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Physico-chemical characteristics and Heavy metal levels in Drinking Water sources in Sokoto metropolis in North-western Nigeria

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ABSTRAC: This study investigated the physico-chemical characteristics of drinking waters collected from tap, well and sachet in Sokoto metropolis in North Western Nigeria. Conductivity and pH values were determined by standard methods while elemental composition was analysed using X-ray Fluorescence spectroscopy. Majority of the water samples had neutral pH (6.80 – 7.20) few were slightly alkaline and one was acidic. Tap water samples had similar conductivity values (180 -190µS/m), sachet water samples had conductivity values ranging from 80µS/m to 260µS/m while well water samples had highest conductivity values with a sample having value above standard limit of 1,500µS/m. Heavy metals (copper and lead), rare earth metals (gallium, rubidium, strontium and vanadium) and other elements (potassium, calcium, chromium, manganese, iron, cobalt, nickel, zinc, arsenic, selenium, bromine and molybdenum) were detected. Result of elemental analysis showed the presence of 18 compounds in the different water samples, of which seven, namely: As, Cr, Mn, Pb, Ni, Se and Br had levels above WHO recommended permissible limits, with their attendant health implications. Generally, all the sampled waters analysed in this study failed chemical tests and therefore not suitable for drinking. @ JASEM

Pollution of water bodies with heavy metals from variety of sources is becoming a matter of global concern (Dike *et al*., 2004). Though effects of chemical contamination of drinking water are not felt on short-term bases (except nitrate), their accumulation over a long period in the body has significant health effects (Musa *et al*., 2004). Sokoto metropolis has been facing a lot of water supply problems, some of which are of great public health significance (Junaidu *et al.*, 2001), and one of such problem is improper treatment of water at the Sokoto Water Works, and broken down pipes among others which buttressed the findings of Ibrahim *et al* (2000) that showed that Sokoto State lacks safe drinking water and has environmental sanitation problem. So far, studies carried out in this environment focused only on the bacteriological quality. Aspects such as chemical contamination of drinking water which have not been investigated is the basis for this study. Therefore, the aim of this research is to characterize the physico-chemical-heavy metal quality of drinking water sources in Sokoto metropolis.

MATERIALS AND METHODS

Study area: The area of study is Sokoto metropolis in north western Nigeria. It has a population of 427,760 by the 2006 National Census. A generally arid region that gradually merges into the desert across the border in Niger republic, it has limited rainfall from mid-May to mid-September and is subjected to the Sahara's harmattan (dry, dust-laden wind) from November to March.

Physico-chemical and Organo-leptic properties of the water samples: Physico-chemical properties such as pH, conductivity and elemental compositions of the water samples were determined at the Centre for Energy Research and Training (CERT), Ahmadu Bello University, Zaria. Colour, taste and odour were observed and recorded while temperature, conductivity and pH values were determined using thermometer (Zeal, England), conductivity meter (LF 90, Wissenschaftliche-Technishen Werkstatten, Weinheim) and pH meter (Jenway, model 3150, U.K.) respectively.

Quantitative determination of metals in the water samples: After the taps were allowed to run for 15-30 seconds, 1-litre sterile containers containing sodium thiosulphate (5mg/litre), to neutralize residual chlorine were used to collect tap water samples from 7 different tap outlets in Sokoto town. 1000ml capacity bottles were used to collect well water samples using local collecting vessel and sachet water samples were bought from 5 different sale points in Sokoto town. All water samples were properly covered (except sachet water samples), carefully labelled and transported to the laboratory in an ice packed cooler for further analysis. Water samples for elemental analysis were preliminarily subjected to acidification. This involved addition of 3 drops of nitric acid to 100ml of each water sample. To the acidified water was added 10% pyrrolidin-1-dithio ammonium carbonate salt (APDC) and allowed to stand for 20-30 minutes. The water was then filtered using membrane filter with the help of a vacuum pump. The precipitate on the filter membrane was allowed to dry and then placed on an Energy Dispersive X-ray Fluorescence (EDXRF) apparatus (Model SL12170, Canberra, Australia) and subjected for analysis. Quantitative analysis of the samples was carried out using the Emission-

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Transmission (E-T) method of Bernasconi *et al*, (1996).

RESULTS AND DISCUSSION

Conductivity, pH, odour and taste of drinking water samples in Sokoto town are presented in Table 1. All the water samples were colourless, odourless and tasteless except water from Sokoto River with its high turbidity and characteristic odour. This river supplies Sokoto Water Board with raw water to be treated and pumped out for consumption of the populace. Majority of the water samples had neutral pH (6.80 - 7.20) except two (T1 and WB (T) which were slightly alkaline while well water sample (W1) was acidic. The high acidity values obtained with the raw water may not unconnected with the presence of heavy metals which is in consonance with the report of Cornish *et al.* (1999) that acidity favours concentration of heavy metal. Conductivity values showed that tap water samples had similar values (180 - 190µS/m). Sachet water samples had variable conductivity values, ranging from 80µS/m to 260µS/m, depending on the brands. Higher and more variable conductivity values were obtained with the well water samples (290 – 1,990µS/m). The conductivity value of one of the well water samples (W2) was above the standard limit of 1,500µS/m set by Radojevic and Bashkin (1999).

Table 1: Organo-leptic Properties, pH and Conductivity Values of Water Samples in Sokoto Metropolis.

S/N	Sample	Colour	Odour	Taste	Tempt (°C)	Conductivity (µS/m)	pH
1	T1	Colourless	Odourless	Tasteless	26	190	7.45
2	T2	,,	,,	,,	26	180	7.16
3	T3	,,	,,	,,	27	180	6.93
4	WB ®	Brownish	,,	,,	27	120	7.10
5	WB (T)	Colourless	,,	,,	27	180	7.31
6	W1	,,	,,	,,	27	350	6.07
7	W2	,,	,,	,,	26	1990*	6.69
8	W3	,,	,,	,,	27	950	6.89
9	W4	,,	,,	,,	27	290	6.85
10	W5	,,	,,	,,	26	250	7.13
11	PW1	,,	,,	,,	27	120	7.18
12	PW2	,,	,,	,,	27	80	7.24
13	PW3	,,	,,	,,	27	210	6.81
14	PW4	,,	,,	,,	27	110	6.92
15	PW5	,,	,,	,,	27	260	6.88

*T =Tap water; W = Well water; PW = Pure (sachet) water ; WB® = Raw water from Sokoto Water Board; WB(T) = Treated water from Sokoto Water Board * = Level above allowable limit.*

Result of the EDXRF elemental analysis of the water samples is shown in Tables 2 to 4. Table II showed the concentrations of the various elements in tap water samples. As depicted in this table, eighteen elements, consisting of heavy metals (copper and lead), rare earth metals (gallium, rubidium, strontium and vanadium); other elements (potassium, calcium, chromium, manganese, iron, cobalt, nickel, zinc, arsenic, selenium, bromine and molybdenum) were detected. Of these elements, seven namely chromium, manganese, nickel, arsenic, selenium, lead and bromine had concentrations above the WHO (2003) allowable limit. Processing of the raw water at the treatment plant (Water Works) did not significantly affect the level of the elements. High concentration of heavy metals and other elements in tap water must have occurred as a result of irregular or intermittent supply of tap water, leading to drying and rusting of the distribution pipes and pollution of the flowing water with dirt and constituent metals from rust which is in agreement with findings of Yakasai *et al*, (2004).

The elemental composition of the well water samples and their concentrations presented in Table III was similar to observations made with respect to tap water samples and also to that of sachet (pure) water as presented in Table IV. However, molybdenum levels in two of the five sachet water samples tested were also above WHO recommended levels. The presence of heavy metals and other elements in relatively high concentrations in these drinking waters is not unusual as presence of heavy metals have been reported in drinking waters in the same geographical zone (Jeb, 1996; Udeh, 1997).

Table 2: Levels of Various Chemicals in Tap Water Samples in Sokoto Metropolis

Element	Concentration (ppm)					WHO Acceptable limit (mg/L) [2003]
	T1	T2	T3	WB(R)	WB(T)	
Potassium (K)	6.500	4.300	6.000	5.500	3.700	NP
Calcium (Ca)	4.600	3.300	3.900	3.900	4.100	NP
Vanadium (V)	1.000	0.920	0.970	0.920	0.850	NG
Chromium (Cr)	0.680	0.650	0.700	0.800	0.850	0.05
Manganese (Mn)	0.670*	0.800*	0.550*	0.550*	0.510*	0.40
Iron (Fe)	0.510	0.460	0.550	0.420	0.500	NH
Cobalt (Co)	0.370	0.370	0.440	0.380	0.340	NG
Nickel (Ni)	0.300*	0.290*	0.310*	0.320*	0.460*	0.02
Copper (Cu)	0.250	0.260	0.260	0.230	0.250	2.00
Zinc (Zn)	0.200	0.220	0.200	0.240	0.190	NH
Gallium (Ga)	0.190	0.180	0.290	0.170	0.230	NG
Arsenic (As)	0.220*	0.280*	0.230*	0.240*	0.250*	0.01
Selenium (Se)	0.140*	0.140*	0.120*	0.150*	0.140*	0.01
Lead (Pb)	0.300*	0.390*	0.310*	0.340*	0.350*	0.01
Bromine (Br)	0.120*	0.100*	0.100*	0.097*	0.110*	0.01
Rubidium (Rb)	0.120	0.110	0.096	0.092	0.089	NG
Strontium (Sr)	0.091	0.110	0.091	0.085	0.085	NG
Molybdenum (Mo)	0.061	0.058	0.062	0.061	0.060	0.07

* = Level above acceptable limit NG = Not mentioned in the WHO Guideline

NP = No value is proposed. NH = Not of health concern at levels found in drinking-water

The high levels of undesired and potentially toxic elements in various drinking waters in Sokoto town are matters of great concern. Appropriate agencies of Sokoto State Government needs to take some remedial steps that would ensure that drinking water sources available for the community are rendered safe.

Table 3: Levels of Various Chemicals in Well Water Samples in Sokoto Metropolis

Element	Concentration (ppm)					WHO Acceptable limit (mg/L) [2003]
	PW1	PW2	PW3	PW4	PW5	
Potassium (K)	5.700	3.700	3.900	4.100	8.300	NP
Calcium (Ca)	6.400	3.200	3.700	3.500	6.200	NP
Vanadium (V)	1.100	0.840	1.000	0.920	1.400	NG
Chromium (Cr)	1.300*	0.790*	0.670*	0.720*	1.500*	0.05
Manganese (Mn)	0.930*	0.510*	0.550*	0.550*	1.200*	0.40
Iron (Fe)	0.580	0.550	0.610	0.580	0.720	NH
Cobalt (Co)	0.530	0.470	0.340	0.430	0.580	NG
Nickel (Ni)	0.460*	0.280*	0.260*	0.310*	0.470*	0.02
Copper (Cu)	0.290	0.400	0.250	0.250	0.510	2.00
Zinc (Zn)	0.250	0.190	0.180	0.210	0.340	NH
Gallium (Ga)	0.230	0.260	0.160	0.180	0.300	NG
Arsenic (As)	0.300*	0.210*	0.250*	0.220*	0.380*	0.01
Selenium (Se)	0.170*	0.150*	0.130*	0.150*	0.250*	0.01
Lead (Pb)	0.430*	0.310*	0.360*	0.300*	0.540*	0.01
Bromine (Br)	0.120*	0.130*	0.140*	0.100*	0.180*	0.01
Rubidium (Rb)	0.120	0.100	0.089	0.120	0.160	NG
Strontium (Sr)	0.110	0.084	0.093	0.088	0.150	NG
Molybdenum (Mo)	0.085*	0.069	0.061	0.060	0.097*	0.07

Key: NP = No value is propose. NH = Not of health concern at levels found in drinking-water

* = Level above acceptable limit. NG = Not mentioned in the WHO Guideline.

Table 4: Levels of Various Chemicals in Sachet (Pure) Water Samples in Sokoto Metropolis

Element	Concentration (ppm)					WHO Acceptable limit (mg/L) [2003]
	W1	W2	W3	W4	W5	
Potassium (K)	4.400	3.400	3.500	3.800	4.200	NP
Calcium (Ca)	3.000	2.900	2.700	3.900	3.300	NP
Vanadium (V)	0.860	1.100	0.850	0.820	0.990	NG
Chromium (Cr)	0.860*	0.660*	0.680*	0.630*	0.700*	0.05
Manganese (Mn)	0.720*	0.600*	0.510*	0.550*	0.630*	0.40
Iron (Fe)	0.430	0.530	0.410	0.650	0.460	NH
Cobalt (Co)	0.320	0.370	0.320	0.430	0.370	NG
Nickel (Ni)	0.280*	0.290*	0.260*	0.360*	0.320*	0.02
Copper (Cu)	0.270	0.250	0.220	0.250	0.280	2.00
Zinc (Zn)	0.180	0.180	0.240	0.190	0.220	NH
Gallium (Ga)	0.170	0.250	0.210	0.170	0.190	NG
Arsenic (As)	0.230*	0.230*	0.190*	0.250*	0.240*	0.01
Selenium (Se)	0.120*	0.120*	0.120*	0.120*	0.150*	0.01
Lead (Pb)	0.320*	0.330*	0.270*	0.350*	0.330*	0.01
Bromine (Br)	0.098*	0.110*	0.100*	0.099*	0.100*	0.01
Rubidium (Rb)	0.094	0.110	0.089	0.089	0.100	NG
Strontium (Sr)	0.078	0.079	0.097	0.090	0.091	NG
Molybdenum (Mo)	0.056	0.052	0.072	0.056	0.062	0.07

NP = No value is proposed. NH = Not of health concern at levels found in drinking-water
* = Level above acceptable limit. NG = Not mentioned in the WHO Guideline.

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