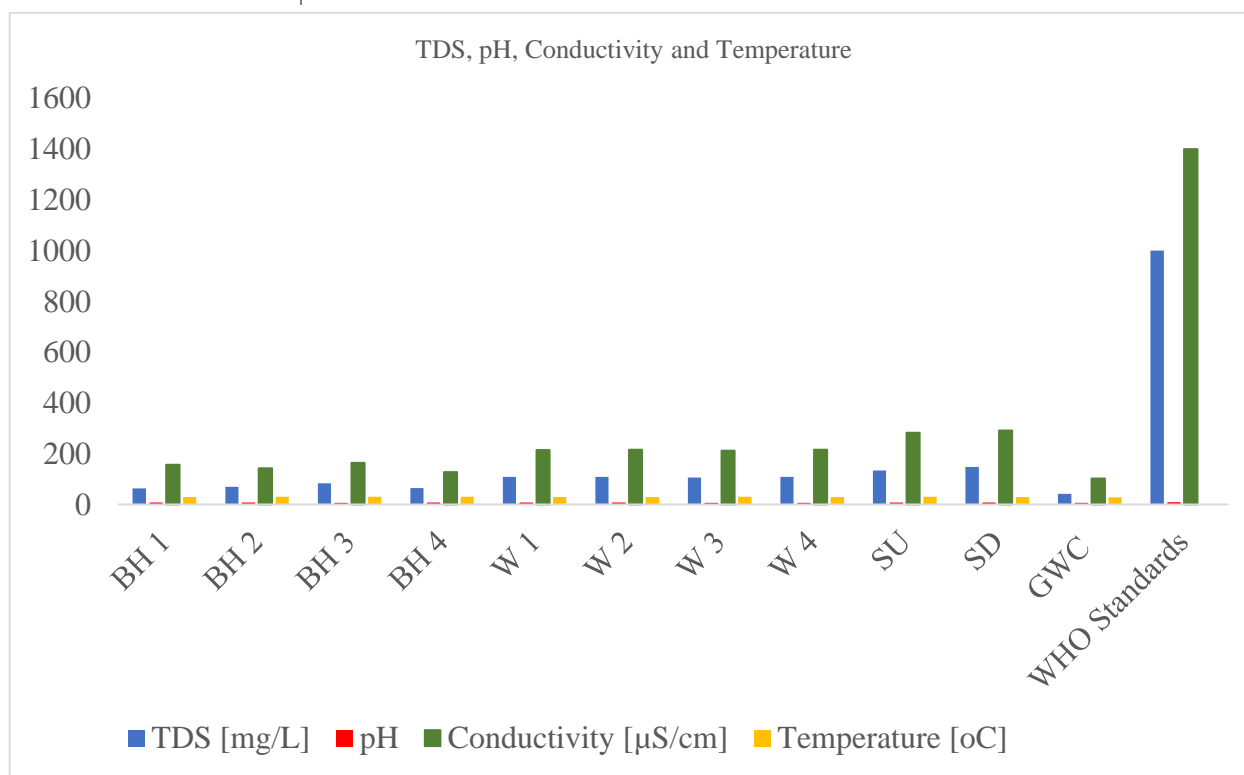


Figure 2: Graphical representation of TDS, Conductivity, pH and Temperature of analyzed samples

3.5 Total Hardness (mg/L): The total hardness recorded for all the samples were below the WHO recommended standards (Table 3). The lowest total hardness was recorded for W 4 as 34 mg/L and the highest was SD at 149 mg/L. The degree of hardness of drinking water may be classified in terms of its calcium carbonate concentration (Table 4) [21,22].

Consequently, we classify BH 1 (68 mg/L), W 1 (72 mg/L), W 3 (67 mg/L) and SU 82 mg/L) as moderately hard water (Table 4). SD is hard water with a total hardness of 149 mg/L and the rest of the sources are soft water sources. None of our sources is in the region of very hard as none is up to 180 mg/L.

3.6 Calcium and Magnesium (mg/L): The level of calcium indicates dissolved soil and rocks from limestone, dolomite and gypsum. The WHO Guideline for maximum contaminant level of calcium in drinking water is 200 mg/L[23]. All the samples analyzed recorded calcium levels below the recommended WHO standards. The lowest calcium content was recorded in W 2 as 18.8 mg/L and the highest in SD as 50.9 mg/L (Table 3, Figure 3) and may be due to the rocky nature of the place.

For the magnesium the lowest was 12.4 mg/L in W 4 and the highest was 98.1 mg/L in the SD. All the samples analyzed had their magnesium levels to be higher than the calcium levels except that for W 4, GWC (Table 3, Figure 3).

Table 3: Total Hardness, Calcium and Magnesium contents of samples

WATER SAMPLE	PHYSICOCHEMICAL PARAMETERS		
	SOURCE	Total Hardness (mg/L)	Calcium (mg/L)
BH 1	68	23.2	44.8
BH 2	57	22.4	34.6
BH 3	58	20.4	37.6
BH 4	46	22.8	23.2
W 1	72	28.5	43.5
W 2	54	18.8	35.2
W 3	67	30.5	36.5
W 4	34	21.6	12.4
SU	82	40.5	41.5
SD	149	50.9	98.1
GWC	39	23.8	15.2
WHO Standard	<300	<200	<150

Table 4: Hardness range for drinking water (Hem, 1970; The British Columbia Groundwater Association, 2007)

Hardness Category	Equivalent Concentration of CaCO ₃ [mg/L]
Soft	Less than 60
Medium/moderately hard	60 – 120
Hard	120 - 180
Very hard	Above 180

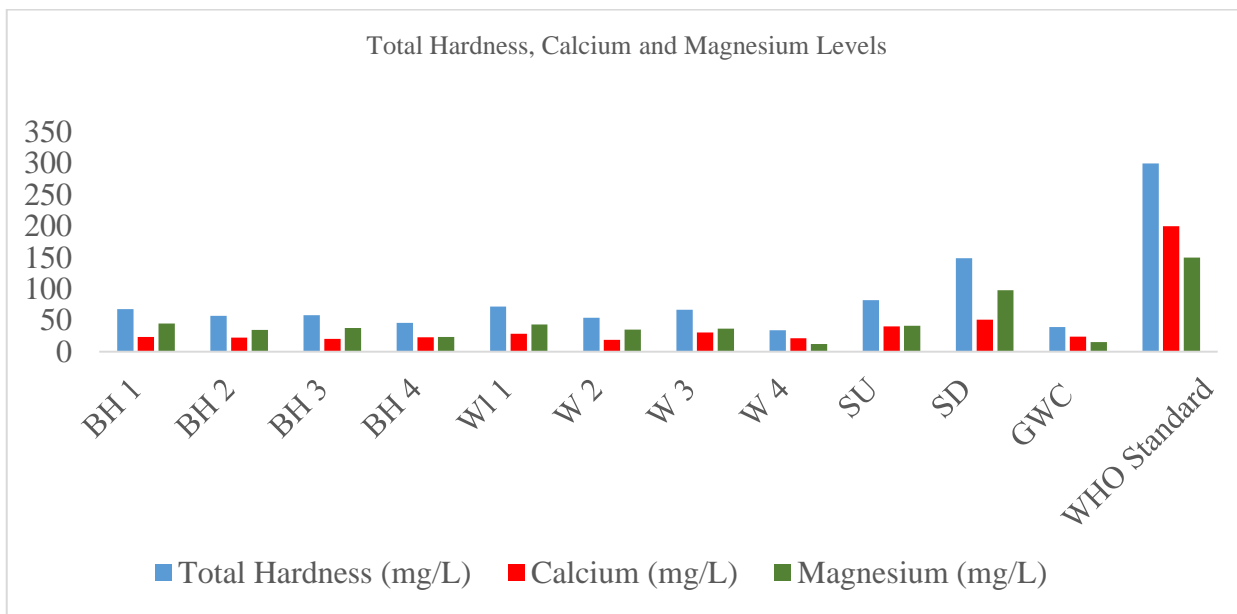


Figure 3: Graphical representation of Total hardness, Calcium and Magnesium levels of analyzed samples

3.7 Chloride (mg/L): Chlorine gas is highly toxic but chloride ions are essential for life [24]. Though chloride ions may be present in natural water, high chloride content may indicate pollution from sewage, industrial waste or intrusion from seawater or saline water into fresh water aquifer [25]. The chloride levels of all the samples were well within the WHO recommended standard of < 250 mg/L (Table 5, Figure 4). The lowest chloride level of 4.20 mg/L was recorded for GWC and highest of 35.45 mg/L were recorded for W 3 and W 4. High chloride content in processed waters may promote pipe corrosion.

3.8 Alkalinity (mg/L): Alkalinity refers to the capacity of water to neutralize acid. This is really an expression of buffering capacity. The alkalinity of natural water is determined by the soil and layers of rock through which it passes. The main sources for natural alkalinity are rocks which contain carbonate, bicarbonate, hydroxide compounds, borates, silicates and phosphates. In effect total hardness has a direct bearing on the alkalinity. SU and SD samples with high total hardness 82 mg/L and 149 mg/L respectively contributed to the high alkalinity levels in the said samples as 230 mg/L and 110 mg/L respectively (Figure 4). The alkalinity levels of the SU and SD are above the WHO standards. These high alkalinity values can be attributed to the presence of the rocks in the streams. The remaining samples had their alkalinity levels within the WHO standards with GWC recording the lowest alkalinity of 22 mg/L (Table 5, Figure 4).

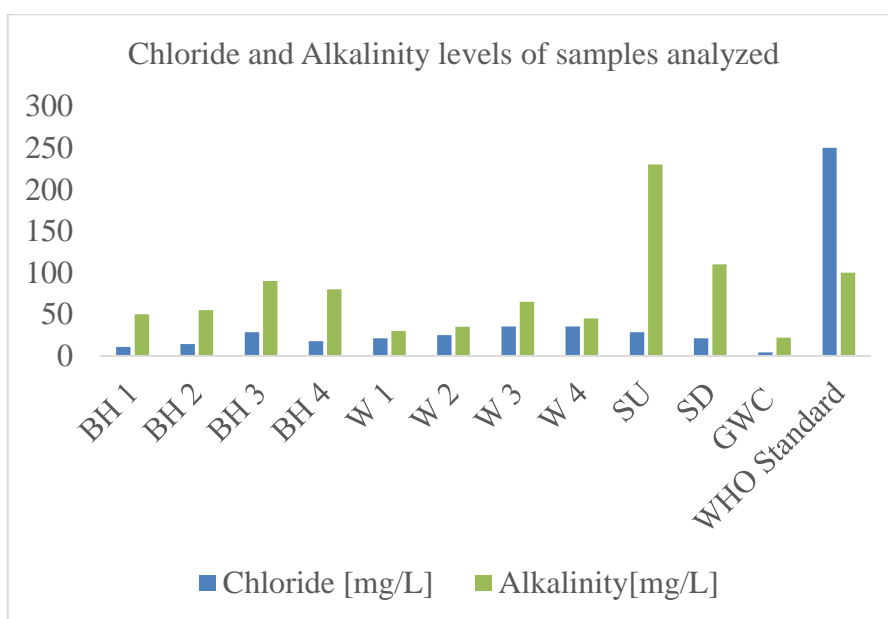


Figure 4: Graphical representation of chloride and alkalinity levels of analyzed samples

3.9 Biological Oxygen Demand (BOD) (mg/L): WHO recommends that for water to be safe for drinking the BOD levels should be less than 6 mg/L. W 1, W 2 and GWC had their BOD levels below the recommended WHO standards (Figure 5). The rest had their BOD levels above the recommended WHO standards. These high levels can be attributed to waste and sewages that get into the water through leaching and direct input by residence around this water sources. These sewages are decomposed by microorganism, hence using up the dissolved oxygen in the water and rendering the water unsafe for drinking.

3.10 Chemical Oxygen Demand (mg/L): WHO recommends that COD should be less than 10 mg/L. BH 4, W 2 and GWC had their COD levels below the WHO recommended standards. The rest of the samples had their COD levels higher than the recommended WHO standards. The higher values can be attributed to oxidable pollutant in the water sources, especially with the stream. This is because of the waste and sewage that find their way into the water sources and these wastes contain some nitrogen containing compounds which easily undergo oxidation; hence depleting the water of oxygen.

Table 5: Chloride, Alkalinity, BOD and COD of samples analyzed

WATER SAMPLE SOURCE	PHYSICOCHEMICAL PARAMETERS			
	Chloride [mg/L]	Alkalinity[mg/L]	BOD [mg/L]	COD [mg/L]
BH 1	10.63	50	14	16
BH 2	14.18	55	12	19
BH 3	28.36	90	13	18
BH 4	17.73	80	7	9
W 1	21.27	30	5.6	40
W 2	24.81	35	4	8
W 3	35.45	65	6	30
W 4	35.45	45	9	12
SU	28.36	230	6.8	232
SD	21.27	110	6.0	240
GWC	4.20	22	3.7	6.3
WHO Standard	<250	<100	<6	<10

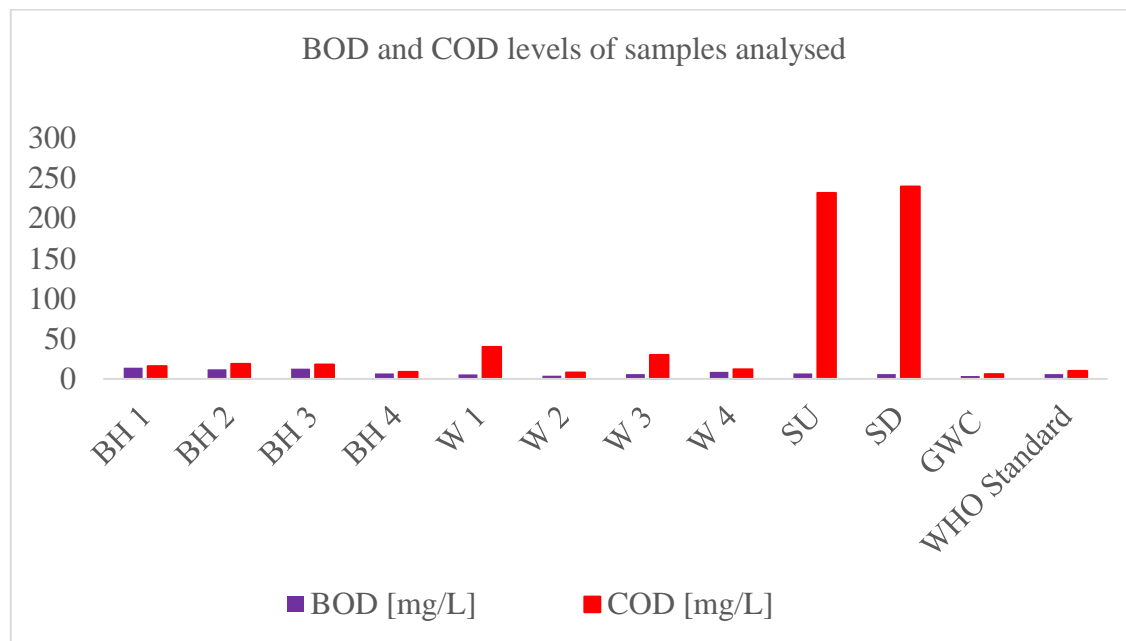


Figure 5: Graphical representation of BOD and COD levels of analyzed samples

4.0 CONCLUSION

The study revealed that all the samples had their pH, electrical conductivity, total dissolved solids, chloride and total hardness levels within the recommended World Health Organization standards. BH 1, BH 2, BH 3, BH 4, SD and SU samples had their COD and BOD levels above the recommended World Health Organization standards. It was also observed that the alkaline levels in the stream were high. This causes itching of the skin and eyes. The community should therefore be cautioned on the use of the stream for bathing and washing purposes. The samples W 1, W 3 and W 4 had either BOD or COD above the recommended World Health Organization standards.

W 2 and GWC were the only samples which had all their physicochemical parameters within the recommended World Health Organization standards.

In other to improve the quality of these water sources, residence in and around Fiapre should be educated on human activities that pollute the water sources in the community. Pathways through which pollutant seep into these water sources should be identified and blocked, regular checking of water quality parameters is very necessary and finally every home in Fiapre should be provided with treated water.

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