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SEASONAL VARIATION IN PHYSICO-CHEMICAL PROPERTIES OF DRINKING WATER QUALITY AROUND SLUM SETTLEMENTS IN LAGOS METROPOLIS, NIGERIA

***OKIMIJI, O.P.,[1] OKAFOR, A.T.,[2] ADEDEJI, O.H.,[1] OGUNTOKE, O.[1] AND SHITTU, O.B.[3]**
[1]Department of Environmental Management and Toxicology, Federal University of Agriculture, Abeokuta, PMB 2240, Ogun State, Nigeria
[2]Department of Environmental Management and Toxicology, Michael Okpara University of Agriculture, Umudike, PMB 7267, Abia State, Nigeria
[3]Department of Microbiology, Federal University of Agriculture, Abeokuta, PMB 2240, Ogun State, Nigeria
Corresponding author: princessokimiji@yahoo.com

Abstract

This study examined the effect of seasonal variation on the physio-chemical and microbial properties of drinking water around slum settlement within Lagos Metropolis. Water samples were collected from different boreholes at different slums around the settlement comprising Group A (Majidun), Group B (Oworoshoki), Group C (Bariga), Group D (Iwaya) and Group E (Ijora Badia) for wet and dry seasons. Parameters of temperature, TDS, pH, hardness, EC, nitrate, sulphate, chloride, E. coli and faecal streptococci are analyzed using standard methods. The obtained data were analysed using SPSS for Windows. Result of the analyses showed that all the parameters have higher concentration during the dry season than in the wet season in all the Groups. Paired sample t-test results revealed that temperature, chloride and sulphate showed no significant variation in all the Groups. Mean values for chloride, hardness, E. coli and faecal streptococci are higher than the WHO guideline provisions. The study concludes that seasonality significantly influences the quality of drinking water in the slums, the water are more polluted during the dry season and recommended that it must be adequately treated if it is to be used for drinking.

Key Words: *Seasonal variation, Groundwater, Slum settlements, Pollution, Drinking water quality*

Introduction

Water is important for sustainable human development and an essential input for sustenance of all living things (Butuala *et al*., 2010). Hence, human needs of water for various purposes is increasing daily due to the continual increase in population, rapid urbanization, changes in life style and growing industrialization (Gajbhiye *et al*., 2014). Messinge (2012) documented that slum dwellers do not have access to potable water pipes within households; rather they utilize temporary communal taps which are often inconveniently erected at least 200 meters away from homesteads. El Haissoufi *et al*. (2011) discovered that the quality of water served to the slum dwellers, especially in Lagos metropolis has been subjected to numerous studies because the effect of the unsafe water consumption has impacted greatly on their health resulting from physical, chemical and microbial contamination. Ravet and Brailowsky (2014) reported that microbes are integral part of water that is not only responsible for nutrient recycling in ground water environment but can also contribute to variety of water borne diseases. Bharti *et al*. (2003) reported that most common diseases caused by contaminated water are diarrhoea, dysentery, schistosomiases and urinary tract infections. This study therefore assessed the physical, chemical and microbial properties of drinking water in slum settlements of Lagos metropolis in order to evaluate its suitability for consumption.

Materials and Methods

Study Area

The study was carried out in slum settlements within Lagos Metropolis, south-western Nigeria. Longitudes 3° 249′ E and latitudes 6° 279′ N with a coastline of approximately 180 km (Odunuga *et al*. 2012). Lagos had a total land area of 3577.28 km^2 out of which 22 % is wetland and population density of approximately 5926 persons per km^2 (Oshodi, 2013). Lagos state population is estimated to be 24.5 million in 2015 (UN-Habitat, 2008) and 29 million by 2020 (Lagos Water Corporation, 2011) with a growth rate of 3.2 and 8 % (Oyegoke *et al*., 2012). Lagos state geology comprises of coastal plain sand and a tidal flat with alluvium (BRNCC, 2012) while vegetation is tropical rainforest zone consisting of mangrove swamps, freshwater swamps, lagoons and creeks. The relief occupies a low-lying topography of 1– 4 % slope, elevation of 0–2 m above sea level (Awosika *et al*., 2000), The State has two distinct climatic seasons; dry and wet (rainy). It also experiences high air temperatures ranging from 30.0 to 38.0 °C (Adejuwon, 2004). Figure 1 presents map of the study area indicating the sample locations.

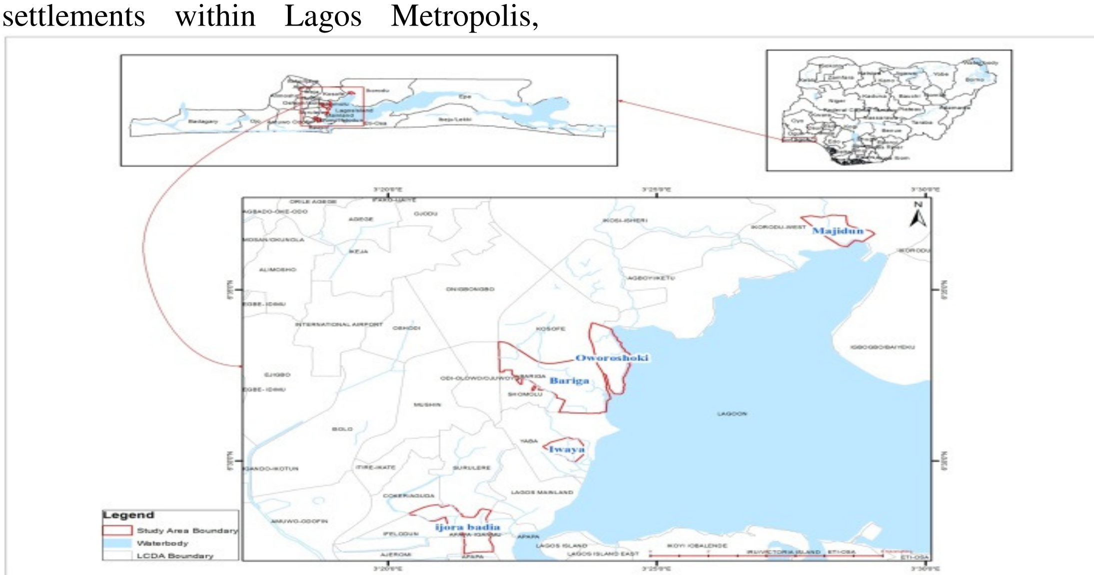

Fig. 1: Map of the study area

Sampling Locations

Drinking water samples were collected from selected boreholes around five selected slum settlements in Lagos metropolis during wet (rainy) and dry seasons from 2018 to 2019. Fifth water samples were collected in the slum settlements of Majidun, Oworoshoki, Bariga, Iwaya and Ijora Badia in each different season for twelve months (six months in wet season and six months in dry season). The samples were labeled with different codes according to the locations (Group A Majidun; Group B Oworoshoki; Group C Bariga; Group D Iwaya; Group E Ijora Badia).

All samples were collected in sterile auto clavable plastics and immediately stored in a cooler containing ice block at 3 - 4°C for preservation. Samples were transported back to the laboratory for analysis. Temperature, pH, EC and TDS were determined at the point of collection of the samples. Other parameters such as nitrate, chloride, hardness, sulphate, TBC and TCC were analyzed respectively.

Sample Collection Points

Geographical coordinates (latitude and longitude) of the sample sites were determined using a GPS device Garmin (GPSMAP 76CSX model). Map of Lagos metropolis was obtained and gridded to create cells of 300 m^2 using Arc Map 10.1 (Figure 2) for a representative collection of data across the entire slums. Ten cells out of the existing cells were randomly selected from each of the study areas using random number table, according to the method proposed by Kriging (Sajil *et al.*, 2011). Figure 2 presents grid map of the study area indicating the sample locations.

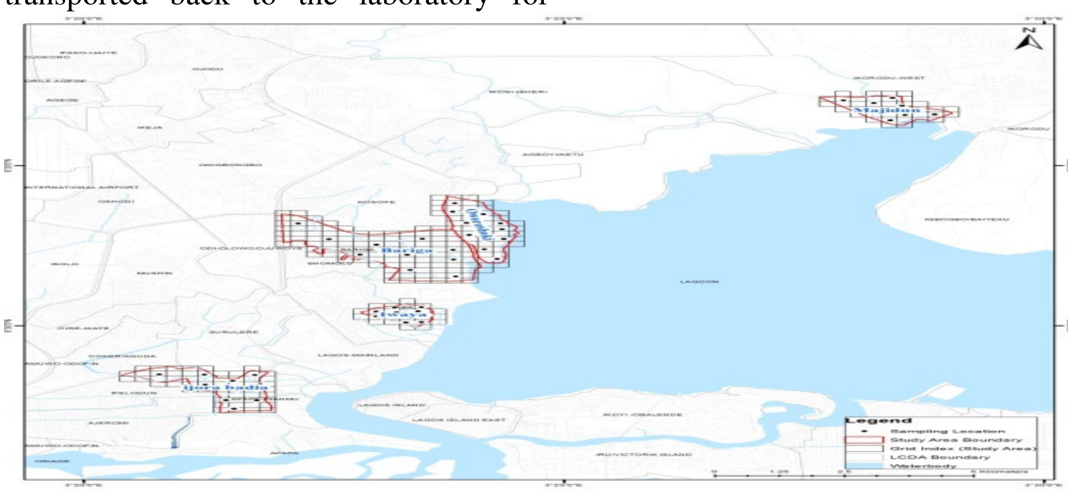

Fig. 2: Grid map of the study area

Methods of Analysis

pH, electrical conductivity and total dissolved solid was measured in situ using pocket sized pH meter Hanna Combo (H198130 model). Temperature was determined by dipping a mercury-in-glass portable thermometer into the water samples to obtain the reading. Total dissolved solids by Evaporation Method (Trivedy and Goel, 1986). Hardness and chloride were measured titrimetrically (APHA, 1998). Nitrate and sulphate was determined by UV-Spectophotometric method (UV-2505 model) (Ademoroti, 1996). Phosphate was determined by Vanado-molybdophosphoric Acid Method. The TBC and TCC (*E. coli* and faecal streptococci) were determined using the membrane filter technique. This technique determines the number of colony forming units per 100 mL (cfu/100 ml) of water sample (APHA, 1998).

Statistical Analysis

Data collected was analysed for inferential statistics (analysis of variance and paired sample student t-test) using SPSS for Windows (version 21.0).

Results and Discussion

Results from the analysis of selected parameters (physico-chemical and microbial) for the dry and wet seasons are presented in Tables 1, 2, 3, 4 and 5 respectively. Group A samples mean values of EC, pH, nitrate, chloride and hardness had higher mean values during the wet season while temperature, TDS, sulphate, *E. coli* and faecal streptococci have higher mean values during dry season.

Paired sample student t-test for Group A (Majidun) water samples in Table 1 showed that parameters such as temperature, TDS, sulphate, chloride, *E. coli* and faecal streptococci had their calculated values (t-calculated) less than the table value at $p>0.05$, indicating no significant seasonal variation. Hence, other parameters such as EC, pH, nitrate and hardness have their calculated t-values greater than the table values, therefore shows significant seasonal variation. The seepage of water into the ground is accompanied by filtration and this could explain the reason for the non-significant seasonal variation in the concentration of most of the groundwater parameters for Group A.

The result in Table 2 showed that Group B (Oworoshoki) water samples parameters such as pH, and nitrate have higher mean values during wet season than dry season, whereas the mean values of temperature, EC, sulphate, chloride, hardness, *E. coli* and faecal streptococci were higher during dry season. Paired sample t-test result for Group B (Table 2) shows that parameters such as pH, and nitrate have their calculated values (t-calculated) greater than the table value at ($p<0.05$), indicating significant seasonal variation; but other parameters such as temperature, EC, TDS, sulphate, chloride, hardness, *E. coli* and faecal streptococci had no significant seasonal variation because their calculated values are less than the table values.

Result of the analyses for Group C (Bariga) water samples showed that temperature, sulphate, *E. coli* and faecal streptococci had higher mean values during the dry season, while the mean values of EC, TDS, pH, nitrate, chloride and hardness are higher during the wet season. Moreover, phosphate means value recorded the same value for both wet and dry season.

Table 1: Paired sample t-test for difference in concentration between wet and dry season drinking water parameters within Majidun (Group A)

Location	Parameter	Pair	Mean ± Std. Error	N	Std.Deviation	d.f	t-calculated	Sig level	Rmks
Majidun	Temperature °C	Wet Season	26.98±0.022	45	0.149	44	-91.000	0.000	NS
		Dry Season	29.00±0.000	45	0.000	44			
	EC µs/cm	Wet Season	2342.89±229.823	45	1541.698	44	6.874	0.000	S
		Dry Season	745.64±7.956	45	53.367	44			
	TDS mg/L	Wet Season	513.96±24.919	45	167.164	44	-3.793	0.000	NS
		Dry season	1310.71±203.654	45	1366.151	44			
	pH	Wet season	7.62±0.102	45	0.684	44	7.302	0.000	S
		Dry Season	6.67±0.071	45	0.477	44			
	Nitrate mg/L	Wet Season	2.60±0.184	45	1.232	44	1.947	0.058	S
		Dry Season	2.22±0.100	45	0.670	44			
	Sulphate mg/L	Wet Season	266.56±39.006	45	261.661	44	-2.750	0.009	NS
		Dry Season	384.00±27.010	45	181.186	44			
	Chloride mg/L	Wet Season	280.64±16.366	45	109.785	44	0.144	0.886	NS
		Dry Season	273.91±38.700	45	259.608	44			
	Hardness mg/L	Wet Season	1078.80±161.206	45	1081.400	44	4.465	0.000	S
		Dry Season	342.04±21.555	45	144.594	44			
	E. coli	Wet Season	1.420±0.421	45	0.941	44	-0.421	0.695	NS
		Dry Season	1.680±0.281	45	0.630	44			
	Faecal streptococci	Wet Season	0.520±0.235	45	0.526	44	-5.275	0.006	NS
		Dry Season	1.980±0.239	45	0.535	44			

Note: S= significant, NS= not significant

Source: Field Work, Lagos Metropolis slums 2018/2019

Table 2: Paired sample t-test for difference in concentration between wet and dry season drinking water parameters within Oworoshoki (Group B)

Location	Parameter	Pair	Mean±Std. Error	N	Std.Deviation	d.f	t-calculated	Sig level	Rmks
Oworoshoki	Temperature °C	Wet Season	26.82±0.073	45	0.490	44	-26.359	0.000	NS
		Dry Season	28.87±0.051	45	0.344	44			
	EC µs/cm	Wet Season	371.84±26.306	45	176.469	44	-7.015	0.000	NS
		Dry Season	1388.82±135.146	45	906.585	44			
	TDS mg/L	Wet Season	407.96±32.989	45	221.2294	44	-5.313	0.000	NS
		Dry season	1078.73±124.203	45	833.182	44			
	pH	Wet season	8.44±0.125	45	0.841	44	22.198	0.000	S
		Dry Season	5.27±0.067	45	0.447	44			
	Nitrate mg/L	Wet Season	3.11±0.307	45	2.058	44	3.209	0.002	S
		Dry Season	2.09±0.138	45	0.925	44			
	Sulphate mg/L	Wet Season	248.40±19.410	45	130.206	44	-6.586	0.000	NS
		Dry Season	401.04±11.271	45	75.610	44			
	Chloride mg/L	Wet Season	43.36±3.337	45	22.383	44	-22.981	0.000	NS
		Dry Season	503.69±19.934	45	133.722	44			
	Hardness mg/L	Wet Season	201.51±21.037	45	141.122	44	-4.751	0.000	NS
		Dry Season	373.53±36.143	45	242.454	44			
	E. coli	Wet Season	1.180±0.222	45	0.496	44	-1.952	0.123	NS
		Dry Season	1.580±0.165	45	0.370	44			
	Faecal streptococci	Wet Season	0.120±0.374	45	0.083	44	-19.297	0.000	NS
		Dry Season	1.400±0.070	45	0.158	44			

Note: S= significant, NS= not significant

Source: Field Work, Lagos Metropolis slums 2018/2019

Table 3: Paired sample t-test for difference in concentration between wet and dry season drinking water parameters within Bariga (Group C)

Location	Parameter	Pair	Mean ± Std. Error	N	Std. Deviation	d.f	t-calculated	Sig level	Rmks
Bariga	Temperature °C	Wet Season	26.69±0.431	45	2.891	44	-4.787	0.000	NS
		Dry Season	28.82±0.97	45	0.650	44			
	EC µs/cm	Wet Season	794.76±153.192	45	1027.642	44	1.018	0.314	S
		Dry Season	570.27±154.424	45	1035.907	44			
	TDS mg/L	Wet Season	283.64±26.894	45	180.413	44	0.127	0.900	NS
		Dry season	276.42±49.200	45	330.040	44			
	pH	Wet season	7.60±0.092	45	0.618	44	11.822	0.000	S
		Dry Season	5.96±0.105	45	0.706	44			
	Nitrate mg/L	Wet Season	1.62±0.107	45	0.716	44	2.229	0.031	S
		Dry Season	1.33±0.084	45	0.564	44			
	Sulphate mg/L	Wet Season	184.16±12.722	45	85.340	44	-6.491	0.000	NS
		Dry Season	362.47±25.336	45	169.958	44			
	Chloride mg/L	Wet Season	289.38±14.147	45	94.900	44	0.244	0.809	NS
		Dry Season	277.38±46.731	45	313.483	44			
	Hardness mg/L	Wet Season	593.13±134.067	45	899.346	44	0.651	0.518	S
		Dry Season	487.73±85.672	45	574.706	44			
	E. coli	Wet Season	1.110±0.273	45	0.610	44	-5.163	0.007	NS
		Dry Season	1.980±0.292	45	0.653	44			
	Faecal streptococci	Wet Season	0.640±0.377	45	0.844	44	-1.543	0.198	NS
		Dry Season	1.420±0.153	45	0.342	44			

Note: S= significant, NS= not significant
Source: Field Work, Lagos Metropolis slums 2018/2019

Table 4: Paired sample t-test for difference in concentration between wet and dry season drinking water parameters within Iwaya (Group D)

Location	Parameter	Pair	Mean ± Std. Error	N	Std. Deviation	d.f	t-calculated	Sig level	Rmks
Iwaya	Temperature °C	Wet Season	26.96±0.031	45	0.208	44	-18.817	0.000	NS
		Dry Season	28.69±0.083	45	0.557	44			
	EC µs/cm	Wet Season	1166.04±208.719	45	1400.127	44	3.299	0.002	S
		Dry Season	433.11±67.935	45	455.721	44			
	TDS mg/L	Wet Season	619.04±138.381	45	928.287	44	3.747	0.001	S
		Dry season	93.60±12.623	45	84.678	44			
	pH	Wet season	7.71±0.093	45	0.626	44	14.910	0.000	S
		Dry Season	6.11±0.047	45	0.318	44			
	Nitrate mg/L	Wet Season	2.22±0.162	45	1.085	44	-2.147	0.037	NS
		Dry Season	44.53±19.684	45	132.044	44			
	Sulphate mg/L	Wet Season	212.53±29.296	45	196.522	44	-2.828	0.007	NS
		Dry Season	315.93±19.962	45	133.909	44			
	Chloride mg/L	Wet Season	266.31±11.428	45	76.661	44	-0.175	0.862	NS
		Dry Season	275.18±48.341	45	324.281	44			
	Hardness mg/L	Wet Season	676.20±160.045	45	1073.612	44	2.661	0.011	S
		Dry Season	262.80±26.300	45	176.428	44			
	E. coli	Wet Season	1.600±0.228	45	0.509	44	-0.286	0.789	NS
		Dry Season	1.680±0.106	45	0.238	44			
	Faecal streptococci	Wet Season	0.400±0.221	45	0.495	44	-2.328	0.080	NS
		Dry Season	1.160±0.227	45	0.507	44			

Note: S= significant, NS= not significant
Source: Field Work, Lagos Metropolis slums 2018/2019

Table 5: Paired sample t-test for difference in concentration between wet and dry season drinking water parameters within Ijora Badia (Group E)

Location	Parameter	Pair	Mean ± Std. Error	N	Std.Deviation	d.f	t-calculated	Sig level	Rmks
Ijora Badia	Temperature °C	Wet Season	26.87±0.051	45	0.344	44	-25.163	0.000	NS
		Dry Season	28.96±0.055	45	0.367	44			
	EC µs/cm	Wet Season	1578.47±214.386	45	1438.143	44	-2.194	0.034	NS
		Dry Season	2100.64±153.919	45	1032.518	44			
	TDS mg/L	Wet Season	481.24±18.988	45	127.377	44	-17.932	0.000	NS
		Dry season	866.11±14.302	45	95.941	44			
	pH	Wet season	7.73±0.080	45	0.539	44	18.817	0.000	S
		Dry Season	6.00±0.055	45	0.369	44			
	Nitrate mg/L	Wet Season	2.58±0.200	45	1.340	44	-2.320	0.025	NS
		Dry Season	83.47±34.913	45	234.206	44			
	Sulphate mg/L	Wet Season	136.44±11.543	45	77.433	44	-5.301	0.000	NS
		Dry Season	393.62±45.875	45	307.741	44			
	Chloride mg/L	Wet Season	274.78±20.612	45	138.269	44	-8.438	0.000	NS
		Dry Season	487.07±12.407	45	83.230	44			
	Hardness mg/L	Wet Season	1698.87±293.052	45	1965.852	44	3.146	0.003	S
		Dry Season	775.44±22.231	45	149.133	44			
	E. coli	Wet Season	1.640±0.240	45	0.536	44	-0.568	0.600	NS
		Dry Season	1.740±0.246	45	0.550	44			
	Faecal streptococci	Wet Season	0.900±0.368	45	0.824	44	-0.487	0.652	NS
		Dry Season	1.140±0.201	45	0.450	44			

Note: S= significant, NS= not significant
Source: Field Work, Lagos Metropolis slums 2018/2019

Paired sample t-test result for Group C (Bariga) Table 3 showed that parameters such as temperature, TDS, sulphate, chloride, *E. coli* and faecal streptococci have their calculated values (t-calculated) less than the table value at $p<0.05$, hence indicating no significant variation but EC, pH, nitrate and hardness have their calculated t-vales greater than the table values and therefore shows significant variation.

Group D (Iwaya) water samples results revealed that parameters such as EC, TDS, pH and hardness have higher mean values in wet season while temperature, nitrate, sulphate, chloride, *E. coli* and faecal streptococci had higher mean values in dry season. Paired sample t-test result for Group D (Table 4) showed that EC, TDS, pH and hardness have their calculated values (t- calculated) greater than table value at $p<0.05$ which indicates significant seasonal variation. And the other parameters such as temperature, nitrate, sulphate, chloride, *E. coli* and faecal streptococci showed no significant seasonal variation because their calculated values are less than the table values.

Table 5 result for Group E (Ijora Badia) water samples depicts that parameters such as pH and hardness have higher mean values in wet season whereas temperature, EC, TDS, nitrate, sulphate, chloride, *E. coli* and faecal streptococci mean values were higher in dry season. The paired sample t-test result for Group E (Table 5) showed that pH and hardness have their calculated values (t- calculated) greater than the table value at $p<0.05$, indicating significant seasonal variation. Although, temperature, EC, TDS, nitrate, sulphate, chloride, *E. coli* and faecal streptococci showed no significant variation because their calculated values are less than the table values.

Variation in water quality in an area is a function of physical and chemical parameters that are greatly influenced by geological formations and anthropogenic activities (Krishna *et al*., 2011). Comparing the seasonal variation in the concentration of the parameters across the five Groups (A, B, C, D and E), thus depicts the influence of certain factors such as environmental conditions, settlement and weather.

Mean temperature values of the drinking water samples across the groups ranged from 26.82 to 26.69°C in wet season while 28.82 to 29.00°C were the highest value obtained in dry season across the groups. Hence, the increase of water temperature during dry season is more likely due to the increased solubility of ions as a consequence of the elevated water temperature and low pH. WHO (2011) reported that increased in potable water temperature may impart undesirable taste and odour as well as the corrosive ability of the water.

EC mean values ranged from 371.84 to 2342.89 µs/cm in wet season while dry season value ranged from 433.11 to 2342.89 µS/cm across the groups. The obtained values were within permissible limits while Group B, D, E values exceeded WHO (2007) permissible limit of 8 – 1000 µs/cm during dry season. Irshad *et al*. (2011) reported that high electrical conductivity values are mostly associated with wastewater discharges from sewerage, agricultural runoff and industries.

TDS mean values across the sample locations ranged from 283.64 to 619.04 mg/L in wet season and 93.60 to 1310.71 mg/L during dry season. The obtained values in wet season were within WHO (2007) recommended standard of 1000 mg/L, while it exceeded permissible limits in group A and B during dry season. Ballester and Sunyer (2000) stipulated that total dissolved solid in drinking water has been associated with natural sources, sewage urban runoff, industrial waste water and chemical used in the water treatment process through aesthetic rather than health hazards

pH values range from 7.60 to 8.44 in wet season and 5.27 to 6.67 during dry season across the groups. pH mean value are higher during wet season compared to dry season. Hence, low pH value may inhibit the growth of microorganisms (Sarairah *et al*., 2008).

Nitrate mean value ranged from 1.62 to 3.11 mg/L in wet season and 1.33 to 83.47 mg/L during dry season. The obtained values were within WHO (2000) permissible limit of 50 mg/L. But exceeded permissible limit (Group E and D) than Group A, B and C respectively. Adeyeye and Abulude (2004) reported that nitrate in natural waters can be traced to percolating NO_3- from sources such as decaying plant and animal materials, agricultural fertilizers and domestic sewage.

Sulphate mean values ranged from 136.44 to 266.26 mg/L in wet season and 315.93 to 401.04 mg/L during dry season. Higher values were recorded during wet season (248.40 mg/L; 2.60 mg/L; 212.53 mg/L) across the groups. WHO (2006) and USEPA (1995) ascertained that high level of sulphate in water sample is believed to have effect on human health, especially adult but young children who are very sensitive to the element. People who are not used to drinking water with high level of sulphate can also experience diarrhea.

The mean value of chloride ranged between 43.36 to 289.38 mg/L in wet season and 273.91 to 503.36 mg/L during dry season. The values obtained exceeded WHO (2007) and USEPA (2003) permissible limit of 250 mg/L in wet season across the groups. Barati *et al*. (2010) reported that high level of chloride makes water not palatable for drinking by imparting salty taste and may harm metallic pipe.

Mean values of hardness range from 202.51 to 1698.86 mg/L in wet season and 262.80 to 775.44 mg/L during dry season. The obtained values exceeded both WHO (2007) and USEPA (2003) permissible limit of 500 mg/L in group A, C, D and E while group B recorded values was within the permissible limits. Robles *et al*. (2004) noted that hard water does not lather well with soap and therefore requires a higher consumption of soap.

Mean TBC (*E. coli*) values ranged from 1.11 ± 0.27 to 1.64 ± 0.24 $\times 10^3$ cfu/mL in wet season and 1.58 ± 0.27 to 1.98 ± 0.29 $\times 10^3$ cfu/mL during dry season across the groups. The values obtained exceeded USEPA (2003) permissible limit of zero per 100 mL. Itah and Akpan (2005) reported that indicator organism most especially *Escherichia coli* with several other heterotrophic bacteria makes water unfit for human consumption.

TCC (Faecal streptococci) mean value ranged from 0.12 ± 0.37 to 0.90 ± 0.37 $\times 10^3$ cfu/mL in wet season and 1.14 ± 0. 20 to 1.98 ± 0.24 $\times 10^3$ cfu/mL dry season. The values obtained exceeded USEPA (2003) recommended standard of zero per 100 mL. High coliform count obtained in water samples may be an indication that the water sources are faecally contaminated (USEPA, 2003).

Conclusion

This study assessed the physical, chemical and microbial properties of drinking water in slum settlements of Lagos metropolis, Nigeria in order to evaluate its suitability for consumption. The result of the paired sample t-test analyses revealed that most parameters have higher concentration in dry season than in the wet season across the groups. Hence, temperature, chloride, sulphate, *E. coli* and faecal streptococci have no significant variation across the groups, while other parameters showed different levels of seasonal variation across the groups. Most of the parameters have mean values within the WHO (2007) guidelines in both seasons. More so, chloride, hardness, *E. coli* and faecal streptococci have values that are higher than the guideline provisions of WHO (2007) and USEPA (2003). The quality of drinking water changes widely due to various types of pollution, seasonal variation and groundwater extraction. The study concludes that seasonality significantly influences the quality of drinking water in the slums which makes the residents prone to diseases. This study therefore recommends that there is the need for the treatment of drinking water before consumption.

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