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Analysis of Trace Metals and Heavy Metals in Sachet and Bottled Water Samples Obtained in Borno State, Nigeria

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Abstract: *Different natural and anthropogenic global events and activities such as urban settlements and industrial development have led to a build-up of numerous pollutants in the environment, creating problems for nature and human health. The provision of safe drinking water is a very important public health priority. Most of the diseases in developing countries are caused by the consumption of contaminated water. The concentrations of six heavy metals and six trace metals were determined in sachet water samples and bottled water samples obtained in Maiduguri markets, Nigeria using Atomic Absorption Spectrophotometry (AAS). Lead concentrations were below the maximum permissible levels except in sample V, sample B, sample Fand sample K. Cadmium was not found in most of the water samples except in sample G, sample J and sample K together with sample W. These levels were above the maximum permissible levels of the WHO. Chromium was found present in all the water samples analyzed although in trace amounts. All other heavy metals analyzed were below the maximum permissible levels. The water samples also contained iron, manganese, calcium, magnesium, sodium and potassium in concentrations that are not harmful to the body. Examination of heavy metals in the water samples showed traces of lead in five sachet water samples and seven bottle water samples together with cadmium in three sachet water samples and three bottled water samples. This may be harmful after being consumed for a long time by the populace.*

Keywords: *Concentration, heavy metals, bottle water, sachet water, WHO.*

Introduction

The increasing accumulation of trace metals and heavy metals water supply chain is a major cause of public health concern. Their high density and non-biodegradable nature make heavy metals, the potent and most challenging environmental contaminants (WHO, 2011). Water is a very essential component of our environment. The provision of safe drinking water is an important public health priority (WHO/UNICEF, 2012). Water in its purest form is odorless, tasteless and colorless. Most of the diseases in developing countries are caused by the consumption of polluted water (Zuthi *et al*., 2009). Over one thirds of deaths in most developing countries are caused by water pollution (Chang *et al*., 2010). Water is necessary for the proper functioning of the human body. About 70% of the human body is made up of water. Potable water is good quality water that has neither smell nor odor and can be taken with no risk of harm (WHO, 2008). Water is a very important component of biochemical processes in the body. Drinking water should conform to standards set by the World Health Organization. Water is a life sustaining drink and it is essential for the survival of all organisms. It is a very important part of metabolic process and it is involved in most biological processes (Hassan and Karzan, 2013). The consumption of water containing toxic chemicals leads to damages in the human body. The metals can accumulate in the human body and poses serious health risks to the people consuming such unwholesome water (WHO, 2011). Water can be rendered undrinkable if its physical qualities are undesirable. Due to this fact, the assessment of drinking water quality and its continuous monitoring are of utmost importance.

Most of the people living in developing countries lack access to clean water due to environmental pollution (Gyamfi *et al.,* 2012). It is the right of every individual to have access to safe drinking water. The presence of heavy metals in drinking water leads to many diseases in the human populace (Al-Saleh and Al-Doush, 1998). Heavy metals are metals that have atomic weights of more than 40. They include arsenic, cadmium, lead, mercury, etc. They do not easily break down once they are in the environment and they have toxic effects on plants and human beings (Kumar *et al*., 2014). Chromium found in water is usually in the hexavalent form which is carcinogenic and highly toxic (WHO, 2004). Lead has no essential function in man and it can be found occurring as metallic lead, lead salts and lead inorganic ions. Food and water are one of the major sources of lead exposure. In humans, about 20-50% of inhaled lead is absorbed while about 5-15% of ingested inorganic lead is absorbed. Once in the blood stream, lead is distributed among the soft tissue, mineralizing tissue and blood. Children are more sensitive to lead because of their rapid growth rate and metabolism (ATSDR, 2008).

Cadmium is naturally present in the environment in soils, the air sediments and sea water. It is emitted into the air by industries using cadmium compounds for pigments, batteries, plastic alloys, etc. (Khan, 2011). People are exposed to cadmium when consuming plant and animal based foods, together with sea foods (WHO, 2006). Cadmium accumulates in the human bodies and it affects the lungs, liver, kidney, brain central nervous system, etc. Other damages include hepatoxic toxicity, reproductive, hematological and immunological toxicities (Apostoli and Catalini, 2011). The WHO guideline for cadmium in drinking water is 0.003 mg/L (WHO, 2004).

Trace metals in minute amounts are essential in the human body because of their involvement in many processes within the human bodies. At higher concentrations, they are associated with increased risks for diabetes, cancer, liver disease, heart disease, endocrine disease, etc. (Couto *et al*., 2014). Trace metals leak into groundwater from natural and anthropogenic sources thereby rendering them undrinkable (Khan, 2011).

One of the UN Millennium Development Goals is to reduce by half, the proportion of people without sustainable access to safe drinking water by the year 2015. The UN convention on the Rights of the child stipulates that all children have the right to safe drinking water (WHO/UNICEF, 2012). The presence of heavy metals or trace metals in water renders it unfit for human consumption. This may lead to accumulation of these metals in the body (UNEP, 2007)].

Trace metals in minute amounts are essential in the human body because of their involvement in many processes within the human body. At high concentrations, they are associated with increased risks for diabetes, cancer, liver disease, endocrine diseases etc. (Buschmann *et al.*, 2008; Sing and Mosely, 2003). Trace metals leak into the ground water from natural and anthropogenic sources and render them undrinkable.

Materials and Methods

Sampling

Fifteen bottled water samples and ten sachet water samples were randomly purchased from different markets in Maiduguri, Nigeria.

pH: The pH of all the water samples was determined using the pH meter and the values recorded.

Heavy metal analysis

100 ml of each water sample were acidified with 20 ml of nitric acid. The mixture was digested in a fume cupboard for one hour at 100ºC until a clear solution was seen and the volume reduces to

20 ml. The mixture was transferred to 100 ml volumetric flask and diluted with deionized water and the mixture made up to 100 ml mark.

The mixture was filtered with filter paper after cooling and analyzed for lead, copper, chromium, calcium, zinc, nickel and cobalt using the Atomic Absorption Spectrophotometer (AAS).

Results

Results found after performing the above methods are shown below (Tables 1-6).

Discussion

Heavy metals enter the environment via natural and anthropogenic means. Such sources include industrial discharges, mining, erosion, sewage discharge water, waste effluents etc. the main route of exposure for most people is through food and water. Consistent exposure to heavy metals at low levels can cause great adverse effects (WHO, 2008; ASTDR, 2008; Mudgal *et al*., 2010).

Bottled Water Samples	**Labelling**	**pH**
Nestle	A	6.76
Eva	B	6.80
Mowa	C	6.21
Cway	D	6.78
Cfresh	E	6.81
Swan	F	6.02
Risbon	G	5.60
Pop	H	5.90
Faro	I	6.30
C’est Bon	J	5.68
Rufaidah	K	5.90
Aqua	L	6.70
Sunar	M	6.83
Aquafina	N	6.76
Evian	O	6.21

Standard pH: 6.5 - 8.5

Table 1: pH of the Bottled Water Samples.

Sachet Water Samples	Labelling	pH
Kuru	Q	6.81
Qatar	R	5.28
Rampoly	S	6.10
Feel Free	T	6.60
Zaimah	U	5.78
Sadu	V	6.36
Mashidimami	W	6.84
Rahama	X	5.77
Unimaid	Y	6.86
Modube	Z	6.90

Standard pH: 6.5 - 8.5

Table 2: pH of the Sachet Water Samples.

Heavy metals have toxic effects on humans, animals, fisheries and plants (Bolawa *et al.,* 2014; Bolawa and Gbele, 2013; Camacho *et al*., 2011; Azizullah *et al*., 2011). They are persistent in the environment and they bioaccumulate in plants and human beings (WHO, 2006; Mridul and Prasad, 2013; Castro-Gonzalez and Mendez-Armenta, 2008). From the analysis carried out on the water samples, it was discovered that lead levels in the sample were within WHO limits with the exception ofsample V, sample B, sample F and sample K. Lead was not detected at all in sample Q, U, W, X, Y, G, H, I, J and L. Out of the fifteen bottled water samples analyzed, cadmium was only detected in four water samples. Nickel and Copper levels were below the WHO permissible limits with the exception of sample B which had a nickel value of 0.06 mg/ml. Zinc level was above the WHO permissible limit in only sample L.

Children are more sensitive to lead because of their rapid growth rate and metabolism (Nwabueze, 2010; Ling *et al.*, 2009). Cadmium is naturally present in the environment in soils, air, sediments and in sea water. It is emitted into the air by industries using cadmium compounds for pigments, plastics, alloys etc. People are exposed to cadmium when consuming plant and animal based foods, together with sea foods (Medairos *et al.,* 2012). Cadmium accumulates in the human body and it affects the lungs, liver, kidney, brain, central nervous system etc. Other damages include hepatic toxicity, reproductive, hematological and immunological toxicities (Mudgal *et al.,* 2010). The WHO Maximum Permissible Level for cadmium in drinking water is 0.003 mg/l (Medairos *et al.*, 2012).

For the trace metals analyzed, iron was present in all the drinking water samples and it was below the permissible limits with the exception of sample L. Manganese concentration was high in sample S, R, B, C and G.

Previous studies have shown iron concentrations to be in high levels in ground and drinking water. The excess concentrations of iron in ground water may be due to the dissolution of rocks into the water system [(Shyamala *et al.*, 2008). High levels of iron in drinking water may alter the appearance, taste, odor of water and may even promote the growth of bacteria in the water system. Copper is a potent neurotoxin and it accumulates in soft tissues and bones after prolonged exposure. The supply of water through piped water system leads to copper water pollution. High levels of copper in drinking water can cause vomiting, chronic anemia, abdominal pain, nausea, diarrhea, etc. Hussain *et al*. (2012), collected water samples to determine the concentrations of metals such as nickel, lead, chromium, cadmium, zinc and copper. The concentrations of heavy metals found in drinking water samples ranged from 0.01 0.10 mg/ml (nickel), 0.00-0.03 mg/ml (lead), 0.01-0.02 mg/ml (chromium), 0.01-0.16 mg/ml (zinc) and 0.00-0.01 mg/ml (copper). These results are similar to the results gotten in this study, with the exception of zinc concentrations which was higher in this study. The water of Mardan tube well can only be fit for drinking after magnesium is removed by boiling the water. Mebrahthu et al. (2011) showed that concentrations of heavy metals in drinking water samples collected from Northern Ethopia have some physiochemical parameter values higher than WHO recommended limits. Samples analyzed showed that arsenic, cadmium, chromium, iron, nickel and lead were above the WHO Maximum Permissible Limits.

Samples	Pb (mg/L)	Ni (mg/L)	Cd (mg/L)	Cr (mg/L)	Cu (mg/L)	Zn (mg/L)
Q	ND	0.01 ± 0.04	ND	0.05 ± 0.02*	0.04 ± 0.03	0.36 ± 0.07
R	0.01 ± 0.02	0.01 ± 0.01	ND	0.01 ± 0.01	0.02 ± 0.01	0.33 ± 0.05
S	0.01 ± 0.01	0.01 ± 0.02	ND	0.01 ± 0.01	0.02 ± 0.04	1.49 ± 0.06
T	0.01 ± 0.02	0.01 ± 0.01	ND	0.01 ± 0.03	0.03 ± 0.03	0.74 ± 0.09
U	ND	ND	ND	0.01 ± 0.02	0.01 ± 0.01	0.43 ± 0.08
V	0.02 ± 0.03	0.02 ± 0.04	ND	0.01 ± 0.01	0.02 ± 0.02	1.43 ± 0.07
W	ND	0.01 ± 0.02	0.01 ± 0.01*	0.01 ± 0.03	0.02 ± 0.04	1.42 ± 1.09
X	ND	ND	ND	0.01 ± 0.01	0.17 ± 0.09	1.00 ± 0.08
Y	ND	0.01 ± 0.02	ND	0.01 ± 0.01	0.03 ± 0.06	1.33 ± 1.86
Z	0.01 ± 0.03*	ND	ND	0.01 ± 0.02	0.02 ± 0.06	2.17 ± 1.98*
WHO STANDARD	0.01	0.02	0.003	0.05	2.00	3.00

*p>0.05

Table 3: Concentration of heavy metals in sachet water samples.

Samples	Pb (mg/L)	Ni (mg/L)	Cd (mg/L)	Cr (mg/L)	Cu (mg/L)	Zn (mg/L)
A	ND	0.02 ± 0.01	ND	0.01 ± 0.01	0.03 ± 0.04	1.33 ± 0.42
B	0.03 ± 0.02	0.06 ± 0.09*	ND	0.01 ± 0.01	0.03 ± 0.02	1.26 ± 0.52
C	0.01 ± 0.01	0.01 ± 0.02	ND	0.01 ± 0.01	0.02 ± 0.01	2.09 ± 0.88*
D	0.01 ± 0.01	0.01 ± 0.01	ND	0.02 ± 0.02*	0.02 ± 0.02	1.30 ± 0.47

E	0.01 ± 0.01	0.01 ± 0.01	ND	0.01 ± 0.02	0.02 ± 0.01	0.78 ± 0.55
F	0.02 ± 0.03*	0.01 ± 0.02*	ND	0.01 ± 0.01	0.03 ± 0.05	0.78 ± 0.52
G	ND	0.01 ± 0.01	0.001 ± 0.001	ND	0.01 ± 0.01	1.43 ± 0.99
H	ND	ND	ND	0.01 ± 0.01	0.03 ± 0.02	1.27 ± 0.78
I	ND	ND	ND	ND	0.01 ± 0.01	1.31 ± 0.78
J	ND	0.003 ± 0.001	0.01 ± 0.01*	0.01 ± 0.01	0.02 ± 0.01	0.79 ± 0.52
K	0.02 ± 0.01*	0.01 ± 0.01	0.01 ± 0.01*	0.01 ± 0.01	0.06 ± 0.08*	5.04 ± 0.97*
L	ND	ND	ND	0.01 ± 0.02	0.04 ± 0.06*	8.23 ± 0.89*
M	0.01 ± 0.01	0.01 ± 0.01	ND	0.01 ± 0.01	0.03 ± 0.02	2.29 ± 0.57
N	ND	0.01 ± 0.01	ND	0.02 ± 0.01	0.05 ± 0.03	0.28 ± 0.33
O	0.01 ± 0.01	0.01 ± 0.01	ND	0.01 ± 0.02	0.02 ± 0.01	0.78 ± 0.55
WHO STANDARD	0.01	0.02	0.003	0.05	2.00	3.00

*p>0.05

Table 4: Concentration of heavy metals in bottled water samples.

Samples	Fe (mg/L)	Mn (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)
Q	0.10 ± 0.09	0.07 ± 0.06	6.60 ± 1.47	0.14 ± 0.30	99.50 ± 10.03	9.84 ± 1.67
R	0.08 ± 0.36	0.45 ± 0.12*	3.93 ± 1.94	0.12 ± 0.53	98.37 ± 17.11	4.59 ± 1.44
S	0.08 ± 0.88	0.60 ± 0.47*	7.07 ± 1.40	0.13 ± 0.69	121.15 ± 14.00	3.60 ± 1.72
T	0.16 ± 0.21*	0.30 ± 0.22	10.81 ± 1.99*	0.14 ± 0.22	130.05 ± 15.87	1.64 ± 1.33
U	0.01 ± 0.01	0.06 ± 0.53	1.09 ± 1.01	0.14 ± 0.16	100.45 ± 13.66	0.99 ± 1.01
V	0.15 ± 0.31*	0.04 ± 0.03	13.75 ± 1.68*	0.15 ± 0.39*	155.15 ± 14.72*	1.95 ± 1.76

W	0.07 ± 0.57	0.08 ± 0.08	11.96 ± 1.45	0.13 ± 0.44	188.45 ± 17.99*	3.32 ± 1.49
X	0.05 ± 0.48	0.04 ± 0.05	8.09 ± 1.55	0.14 ± 0.28	100.15 ± 14.68	4.65 ± 1.44*
Y	0.07 ± 0.62	0.07 ± 0.09	18.51 ± 1.73*	0.16 ± 0.71*	194.55 ± 12.77*	2.38 ± 1.79
Z	0.18 ± 0.29*	0.08 ± 0.07	17.73 ± 1.33*	0.13 ± 0.47	120.15 ± 15.32	1.67 ± 1.22
MCL	0.30	0.40	-	-	200.00	10.00

*p>0.05

Table 5: Concentration of trace metals in sachet water samples

It is therefore advisable for manufacturers of drinking water either in sachet or bottle form to treat the water using iron filters before packaging them (WHO, 2011). Trace metals are required by the body in small amount for various metabolic activities but at high concentrations, they can cause adverse effects to the body. On the other hand, toxic metals have no beneficial effects in humans. Exposure to them leads to toxic human health effects (Buschmann *et al*., 2008).

Samples	Fe (mg/L)	Mn (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)
A	0.06 ± 0.03	0.08 ± 0.77	8.53 ± 1.02	0.16 ± 0.88*	97.15 ± 12.33	7.95 ± 1.08*
B	0.09 ± 0.05	0.49 ± 0.13*	2.10 ± 1.01	0.14 ± 0.25	101.95 ± 15.66	5.97 ± 1.06*
C	0.09 ± 0.08	0.53 ± 0.11*	33.59 ± 1.80*	0.15 ± 0.41	101.55 ± 16.87	4.98 ± 1.22
D	0.09 ± 0.06	0.40 ± 0.16*	6.29 ± 1.22	0.16 ± 0.10*	129.45 ± 13.99	3.26 ± 1.02
E	0.08 ± 0.09	0.06 ± 0.12	7.52 ± 1.53	0.17 ± 0.12*	121.15 ± 16.25	1.07 ± 1.00
F	0.18 ± 0.05	0.02 ± 0.03	6.10 ± 1.32	0.15 ± 0.14	164.65 ± 19.20*	1.21 ± 1.01
G	0.09 ± 0.07	0.46 ± 0.13*	14.95 ± 1.88*	0.15 ± 0.13	178.75 ± 16.47*	3.66 ± 1.20
H	0.06 ± 0.03	0.06 ± 0.04	5.93 ± 1.10	0.14 ± 0.11	95.30 ± 10.04	2.13 ± 1.09
I	0.06 ± 0.05	0.07 ± 0.08	10.22 ± 1.98	0.16 ± 0.18*	145.75 ± 19.72*	5.98 ± 1.53*
J	0.06 ± 0.05	0.05 ± 0.02	7.36 ± 1.33	0.17 ± 0.12*	178.15 ± 13.98*	1.78 ± 1.52
K	0.28 ± 0.12	0.09 ± 0.06	11.25 ± 1.79*	0.13 ± 0.19	110.95 ± 10.88	1.75 ± 1.88
L	0.40 ± 0.11	0.06 ± 0.02	7.19 ± 1.68	0.14 ± 0.15	117.15 ± 12.57	2.27 ± 1.05
M	0.18 ± 0.13	0.07 ± 0.04	7.55 ± 1.66	0.16 ± 0.14	156.50 ± 12.89*	2.23 ± 1.00
N	0.06 ± 0.03	0.06 ± 0.04	5.93 ± 1.10	0.14 ± 0.11	95.30 ± 10.04	2.13 ± 1.09
O	0.22 ± 0.12*	0.08 ± 0.05	8.13 ± 1.99	0.14 ± 0.14	110.45 ± 14.01	1.11 ± 1.01
WHO STANDARD	0.30	0.40	-	-	200.00	10.00

*p>0.05

Table 6: Concentration of trace metals in bottled water samples.

Conclusion

It is recommended that all water samples intended for drinking purposes should be treated considerable to reduce the levels of heavy metals and trace metals present in to them to levels that are not harmful to the human body.

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