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Determination of heavy metals concentration in some sachet water commonly in Abuja Municipal Council, Nigeria

Abejide Olugbenga[1], Umar Ibrahim[2], Abdullahi Mundi[2] and Yusuf S. D[2]

[1*]Department of Authorization and Enforcement, Nigerian Nuclear Regulatory Authority.
[2] Department of Physics, Nasarawa State University, Keffi, Nasarawa State, Nigeria.

**Corresponding author: gabejide@yahoo.com*

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Abstract

The aim of the study was undertaken to assess heavy metal concentration in some sachet water commonly consumed in Abuja Municipal Council, Nigeria. This was done by measuring heavy metal concentration using Atomic Absorption Spectrometer at the advance chemistry laboratory, Sheda Science and Technology Complex (SHETSCO), FCT, then estimating carcinogenic and non carcinogenic exposure, contamination factor, degree of contamination and pollution load index. The samples were all obtained randomly within Abuja Metropolis. The carcinogenic and non- carcinogenic exposure are far less than 1. The concentration of the heavy metals in sachet water for Cd, Mn, Pb, Cu and Zn are 0.019 mg/l, 0.173 mg/l, 0.219 mg/l, 1.250 mg/l and 0.0760 mg/l respectively. The value of Cd, Pb exceed the recommend standard of 0.01 set by WHO (2008) while the concentration of Mn, Cu and Zn are below the permissible limit of 0.5 mg/l, 2 mg/l and 5 mg/l. The estimated heavy metal risk resulting from exposure to Cd and the estimated concentration of Pb in this study, was higher than the acceptable limit range provided by WHO. This indicates adverse health effects for people who consume sachet water in Abuja municipal council.

Keywords Heavy metals, Atomic Absorption Spectrometer, Contamination factor, Contamination Degree, Pollution Load Index

INTRODUCTION

In Nigeria, sachet water commonly refers to as ‘pure water’ has over the years become the main source of drinking water in towns and cities. This is partly due to the growing awareness that the consumption of unsafe or untreated drinking water is the cause of many diseases especially water-borne diseases. The National Agency for Food and Drug Administration and Control (NAFDAC) has formulated sachet drinking water quality standards and has been enforcing the standards. The standards emphasize the physio-chemical parameters (non-radioactive contaminants) at the expense of natural activity concentration limits [1]. Heavy metals could be released into the environment either through natural or anthropogenic sources [6]. Heavy metals can enter a water supply by industrial and consumer waste, or even from Heavy metals are a class of metallic elements which are abundant in earth’s crust. Heavy metal contamination has been a serious concern throughout the world. Humans may require trace amounts of heavy metals such as copper and zinc.

Unfortunately, these metals can be dangerous at high levels. Heavy metal accumulation at higher levels can result even in death. Heavy metal toxins contribute to a variety of adverse effects [10]. Urbanization and industrialization are one of the main indices of national and global development, but sometimes, while it enhances the quality of life, it also poses serious threats to the management of the natural ecosystem and public health [11]. Evaluation and understanding of the sources and impacts of the effects of heavy metals and physicochemical parameters of water is important for effective water management and preservation of water sources. The assessment of water quality is therefore a vital tool to manage water resources within a particular catchment [2]. Heavy metals such as Cd, Cr, Co, Hg, Ni, Pb, Zn etc in drinking water containing has bad effects on human health and its concentration in water may be due to anthropogenic and geogenic sources. The geogenic sources of metals include ore deposits, rocks and volcanic activities while Heavy metals comprising Hg, Pb, Cd, Co, Zn, Cr and Ni are harmful to human health [5]. Many developing countries suffer from either clean water shortages or the easily available water resources are contaminated. The improper increase in population growth badly suffers insufficient and poor water resources or poor water sanitation system will increase diseases relevant to water [9].

MATERIALS AND METHODS

Study Area

The study involved two (2) samples per brand of twenty (20) different sachet water obtained from within Abuja metropolis, Federal Capital Territory, Nigeria. The maps of the study area is shown in Figure 1

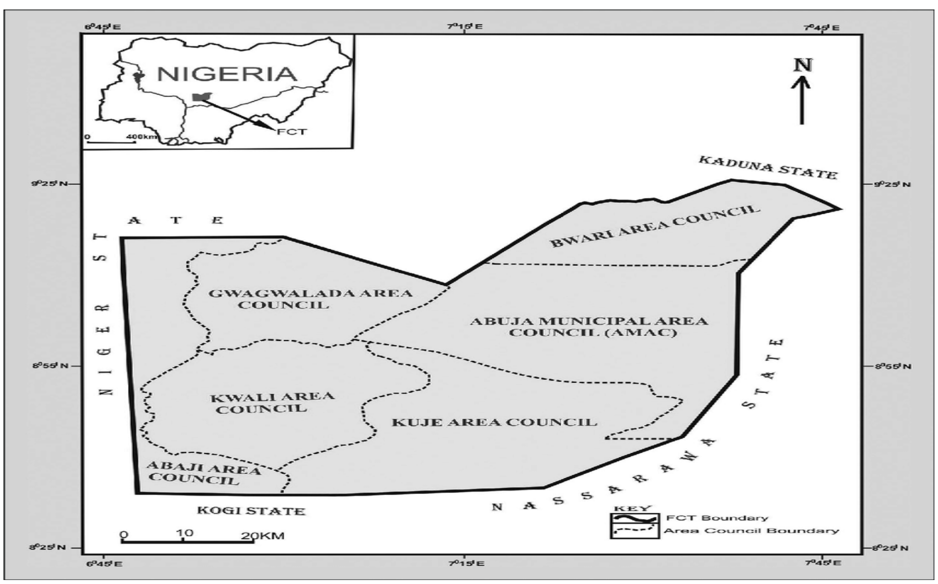

Figure 1.

METHOD OF SAMPLE COLLECTION

Samples of water was collected directly into 100ml bottles after washing the containers properly and rinsed with the water sample collected. The water sample bottles were shaken thoroughly in their plastic containers by use of hand. A volume of 100 ml of the sample was measured using a 100 ml volumetric flask and put in a conical flask

Method of Sample Preparation

At SHETSCO, 20ml of the sample were measured into a clean beaker and about 5ml of concentrated HNO_3 was added in order to digest any biological material. Distilled deionized water was added to the 5ml of HNO_3 to serve as a control. . The digested solution was analyzed for metal of interest using iCE 3000 thermo Scientific Atomic Absorption Spectrophotomer with specific hallow cathode lamp for each of the metal. Concentrations of different metal in the digest sample were later determined by corresponding standard calibration curves obtained by using standard grade solutions of the elements.

Carcinogenic and Non -carcinogenic health risk

The average daily dose potential toxic element for children via ingestion exposure route equation was applied.

$$\text{ADD ingestion} = C_W \times DI \times ABS \times EF \times \frac{ED}{BW \times AT} \qquad 1.0$$

where, ADD ingestion (mg/kg) represents the exposure dose through ingestion, Cw is the mean concentration of the trace elements in water (mg/L); DI is both direct and indirect intake rate of drinking water (1 L day for the child), ED is the exposure duration (6 years for the child), EF is the exposure frequency to pollutants (365 days/year), BW represents the total body weight (15 kg for the child), AT is equal to ED×365 for non-carcinogenic risk, which is 2190 for the child . For carcinogenic risk, AT is the average life expectancy of people, which is 70×365 = 25550 for both the child

Contamination Factor (CF)

Contamination factor (CF) is used to assess contamination level in relative to average concentration of the respective heavy metals in the environment [7]. The mathematical expression in equation 2 was used for calculating the Contamination Factor:

$$CF = \frac{C_m}{C_{ref}} \qquad 2.0$$

Where C_m = mean concentration of the heavy metal in the water sample
C_{ref} = reference concentration of the metal

If the values of 'CF < 1', '1 ≤ CF <3','3 ≤ CF < 6 and 'CF ≥ 6 it indicates 'low risk', 'moderate risk', 'considerable high risk', and 'very high risk'[4][8].

Contamination Degree (CD)

Contamination Degree (CD) is sometimes known as degree of contamination. CD is sum of all contamination factors which provides information about total contamination in a particular sampling location [11] and it is shown in table 4 below

Contamination degree is often expressed as:

$$CD = \sum CF_{Cd} + CF_{Mn} + CF_{Pb} + CF_{Cu} + CF_{Zn} \qquad 3.0$$

Where CF_{Cd}, CF_{Mn}, CF_{Pb}, CF_{Cu} and CF_{Zn} were contamination factors for Cadmium, Magnese, Lead, Copper and Zinc respectively. If 'CD < 8', '8 ≤ CD < 16', '16 ≤ CD < 32 and 'CD ≥ 32' it indicates 'low risk', 'Moderate risk', 'considerable high risk'

Pollution Load Index (PLI)

The basis of determining the pollution load is to estimate the extent of heavy metals pollution in sachet water samples in comparison to its reference acceptable limits with WHO standards. The expression given in equation 4.0 was used for calculating the pollution load index (PLI) base on the toxic heavy metals detected with a view of determining the suitability of sachet water for human consumption

$$PLI = (CF_1 \times CF_2 \times CF_3 \times CF_4 \ldots\ldots\ldots\ldots \times CF_n)^{1/n} \qquad 4.0$$

Where,

n = Number of metals considered in the study

CF = Contamination Factor for each individual metal

If ‘PLI < 1’, 1< PLI< 2’, ‘2 < PLI < 3’ and PLI > 3’, it indicates ‘No Pollution’, ‘Moderate Pollution’, ‘Heavy Pollution’, and ‘Extremely Heavy Pollution’ respectively

RESULTS AND DISCUSSION

Mean concentration of Heavy metals in sachet water

The heavy metals concentration in twenty (20) sachet water was also evaluated using atomic absorption spectrum and presented in Table 1. The Cadmium concentration ranged from 0.0090 mg/l to 0.049mg/l with an average value of 0.189 mg/L. The maximum value was observed in A1 sachet water with a value of 0.049mg/l while, the minimum value was found to be 0.009 mg/l in A5 sachet water.

The manganese concentration varied in the range of 0.1468mg/l to 0.238mg/l with an average of 0.174 mg/l. The maximum value was recorded in A17 sachet water with a value of 0.238mg/l while the minimum was found in A18 sachet water with a value of 0.1468mg/l.

Lead concentration ranged from 0.0264mg/l to 0.5513 mg/l with an average of 0.219 mg/l. The maximum was observed in A2 sachet water with a value of .0264mg/l while, the minimum was revealed in A7 sachet water with a value of .0264mg/l.

The concentration of copper ranged from 0.402 mg/l to 2.099 mg/l with a mean value of 1.251 mg/l. The maximum value was found to be 2.099 mg/l in A13 sachet water while, the minimum value was revealed in A11 sachet water with a value of 0.402 mg/l.

Zinc concentration varied in the range of 0.0049 mg/l to 0.1387 mg/l with an average value of 0.076 mg/l. The maximum was revealed in A10 sachet water with a value of 0.1387 mg/l while, the minimum was found in A9 sachet water with a value of 0.0049 mg/l.

Table 1. Heavy metal concentration in sachet water

S/N	SAMPLE CODE	Cd mg/l	Mn mg/l	Pb mg/l	Cu mg/l	Zn mg/l
1	A1	0.0494	0.1680	0.3088	1.6485	0.0546
2	A2	0.0287	0.1674	0.1500	1.9852	0.0152
3	A3	0.0090	0.1624	0.2644	2.0083	0.0052
4	A4	0.0180	0.1574	0.1927	1.9557	0.0049
5	A5	0.0140	0.1903	0.0975	2.0996	0.0188
6	A6	0.0224	0.1714	0.1031	1.9260	0.0197
7	A7	0.0183	0.1801	0.0333	0.4021	0.0193
8	A8	0.0144	0.1703	0.2036	0.5432	0.0209
9	A9	0.0133	0.1671	0.2857	0.7975	0.0279
10	A10	0.0122	0.1468	0.1363	0.8498	0.0337
11	A11	0.0198	0.1878	0.3490	0.7761	0.1336
12	A12	0.0193	0.1788	0.3001	0.9914	0.1387
13	A13	0.0149	0.2378	0.2619	1.0319	0.1339
14	A14	0.0201	0.1869	0.5513	0.9133	0,1290
15	A15	0.0186	0.1742	0.2034	1.0040	0.1248
16	A16	0.0112	0.1747	0.0454	0.9747	0.1296
17	A17	0.0158	0.1587	0.2789	1.2089	0.1260
18	A18	0.0192	0.1653	0.0264	1.2460	0.1311
19	A19	0.0199	0.1665	0.3726	1.1359	0.1269
20	A20	0.0197	0.1621	0.2347	1.5165	0.1277
	MIN	0.009	0.1468	0.0264	0.4021	0.0049
	MAX	0.0494	0.2378	0.5513	2.0996	0.1387
	MEAN	0.019	0.173	0.219	1.250	0.0760
	WHO	0.003	0.5	0.01	2	3

Carcinogenic and Non-carcinogenic exposures

The average daily dose analysis of carcinogenic and non-carcinogenic exposure from drinking water was calculated using equation (1) and the result was presented in Table 2.

$$\text{ADD ingestion} = C_W \times DI \times ABS \times EF \times \frac{ED}{BW \times AT} \qquad 2.0$$

where, ADD ingestion (mg/kg) represents the exposure dose through ingestion, Cw is the mean concentration of the trace elements in water (mg/L); IR is both direct and indirect intake rate of drinking water (1 L day for the child), ED is the exposure duration (6 years for the child), EF is the exposure frequency to pollutants (365 days/year), BW represents the total body weight (15 kg for the child), AT is equal to ED×365 for non-carcinogenic risk, which is 2190 for the child . For carcinogenic risk, AT is the average life expectancy of people, which is 70×365 = 25550 for both the child

Table 2. Radiological hazard in samples

Heavy Metals	Non-carcinogenic Exposures (mg/kg)	Carcinogenic exposures (mg/kg)
(Cd) 0.0189	$1.26x10^{-3}$	$1.08x10^{-4}$
(Mn) 0.174	$1.1x10^{-2}$	$9.9x10^{-4}$
(Pb) 0.219	$1.4x10^{-2}$	$1.25x10^{-3}$
(Cu) 1.251	$8.3x10^{-2}$	$7.1x10^{-3}$
(Zn) 0.0760	$5.1x10^{-3}$	4.310^{-4}

The average daily dose of children for non- carcinogenic and carcinogenic risk in sachet water for Cd ,Mn, Pb Cu and Zn ranged from$1.26x10^{-3}$ to $1.08x10^{-4}$, $1.1x10^{-2}$ to $9.9x10^{-4}$, $1.4x10^{-2}$ to $1.25x10^{-3}$, $8.3x10^{-2}$ to $7.1x10^{-3}$, $5.1x10^{-3}$ to 4.310^{-4}.

Contamination Factor, Contamination Degree and Pollution Load Index of Heavy Metals in sachet water

Contamination Factor (CF) which is used in assessing the level of contamination of heavy metals in sachet water in Abuja municipal council is in the of order of Zn < Mn < Cu < Cd < Pb with their values ranging between 0.025 to 21.9. The values of Cu, Mn and Zn are less than 1 indicating low risk of contamination, while the value of Cd and Pb is greater than 6 indicating high risk of contamination. The result is presented in table 3

The Degree of Contamination (CD) by heavy metals in sachet water is 29.2 which indicate that the risk is considerably high. The result is presented in table 3
The Pollution load index value observed is less than 1 indicting that the sachet water samples were not polluted by Cd, Mn, Pb, Cu and Zn

Table 3. Contamination Factors (CF), degree of contamination (CD), pollution Load Index of heavy metals in sachet water samples

Contamination Factor(CF)					Degree of Contamination (CD)	Pollution Load Index (PLI)	
Cd	Mn	Pb	Cu	Zn			
1.9	0.346	21.9	0.625	0.025	29.2	0.92	unpolluted

.

CONCLUSION

The estimated heavy metal risk resulting from exposure to Cd and the estimated concentration of Pb in this study, was higher than the acceptable limit range provided by WHO. This indicates adverse health effects for people who consume sachet water in Abuja metropolis. Conclusively, water contributed the most to the health risk of the people in Abuja metropolis. The high value of CF in lead (Pb), the considerable high risk of the CD makes room for further studies. The value of the PLI indicates the heavy metals in the sachet waters are not polluted.

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