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Characteristics and Quality Assessment of Drinking Water in Some Major Towns of Osun State, South-Western Nigeria

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Abstract: *The characteristics and quality of drinking water of four different sources (Borehole, tap, stream and well) in five major towns covering the three senatorial districts of Osun State, Nigeria were analysed in order to determine their potability status. Water samples were collected for a period of six months and analyzed for seven physico-chemical parameters using standard literature methods. The mean values and ranges of the parameters measured were as follows: pH 8.85 ± 0.96 (6.0 -10.70); temperature 26.05 ± 2.27 (22.50- 30.00ºC); conductivity 218.74 ± 129.56 (90-560 µS/cm); chloride39.66 ± 24.24 (ND-139.96) mg/L; phosphate 0.61 ± 0.41 (ND-2.60) mg/L; sulphate 4.06 ± 9.31 (0.14-57.05) mg/L; and nitrate 0.79 ± 1.74 (ND-13.14) mg/L. Generally, results compared favourably with the WHO (2008) and Nigerian Standards for Drinking Water Quality (NSDWQ) except temperature which was slightly higher than the ambient temperature. The pH was also above the specified limit of 6.5 - 8.5 indicating alkaline nature of the water samples. This implies that the water samples may enhance the growth of micro-organisms, hence increase in the problems related to taste, odour, colour and corrosion. Periodical assessment of both physicochemical and microbial analysis of the areas is highly recommended, as this would be helpful in early detection of any future deterioration.*

Keywords: physico-chemical, water quality, pH, conductivity, drinking water

Introduction

Osun state in South Western Nigeria was created in August 1991. It has a land mass of 9,251 km^2, a population of 3.42 million by the 2006 population census, and is located on longitude 7º 30′N and latitude 4º 30′E [1]. The state, which hosts eight Universities with a good number of Polytechnics and Colleges of Education, has witnessed increase in population as a result of her educational endowment, cultural heritage, staggered industrial activities and many agricultural activities. Clean water is highly essential for the survival of this great population coupled with the industrial and agricultural practices.

Water is an essential natural resource for sustaining life and environment and has always been thought to be available in abundance and a free gift of nature [2]. In Osun state, drinking water is assessed from ground water and surface water including streams, rivers, lakes and reservoirs. The manner of disposal of agricultural, industrial and domestic wastes into natural water bodies may thus pose serious contamination threat [3].

Drinking water is a relative term that relates the composition of water with effects on natural processes and human activities [4]. Anthropogenic influences (urban, industrial and agricultural activities, increasing consumption of water resources) as well as natural processes (changes in precipitation inputs, erosion, weathering of crustal materials) poses serious public health threat to the surface waters and impair their use for drinking, industrial, agricultural, recreation or other purposes [5]. Rainfall is a major factor that affects water quality as it washes dissolved nutrients into the water, shed and increase organic carbon level, leading to reduction in alkalinity levels and stimulate corrosion. Similarly, the absence of rain can result in proportionally high levels of dissolved minerals or nutrients in a particular water source [4].

The quality of surface water is dynamic and can change within the catchment area. Small streams may carry clear water for most parts of the year [6]. During the rainy season, however, the water may carry moderate amount of dirt, organic debris and suspended materials. As rivers move close to inhabited areas, water quality can deteriorate further, although, rivers have the tendency of natural self-purification [4].

Ground water is an important source of drinking water for more than half a nation's population and nearly all its rural population [7]. Ground water is relatively uniform throughout the aquifer. Changes in quality occur slowly due to the fact that it is not exposed to the air and it is not subjected to direct pollution and contamination from runoff as surface water [4]. It is generally a very good source of drinking water because of the self-purifying properties of the soil [8]. Due to natural filtering action of the aquifer, the ground water is relatively freer from microbes than surface water [4]. In most cases, contamination results either from improper well construction or poor waste disposal facilities [6]. In recent times, widespread reports of bacteria, nitrate, synthetic organic chemicals and other pollutants in groundwater had increased public concern about the quality of groundwater [9].

The aim of this research work was to assess the potability of drinking water sources available to the people in some towns in the three senatorial districts in Osun State, Nigeria, with respect to the characteristics and the physicochemical parameters.

Materials and Methods

Study area

Drinking water samples were collected from four different sources (borehole, tap, well and stream) from the three senatorial districts of Osun state. The sampling was carried out over a period of six months, three months each in 2009 and 2010. Table 1 shows the geographical senatorial district distribution of the four sources of water sampled for the analysis of the physicochemical parameters. The sampled water was collected from Iwo (Osun West), Osogbo (Osun Central), Ile-Ife (Osun East), Ejigbo (Osun West) and Ilesa (Osun East). All the sampling locations were the main sources of drinking water for the local population.

Table 1: Senatorial districts spread and the types of water sampled for physicochemical analysis

Senatorial District	Boreholes	Stream	Tap	Well	Total sample per area
Osun West	2	2	2	2	8
Osun East	2	2	2	2	8
Osun Central	1	1	1	1	4
Total	5	5	5	5	20

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Sample Collection

Samples for water quality studies were collected in 2 L plastic bottles that had been previously soaked in 10 % nitric acid for 48 hrs, and rinsed with distilled water. The containers were rinsed three times at the site with the sample water before collecting the sample for analysis. All samples were filtered with cellulose acetate filters and stored immediately in a cooler, in order to ensure that the physical properties of the water samples were maintained, and transported to the laboratory where it was stored in the refrigerator prior to analysis.

Determination of Physico-chemical Parameters

All chemicals used were AnalaR grade (BDH, England). Water temperature, and conductivity were determined using Testr II dual range meter (Eutech Instruments, Malaysia) after calibrating with standard buffer solutions while pH was measured using a pH Testr meter (Eutech Instruments, Malaysia). Sulphate was determined by turbidimetric method [10]; chloride by using argentometric titration; phosphate by colorimetric technique and nitrate was determined by ultraviolet screening method [11].

Quality Assurance and Control

To assess the precision and accuracy of results, replicate analysis of blank, standard and samples was done. The standard deviations were determined to find the precision of the analysis.

Quantification process

Raw data were used in calculating the mean standard deviation for the physicochemical parameters from three replicate measurements.

Results and Discussion

The mean values of the physicochemical parameters for the four sources of drinking water and from the various sampling locations are presented in Tables 2-5.

Table 2: Mean of Physicochemical Parameters for Borehole Water Samples

	TempºC	*pH*	*Conductivity (µS/cm)*	*Chloride (mg/L)*	*PO_4^{3-} (mg/L)*	*SO_4^{2-} (mg/L)*	*NO_3^- (mg/L)*
Ejigbo	26.38±1.18	8.52±0.68	236.67±148.14	31.65±27.68	0.58±0.23	3.03±5.78	2.38±5.27
Ile-Ife	26.02±1.18	8.33±1.23	168.33±113.56	32.56±27.05	0.56±0.32	3.32±6.03	0.47±0.55
Ilesa	25.67±1.28	9.05±0.82	150.00±44.27	37.47±18.89	0.91±0.85	11.37±22.24	0.44±0.33
Iwo	27.15±1.99	9.25±0.81	111.67±19.41	38.32±18.88	0.59±0.34	3.98±8.21	0.48±0.41
Osogbo	26.02±1.12	8.63±1.21	275.00±131.87	29.15±20.35	0.81±0.44	4.35±7.69	0.31±0.31
WHO(2006)	25ºC	6.5-8.5	1000	250	2.2	250	50

Table 3: Mean of Physicochemical Parameters for Stream water Samples

	Temp	*pH*	*Conductivity*	*Chloride*	*PO_4^{3-}*	*SO_4^{2-}*	*NO_3^-*
Ejigbo	25.67±1.62	9.00±0.82	246.67±160.08	43.28±31.29	0.60±0.34	2.82±3.13	2.46±5.16
Ile-Ife	25.78±1.99	8.82±0.52	203.67±170.46	31.32±20.79	0.58±0.25	2.95±5.11	1.22±1.13
Ilesa	25.53±1.53	9.37±0.55	270.00±136.53	30.82±13.19	0.62±0.32	0.89±0.67	0.86±0.93
Iwo	23.67±7.06	8.52±0.35	243.33±171.66	34.16±17.72	0.47±0.26	3.58±6.98	0.50±0.68
Osogbo	26.00±3.41	8.78±1.21	248.33±129.06	42.02±18.95	0.45±0.16	2.42±4.63	0.82±0.64
WHO(2006)	25ºC	6.5-8.5	1000	250	2.2	250	50

Table 4: Mean of Physicochemical Parameters for Tap Water Samples

	Temp	*pH*	*Conductivity*	*Chloride*	*PO_4^{3-}*	*SO_4^{2-}*	*NO_3^-*
Ejigbo	26.15±1.51	8.32±1.41	280.00±173.67	43.23±33.82	0.65±0.25	4.05±7.15	0.28±0.18
Ile-Ife	26.93±2.07	8.48±1.06	205.00±102..32	52.48±46.22	0.49±0.18	1.96±3.76	0.29±0.26
Ilesa	26.75±1.56	8.98±0.88	121.67±20.41	46.16±28.93	0.63±0.30	4.68±9.34	0.32±0.42
Iwo	26.55±1.64	9.33±0.84	176.67±66.23	58.32±13.29	0.52±0.25	1.68±1.81	0.79±0.60
Osogbo	26.95±2.26	8.58±1.13	208.33±144.00	54.89±30.72	0.57±0.31	4.73±8.29	1.04±0.82
WHO(2006)	25ºC	6.5-8.5	1000	250	2.2	250	50

Table 5: Mean of Physicochemical Parameters for Well Water Samples

	Temp	*pH*	*Conductivity*	*Chloride*	*PO_4^{3-}*	*SO_4^{2-}*	*NO_3^-*
Ejigbo	26.47±1.40	9.03±0.85	232.00±165.60	37.49±28.41	0.66±0.53	6.52±14.59	0.79±1.19
Ile-Ife	26.18±1.49	8.98±1.14	241.67±87.04	44.98±10.49	1.20±0.89	10.04±23.03	0.60±0.82
Ilesa	25.43±2.02	9.05±1.15	289.17±191.01	36.64±16.32	0.53±0.33	2.86±4.07	0.49±0.45
Iwo	26.13±1.16	8.90±0.74	205.00±103.88	23.32±20.89	0.39±0.11	2.76±4.59	0.67±1.12
Osogbo	25.97±1.07	9.02±1.13	261.67±129.22	44.99±19.23	0.39±0.14	3.13±5.40	0.52±0.62
WHO(2006)	25ºC	6.5-8.5	1000	250	2.2	250	50

Water temperature is important for its effects on the chemical and biochemical reactions in organisms [12]. Temperature (°C) of borehole water ranged from 25.67± 1.28 (Ilesa) to 27.15±1.99 (Iwo); stream water 23.67 ± 7.06 (Iwo) to 26.00 ± 3.41 (Osogbo); tap water 26.15 ± 1.51 (Ejigbo) to 26.95 ± 2.26 (Osogbo); and well water 25.43 ± 2.02 to 26.47 ± 1.40 (Ejigbo). In all the four sources and in all the locations considered in this study, water temperature was found to be higher than the 25ºC recommended for drinking water by WHO [13] with the exception of stream water of Iwo with mean value of 23.67 ± 7.06 ºC (Table 3). Temperature of water affects the efficiency of treatment units, for instance, low temperature increases the viscosity, which in turn diminishes the efficiency of settling the solids that the water may contain because of the resistance that the high viscosity offers to the downward motion of the particles as they settle [12].

pH is the log of the hydrogen ion activity and a measure of acidity and alkalinity in water bodies. pH is one of the most important operational water quality parameters. In borehole water, pH ranged between 8.33± 1.23 (Ile-Ife) and 9.25 ± 0.81 (Iwo) for stream water; it ranged from 8.52 ± 0.35 (Iwo) to 9.37 ± 0.55 (Ilesa); tap water 8.32 ± 1.41 (Ejigbo) to 9.33± 0.84 (Iwo); and well water 8.90 ± 0.74 (Iwo) to 9.03± 0.85 (Ejigbo). In all the locations and for all the four sources of drinking water sampled and analyzed, the pH was in the alkaline range and above pH 6.5-8.5 recommended for drinking water [13]. A pH above 7 indicates that the water is probably hard and contains calcium and magnesium ions [14]. High alkalinity (> pH 9) may also be due to solid wastes [12].

Conductivity values for all locations and for all the four sources of drinking water were lower than recommended standard of 1000 µS/Cm for drinking water by WHO [13] and Nigerian Standard for Drinking Water Quality (NSDWQ) [15].

Chloride is widely distributed in nature as salts of sodium chloride, potassium chloride and calcium chloride [4]. Chlorides are leached from various rocks into soil and water by weathering [16]. Chloride in surface and ground water may originate from both natural and anthropogenic sources such as the use of inorganic fertilizer, landfill, septic tank effluents, animal feed and industrial effluents [4].The concentration of Chloride (mg/L) in borehole water ranged from 29.15 ± 20.35 (Osogbo) to 38.32 ± 18.85 (Iwo); stream water: 30.82± 13.19 (Ilesa) to 43.28 ± 31.29 (Ejigbo); tap water: 43.23 ± 33.82 (Ejigbo) to 58.32 ± 13.29 (Iwo); and well water: 23.32 ± 20.89 (Iwo) to 44.99 ± 19.23 (Osogbo). Chloride levels in unpolluted waters are often below 10 mg/L [17]. The chloride ions behave in water as mineral solvent. Chloride content in all locations and for all the four sources of drinking water were below the allowable value of 250 mg/L for drinking water by WHO [13] and NSDWQ [15]. The chloride content was very high in tap water compared to other sources of water considered in this study. This might be due to chlorination of water during treatment. Chloride in excess of about 250 mg/L can give rise to detectable taste in water depending on the associated cations.

The presence of sulphate in drinking water can cause noticeable taste, and very high level might cause a laxative effect in unaccustomed consumers [13].The sulphate content (mg/L) in borehole water ranged from 3.03 ± 5.78 (Ejigbo) to 11.37 ± 22.24 (Ilesa); 0.89 ± 0.67(Ilesa) to 3.58 ± 6.98 (Iwo) in stream water; 1.68 ± 1.81 (Iwo) to 4.73 ± 8.29 (Osogbo) in tap water; and 2.76 ± 4.59 (Iwo) to 10.04 ± 23.03 (Ile-Ife) in well water. Sulphates are common in natural waters, but levels can increase due to industrial contamination with sulphuric acid, bisulphate and aluminium sulphate used in water purification plants [12].This might be the reason why the levels of sulphate in well and tap water were slightly higher than for stream and borehole water. The mean value for sulphate in all locations and in all the four sources of drinking water was below the maximum permissible level of 250 and 100 mg/L recommended by WHO [13]and NSDWQ [15] for drinking water.

Phosphate comes from fertilizers, pesticides, industry and cleaning compounds. Natural sources include phosphate containing rocks and solid or liquid wastes [12]. For the present analysis, the phosphate content (mg/L) in borehole water ranged from 0.56 ± 0.32 (Ile-Ife) to 0.91 ± 0.85 (Ilesa); 0.45 ± 0.16 (Osogbo) to 0.62 ± 0.32 (Ilesa) in stream water; 0.49 ± 0.18 (Ile-Ife) to 0.65 ± 0.25 (Ejigbo) in tap water; and 0.39 ± 0.11 (Iwo) to 1.20 ± 0.89 (Ile-Ife) in well water. For all locations and all sources of water analysed, the mean value of phosphate was lower than the permissible value of 250 mg/L by WHO for drinking water. This suggests that the water is safe for drinking and free from contamination that may arise due to agricultural practices.

Nitrate is a naturally occurring compound and is an important component of vegetables because of its potential to accumulate. Nitrate is relatively non-toxic, but its metabolites, nitrite, nitric oxide and N-nitroso compounds are; and nitrate conversion to nitrite plays an important antimicrobial role in the stomach, whereas other nitrate metabolites also have important physiological and pharmacological roles [18]. The nitrate content in mg/L in borehole water ranged from 0.31±0.31 (Osogbo) to 2.38 ± 5.27 (Ejigbo); 0.86 ± 0.93 (Ilesa) to 2.46 ± 5.16 (Ejigbo) in stream water; 0.28 ± 0.18 (Ejigbo) to 1.04 ± 0.82 (Osogbo) in tap water and 0.49 ± 0.45 (Ilesa) to 0.79 ± 1.19 (Ejigbo) in well water. The concentration of nitrate in borehole water and stream in Ejigbo was conspicuously higher than in other locations, yet the concentration of nitrate in all the location and water sources were below the limit of 50 mg/L specified by WHO and NSDWQ. Generally, nitrate and nitrite concentrations had been predicted to decrease with depth of the water [19]. High concentration in borehole water from Ejigbo might be due to geological properties of the area while the stream might be due to anthropogenic influences. RADWQ [20] reported that though ground water in Nigeria is better than surface water in terms of health criteria but most of the ground water is corrosive, and some areas have iron, nitrate and fluoride concentration above the WHO limits for drinking water.

Figure 1 presents the mean values of the physical parameters measured for all the four water sources considered in this study. Generally, the pH values of the entire water medium with exception of tap water were above the maximum permissible level recommended by WHO. The pH of stream and well water were also higher than the other two media, this might be attributed to domestic sewage and poor / indiscriminate dumping of refuse prevailing in parts of the state. Municipal and industrial discharge may also influence pH values of rivers and wells [21]. In this study, the EC of stream and well water were higher, which is likely due to anthropogenic influence. In a similar study, Oluyemi *et al* [3] reported a higher EC value in borehole water of Edunabon and Ipetumodu and attributed it to soluble minerals from the bedrocks.

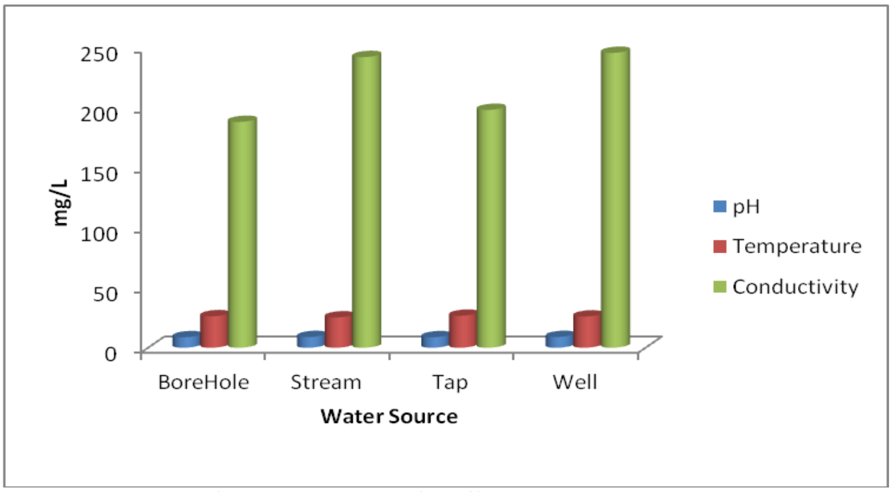

Figure 1: Mean value of physical parameters for different water medium

Figure 2 presents the graphical comparison of the mean values of the nutrient parameters considered in this study. Generally, the chloride values were lower than the permissible level of 250 mg/l recommended by WHO but the value for tap water was expectedly higher. This might be due to the chemicals used in water treatment [22] as well as the age of pipes. Similarly Napacho and Manyele [4] observed that distance travelled, age of pipes and extent of internal deposition in mains and conduits are the key factors contributing towards drinking water contamination.

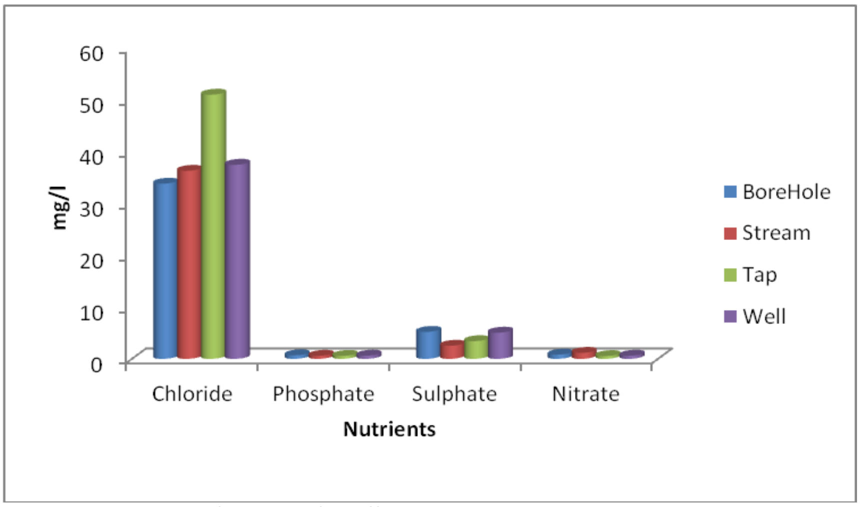

Figure 2 Mean values of nutrients for different water medium

Figure 3 shows the monthly mean values of the physical parameters for all the sample locations and for all the four sources of drinking water. The pH value was slightly above the WHO and NSDWQ recommended limit, showing the water to be alkaline, while the temperature was slightly above ambient temperature. In most of the natural waters, pH is controlled by the carbon dioxide-carbonate-bicarbonate equilibrium system. Increase in carbon dioxide will lower pH where as a decrease in carbon dioxide will cause it to rise [4].This might be the reason why the pH values observed during the early rain was higher than that observed during the peak of the rainfall season. Other parameters analysed were below the maximum permissible limit recommended by WHO and NSDWQ. Conductivity is expected to be lower during the period of heavy rainfall due to dilution with rain water while minima in early rainy season owing to evaporation; but in this study, conductivity values increased as we move from early rain to double maxima rain which might be due to decomposition and mineralization of organic matter.

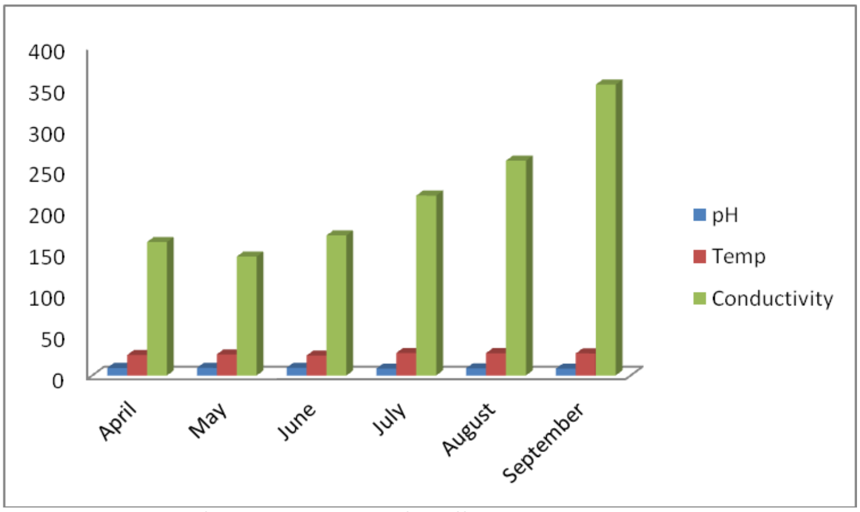

Figure 3: Monthly Mean value of physical parameters for different water medium

In Figure 4, a significant trend is observed in nitrate and phosphate as we move from early rain to peak rainfall which might be due to agricultural runoff and utilization as nutrient by algae and other aquatic life. Of all the nutrients analysed in this study, chloride content is very high though far below the recommended standards. Chloride ion is highly mobile and is eventually transported in water medium.

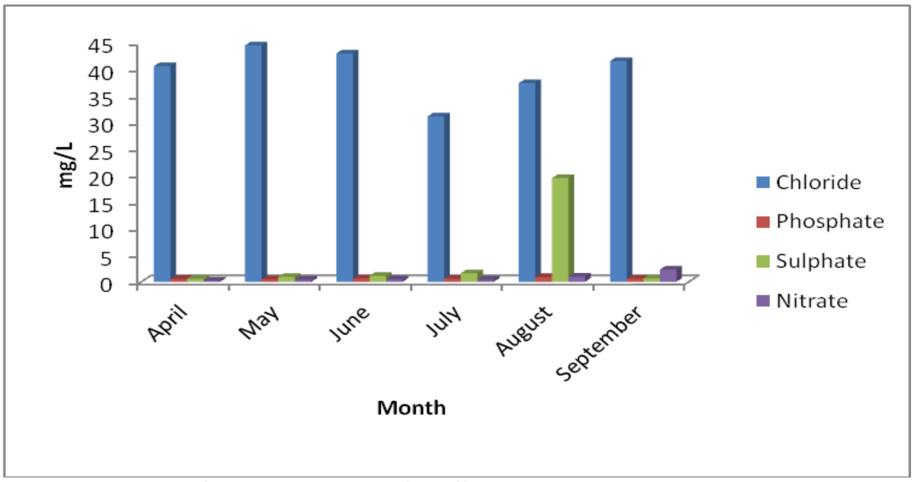

Figure 4: Monthly Mean value of nutrient parameters for different water medium

Conclusion

These results have shown that the water quality parameters analysed were below the permissible WHO and NSDWQ standards for drinking water with the exception of pH that was slightly above the recommended limit and temperature that was above the ambient temperature. These findings suggest that the water samples may enhance the growth of micro-organisms, hence increase the problems related to taste, odour, colour and corrosion. Periodical assessment of both physicochemical and microbial analysis of the areas is highly recommended, as this would be helpful in early detection of any future deterioration.

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