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Physico-Chemical and Bacteriological Analyses of Borehole Water Samples around The Federal University of Technology, Akure, Nigeria

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ABSTRACT

Three water samples were collected around The Federal University of Technology, Akure (FUTA), Nigeria. The samples were analyzed for physicochemical properties such as temperature, acidity alkalinity, conductivity, chemical oxygen demand (COD), biochemical oxygen demand (BOD), nitrate, phosphate and sulphate, total hardness and suspended solids. The levels of heavy metals in the samples were also investigated. Microbial analysis was carried out on the samples to assess faecal contamination and type of bacteria present. For the physicochemical properties, chemical oxygen demand (COD) values for samples A and B deviated from 10 mg/L specified by WHO whereas the value for sample C was within the standard. Total alkalinity and phosphate values exceeded WHO standard limits. Also, the values of dissolved oxygen (DO) (8.28 - 10.97 mg/L) and pH (5.79 – 5.95) failed the standards set by WHO. Sample C was below WHO standard for total hardness having 93.60 mg/L as against 100 mg/L (minimum). However, calcium hardness, suspended solid, dissolved solids, BOD, and concentrations of heavy metals in the samples were within WHO permissible limits for drinking water. The microbial analysis showed that the samples contained some undesirable microorganisms such as *E. coli* (an indication of faecal contamination).

Keywords: *Bacteriological Analyses, Water, Federal University of Technology,*

INTRODUCTION

There is no doubt that the world at large requires substantial increase in global food production to prevent want of daily food for the masses. However, increase in food production requires more water [1]. Today, industrial, domestic and agricultural activities constantly add wastes into groundwater systems at alarming rate, as a result of this, both the quantity and quality of water are affected by increased anthropogenic activities [2]. Water, being the Earth's primary integrating medium, has the tendency to reduce poverty by increasing food security, improve human health, contribute to sustainable energy sources, and preserves ecosystem integrity [1].

Groundwater quality depends on diverse chemical constituents and their concentrations [3]. Water bodies which include underground water are being contaminated in many ways. The pollution and contamination of water results majorly from the manner water is being used by humans and this calls for urgent attention as a result of the grave consequences involved. Contaminants may be (as well) present in water as a result of natural processes. Contamination may be from point source or non-point source. The quality of ground water depends on various chemical constituents and their concentrations [3]. Improved sanitation alone could reduce related deaths by 60% [1]. In 2002, the then UN Secretary-General, Kofi Annan, pointed out that no single measure would do more to reduce disease and save lives in the developing world than bringing safe water and sanitation to all [4].

Water pollution does not happen by chance, for water from a particular source to have been considered unfit for drinking, something must have happened somewhere. Available water is considered non-potable if the concentrations of heavy metal are beyond permissible limits [3]. The possibility of water to flow from farm land into rivers or percolate into underground water makes agricultural practice a significant water pollutant, considering the considerable amount of potentially harmful substances such as soluble salts and heavy metals present in the soil.

Estimation shows that over 250 million cases of waterborne diseases are reported worldwide [5] and 25 million deaths are associated with waterborne diseases annually (Cunningham, 2005). World Health Organization (WHO) reported that 80% of all sicknesses and diseases in developing countries are due to waterborne pathogens and inadequate sanitation system [6].

Significance of water as a potent ecological factor can be appreciated only by studying its physico-chemical and microbial characteristics [7]. The study is therefore designed to assess the qualitiy of water utilized for various purposes by the residents living around The Federal University of Technology, Akure (FUTA), Nigeria.

MATERIALS AND METHOD

Sample collection

Three water samples were collected from three different locations (Fig. 1) and the coordinates are presented in Table 1. Sample A was collected from "Jibowu Hostel" (Annex 1) within The Federal University of Technology, Akure (FUTA); Sample B was collected from "Only Jesus Hostel" located at FUTA South gate; Sample C was obtained from "Christian Star Hostel" located at FUTA North Gate.

Table 1. Co-ordinates of the sample locations

Sample	Location	Longitude	Latitude	Altitude
A	Jibowu Hostel	5.1417	7.305037	378 m
B	Only Jesus Hostel	5.148524	7.290572	355 m
C	Christian Star Hostel	5.138852	7.304123	386 m

Fig. 1 Sample locations

METHODOLOGY

The water samples were subjected to physicochemical and microbial analyses. Physicochemical parameters such as Temperature, pH, Conductivity, Total Solids, Dissolved Solids, Suspended Solids, Dissolved Oxygen, Biochemical Oxygen Demand (BOD), Total Alkalinity, Total Hardness, Calcium Hardness, Chloride, Phosphate, Nitrate, Sulphate, and Chemical Oxygen Demand (COD) were analyzed using standard methods of Analysis.

The water samples were digested and subsequently analyzed for heavy metal concentrations using Atomic Absorption Spectrophotometer (AAS Buck Scientific 210).

The most probable number (MPN) of coliforms in water samples was determined using the method of Chatterjee *et al*. [8], and total viable bacterial counts was carried out according to the method of Cheesbrough [9].

RESULTS AND DISCUSSION

Physicochemical parameters of the water samples

The three water samples had moderate temperature as the values were compared to WHO standards. Water temperature could be affected by seasonal and climatic changes in the environment. The pH values for the samples ranged from 5.79 (Sample C) – 5.95 (Sample A) (slightly acidic) as against 6.5 – 8.5 set by WHO [10]. pH dictates the acidic or alkaline nature of water [11]. Acidic water seems to be corrosive and soft [12]. Low pH values in boreholes may be due to mineral salts dissolved in them [13].

The values of calcium hardness (105.91, 99.05, and 77.55 mg/L), biochemical oxygen demand (BOD) (2.38, 4.45, and 2.07 mg/L), total dissolved solids (0.27, 0.26, and 0.21 mg/L) and total suspended solids (0.01, 0.03, and 0.02 mg/L) for samples A, B, and C, respectively were within WHO [10] standards for drinking water. This is similar to the results obtained by Adeyeye and Abulude [14]. Hardness in water measures the ability of water to form lather with soap during washing. The values of total hardness for samples A and B which were 118.56 and 110.24 mg/L, respectively and both values fell within WHO permissible limits of 100-500 mg/L, whereas that of sample C (93.60 mg/L) was below the minimum requirement of 100 mg/L. The implication is that the water samples under investigation are not hard water. The values of conductivity (240, 194, and 176 µS/cm), chloride (31.79, 15.06, and 15.06 mg/L), and nitrate (0.56, 4.61, and 0.62 mg/L) for samples A, B, and C, respectively were all outside the limits of WHO (2008) standards. Electrical conductivity (EC) has close relationship with total dissolved solids [12], hence, the relatively low values of dissolved solids in the samples probably accounted for the low electrical conductivity. The conductivity values obtained were similar to the findings of John *et al.* [13]

The chemical oxygen demand (COD) for sample C (8.00 mg/L) was within WHO permissible limit, whereas the values of samples A (28.80 mg/L) and B (16.00 mg/L) were higher than 10 mg/L specified by WHO [10]. Alkalinity is composed primarily of carbonate (CO_3^{2-}) and bicarbonate (HCO_3^-) ions which are also the primary ions responsible for hardness, the alkalinity values (242.64, 154.40, and 210 mg/L) of samples A, B, C, respectively exceeded WHO standard of 100 mg/L for total alkalinity in drinking water. Phosphate contents of samples A, B and C (72.78, 87.66 and 85.76 mg/L, respectively) were higher than WHO permissible limit of 5.0 mg/L. The values of dissolved oxygen (DO) for the three samples ranged from 8.28 (sample A) – 10. 97 (sample B), and were higher than 7.5 mg/L stipulated by WHO.

Table 2: Physicochemical Parameters of the Water Samples

Parameter	Sample A	Sample B	Sample C	WHO (2008)
Temperature (^oC)	28	30	32	Ambient
pH	5.95	5.86	5.79	6.5-8.5

Conductivity (µS/cm)	240	194	176	900-1200
Total solids (mg/L)	0.28	0.29	0.23	500-1500
Total dissolved solids (mg/L)	0.27	0.26	0.21	<500.00
Total suspended solids (mg/L)	0.01	0.03	0.02	<500.00
Dissolved oxygen (mg/L)	8.28	10.97	10.76	5.0 - 7.50
BOD (mg/L)	2.38	4.45	2.07	2.0 – 5.0
Total alkalinity (mg/L)	242.64	154.40	210.40	100
Total Hardness (mg/L)	118.56	110.24	93.60	100-500
Ca^{2+} Hardness (mg/L)	105.91	99.05	77.55	75-200
Mg^{2+} Hardness (mg/L)	12.65	11.19	16.05	50-150
Chloride (mg/L)	31.79	15.06	15.06	200-250
Phosphate (mg/L)	72.78	87.66	85.76	5.00
Nitrate (mg/L)	0.56	4.61	0.62	10-50
Sulphate (mg/L)	28.32	BDL	27.34	250-500
COD (mg/L)	28.80	16.00	8.00	<10.00

BDL - below detection limits

Table 4: Heavy metal concentrations (mg/L) in the Water Samples

Sample	Mn	Fe	Cu	Zn	Co	Cr	Cd	Pb	Ni
A	BDL	BDL	0.02	0.02	BDL	BDL	BDL	BDL	BDL
B	BDL	BDL	0.01	0.01	BDL	BDL	BDL	BDL	BDL
C	BDL	BDL	0.01	BDL	BDL	BDL	BDL	BDL	BDL
WHO (2008)	0.10-0.40	1.00-3.00	0.50-2.00	0.01-3.00	-	0.050	0.003	0.010	0.002

BDL - below detection limit

Table 3. Correlation matrix for the seventeen physicochemical parameters

	Temp.	pH	Cond.	TS	TDS	TSS	DO	BOD	TA	TH	Ca-H	Mg-H	Cl^-	PO_4^{2-}	NO_3^-	SO_4^2	COD
Temperature	1																
pH	-.997*	1															
Conductivity	-.970	.985	1														
TS	-.778	.730	.600	1													
TDS	-.933	.905	.817	.952	1												
TSS	.500	-.561	-.697	.156	-.156	1											
DO	.829	-.867	-.941	-.293	-.572	.899	1										
BOD	-.120	.048	-.127	.717	.468	.800	.456	1									
T. Alkalinity	-.361	.427	.578	-.305	.002	-.988	-.821	-.883	1								
T. Hardness	-.982	.966	.906	.882	.984	-.327	-.708	.305	.178	1							
Ca-Hardness	-.958	.935	.859	.925	.997*	-.232	-.634	.398	.080	.995	1						
Mg-Hardness	.682	-.627	-.482	-.990	-.899	-.293	.156	-.808	.436	-.808	-.862	1					
Cl^-	-.866	.900	.962	.359	.629	-.866	-.998*	-.393	.779	.756	.687	-.225	1				
PO_4^{2-}	.801	-.842	-.923	-.247	-.533	.919	.999*	.498	-.847	-.674	-.597	.109	-.993	1			
NO_3^-	.013	-.085	-.257	.619	.347	.872	.570	.991	-.937	.176	.273	-.723	-.511	.608	1		
SO_4^2	-.030	.102	.274	-.605	-.331	-.881	-.585	-.989	.943	-.159	-.256	.710	.526	-.622	-1.000*	1	
COD	-.991	.998*	.993	.688	.878	-.610	-.895	-.012	.481	.948	.912	-.579	.924	-.873	-.145	.162	1

*Correlation is significant at the 0.05% level

The correlation matrix for the seventeen physicochemical parameters under investigation at 0.05% level is presented in Table 3. There are positive correlations between pH and COD, DO and phosphate, and TDS and calcium hardness. However, negative correlation was observed between temperature and pH, DO and chloride, and nitrate and sulphate.

Heavy Metal Analysis of Water Sample

The water samples were analysed for heavy metals and the results are presented in Table 4. The results showed that Mn, Fe, Co, Cr, Cd, Pb, and Ni were below detection limits in the samples. However, copper was detected in all the three samples and the values (0.01 – 0.02 mg/L) were within WHO permissible limits. On the other hand, zinc was detected in samples A and B only and the values (0.02 and 0.01 mg/L) were within standard limits of WHO.

Microbial Analysis of Water Samples

Samples were analysed for microbial properties (Tables 5 and 6). The results of the most probable number (MPN) are presented in Table 5. Samples A, B and C had MPN of 220, 350 and 540 MPN/100 mL respectively. The microbial results showed that the three water samples had high coliform counts. Similar results of high number of total coliforms were reported by Rajurkar *et al*. [15] and Radha *et al*. [16] in different water bodies in India. High coliforms can result in serious gastrointestinal disorder.

The total bacterial counts (Table 5) showed that sample C had the highest value (89×10^4) while sample A had the lowest value (66×10^4). The total bacterial counts in the three samples were high. In a similar study conducted by Hamida *et al.* [17], it was reported that only 8% of the samples investigated were found free from bacterial contamination while the remaining 92% samples were positive for bacterial contamination and therefore unfit for drinking.

Five different bacteria were isolated from each of the three water samples and the characteristics of the bacteria are presented in Table 6. The presence of *E. coli* in the samples is a further proof of faecal contamination in the water samples. Similar findings were reported by Franciska *et al*. [18]. Roohul *et al.* [12] reported that *E. coli* had been isolated from drinking water sources in different regions of the world. WHO standard for coliform counts and *E. coli* is 0 MPN/100 mL [12]. Polluted water contaminates food and allows multiplication of the pathogens [7].

Table 5: Total coliform and total bacterial counts in water samples

Sample	Most probable number (MPN/100 mL)	Total bacterial count (cfu/mL)
A	220	66 x10^4
B	350	78 x10^4
C	540	89 x10^4

Table 6. Biochemical characterization of isolates

Bacteria isolates	Colour	Shape	Elevation	Cell shape	Gram reaction	Spore	Catalase	Oxidase	Coagulase	Citrate utilization	Methyl red test	Starch hydrolysis	Motility	Organism
1	Green metallic sheen	Round	Raised	Rod	-	-	+	-	-	-	+	-	+	*E.coli*
2	Pinkish	Round	Raised	Rod	-	-	-	-	-	+	+	-	+	*Enterobacterspp*
3	White-pinkish	Round	Raised	Rod	-	-	+	-	-	-	-	-	-	*Shigellaspp*
4	Cream	Round	Raised	Cocci	+	-	+	-	+	+	+	+	-	*Staphylococcus aureus*
5	White	Irregular	Flat	Rod	+	+	+	-	-	-	-	-	+	*Bacillus spp*

Conclusion

The study showed close similarity in physicochemical and microbial properties among samples A, B, and C which suggested there could be a link in the direction of flow of the water-bed. Moreover, the similarity could also be due to geomorphologic features. The detection of microorganisms and faecal contamination in the samples was probably due to the proximity of the borehole locations to septic tanks and refuse dumps. Since the results obtained for most of the parameters analyzed were not within the limits of WHO standard for potable water, therefore, the water samples are unfit for consumption. Hence, it is recommended that proper treatment of the water should be carried out before consumption.

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