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Assessment level of Physicochemical properties and trace metals of water samples from Lagos, Nigeria

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Abstract

Water quality assessment largely depends on the physicochemical parameters as well as organic and inorganic compounds that are dissolved or suspended in it. Current study investigates the physico-chemical parameters of borehole and Lagos lagoon water samples, as well as mean concentrations of trace metals (Fe, Ni, Cr, Zn and Cu) in commercial sachet and bottled water samples. Prior to analysis with Flame Atomic Absorption Spectrophotometry, samples were digested by aqua-regia technique. The pH values ranges from 7.30-8.5 for lagoon and borehole water samples and 6.30-7.35 for sachet and bottled water samples, other physicochemical parameters ranges are: Dissolved oxygen (bottled > bore hole > sachet > Lagos lagoon); Alkalinity (Lagos lagoon > borehole > bottled > sachet water), Electrical conductivity (Lagos lagoon > sachet > bottled > borehole) and salinity (Lagos lagoon > borehole > bottled > sachet). Also, Total dissolved solids were in the order: Lagos lagoon > borehole > sachet > bottled water. The occurrence of trace metals include Fe > Cu > Zn > Cr > Ni and while Fe, Ni, Zn and Cu were detected in all the samples, Cr was detected in 70 and 10% of bottled and sachet water samples respectively. Mean concentrations of the trace metals were generally lower in sachet than in bottled water samples. All the measured parameters except mean concentration of Fe and Ni were below the maximum allowable limit set by World Health Organization.

Keywords: Physicochemical parameters trace metals, Lagos lagoon water, sachet and bottled water allowable limit.

Introduction

Water of all earth's natural resources is the most essential to life. Unfortunately, clean water sources are at great risk as chemical and biological contamination threatens existing supplies, and emerging hazards are being recognised each year (Raji et al., 2010). It has been a great concern that access to safe drinking water is still a major challenge to many people globally, especially those living in developing countries (Mansour et al,. 2002). According to a recent report on access to drinking water and sanitation, there are about 663 million people living without access to adequate and improved water supplies, 319 million (49%) of which live in Sub-Saharan Africa (WHO/UNICEF JMP 2015). As a result of increased population, industrialization and other anthropogenic activities, both ground and surface water tends to be highly polluted with different harmful contaminants (Miller et al., 2004). Groundwater resources are used extensively for domestic, industrial and agricultural purposes, because of its wide availability and being more of chemical and microbial quality than surface water (Grönwall et al., 2010). Also, the sale and consumption of bottled and sachet drinking water continues to grow rapidly in most countries of the world including Nigeria due to inadequacy of reliable and safe municipal water in most of the urban areas (Oyedeji et al. 2010). Sachet water was introduced into the Nigerian market as a less expensive means of accessing drinking water and improvement over the former types of drinking water packaged for sale in hand filled and hand tied polythene bags The introduction of sachet water also provide safe and hygienic instant drinking water to the public and to curb the magnitude of water borne infections in the communities (Fajobi and Shittu 2008). Most bottled water manufacturers in Nigeria also engage in sachet water packaging and obtain their raw water mostly from local municipal piped water and hygiene in various stages of production can vary among manufacturers. While some employ sophisticated techniques such as ionization and reverse osmosis, some use ordinary boiling of well water sources and exclusion of particles by use of unsterilized filtration materials (Oyedeji et al. 2010).

The water quality assessment is widely determined by physicochemical parameters as well as organic and inorganic compounds that are either dissolved or suspended in it (Ubalua and Ezeronye 2005). For instance, pH value of water largely determines the solubility of trace and heavy metals such that at low pH, trace metals tend to dissolve more (Muhammad et al., 2007). Various human activities from industrial and atmospheric pollution as well as agricultural run-offs and leaching may result in increasing levels of trace metals in the environment (Hudson-Edward et al. 2003). In aquatic medium, heavy metals are non-biodegradable and when accumulated pose chronic toxicity to marine organisms and man (Calderon, 2000). Although, some trace metals particularly Cu, Fe, Mn, Ni, Cr and Zn constitute essential micro-nutrients and play a very important role in biological systems, but these have proved detrimental to humans when accumulated beyond certain limit (Nwaje et al., 2007). Hence, several regulatory bodies have listed these metals among the toxic metals and have set a maximum contaminant level (MCL) in water samples (Watt et al. 2000). In many urban centres in developing countries including Lagos, Nigeria, indiscriminate disposal of sewage, industrial effluents and several human activities can result into diverse physicochemical parameters (Hung and Hsu, 2004). The wastes indiscriminately disposed-off into inland and coastal water bodies has resulted in elevation in various nutrient loading and oxygen demand, thereby promoting growth of toxic algae and other aquatic plants (Ekiye et al., 2010). In order to safe guard public health, it is important to ensure that available water including lagoon, borehole, bottled and sachet water are of highest quality standards through comprehensive regulatory programs at both federal and state levels (Anunobi et al. 2006). For monitoring purpose, current study investigates the physicochemical parameters of borehole and Lagos lagoon water samples, as well as mean concentrations of Fe, Ni, Cr, Zn and Cu) in ten brands of commercial sachet and bottled water samples vended in mainland area of Lagos, Nigeria. Samples were pre-concentrated by aqua-regia digestion and analysed with Flame Atomic Absorption Spectrophotometry (FAAS).

Materials and Methods

Materials

All chemicals and reagents were HPLC grade, while deionised water, nitric acid, hydrochloric acid were obtained from Sigma-Aldrich (Buchs, St Gallen, Switzerland). A reference standard of each metal was obtained from Fisher scientific (Fair Lawn, NJ). Also, filter paper (Whatman International Limited, Maidstone England, 110mm Diax 100 circle) were obtained from Fisher scientific and multiparameter water quality metres (Horiba U-10) was obtained from Horiba Ltd, Japan. Trace metals in samples were analysed with FAAS (Agilent 200A model).

Methods

Sampling

The sampling location including Lagos lagoon have been described in previous studies (Adeyemi et al, 2011, Popoola et al., 2015). Six water samples from different locations of Lagos lagoon and coordinates of sampling sites were measured at various depth, ten borehole water samples were collected from mainland areas of Lagos environment. Also ten samples of bottled and sachet water were also purchased from commercial vendors from mainland area of Lagos, the brand name, batch no and manufacturers contact were noted for record purposes. Samples were collected same day into appropriately labelled glass containers which have been previously washed with 10% HNO_3 and HCl for 48h (Adekunle et al., 2007). Samples were then filtered through 0.45mm millipore membrane filter and stored in refrigerator at - 5°C prior to analysis.

Physicochemical parameters and trace metal analysis

The physicochemical parameters were measured using multiparameter water quality metres (A.O.A.C. 2005). The trace metal analysis was done according to modified standard method for heavy metals determination (Adedeji and Okocha 2011). A 50 ml of water sample was measured into a Kjeldahl flask and 5mls of freshly prepared aqua regia (HNO_3 + HCl in ratio 1:3) was added in a fume cupboard.

The beaker was covered and the contents heated for 2 hours on the medium heat of a hot plate. The mixture was allowed to cool, filtered into a 100 ml standard volumetric flask and filtrate was diluted to mark with de-ionized distilled water. The nebulizer of AAS was rinsed by aspirating distilled deionized water and trace metals in the samples were determined by direct aspiration into air acetylene flame. Absorption of metal in samples and the blank were determined at 248.3 nm for Fe, 324.8nm for Cu, 213.9 nm for Zn, 183.5 nm for Pb, 228.8nm Ni and 357.9 nm for Cr (L'vov, 2005).

Quality assurance

Stock solutions of each metal ions were prepared by dissolving 100mg of each metal ion in 10ml of deionized water, while the working concentrations were prepared daily from stock solution by dilution in de-ionized water. The standard solutions were first sprayed into the FAAS to give standard values which were used to plot the calibration curve. Calibration curves were plotted using excel, while regression equation was used to obtain the mean concentrations. All glassware were thoroughly washed with acid, cleaned and dried prior to use. Precision was defined as RSD which was determined using SD divided by the mean for three replicated analysis, while recoveries were obtained by comparing the analytical result with concentration of the spike expressed as a percentage. For every set of 10 samples, a procedural blank consisting of all reagents was run to check for interference and cross-contamination. Analysis of blank de-ionized water produced no recoveries for metal ions indicating that de-ionized water used in the analysis were free of investigated metals. Calibration curves were prepared by spiking aliquots of de-ionized water at five different concentrations of metal ions in triplicate. Data collected were computed in to means, with standard deviation (SD) and relative SD (RSD) and for easy statistical analysis; metals not detected were assigned a value of zero. The regression coefficient (R^2) of the calibration curves of each metal were also determined

Results and Discussion

Levels of Physicochemical parameters and trace metals of water samples

The physicochemical parameters of Lagos lagoon water (Table 1) were as follows: [temperature (T); 29.0.-29.8^{o}C. pH; 7.3-8.5; electrical conductivity (EC); 37.4-47.8 mS/cm, salinity; 23.6-31.3, while dissolved oxygen (DO); total dissolved solid (TDS), alkalinity and turbidity ranges were 3.5-7.8, 22.4-30.0, 23.5-62.5, and 9.0-41.0 mg/l respectively. For Borehole water [(T); 28.5.-29.8^{o}C. pH; 7.6-8.4; EC; 0.30-0.65 mS/cm while DO; TDS, salinity and alkalinity were 7.4-7.72, 0.54-7.86 0.406.36 and 5.92-87.06 mg/l respectively (Table 2). Sachet waters [(T); 29.8-30.5; pH; 6.37-7.35; EC; 1.41-7.93 mS/cm while DO, TDS, Salinity and alkalinity ranges were 5.94-7.35, 0.68-3.82, 0.2-4.7 and 8.00-50.0 mg/l respectively (Table 3). For bottled waters [(T); 31.0-31.8^{o}C; pH; 6.3-7.2 and EC; 0.77-14.55 mS/cm while DO, TDS, salinity and alkalinity ranges were 7.08-7.87, 0.38-6.96, 0.37-8.20 and 2.05-78.2 mg/l respectively (Table 4). The mean value of temperature, TDS and alkalinity in this study were higher, while conductivity was lower, when compared to previous studies on water samples from Ondo state (Adefemi and Awokunmi, 2010). The measured temperatures were in the range of 28.5-31.8 ^{o}C, the growth of excised different plant parts has been studied at different temperatures and the value at which most physiological processes proceeds optimally ranges from 25- 40^{o}C, while a very low or high temperature may cause adverse effects (Wang and Zheng 2001). Oxygen is measured in its dissolved form as DO and this was lower in sachet than in bottled waters. The properties of low solubility of oxygen in water coupled with rapid use, despite the slow replenishment may cause an adverse change in DO concentration, even though the level may be managed with aeration (Darren et al. 2013). Dissolved oxygen is an important environmental parameter for the survival of aquatic life, if more oxygen is consumed than is produced, DO levels would decline and sensitive animals would either move away, be weakened or die (Agbaire and Obi, 2009). The DO ranges were bottled > bore hole > sachet > Lagos lagoon and values were least in Lagos lagoon samples and this may result from various factors. The common practice of dumping domestic and industrial wastes in water bodies have been implicated in increased nitrate and phosphate levels in surface waters which results in increased plant and algal growth in water and depletion of oxygen levels. Also, farm practices along some bed of lagoon could also result in depletion of oxygen because nitrate and phosphates from fertilizers may get leached into water bodies resulting in adverse physicochemical parameters of water samples (Dike et al., 2010). Numerous scientific studies suggest that 4 - 5 mg/L of DO is the minimum required to support a large, diverse fish population and generally average of 9.0 mg/L is considered very suitable, but when low (< 3.0 mg/L), fish and some aquatic animals may die in large numbers, also, a high DO concentrations (> 20 mg/L)

Table 1: Physicochemical parameters of Lagos lagoon water samples

Location	Abbreviation	Coordinate	Depth (m)	Temp (^{O}C)	pH	EC (S/M)	D.O (mg/L)	T.D.S (Mg/L)	Salinity (mg/L)	Alkalinity	Turbidity (mg/L)
NIOMR Jetty (N)	NSW	Lat.N 0 6º25’13.0”, Long.E 003º24’27.1”	0.01	29.1	7.9	47.3	5.5	28.4	30.9	62.53	15
	NBW	Lat.N 06º26’27.2”, Long.E 003º24’11.8”	7.27	29.2	8.1	47.8	3.8	26.7	31.3	43.12	17
Bony Camp (B)	BSW	Lat.N 0 6º25’14.0”, Long.E 003º24’26.1”	0.01	29.3	7.6	41.5	7.8	24.9	26.6	23.45	9
	BBW	Lat.N 0 6º25’14.0”, Long.E 003º24’26.1	4.36	29.0	8.2	43	6.8	25.8	27.6	36.45	9
Falomo (F)	FSW	Lat.N 06º26’25.5”, Long.E 003º25’33.7”	0.01	29.6	7.4	39.5	6.2	23.7	24.8	36.50	9
	FBW	Lat.N 06º26’25.5”, Long.E 003º25’33.7”	0.85	29.7	7.9	45.8	4.8	27.5	29.9	55.65	10
Apapa (A)	ASW	Lat.N 06º28’60.0”, Long.E 003º23’02.2”	0.01	29.2	8.1	45.6	3.5	27.4	29.7	34.75	15
	ABW	Lat.N 06º28’60.0”, Long.E 003º23’02.2”	6.32	29.3	8.2	46	3.1	27.6	30.2	40.50	38
Ijora (I)	ISW	Lat.N 06º28’49.0”, Long.E 003º23’73.9”	0.01	29.6	7.5	43.3	4.9	30.0	28.3	35.67	15
	IBW	Lat.N 06º28’49.0”, Long.E 003º23’73.9”	0.73	29.8	8.2	44.2	5.8	26.5	28.6	57.80	12
Oko Baba (O)	OSW	Lat.N N06º29’42.4”, Long.E 003º23’73.9”	0.01	29.4	7.3	37.4	5.0	22.4	23.6	43.54	23
	OBW	Lat.N N06º29’42.4”, Long.E 003º23’73.9”	3.10	29.2	8.5	37.7	3.3	22.6	24.0	38.73	41

Temp = temperature; EC = Electrical conductivity, TDS = total dissolved solid, DO = dissolved oxygen, SW= Surface water, BW= Bottomed water

Table 2: Physicochemical parameters of borehole water samples.

Sample code	Temperature (^{O}C)	pH	EC (S/cm)	DO (mg/l)	TDS (Mg/L)	Salinity (mg/L)	Alkalinity
BH 1	29.0	8.4	0.30	7.67	5.34	0.40	12.53
BH 2	29.4	8.3	0.65	7.60	7.86	6.36	87.06
BH 3	29.5	8.0	0.56	7.40	0.54	5.43	7.05
BH 4	29.0	7.6	0.48	7.68	1.42	1.92	42.30
BH 5	28.5	8.4	0.35	7.72	6.35	4.90	47.32
BH 6	28.5	7.8	0.42	7.70	1.32	1.63	64.30
BH 7	29.0	7.6	0.57	7.68	0.75	0.93	6.05
BH 8	29.2	8.1	0.60	7.50	2.46	0.87	9.15
BH 9	29.0	7.6	0.57	7.68	5.87	1.43	5.92
BH 10	29.2	8.1	0.60	7.50	1.41	2.05	38.73
Mean values							

EC = Electrical conductivity; DO = dissolved oxygen TDS =total dissolved solid, BH: borehole water samples

Table 3: Physicochemical parameters of commercial sachet and bottled water samples

Sample	Temp. (^{O}C)	pH	EC (S/M)	DO (mg/l)	TDS (Mg/L)	Salinity (mg/L)	Alkalinity
SW1	30.1	7.20	3.60	7.21	3.70	0.20	50.00
SW2	29.8	6.80	7.93	7.35	3.82	4.36	28.00
SW3	30.2	7.35	6.42	6.87	3.08	3.43	14.3
SW4	30.0	6.37	1.85	7.46	0.88	0.92	8.00
SW5	30.3	7.16	8.21	6.56	3.94	4.70	12.01
SW6	30.1	7.23	1.41	7.05	0.68	0.69	8.67
SW7	30.1	6.82	2.12	6.94	1.02	1.06	10.05
SW8	30.2	6.76	1.59	7.32	0.76	0.79	8.00
SW9	30.5	7.01	1.84	5.94	0.88	0.92	9.98
SW10	30.5	7.30	2.00	6.50	0.96	1.00	30.67
Mean values							
BW1	31.5	6.6	6.74	7.37	3.24	3.59	11.33
BW2	31.8	6.9	14.55	7.42	6.96	8.20	92.65
BW3	31.4	6.8	2.07	7.72	0.98	1.02	8.01
BW4	31.0	6.3	0.77	7.45	0.38	0.38	78.20
BW5	31.8	6.8	9.9	7.87	4.70	5.42	58.58
BW6	31.2	6.6	1.05	7.93	0.50	0.50	72.60
BW7	31.2	7.2	0.78	7.56	0.38	0.37	2.05
BW8	31.4	7.04	2.62	7.48	1.26	1.31	8.04
BW9	31.4	6.8	13.7	7.08	6.58	7.72	8.70
BW10	31.5	7.1	5.77	7.43	2.77	3.04	69.90
Mean values							

EC = Electrical conductivity, DO = dissolved oxygen, TDS= total dissolved solid, SW = sachet water, BW = bottled water

Table 4: Mean concentrations (mg/L) of selected trace metal ions in commercial sachet (SW) and bottled water (BW) samples

Sample	Fe	Ni	Zn	Cu	Cr
SW1	0.253	0.085	0.256	0.430	0.000
SW2	0552	0.068	0.368	0.325	0.000
SW3	0.279	0.078	0.170	0.316	0.000
SW4	0.249	0.033	0.280	0.221	0.004
SW5	0.259	0.049	0.172	0.267	0.000
SW6	0.901	0.047	0.203	0.276	0.000
SW7	0.350	0.058	0.225	0.330	0.000
SW8	0.469	0.102	0.749	0.388	0.000
SW9	0.270	0.079	0.178	0.191	0.000
SW10	0.282	0.073	0.370	0.461	0.000
Mean concentrations in samples (mg/L)	0.055	0.059	0.280	0.289	0.0004
BW1	3.054	0.150	0.612	1.636	2.533
BW2	2.751	0.087	0.258	0.408	0.061
BW3	2.197	0.114	0.238	0.472	0.076
BW4	1.173	0.090	0.265	0.626	0.026
BW5	1.175	0.076	0.241	0.426	0.028
BW6	1.124	0.064	0.321	0.604	0.000
BW7	0.920	0.092	0.231	0.541	0.000
BW8	0.680	0.055	0.255	0.606	0.083
BW9	3.049	0.135	0.343	0.731	0.022
BW10	1.015	0.066	0.202	0.419	0.000
Mean concentrations in samples (mg/L)	1.714	0.093	0.297	0.647	0.283
WHO acceptable limit (WHO,1996)	0.30	0.020	3.00	5.000	0.050
Nigerian standards for drinking water (mg/L)	0.30	-	3.00	-	0.050
Analytical parameters					
Detection limit (Mg/L)	0.003	0.005	0.006	0.001	0.001
SD	0.000-0.003	0.000-0.001	0.000-0.002	0.000-0.004	0.000-0.004
RSD (%)	0.2791-2103.572	0.7487-120.00	0.0000-15.1100	0.0390-205.905	0.5078-135.959
R^2 value	0.9991	1.0000	0.9999	0.9995	0.9999

are toxic and could cause developmental abnormalities and physiological dysfunctions in fish (Ajibare Adefemi Olatayo, 2014). A high DO level in a community water supply is good as it makes drinking water taste better. The level of DO measured in current study (3.5-7.8mg/l) is considered moderate for all intent and purposes. An inverse correlation of DO with temperature within the range of 0-45^{0}C has been reported in literature (Ana Denisse and Fernando Díaz., 2011) and results of this study quite agree. Plants exhibit variation in their tolerance limit to soil acidity such that plants grown in adverse pH conditions are more often prone to fungal attack and availability of plant nutrients is considerably affected by the soil pH (Gupta et al., 2009). For instance, Ca, K, Mg and Na are alkaline elements which could be lost with increasing acidity (Jianyun Ruan et al. 2007). Extreme acidity can also significantly induce deficiencies of micronutrients such as Mo and Cu, while Mn and Fe may be deficient due to low solubility at high pH, the deficiency of which produces chlorotic conditions of yellowing of leaves and stunted growth (Akhtar Shekafandeh, 2010). In this study, slightly alkaline pH values (7.30-8.5) were reported for borehole and lagoon samples, while a weakly acidic to slightly alkaline value (6.30-7.35) were obtained for sachet and bottled water samples. Even though no health-based guideline value was proposed for pH initially, it is one of the most important operational water quality parameters, as extremes of pH can affect the palatability of water and corrosive effect most especially on copper pipes (Adetoyinbo et al., 2015). The effect of pH on fish is also an important consideration and values which depart increasingly from the normally found levels will have a more marked effect on fish, leading ultimately to mortality. The values of pH in this study (6.30-7.35) were considered suitable for fisheries and also within the acceptable range of 6.5 to 9.0 approved for drinking water (WHO, 2006). The total alkalinity value of water is expressed as the acid neutralizing ability and is determined by how much carbonate, bicarbonate and hydroxide is present. Excess alkalinity can result in unpleasant taste and scale formation and hence alkalinity measurement is important in determining a stream's ability to neutralize acidic pollution from rainfall or wastewater (Orewole et al., 2007). Alkalinity values in this study vary in the order: Lagos lagoon > borehole > bottled > sachet water and were highest for Lagos lagoon water. Lagos lagoon receives effluents from various sources including pharmaceuticals, soap and detergent industry some of which may not have been adequately treated to take care of the effect on the pH and eventually result in the bioavailability of some trace metals in water (Akhtar, 2010). Another influential water quality parameter on crop productivity is the water salinity hazard as measured by electrical conductivity (EC). If water of high EC is applied in irrigation, it results in significant high EC soil conditions which is capable of causing water stress at the root zone of plant, even though the soil may appear wet (Vijaya et al., 2010). Also, a significant effect of high EC on crop productivity is the inability of the plant to compete with ions in the soil solution for water. As a result, plants under water stress often show signs of leaf drooping and loss, which may eventually result in to plant death (Ya Lung Li et al., 2001). In current study, the EC and salinity of water samples were in the order, Lagos lagoon > sachet > bottled > borehole and Lagos lagoon > borehole > bottled > sachet respectively.

Water with EC less than 0.7 mS/cm, as recorded for borehole water samples is considered to be safe, but a relatively higher value as reported for Lagos lagoon and packaged water can be an indicator of concern. TDS are the total amount of mobile charged ions including salts, minerals or metals and some small amounts of organic matter *dissolved* in water. The value of TDS in current study varies in the order: Lagos lagoon > borehole > sachet > bottled water and were below the EPA approved MCL of 500mg/l (USEPA, 2002). It has been reported that high levels of TDS may be caused by the presence of potassium, chlorides and sodium ions and may indicate presence of trace metal ions (Oyhakilome et al., 2012). The relatively low conductivity and TDS values for borehole and packaged water samples in this study reflect freshness of the water source. Recently, most of the water purification systems are being monitored for TDS in order to ensure that filtering membranes are effectively removing unwanted particles and bacteria from water samples to avoid undesirable tastes.

All the metals investigated in this study (Zn, Fe, Cr, Ni and Cu) are important to biological systems at trace levels, For instance, Zn, Cr and Cu supplements is important in proper functioning of immune system and in control of diabetes while Fe and Ni plays major roles in human blood and metabolic processes (Florea et al., 2006). On the other hand, the metals are potentially toxic at high concentrations, for instance, Zn and Cu on accumulation can cause human systemic poisonings, while excess of Fe can result in metabolic acidosis and liver damage (Ochoa-Herrera et al., 2011). Although Cr and Ni are not regarded as cumulative poison, high concentrations could result in allergic reactions and cancers (Ukabiala et al., 2010).

The mean concentration (mg/l) range of trace metals in sachet and bottled water samples (Table 4) are as follows: Fe (0.253-0.901; 0.680-3.054), Zn (0.170-0.749; 0.202-0.612), Cu (0.191-0.461; 0.408-1.636), Cr (0.00-0.004; 0.000-2.533), and Ni (0.033-0.102; 0.055-0.150). The occurrences in samples were in the order: Fe > Cu > Zn > Cr > Ni and results indicated that Fe, Ni, Zn and Cu were detected in all samples, while Cr was detected in 10 and 70% of sachet and bottled water samples respectively. Detection of Fe in all samples is similar to previous studies which reported Fe in high concentrations in some Nigerian soils (Overal et al., 2012). The mean concentrations of Cr, Cu and Ni in this study were higher, while those of Zn and Fe were lower, when compared to similar studies on water samples from Itaogbolu area of Ondo state (Adefemi and Awokunmi, 2010). The analytical parameters for trace metals in water samples are as shown in Table 5. The mean concentrations of Fe, Zn and Cr were higher than WHO approved maximum residual limits (WHO, 2006) in 14, 20 and 4% of samples respectively, while those of Zn and Cu were all below the WHO MRL in all the samples investigated.

Table 5. Atomic absorption characteristics for metal ions in samples

Parameter	Fe	Ni	Zn	Cu	Cr
Number of Samples with detectable metal ions	20	20	20	20	8
% of samples with detectable metal ions	100	100	100	100	40
Minimum conc. of metal ion detected (mg/L)	0.253	0.033	0.170	0.191	0.000
Maximum conc. of metal ion detected (mg/L)	3.054	0.150	0.749	1.636	2.533
WHO maximum allowable limits (mg/L)	0.300	0.020	3.00	2.000	0.050
Number of samples above WHO maximum allowable limits (mg/L)	14	20	0	0	4
% of samples above WHO maximum allowable limits (mg/L)	70	100	0	0	20

Conclusion

The physicochemical characteristics of bottled and sachet water samples indicates a fresh potable water with low chemical burden. The mean concentrations of the trace metals were generally lower in sachet than in bottled water. The Lagos lagoon water contained relatively higher level for suspended solids and salinity both of which could lead to adverse health effects in biological communities and hence need to be properly controlled.

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