Nigerian Research Journal of Chemical Sciences **(ISSN: 2682-6054)**
Volume 12, Issue 1, 2024

ASSESSMENT OF LEVELS AND HEALTH RISK OF TOXIC METALS IN SELECTED SACHET WATER PACKAGED AND SOLD IN LAFIA METROPOLIS, NASARAWA STATE, NIGERIA

*[1]Silas I. Ioryue, [2]Raymond A. Wuana, [2]Rufus Sha'Ato, [2]Sesugh Ande

[1]Department of Biochemistry, Federal University of Technology, Ikot Abasi, Akwa Ibom State, Nigeria

[2] Department of Chemistry, Joseph Sarwuan Tarka University, Makurdi, Benue State, Nigeria

*Corresponding Author: silasoo4real@gmail.com

ABSTRACT

This study assessed the levels and health risk of toxic metals, namely, chromium (Cr), cadmium (Cd), nickel (Ni), copper (Cu), lead (Pb), arsenic (As) and zinc (Zn) in some samples of sachet water sold within Lafia metropolis, Nasarawa State, Nigeria, using an atomic absorption spectrophotometer. Samples of sachet water from sixteen producers were purchased for two months (March and July, 2020) and analyzed for the concentrations of these heavy metals in them. Furthermore, health risk indicators, hazard quotient (HQ), total hazard index (THI), cancer risk (CR), and total cancer risk (TCR) for children and adults, were calculated. The metal concentrations were compared with allowable limits set by the World Health Organization (WHO), 2017, and the United States Environmental Protection Agency (USEPA), 2017. High concentrations of Pb, Ni, Cd and Cr were found in all the sixteen samples and exceeded the maximum allowable limits of all the standards considered except As that was not detected, while Cu and Zn were within permissible limits. The calculated non-carcinogenic effects using hazard quotient toxicity potential and total hazard index of sachet water through ingestion and dermal adsorption pathways were above unity (HQ and THI>1), which indicated that consumption of the water samples could pose significant health risk. Maximum estimated values for an individual exceeded the risk limit of 10^{-6} and 10^{-4} with the highest estimated carcinogenic exposure risk (CR_{ing}) for Pb, Ni, Cd and Cr in sachet water. This could pose health risk to both adults and children exposed to the investigated water samples. Therefore, precaution needs to be taken to avoid potential cancer risk on ingestion to people, especially children, using the sachet water. Proper and effective treatment of the water is required before packaging to safeguard the health of consumers.

Keywords: Health risk assessment, Lafia, toxic metals, sachet water

INTRODUCTION

Packaged water (sachet water) is any commercially treated water, manufactured, packaged and distributed for sale in sealed polythene containers and intended for human consumption [1]. In Nigeria, this water is popularly referred to as "pure water" or sachet water. It is affordable, good looking and widely accepted [2], making sachet water production a booming business in Nigeria [3]. In addition, low capital investment is required for the production of packaged water. Consumption of sachet water in Nigeria is on the increase irrespective of whether they have the National Agency for Food and Drug Administration and Control (NAFDAC) certification or not. In spite of the strong effort by NAFDAC in the regulation and quality assessment of sachet water, there are a growing number of reported public illnesses after drinking sachet water, mainly resulting from lack of proper treatment and adhering to standard hygiene practices [4, 5].

Various researchers have found disease-causing microorganisms and heavy metals in packaged waters sold in most part of the country [6-12]. Adamu *et.al* [13] analyzed the heavy metal content of sachet water in Gombe, Nigeria, by using an atomic absorption spectrophotometer (AAS). None of the analysed sachet water samples had the date of manufacture or expiry date while about 23% had no NAFDAC registration numbers. All the samples had lead levels above the WHO safety limits of 0.01mg/L. Mercury, cadmium and arsenic levels were higher than the safety limits in 23%, 15% and 5% of the samples respectively. No nickel was detected in all the samples. Orish *et al* [14] assessed sachet water samples sold in Eastern Nigeria by using an AAS. They analyzed levels of lead, cadmium, copper, and nickel. They also analyzed other parameters, such as nitrates, sulfates, chlorides, salinity, total hardness, biological oxygen demand, total dissolved solids, and pH level. Lead levels ranged from 0.002 to 0.036 mg/L in the samples: 5 samples (12.2%) had lead levels above the maximum contaminant level (MCL) of 0.015 mg/L. Lead was not detectable in 20 samples (48.8%). Cadmium levels ranged from 0.002 to 0.036 mg/L and exceeded the MCL of 0.005 mg/L in 8 samples (19.5%); and was not detectable in 23 samples (56.1%). Copper was not detected in 2 (0.05%) of the samples. Its range was between 0.018 and 1.401 mg/L, while 2 samples (0.05%) had copper levels above the MCL (1.30 mg/L). Nickel levels ranged from 0.003 to 0.050 mg/l. The biological oxygen demand of the samples ranged from 3.20 to 36.80 mg/L. Other parameters were normal.

Since sachet water is sealed, it implies that contamination might have occurred during the production or storage process by virtue of its package. Sachet water is a source of affordable

drinking water for low-income socio-economic class. However, contamination by toxic metals could pose severe adverse health risk to consumers. When water quality is good at the source, it may deteriorate through subsequent handling, transportation, and storage.

Because of the increased reliance of the Nigerian public on sachet water, government regulatory agencies such as the NAFDAC have sought to establish controls designed to protect consumers from unscrupulous business practices as well as to ensure the safety of marketed products. However, data on the safety of the water sources available to the Nigerian public are virtually nonexistent. To provide a scientific basis for regulatory policies and to assess possible human health hazards to which Nigerians purchasing sachet water may be exposed, the quality of representative commercial drinking waters packaged and distributed in Lafia metropolis, Nigeria, was evaluated.

The aim and objective of the study is to assess the levels and health risk of toxic metals in selected sachet water samples packaged and sold around Lafia metropolitan in Nasarawa State, Nigeria.

Study area

The study was conducted in Lafia metropolis which is located in Northcentral Nigeria. Lafia Local Government Area (LGA) is located in Nasarawa State (Figure 1) and lies between latitudes 8°33‟ and 8°52‟ north and between longitudes 8°14‟ and 8°39‟ east. Lafia town is the administrative headquarters of Lafia Local Government Area and located on the ever-busy Abuja-Makurdi road. The four locations that make up the lafia metropolis are Lafia north (Shabu), south (Gandu), west (Tudun-Amba) and East (Akurba) served as the sampling points (Figure 1).

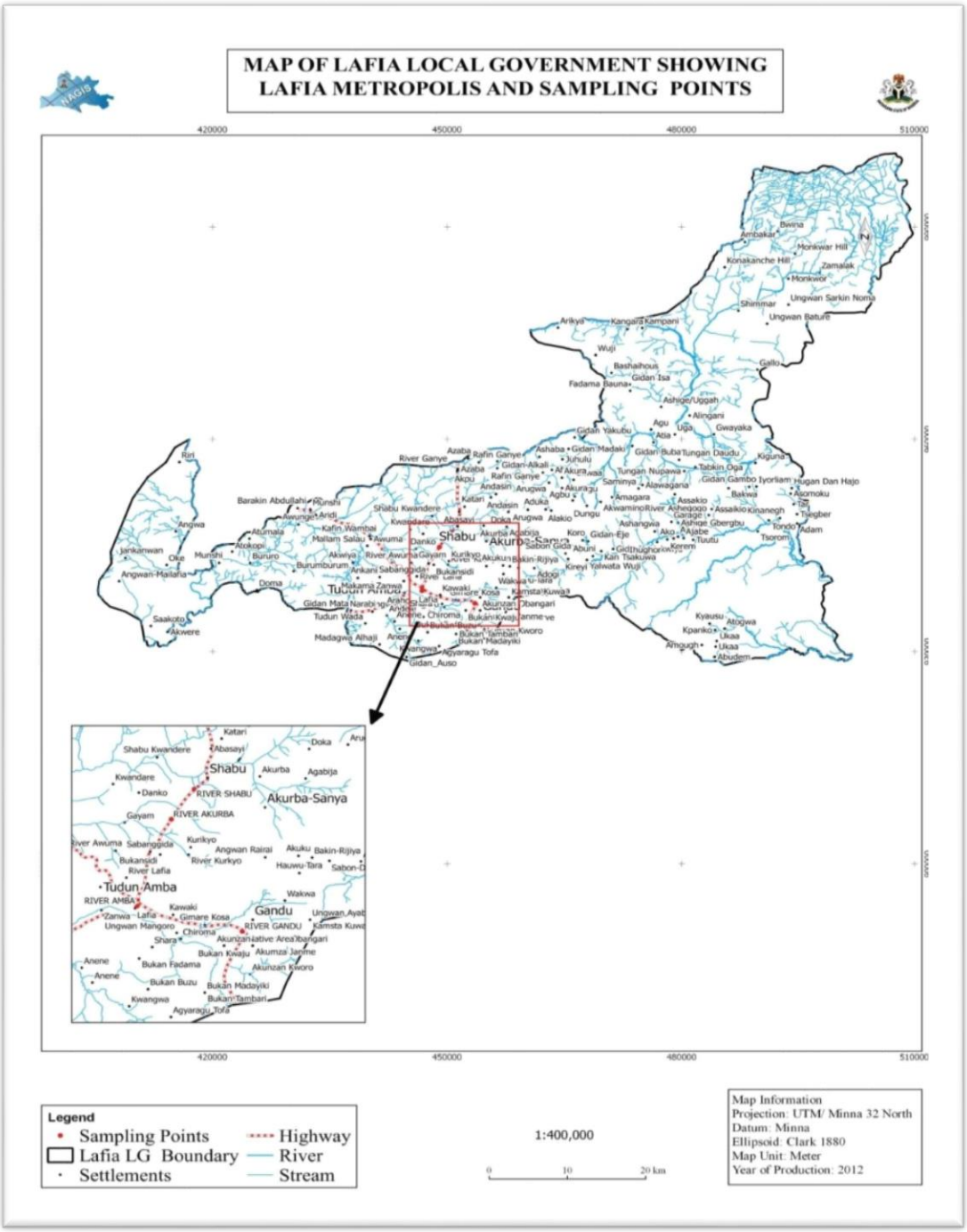

Figure 1: Sampling points

MATERIALS AND METHODS

Chemicals

Only chemicals of analytical grade (99.9% purity) were utilized and were obtained from reputable chemical distribution companies. The following chemicals were used for the analyses: Trioxonitrate (V) acid (analytical grade), hydrogen peroxide, tetraoxosulphate (VI) salts of As, Cd, Cr, Pb, Zn, Ni and Cu.

Apparatus

An AA 6800 SHIMADZU Atomic Absorption spectrophotometer was used for Cd, Cr, Cu, Ni, Pb, As and Zn determinations as well electronic weighing scale.

Sampling and digestion of sampled water

Water sampling was done according to the procedure described by Ndimele and Kumolu-Johnson [15]. Water samples were randomly collected from four sampling points from the sachet water processing companies around the sites. Samples were digested with concentrated nitric acid. Exactly 50 mL of the water sample was measured and 10 mL of nitric acid was added to the water sample in a 250 mL conical flask. The mixture was evaporated to half its volume on hot plate after which it was allowed to cool and then filtered with Whatman No. 42 filter paper. The filtrate was diluted to 50 mL with de-ionized distilled water. A blank solution was prepared according to standard method [16].

Analysis

A total of 16 selected sachet water brands were purchased and analyzed for seven heavy metals using an AAS. Recovery experiment was conducted to validate the performance of the used analytical method. Blank samples were also run to cancel the matrix effect of the analyzing reagents, and to calculate the limit of detection. Health risk assessment was conducted for chronic daily intake, hazard quotient, total hazard index, cancer risk and total cancer risk for both adults and children. Body weight for adults and children were 70 and 15 kg respectively. Exposure frequency was 365 days for both adults and children. Duration was 15 and 70 years for both children and adults respectively.

Chronic daily intake (CDI) indices

The CDI through water and ingestion was calculated according to the modified equation from Chrostowski [17]:

$$\text{CDI} = \frac{\text{C}*\text{DI}}{\text{BW}} \quad (1)$$

Where C, DI and BW represent the concentration of heavy metal (mg/L), average daily intake rate (2 L/day) and body weight (70 kg), respectively [18].

$$\text{HQ} = \frac{ADD}{RfD} \quad (2)$$

Where ADD is average daily dose and RfD is reference dose

For n number of heavy metals, the non-carcinogen effect to the population is as a result of the summation of all the HQs due to individual heavy metals. This is considered to be another term called the Hazard index (HI) as described by USEPA document [19].

The Total Hazard index is used to assess the overall non-carcinogen risk posed by more than one toxicant. For multiple hazardous substances, the hazard index, is the sum of HQ of the individual toxic element. If the value of HQ is less than one, it is unlikely to create adverse health effects for exposed populations. If the value of HQ or HI exceeds one (> 1), it is not in the acceptable range and the greater the value, the greater the probability of the occurrence of adverse health effects [20].

Equation 3 shows the mathematical representation of this parameter total hazard index below:

$$\text{THI} = \sum_{k=1}^{n} \text{HQk} = \sum_{\text{k=1}}^{\text{n}} \text{ADIk}/_{\text{RfDk}} \quad (3)$$

Where HQ_k, ADI_k and RfD_k are values of toxic metal. If the THI value is less than one, the exposed population is unlikely to experience adverse health effects. If the THI value exceeds one, then there may be concern for potential non-carcinogen effects [21].

Carcinogen risk can be evaluated by the following linear equation.

Cancer risk (CR) = CDI x CSF

Or

$$\text{Risk}_{\text{pathway}} = \sum_{k=1}^{n} \text{ADDk} \times \text{CSFk} \quad (4)$$

$$\text{Total Cancer Risk}(TCR) = \sum_{i=1}^{k} CDI_k \times SF_k \quad (5)$$

CDI_k is the chronic daily intake ($mg \cdot kg^{-1} \cdot d^{-1}$) of a single toxic metal k;

SF_k is the slope factor for the toxic metal k ($Kgd^{-1}mg^{-1}$).

The acceptable or tolerable maximum limit for TCR, for regulatory purpose, is within the range of 10^{-6}-10^{-4} [22].

Measurement of the concentration of heavy metals using AAS

The digested water samples were analyzed for the presence of arsenic, lead, chromium, cadmium, Nickel copper and Zinc using AA 6800 SHIMADZU AAS at the Federal Ministry of Agriculture, Kaduna Laboratory. The calibration curves were prepared by running different concentrations of the standard solution and were used as a standard for sample measurement. The instrument was set to zero by running the respective reagent blanks, Air-acetylene was the flame type and hollow cathode lamp of the corresponding element was provided and the wavelength for the determination of the elements. The digested water samples were analyzed and the concentration of the metals present displayed in mg/L by the instrument.

Heavy metal data were evaluated from descriptive and inferential statistics using SPSS for windows.

RESULTS AND DISCUSSION

Distribution of the metals concentration in sachet water

Table 1 presents the results of the mean values of the tested metals in the sampled waters.

Table 1: Mean values of toxic metals concentration (mg/L) in sachet water obtained from four sampling stations during dry season (March, 2020**)**

Toxic Metal	Shabu (Mean±S.D**)**	Tudun-Amba (Mean±S.D)	Akurba (Mean±S.D)	Gandu (Mean±S.D)	Mean	Range
Arsenic	ND	ND	ND	ND	ND	ND
Lead	0.049±0.0004	0.057±0.0004	0.115±0.0011	0.165±0.0005	0.097	0.165-0.049
Nickel	0.202±0.0006	0.168±0.0006	0.155±0.0008	0.126±0.0006	0.163	0.202-0.126
Cadmium	0.313±0.0008	0.380±0.0020	0.430±0.0018	0.492±0.0003	0.404	0.492-0.313
Copper	0.065±0.0003	0.051±0.0009	0.062±0.0004	0.075±0.0005	0.063	0.075-0.051
Chromium	0.159±0.0002	0.228±0.0001	0.252±0.0002	0.236±0.0003	0.219	0.252-0.159
Zinc	0.129±0.0012	0.249±0.0023	0.326±0.0022	0.115±0.0128	0.205	0.326-0.115

Arsenic: As was not detected in both the dry (March) and rainy (July) seasons in all the sampling points.

Lead: Lead was detected in both dry and rainy seasons in all the sampling sites. During the dry season (March) lead ranged between 0.165 and 0.049 mg/L and ranged between 0.117 and 0.052 mg/L during the rainy season (July). The highest mean concentration was recorded in Gandu (0.165±0.0005 mg/L) during the dry season and the least concentration was recorded in Tudun Amba (0.0117±0.001 mg/L) during the rainy season (July). In all the sampling points the mean concentration of Pb was above the permissible limits of 0.01 mg/L by the WHO [23] for drinking water. Higher values of lead in the water samples may be due to anthropogenic sources in the vicinity of the sachet water packaging or the water sources.

Nickel: Ni mean concentration ranged between 0.202 and 0.126 mg/L in March (dry season) with Shabu having the highest mean value of 0.202±0.0006 mg/L. During the rainy season, mean values ranged between 0.200 and 0.101 mg/L with Tudun-Amba recorded the highest mean value of 0.97±0.0004 mg/L and the least at Shabu with 0.101±0.0007 mg/L. Both values in all the sampling points during the dry and rainy seasons were above the 0.02 mg/L permissible limits set by the WHO [23] for drinking water (Tables 1and 2).

Cadmium: Cd mean concentration in sachet water during the dry and rainy season ranged between 0.492 and 0.313; 0.394 and 0.055 mg/L respectively. The highest value was recorded in Tudun-Amba sampled point in July with the value of 0.504±0.0113 mg/L and the least value was recorded in Shabu in July with value of 0.306±0.0004 mg/L. In March the values increased rapidly from Shabu to Gandu while in July the values increased from Shabu to Tudun Amba and decreased from Akurba to Gandu (Tables 1 and 2). This increased and decreased in concentration of Cd in sachet water was as a result of areas that were prone to Cd contamination sources. In all the sampling points in dry and rainy season, Cd concentrations were above the permissible limit of 0.003 mg/L and 0.01 mg/L set by the WHO [23] and NESREA [24] for drinking water.

Copper: The mean concentration of Cu during the dry (March) and rainy (July) seasons ranged between 0.075 and 0.051; 0.091and 0.074 mg/L respectively. The highest and lowest concentrations were recorded in Gandu (0.091±0.0001) mg/L and Tudun-Amba (0.051±0.0009)

mg/L in July and March respectively. In all the sampling points in both seasons the mean concentrations were below the permissible limits guidelines of 2.0 mg/L set by the WHO [23] for drinking water (Tables 1 and 2).

Chromium: The mean concentrations of Cr in water during the dry and rainy seasons were presented in Tables 1and 2. The Mean Cr concentrations ranged between 0.252 and 0.159 mg/L; 0.224 and 0.179 mg/L during the dry (March) and rainy seasons respectively. The highest and lowest concentrations were recorded both in March at Akurba (0.252±0.0002) mg/L and Shabu (0.159±0.0002) mg/L respectively. In March, the concentration increased from Shabu to Akurba and decreased from Gandu while in July, the concentrations decreased from Shabu to Gandu. Higher concentrations were recorded during the rainy season than the dry season. In both seasons the values were above the permissible limits of 0.05 mg/L set by the WHO [23] for drinking water. The research results are in agreement with the findings of Obire *et.al* [25] and that of Ioyue *et.al* [26].

Table 2: Mean values of toxic metals concentration (mg/L) in Sachet water obtained from four sampling stations during rainy season (July**,** 2020)

Toxic Metal	Shabu (Mean±S.D**)**	Tudun-Amba (Mean±S.D)	Akurba (Mean±S.D)	Gandu (Mean±S.D)	Mean	Range
Arsenic	ND	ND	ND	ND	ND	ND
Lead	0.064±0.0005	0.0117±0.001	0.052±0.0008	0.065±0.0003	0.249	0.117-0.052
Nickel	0.101±0.0007	0.97±0.0004	0.200±0.0011	0.196±0.0028	0.149	0.200-0.101
Cadmium	0.306 ±0.0004	0.504±0.0113	0.390±0.0010	0.394±0.0011	0.286	0.394-0.055
Copper	0.075±0.0005	0.074±0.0004	0.088±0.0003	0.091±0.0001	0.082	0.091-0.074
Chromium	0.224±0.0000	0.222±0.0004	0.206±0.0002	0.179±0.0006	0.208	0.224-0.179
Zinc	0.512 ±0.0028	1.006±0.0218	0.207±0.0011	0.274±0.0002	0.499	1.006-0.207

Zinc: The mean concentrations of Zn during the dry and rainy season were 0.326-0.115mg/L and 1.006-0.207mg/L respectively. The highest and lowest values were recorded in Tudun-Amba (1.006±0.0218) mg/L and Gandu (0.115±0.0128) mg/L in July and March respectively. In March the concentration increased from Shabu to Akurba and decreased from Gandu, while in July, it increased from shabu to Tudun-Amba with a decreased value in Akurba and an increase to Gandu

(Tables 1 and 2). In all the sampling points during the dry and rainy seasons, the concentrations were below the permissible limits of 3.0 mg/L by the WHO for drinking water [23]. The research results are in agreement with the findings of Obire *et.al* [25] and that of Ioryue *et.al* **[**26**].**

Human Health Risk Indices

Chronic daily intake

The calculated CDI values for drinking sachet water in March and July CDI_{ing} showed values for Cd, Pb, Ni and Cr in both adults and children being higher than their RfD while CDI_{derm} values were below the RfD, except for As that was not detected (Tables 3 and 4). Hazard quotient values greater than one (HQ>1) indicate that there might be concern for non-carcinogenic effects. Total hazard index was introduced to evaluate the total potential for non-carcinogenic effects posed by more than one pathway, which is the sum of the HQs from all applicable pathways. THI>1 showed a potential for adverse effects on human health. Non-carcinogenic and carcinogenic health risks posed by oral ingestion and dermal contact of sachet water were investigated through the following indices:

Hazard quotient

Non-carcinogenic hazard quotient for sachet water values of toxic metals exposure through ingestion (HQ_{ing}) in March, recorded values greater than one for Cd and Cr for both adults and children and that of Pb for children. As was not detected, while Ni, Cu and Zn were less than one and posed no harm to human for consumption of the sachet water.

HQ_{derm} for all the seven metals in all the sampling points posed no harm for dermal contact or bathing with the water. In July, HQ_{ing} values for Cd and Cr for both adults and children and that of Pb for children recorded values of HQ>1. With exception of As that was not detected, Ni, Cu and Zn HQ was less than one, HQ<1. The HQ_{derm} values were less than one for all the toxic metals in all the sampling points for both adults and children that consumed the water and therefore, will not experience any human health effects (Tables 4-5).

Table 3: Chronic Daily Intake (Mg/L) of Toxic Metals by Adults and Children due to Ingestion and Dermal Contact of Sachet Water in March, 2020 (Dry Season)

Month/ Sample ID	As		Pb		Ni		Cd		Cu		Cr		Zn	
March,2020	CDI_{AD}	CDI_{CH}	CDI_{AD}	CDI_{CH}	CDI_{AD}	CDI_{CH}	CDI_{AD}	CDI_{CH}	CDI_{AD}	CDI_{CH}	CDI_{AD}	CDI_{CH}	CDI_{AD}	CDI_{CH}
CDI_{ing}														
SWS_1	ND	ND	1.4E-3	5.1E-3	5.8E-3	2.1E-2	8.9E-3	3.3E-2	1.9E-3	6.8E-3	4.5E-3	1.7E-2	3.7E-3	1.4E-2
SWT_1	ND	ND	1.6E-3	5.9E-3	4.8E-3	1.8E-2	1.1E-2	3.9E-2	1.5E-3	5.4E-3	6.5E-3	2.4E-2	7.1E-3	2.6E-2
SWA_1	ND	ND	3.3E-3	1.2E-2	4.4E-3	1.6E-2	1.2E-2	4.3E-2	1.8E-3	6.5E-3	7.2E-3	2.6E-2	9.3E-3	3.4E-2
SWG_1	ND	ND	4.7E-3	1.7E-2	3.6E-3	1.3E-2	1.4E-2	5.2E-2	2.1E-3	7.9E-3	6.7E-3	2.5E-2	3.3E-3	1.2E-2
$\sum CDI_{ing}$	ND	ND	1.1E-3	4.0E-2	1.9E-2	6.8E-2	4.6E-2	1.7E-1	7.3E-3	2.7E-2	2.5E-3	9.2E-2	2.3E-3	8.6E-2
RfD	$3.0X10^{-4}$		$3.6X10^{-3}$		$2.6X10^{-2}$		$5.0X10^{-4}$		$3.7X10^{-2}$		$3.7X10^{-2}$		$3.0X10^{-1}$	
Concern			NO	YES	NO	YES	YES	YES	NO	NO	NO	YES	NO	NO
CDI_{derm}														
SWS_1	ND	ND	2.9E-5	2.1E-4	1.2E-4	8.9E-4	4.7E-5	3.4E-4	9.7E-6	7.2E-5	4.7E-5	3.5E-4	1.2E-5	8.5E-5
SWT_1	ND	ND	3.4E-5	2.5E-4	1.0E-4	7.4E-4	5.7E-5	2.4E-4	7.6E-6	5.6E-5	6.8E-5	5.0E-4	2.2E-5	1.6E-4
SWA_1	ND	ND	6.9E-5	5.1E-4	9.2E-5	6.8E-4	6.4E-5	4.7E-4	9.2E-6	6.8E-5	7.5E-5	5.5E-4	2.9E-5	2.2E-4
SWG_1	ND	ND	9.8E-5	7.3E-4	7.5E-5	5.5E-4	7.3E-5	5.4E-4	1.1E-5	8.2E-5	7.0E-5	5.2E-4	1.0E-5	7.6E-5
$\sum CDI_{derm}$	ND	ND	2.3E-5	1.7E-3	3.9E-4	2.9E-3	2.4E-5	1.6E-4	3.8E-5	2.8E-4	2.6E-4	1.9E-3	7.3E-5	5.4E-4
RfD	$3.0X10^{-4}$		$3.6X10^{-3}$		$2.0X10^{-2}$		$5.0X10^{-4}$		$3.7X10^{-2}$		$3.0X10^{-3}$		$3.0X10^{-1}$	
Concern			NO	NO	NO	NO		NO	NO	NO	NO	NO	NO	NO

ND= Not detected

Table 4: Chronic Daily Intake (Mg/L) of Toxic Metals by Adults and Children due to Ingestion and Dermal Contact of Sachet Water in July, 2020 (Rainy Season)

Month/ Sample ID	**As**		Pb		Ni		Cd		**Cu**		**Cr**		**Zn**	
JULY, 2020	CDI_{AD}	CDI_{CH}	CDI_{AD}	CDI_{CH}	CDI_{AD}	CDI_{CH}	CDI_{AD}	CDI_{CH}	CDI_{AD}	CDI_{CH}	CDI_{AD}	CDI_{CH}	CDI_{AD}	CDI_{CH}
CDI_{ing}														
SWS_2	ND	ND	1.8E-3	6.7E-3	2.9E-3	1.1E-2	8.7E-3	3.2E-2	2.1E-3	7.9E-3	6.4E-3	2.4E-2	1.5E-2	5.4E-2
SWT_2	ND	ND	3.3E-3	1.2E-2	2.8E-3	1.0E-2	1.6E-3	5.8E-3	2.1E-3	7.8E-3	6.3E-3	2.3E-2	2.9E-2	1.1E-1
SWA_2	ND	ND	1.5E-3	5.5E-3	5.7E-3	2.1E-2	1.1E-2	4.1E-2	2.5E-3	9.2E-3	5.9E-3	2.2E-2	5.9E-3	2.2E-2
SWG_2	ND	ND	1.8E-3	6.6E-3	5.6E-3	2.1E-2	1.1E-2	4.1E-2	2.6E-3	9.6E-3	5.1E-3	1.9E-2	7.8E-3	2.9E-2
$\sum CDI_{ing}$	ND	ND	8.4E-3	3.1E-2	1.7E-2	6.3E-2	3.2E-2	1.2E-1	9.3E-3	3.5E-2	2.4E-2	8.8E-2	5.8E-2	2.2E-1
RfD	$3.0X10^{-4}$		3.6E-3		$2.0X10^{-2}$		$5.0X10^{-4}$		$3.7X10^{-2}$		$3.0X10^{-3}$		$3.0X10^{-1}$	
Concern			YES	NO	NO	YES	YES	YES	NO	NO	YES	YES	NO	NO
CDI_{derm}														
SWS_2	ND	ND	3.8E-5	1.1E-4	6.0E-5	1.8E-4	4.6E-5	1.3E-4	1.1E-5	3.3E-5	6.7E-5	9.9E-5	4.6E-5	1.4E-4
SWT_2	ND	ND	6.9E-5	2.1E-4	5.8E-5	1.7E-4	8.6E-6	2.4E-5	1.1E-5	3.3E-5	6.6E-5	9.8E-5	9.0E-5	4.4E-4
SWA_2	ND	ND	3.1E-5	9.2E-5	1.2E-4	3.5E-4	5.8E-5	1.7E-4	1.3E-5	3.9E-5	6.1E-5	1.8E-4	1.9E-5	5.5E-5
SWG_2	ND	ND	3.8E-5	1.1E-4	1.2E-4	3.4E-4	5.9E-5	1.7E-4	1.4E-5	4.0E-5	5.3E-5	1.6E-4	2.5E-5	7.2E-5
$\sum CDI_{derm}$	ND	ND	1.8E-4	5.2E-4	3.6E-4	1.0E-3	1.7E-4	4.9E-4	4.9E-5	1.5E-4	2.5E-4	5.4E-3	1.8E-4	7.1E-4
RfD	$3.0X10^{-4}$		$3.6X10^{-3}$		$2.0X10^{-2}$		$5.0X10^{-4}$		$3.7X10^{-2}$		$3.0X10^{-3}$		$3.0X10^{-1}$	
Concern			NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

Table 5: Hazard Quotients and Total Hazard Index of Adults and Children due to Ingestion and dermal Contact of Sachet Water in March, 2020 (Dry Season)

Month/ Sample ID	As		Pb		Ni		Cd		Cu		Cr		Zn	
March,2020 HQ_{ing}	HQ_{AD}	HQ_{CH}	HQ_{AD}	HQ_{CH}	HQ_{AD}	HQ_{CH}	HQ_{AD}	HQ_{CH}	HQ_{AD}	HQ_{CH}	HQ_{AD}	HQ_{CH}	HQ_{AD}	HQ_{CH}
SWS_1	ND	ND	0.400	1.457	0.2900	1.050	17.800	66.00	0.0514	0.184	1.5000	5.667	0.0123	0.0467
SWT_1	ND	ND	0.457	1.686	0.2400	0.900	22.000	78.00	0.0405	0.146	2.1667	8.000	0.0237	0.0867
SWA_1	ND	ND	0.943	3.429	0.2200	0.800	24.000	90.00	0.0486	0.176	2.4000	8.667	0.0310	0.1133
SWG_1	ND	ND	1.343	4.857	0.1800	0.650	28.000	104.0	0.0568	0.214	2.2333	8.333	0.0110	0.0400
THI	ND	ND	3.143	11.429	0.9300	3.400	91.000	338.0	0.1973	0.719	8.3000	30.66	0.0780	0.2867
RfD_{ing}	0.0003		0.0035		0.020		0.00050		0.037		0.0030		0.30	
Concern			Unsafe	Unsafe	Unsafe	unsafe	unsafe	unsafe	Unsafe	Unsafe	unsafe	Unsafe	safe	safe
HQ_{derm}														
SWS_1	ND	ND	0.0083	0.0600	0.0214	0.159	0.0940	0.680	0.00040	0.003	0.0157	0.117	0.00016	0.0011
SWT_1	ND	ND	0.0097	0.0714	0.0179	0.132	0.1140	0.480	0.00032	0.023	0.0227	0.167	0.00029	0.0021
SWA_1	ND	ND	0.0197	0.1457	0.0164	0.122	0.1280	0.940	0.00038	0.028	0.0250	0.183	0.00039	0.0029
SWG_1	ND	ND	0.0280	0.2086	0.0134	0.098	0.1460	1.080	0.00046	0.034	0.0233	0.173	0.00013	0.0010
THI	ND	ND	0.0657	0.4857	0.0691	0.511	0.4820	3.180	0.00160	0.012	0.0867	0.640	0.00097	0.0071
RfD_{derm}	0.0003		0.0035		0.0056		0.00050		0.024		0.0030		0.075	
Concern			Unsafe	Unsafe	Unsafe	unsafe	unsafe	unsafe	Safe	Safe	unsafe	Unsafe	safe	safe

Table 6: Hazard Quotients and Total Hazard Index of Adults and Children due to Ingestion and Dermal Contact of Sachet Water in July, 2020 (Rainy Season)

Month/ Sample ID	As		Pb		Ni		Cd		**Cu**		**Cr**		**Zn**	
JULY, 2020	HQ_{AD}	HQ_{CH}	HQ_{AD}	HQ_{CH}	HQ_{AD}	HQ_{CH}	HQ_{AD}	HQ_{CH}	HQ_{AD}	HQ_{CH}	HQ_{AD}	HQ_{CH}	HQ_{AD}	HQ_{CH}
HQ_{ing}														
SWS_2	ND	ND	0.5143	1.9143	0.1450	0.5500	17.4000	64.000	0.0568	0.2135	2.1333	8.000	0.0500	0.1800
SWT_2	ND	ND	0.9429	3.4286	0.1400	0.5000	3.2000	11.600	0.0568	0.1703	2.1000	7.6667	0.0967	0.3667
SWA_2	ND	ND	0.4286	1.5714	0.2850	1.0500	22.0000	82.000	0.0676	0.2486	1.9667	7.3333	0.0197	0.0733
SWG_2	ND	ND	0.5143	1.8857	0.2800	1.0500	22.0000	82.000	0.0703	0.2595	1.7000	6.3333	0.0260	0.0967
THI	ND	ND	2.4001	8.8000	0.8500	3.1500	64.6000	239.60	0.2515	0.8919	7.9000	29.333	0.1924	0.7167
RfD_{ing}	0.0003		0.0035		0.020		0.00050		0.037		0.0030		0.30	
Concern			Unsafe	Unsafe	Unsafe	Unsafe	Unsafe	Unsafe	Unsafe	Unsafe	Unsafe	Unsafe	Safe	Unsafe
HQ_{derm}														
SWS_2	ND	ND	0.0109	0.0314	0.0107	0.0321	0.0920	0.2600	0.00046	0.0014	0.0223	0.0330	0.0061	0.0019
SWT_2	ND	ND	0.0197	0.0600	0.0104	0.0304	0.0164	0.0480	0.00046	0.0014	0.0220	0.0327	0.0012	0.0059
SWA_2	ND	ND	0.0088	0.0263	0.0214	0.0625	0.1160	0.3400	0.00054	0.0016	0.0203	0.0600	0.00025	0.0073
SWG_2	ND	ND	0.0109	0.0314	0.0214	0.0607	0.1180	0.3400	0.00058	0.0017	0.0177	0.0533	0.00033	0.0096
THI	ND	ND	0.0503	0.1491	0.0639	0.1857	0.3424	0.9880	0.00200	0.0061	0.0823	0.1790	0.0024	0.0095
RfD_{derm}	0.0003		0.0035		0.0056		0.00050		0.024		0.0030		0.075	
Concern			Unsafe	Unsafe	Unsafe	Unsafe	Unsafe	Unsafe	safe	Safe	Unsafe	Unsafe	Safe	safe

Total Hazard Index

The hazard index values for sachet water were calculated and presented in Tables 5 and 6.

March and July sachet water THI_{ing} for Pb, Cd and Cr for both adults and children and Ni for children showed values above one with exception of Cu and Zn for both adults and children. As was not detected and Ni for adults which showed values of THI<1.

THI_{derm} for all the metals in all the sampling points for both adults and children recorded values less than one showing that there was no health risk or indicating that risk may occur via the ingestion pathway only.

The increasing order for THI_{ing} and THI_{derm} for all the metals for both adults and children were AS<Cu<Zn<Pb<Ni<Cr<Cd and As<Cu<Zn<Cr<Ni<Pb<Cd.

Cancer risk

Cancer risk or carcinogenic risk is the probability for an adult or child to have cancer over time. Potential risk of cancer can be increased by As, Pb, Ni, Cd and Cr in humans [27]. Long term exposure to even low amounts of toxic metals could result in many types of cancer. CR_{ing} for sachet water in March and July showed values of As, Pb, Ni, Cd and Cr far above the range of $1x10^{-6}$ to $1x10^{-4}$ for both adults and children while the CR_{derm} showed values above the range with exception of Pb in which the values were below the range> Also, As was not detected in both pathways. These showed clearly the possibility of those taking or contacting the water developing cancerous cells with time. The decreasing carcinogenic risk contribution order for the metals for both adults and children in sachet water samples was Cd>Cr>Ni>As>Pb.

From the results recorded the CR_{ing} pathway for both adults and children contributed greatly to the total cancer risk than the CR_{derm} pathway (Tables 7 and 8).

Table 7: Carcinogenic Risk of Adults and Children due to Ingestion and Dermal Contact of Sachet Water in March, 2020 (Dry season)

Month/Sample ID		As		Pb		Ni		Cd		Cr
March, 2020	CR_{AD}	CR_{CH}	CR_{AD}	CR_{CH}	CR_{AD}	CR_{CH}	CR_{AD}	CR_{CH}	CR_{AD}	CR_{CH}
CR_{ing}										
SWS_1	ND	ND	1.2E-5	4.3E-5	4.9E-3	1.8E-2	1.3E-1	4.9E-1	2.3E-3	8.5E-3
SWT_1	ND	ND	1.4E-5	5.0E-5	4.0E-3	1.5E-2	1.7E-1	5.9E-1	3.3E-3	1.2E-2
SWA_1	ND	ND	2.8E-5	1.0E-4	3.7E-3	1.3E-2	1.8E-1	6.8E-1	3.6E-3	1.3E-2
SWG_1	ND	ND	3.9E-5	1.4E-4	3.0E-3	1.1E-2	2.1E-1	7.8E-1	3.4E-3	1.3E-2
$\sum CR_{ing}$	ND	ND	9.3E-5	3.3E-4	1.6E-2	5.7E-2	6.9E-1	2.5E-1	1.3E-2	4.7E-2
CR_{derm}										
SWS_1	ND	ND	2.5E-7	1.8E-6	1.0E-4	7.5E-4	7.1E-4	5.1E-3	2.4E-5	1.8E-4
SWT_1	ND	ND	2.9E-7	2.1E-6	8.4E-5	6.2E-4	8.6E-4	3.6E-3	3.4E-5	2.5E-4
SWA_1	ND	ND	5.9E-7	4.3E-6	7.7E-5	5.7E-4	9.6E-4	7.1E-3	3.8E-5	2.8E-4
SWG_1	ND	ND	8.3E-7	6.2E-6	6.3E-5	4.6E-4	1.1E-3	8.1E-3	3.5E-5	2.6E-4
$\sum CR_{derm}$	ND	ND	1.9E-6	1.4E-5	3.2E-4	2.4E-3	3.6E-3	2.4E-2	1.3E-4	9.7E-4
TCR_{AD}	7.33E-1									
TCR_{CH}	4.00E-1									

Table 8: Carcinogenic Risk of Adults and Children due to Ingestion and Dermal Contact of Sachet Water in July, 2020 (Rainy Season)

Month/Sample ID		As		Pb		Ni		Cd		Cr
JULY,2020	CR_{AD}	CR_{CH}	CR_{AD}	CR_{CH}	CR_{AD}	CR_{CH}	CR_{AD}	CR_{CH}	CR_{AD}	CR_{CH}
CR_{ing}										
SWS_2	ND	ND	1.5E-5	5.7E-5	2.4E-3	9.2E-3	1.3E-1	4.8E-1	3.2E-3	1.2E-2
SWT_2	ND	ND	2.8E-5	1.0E-4	2.4E-3	8.4E-3	2.4E-2	8.7E-2	3.2E-3	1.2E-2
SWA_2	ND	ND	1.3E-5	4.7E-5	4.8E-3	1.8E-2	1.7E-1	6.2E-1	2.9E-3	1.1E-2
SWG_2	ND	ND	1.5E-5	5.6E-5	4.7E-3	1.8E-2	1.7E-1	6.2E-1	2.6E-3	9.5E-3
$\sum CR_{ing}$	ND	ND	7.1E-5	2.6E-4	1.4E-3	5.4E-2	7.1E-1	1.8E-1	1.2E-3	4.5E-2
CR_{derm}										
SWS_2	ND	ND	3.2E-7	9.4E-7	5.0E-5	1.5E-4	6.9E-4	1.9E-3	3.4E-5	4.9E-5
SWT_2	ND	ND	5.9E-7	1.8E-6	4.9E-5	1.4E-4	1.2E-4	3.6E-3	3.3E-5	4.9E-5
SWA_2	ND	ND	2.6E-7	7.8E-7	1.0E-4	2.9E-4	8.7E-4	2.6E-3	3.1E-5	9.0E-5
SWG_2	ND	ND	3.2E-7	9.4E-7	1.0E-4	2.9E-4	8.9E-4	2.6E-3	2.7E-5	8.0E-5
$\sum CR_{derm}$	ND	ND	1.5E-6	4.5E-6	2.9E-4	8.7E-4	2.6E-4	7.5E-3	1.3E-5	2.7E-5
TCR_{AD}	7.13E-1									
TCR_{CH}	2.88E-1									

Total Cancer risk

The calculated total cancer risk for As, Pb, Ni, Cd and Cr for both adults and children in Shabu, Tudun-Amba, Akurba and Gandu were as recorded in Tables 7 and 8.

Sachet water risk values on utilization for both adults and children were 7.23E-1 and 3.82E-1, 7.13E-1 and 2.88E-1 respectively for March and July. These values showed that sachet water intake by both adults and children might result to cancer with time.

The total cancer risk (TCR) showed values above the range $1x10^{-6}$ to $1x10^{-4}$. This showed that sachet water for both adults and children for ingestion and dermal pathways can result to cancer with time as a result of As, Pb, Ni, Cd and Cr present in the water samples.

CONCLUSIONS

Heavy metals mean concentrations for Pb, Ni, Cd and Cr in the water samples from March and July in all the sampling points recorded higher values above the permissible limits for drinking water by WHO and NESREA except Cu and Zn that recorded values below the permissible limits and As that was not detected. Health risk assessment revealed that in all the sampling points there was high non-cancer and cancer risk for both adults and children with ingestion pathway contributing the highest. The enhanced heavy metals' concentrations in sachet water are implicated for causing risk to human health. These metals can cause cancer in the case of drinking such water over a long period.

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