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Analysis of selected heavy metals in sachet water from Lokoja metropolis, Kogi state, Nigeria

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Abstract
The concentrations of selected heavy metals (Cd, Cr, Cu, Fe, Mn, Pb, and Zn) in three brands of sachet water sold within Lokoja, Nigeria, were determined using Atomic Absorption Spectroscopy (AAS). The results revealed that the sachet water samples contained varying levels of these heavy metals. All the metals were present in all the tested brands at concentrations below the WHO and US EPA permissible limits for drinking water. For Cd, the estimated daily intake (EDI), was calculated to be slightly higher than the RfD or reference limit, making it a source of health concern. All the other metals had EDIs that are less than their RfDs. Overall, the sachet water brands were found safe for drinking.

Keywords: analysis of selected, heavy metals, safe for drinking

Introduction

Sachet water, also known as "pure water," has become an essential source of drinking water for millions of people in Nigeria, particularly in regions where access to clean and safe water is limited. Nigeria, like many other developing countries, heavily relies on sachet water as a primary drinking water source due to its affordability and availability (Ajala *et al*., 2020) [1]. However, the quality and safety of sachet water have raised concerns, especially regarding the presence of heavy metals, which can pose significant health risks to consumers (Ajala *et al*., 2020) [1].

Background and Significance of the Study

Heavy metals are naturally occurring elements that are widely distributed in the environment. However, anthropogenic activities such as mining, industrial processes, and agricultural practices have significantly increased their concentrations in water sources (Zamora-Ledezma *et al*., 2021) [21]. These metals, including zinc (Zn), lead (Pb), copper (Cu), iron (Fe), cadmium (Cd), chromium (Cr), and manganese (Mn), are of particular concern due to their toxicity and potential health hazards (Zamora-Ledezma *et al*., 2021) [21]

The ingestion of water contaminated with elevated levels of heavy metals has been linked to various adverse health effects, including kidney damage, liver dysfunction, neurological disorders, and even cancer (Jaishankar *et al*., 2014) [9]. Therefore, the determination of heavy metal levels in sachet water is of utmost importance to ensure the safety and well-being of consumers (Witkowska *et al*., 2021) [19].

Objective of the Study

The main objective of this study is to determine the concentrations of selected heavy metals (Cd, Cr, Cu, Fe, Mn, Pb, and Zn) in sachet water samples collected within Lokoja, Nigeria, using Atomic Absorption Spectroscopy (AAS). By analysing the heavy metal content in sachet water, we aim to assess the potential health risks associated with their consumption and evaluate the overall quality of the sachet water supply in the study area.

Overview of Heavy Metals and Their Health Implications

Heavy metals can enter water sources through various routes, including industrial discharge, agricultural runoff, and atmospheric deposition (Zamora-Ledezma *et al*., 2021) [21]. Once present in water, these metals can accumulate in the human body over time, leading to chronic exposure and subsequent health effects (Mengistu, 2021) [11].

Each heavy metal has its own set of health implications. For instance, lead (Pb) is a potent neurotoxin that can impair cognitive development in children (Witkowska *et al*., 2021) [19], while cadmium (Cd) is known to cause kidney damage and skeletal abnormalities (Jaishankar *et al*., 2014) [9]. Nickel (Ni) and chromium (Cr) have been associated with respiratory problems and increased cancer risks (Balali-Mood *et al*., 2021) [2]. It is crucial to understand the potential health effects associated with these heavy metals to safeguard public health.

Importance of Determining Heavy Metal Levels in Sachet Water

Given the widespread consumption of sachet water in Nigeria, assessing the heavy metal content in these products is crucial for public health and regulatory purposes (Omole *et al*., 2015) [12]. This study aims to fill the existing knowledge gap regarding the levels of heavy metals in sachet water in Lokoja, Nigeria. The findings will provide valuable insights into the potential health risks associated with consuming sachet water and contribute to the development of appropriate strategies for water quality management and regulation.

Methodology
Sample Collection and Preparation
Collection of Sachet Water Samples
A total of 18 sachets (six each of three different brands of sachet water samples, here labelled as A, B and C were collected from various shops around Lokoja, Nigeria. Care was taken to collect samples at random to ensure unbiased representation. Samples of the same brand were combined in a clean and dry beaker and mixed thoroughly to obtain a homogenous sample. The samples were then acidified with 0.15 ml HNO_3, transferred into sample bottles, appropriately labelled and stored at 4 °C (S˙liwka- Kaszyńska *et al*., 2003) [16] to minimize any degradation of the heavy metals prior to analysis.

Instrumentation and Analysis
Atomic Absorption Spectroscopy (AAS) as the Analytical Technique
AAS was used as the primary analytical technique for the determination of selected heavy metals (Cd, Cr, Cu, Fe, Mn, Pb, and Zn) in the sachet water samples. The machine used is the Buck 210VGP Atomic Absorption Spectrophotometer (Buck scientific inc., USA)

Preparation of Standards and Calibration Curves
Standard solutions of known concentrations for each heavy metal were prepared by accurately weighing and dissolving appropriate metal salts in deionized water. A series of standard solutions covering the expected concentration range of the heavy metals were prepared. Calibration curves were constructed by plotting the absorbance of the standard solutions against their respective concentrations. (Prichard & Barwick, 2003) [14], (Carter *et al*., 2018) [3]

Determination of Heavy Metals in Sachet Water Samples
Aliquots of the samples were acidified to preserve the integrity of the heavy metals. The acidified samples were then analysed using the AAS. The absorbance of each sample was measured at the appropriate wavelength, and the concentrations of the heavy metals were determined using the calibration curves.

Quality Control and Assurance
Blank and Replicate Analysis
Blank solutions, consisting of deionized water subjected to the same treatment as the samples, were analysed to account for any background contamination or interference. Replicate analysis of selected samples was conducted to assess the precision and accuracy of the analytical method.

Laboratory Procedures and Precautions
Strict adherence to standard laboratory procedures and precautions was followed during the entire analysis. All glassware and equipment used were properly cleaned and rinsed to prevent contamination. Safety measures, such as the use of appropriate personal protective equipment, were implemented to ensure the well-being of laboratory personnel.

Assessment of Potential Health Risks Associated with Heavy Metal Exposure
Based on the determined concentrations of heavy metals in the sachet water, a health risk assessment was conducted to evaluate the potential adverse effects on consumers. The estimated daily intake (EDI) and health risk index (HRI) for each heavy metal were used to assess the health risks.

Estimated Daily Intake (EDI)
The estimated daily intake (EDI) is a measure of the amount of a substance that is ingested daily (Renwick, 1993) [15]. The calculation of EDI can vary depending on the substance being measured and the population being studied. The formula used to calculate the EDA below is adapted from the Center for Food Safety and Applied Nutrition, (CFSAN, 2023) [4].

$$EDI = \frac{M_c \times IR}{B_w \times 10^{-3}}$$

where M_c is the metal concentration in the sachet water (mg/L), IR is the ingestion rate (L/day), and B_w is the body weight. The ingestion rate was adapted from that published by the institute of medicine, USA, as an average of 3.7L/day for adult males and 2.7L/day for adult females (Institute of Medicine, 2005) [8]. Average body weight (Bw) was taken as 68.0 Kg for men and 60.5 Kg for women (Igiri *et al*., 2009) [7].

Health Risk Index (HRI)

The health risk index (HRI) is a measure of the potential health risks associated with exposure to heavy metals in drinking water. The HRI is a numerical value from 1 to 100 where higher numbers indicate higher risk as assessed by calculations. The lower the number, the fewer risk factors that will require mitigation (Prasad *et al*., 2022) [13]. An HRI value less than 1 indicates that there is no significant health risk to the exposed population (Lu *et al*., 2013) [10]. The HRI is calculated using the following formula:

$$HRI = \sum \left(\frac{EDI}{RfD} \right)$$

Where EDI is the estimated daily intake of the heavy metal (mg/kg/day), RfD is the reference dose for the heavy metals (mg/kg/day), Σ is the sum of the EDI/RfD values for all heavy metals. The RfD for Cd, Cr, Cu, Fe, Mn, Pb, and Zn are 5.00E-07, 1.50E-3, 4.00E-05, 7.00E-01, 2.40E-05, 5.00E-06, and 3.00E-04 mg/kg/day (US EPA, 2013), (US EPA, 2021).

Results and Discussion

Overview of Heavy Metal Concentrations in Sachet Water Samples

The concentrations of selected heavy metals (Zn, Pb, Cu, Fe, Cd, Cr, and Mn) in the sachet water samples collected from Lokoja, Nigeria, were determined using Atomic Absorption Spectroscopy (AAS). Table 1 summarizes the mean concentrations of each heavy metal along with their standard deviations.

Table 1: Concentrations of Cd, Cr, Cu, Fe, Mn, Pb and Zn in Sachet Water Brands A, B and C

	Brand A		Brand B		Brand C	
Heavy Metal	**Concentration (mg/l)**	**Standard Deviation**	**Concentration (mg/l)**	**Standard Deviation**	**Concentration (mg/l)**	**Standard Deviation**
Cd	0.0012	0.007	0.0027	0.005	0.0028	0.011
Cr	0.000	0.000	0.000	0.000	0.000	0.000
Cu	0.041	0.048	0.033	0.029	0.000	0.032
Fe	0.048	0.019	0.037	0.020	0.023	0.037
Mn	0.016	0.013	0.012	0.015	0.003	0.007
Pb	0.0060	0.055	0.0081	0.002	0.000	0.017
Zn	0.000	0.000	0.001	0.001	0.095	0.000

To assess the safety of sachet water consumption, the obtained heavy metal concentrations were compared with the regulatory standards or guidelines established by national and international bodies. Table 2 presents the permissible limits for each heavy metal in drinking water, as set by the relevant regulatory authorities.

Table 2: Permissible Limits of Cd, Cr, Cu, Fe, Mn, Pb and Zn According to WHO and EPA

	Permissible limits (mg/l)	
Heavy Metal	**WHO**	**EPA**
Cd	0.005	0.005
Cr	0.05	0.05
Cu	1.5	1.3
Fe	0.2	0.2
Mn	0.4	-
Pb	0.05	0.015
Zn	5	5

Sources: (World Health Organization, 2017) [20], (Griffiths *et al*., 2012) [6]

As seen in table 1 above, the concentrations of Pb in brands A and B are relatively high compared to the other elements, however, these figures are still well below the minimum permissible levels recommended by the WHO and the US EPA (Table 2). Overall, the concentrations of the selected heavy metals in the three brands of sachet water are within the maximum permissible limits recommended by the regulatory agencies. Thus, these brands of sachet water can be considered relatively free from contamination from the selected heavy metals.

Discussion of Potential Health Risks Associated with Heavy Metal Exposure

Estimated daily intake (EDI), are shown in table 3. The EDI values for Cd are greater than the reference values, RfD (Table 4) across the board. Thus, there is a potential health risk associated with Cd (Fan *et al*., 2020). However, the differences between the EDI and RfD values is not much (less than an order of magnitude). EDI values for all the order heavy metals are below their RfD values in all the sachet water brands and for both male and female adult members of the population. Consequently, no health risk is associated with these elements.

Table 3: Calculated Estimated Daily Intake (EDI) Values

	Brand A		Brand B		Brand C	
	EDI (mg/kg bw/day)		EDI (mg/kg bw/day)		EDI (mg/kg bw/day)	
Heavy Metal	Male	Female	Male	Female	Male	Female
Cd	6.348E-07	5.207E-07	1.469E-06	1.205E-06	1.524E-06	1.250E-06
Cr	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Cu	2.213E-06	1.815E-06	1.814E-06	1.488E-06	0.000E+00	0.000E+00
Fe	2.630E-06	2.157E-06	2.013E-06	1.651E-06	1.251E-06	1.026E-06
Mn	8.706E-07	7.140E-07	6.348E-07	5.207E-07	1.632E-07	1.339E-07
Pb	3.247E-06	2.663E-06	4.425E-06	3.630E-06	0.000E+00	0.000E+00
Zn	0.000E+00	0.000E+00	3.627E-08	2.975E-08	5.169E-06	4.240E-06

Table 4: 4RfD Values

Heavy metals	RfD (mg/kg/day)
Cd	5.00E-07
Cr	1.50E-53
Cu	4.00E-05
Fe	7.00E-01
Mn	2.40E-05
Pb	5.00E-06
Zn	3.00E-04

The Health Risk Indices (HRI) are shown in the table below. All the calculated values are way below unity, implying the sachet water brands pose little or no health risk to the consumers (Prasad *et al*., 2022) [13], (Lu *et al*., 2013).

Table 2: Permissible Limits of Cd, Cr, Cu, Fe, Mn, Pb and Zn According to WHO and EPA

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Zn	5	5

Sources: (World Health Organization, 2017) [20], (Griffiths *et al*., 2012) [6]

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	EDI (mg/kg bw/day)		EDI (mg/kg bw/day)		EDI (mg/kg bw/day)	
Heavy Metal	Male	Female	Male	Female	Male	Female
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Cr	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Cu	2.213E-06	1.815E-06	1.814E-06	1.488E-06	0.000E+00	0.000E+00
Fe	2.630E-06	2.157E-06	2.013E-06	1.651E-06	1.251E-06	1.026E-06
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Heavy metals	RfD (mg/kg/day)
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Pb	5.00E-06
Zn	3.00E-04

The Health Risk Indices (HRI) are shown in the table below. All the calculated values are way below unity, implying the sachet water brands pose little or no health risk to the consumers (Prasad *et al*., 2022) [13], (Lu *et al*., 2013).

Table 5: Calculated Health Risk Index (HRI) Values

Brand A		Brand B		C	
HRI		HRI		HRI	
Male	Female	Male	Female	Male	Female
1.185E-05	1.434E-05	1.283E-05	1.426E-05	1.001E-05	1.468E-01

Conclusion

Summary of Findings

This study aimed to determine the concentrations of selected heavy metals (Zn, Pb, Cu, Fe, Cd, Ni, Cr, and Mn) in three brands of sachet water samples collected from Lokoja, Nigeria, using Atomic Absorption Spectroscopy (AAS). The results revealed that the sachet water samples contained varying levels of these heavy metals. All the metals were present in all the tested brands at concentrations below the WHO and US EPA permissible limits for drinking water. For Cd, the estimated daily intake was calculated to be slightly higher than the RfD or reference limit, making a source of health concern. All the other metals EDIs that are less than their RfDs. Overall, the sachet water brands were found safe for drinking.

Implications of the Study

Recommendations for Further Research

This study provides a foundation for future research on heavy metal contamination in sachet water. Further investigations should focus on the identification of specific sources of heavy metal contamination, such as industrial activities, agricultural practices, and packaging materials. Additionally, long-term studies are needed to monitor the temporal variation of heavy metal levels in sachet water and assess their potential health risks over time. Studies that explore the efficacy of different water treatment methods and quality control measures in reducing heavy metal concentrations in sachet water would also be valuable.

Suggestions for Mitigating Heavy Metal Contamination in Sachet Water

Based on the findings of this study, several recommendations can be made to mitigate heavy metal contamination in sachet water. First and foremost, it is essential to improve the regulatory framework and enforcement of quality standards for sachet water production. Stringent monitoring and quality control measures should be implemented throughout the production process to ensure that heavy metal levels are within acceptable limits.

Furthermore, promoting public awareness regarding the potential health risks associated with heavy metal contamination in sachet water is crucial. Educating consumers about the importance of purchasing sachet water from reliable and certified sources can help them make informed choices and avoid potential health hazards.

Investments in water treatment technologies and infrastructure should also be prioritized. Implementing advanced filtration systems and effective water treatment processes can significantly reduce heavy metal concentrations in sachet water. Regular maintenance and monitoring of water treatment facilities are essential to ensure their optimal performance.

In conclusion, this study highlights the presence of selected heavy metals in sachet water samples from Lokoja, Nigeria. The findings emphasize the need for further research, stricter regulatory measures, and improved water treatment practices to safeguard public health. Mitigating heavy metal contamination in sachet water requires a comprehensive approach involving stakeholders from the government, water suppliers, and consumers to ensure the provision of safe and quality drinking water for the population.

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