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Analysis of heavy metals content in well water and its predictive insights for students' wellbeing in Almajiri Schools, Sokoto East, Nigeria

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Abstract

Education is a right to every child, but Sokoto is suffering from many issues ravaging education, therewith, a major issue is the Almajiri school. Because the Almajiri schools are abandoned there is every tendency that their drinking water is contaminated considering the rising pattern of pollution across the globe. The aim of the study was to carry out an analysis of heavy metal content in well water and propel some predictive insights for students well-being in Almajiri schools in Sokoto, Nigeria. Samples of well water were collected from Almajiri schools in Sokoto state and metals were analyzed using atomic abortion spectroscopy. 60.10 ± 5.1 to 600.1± 0.01, 100.1 ± 0.5 to 600.0 ± 0.02, are the ranges of calcium, and magnesium macroelements determined. The ranges for essential heavy metals zinc, and iron are as follows; 2.34 ± 0.05 to 5.00 ± 0.02 (zinc), and 0.54± 0.05 to 10.43 ± 0.5 (iron) respectively. The ranges of Pb, Hg, and Cd assessed are as follows: lead (0.0 to 1.06 ± 0.005), mercury (0.10 ± 0.002 to 2.501 ± 0.01), and cadmium (0.00122 ±0.0004 to 0.0761 ± 0.0001). The HI for the heavy metals determined are in the order of schools B>D>A>C. The metals determined are either excess or little (with respect to essential heavy metals) in many cases. In one school, the HI is far above 1 and therefore risk the population with effects. Thus, can elicit harm to the consumers. They can affect the academic, cognitive capacity of the Alamjiri children. There is need to take proper measures to save the health and future development of the Almajiri child against heavy metals poisoning possibility.

Keywords: *School; Almajiri; heavy metals, risk, cognitive capacity, academic performance, health, education*

INTRODUCTION

Education involves training a person or group of persons to read, write, and be proficient in specific aspects of life and to be able to conform to acceptable norms of society (Bello et al., 2017). Nowadays, education is a pertinent pillar that is required for growth and development of people, communities, individuals, and societies. The significance of education in the empowerment, progressiveness and guidance of any person through the course of life cannot be overemphasized. Education provides students and learners with bright future by giving needed skills and employability skills or credits to be more educated (Ibrahim et al., 2021).

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Nevertheless, Almajiri system of education is an education that employs boarding school system to teach children the Holy Quran. It is mostly happening in Northern Nigeria and neighbors. However, the system has not been supported properly by the government or the public; thus, it languishes with a number of challenges. It suffers the problem of poor water, sanitation, and hygiene. And because of the current increase in pollution due to (heavy) metals, the Almajiri school drinking water could have be contaminated. Contamination with heavy metals could invariably affect the academic, cognitive, and other abilities of Almajiri students consequently (Bello et al., 2017; Mohammed et al., 2022; sarkingobir et al., 2022).

All the elements found on Earth are either classified as metals or non- metals or metalloids. Non-metals are poor conductors of electricity, non- malleable and non-ductile. While metalloids are at the interplay state between the metals and non- metals (Al-thani et al., 2023). However, the metals possessed properties that are in conflict with those of the non- metals. Metals are elements with distinctive properties such as lustre, opaqueness, ability to conduct electricity and heat at high rate, malleability, ductility, high light reflectivity, and relations (Labbo et al., 2021, Umar et al., 2022, Al-thani et al., 2023).

About 2-3 of the presently identified elements on Earth are regarded as metals, that is why metals are among the most abundant elements on Earth. For instance, in case of Fe, Na, K, Ca, Mg and relations (Hamza et al., 2023, Mafuyai et al., 2020, Umar et al., 2022).

Some metals are classified into different classes based on certain criteria taken into cognizance certain distinguishing features. Metals can be essential ones, when they are nutritionally beneficial, for example in the case of Cu, Fe, Zn, Mg, Ca, Na, K, and the likes. These metals need to be taken usually through diet at certain optimum amounts for the body to properly execute biological metabolic activities (Olagunju et al., 2020). Therefore, any little distortion of concentration of these individual or combo of metals, leading to high or low intake could elicit harmful effect in the biological system (Njoga et al., 2021). Likewise, some groups of metals are technically dubbed as heavy metals. Heavy metals are a group of metals or metalloids possessing comparatively high density (above 5g/cm3), and possessed other inimical properties including bioaccumulation ability, high Toxicity, and ability to elicit Toxicity at very minute concentration (Umar et al., 2023).

Furthermore, heavy metals are classified as essential and non-essential. In case of elements like iron, and Zinc, they acquire biological functions required by human body. While, in the case of some metallic elements, they are regarded as non-essential heavy metals because there is no known function which they play in the human biological. Elements like Cd, Pb, Hg and some forms of Chromium metal belong to this category (Njoga et al., 2021).

Certainly, heavy metals and other metallic forms naturally exist in the earth's crust. However, the increasing rise in the anthropogenic activities such as indiscriminate waste disposal, agrochemicals application, crude oil spillage, improper disposal effluent, livestock production fishing, aquatic transportation, aquatic farming, mining e.t.c. (Witkowska et al., 2021) across the parts of the world has sufficiently divulged excess heavy metals into the midst of biological systems (Olagunju et al., 2020). Consequently, these metals through pollution find their ways into all phases of the environment including water and food for the ultimate intake by humans and other organisms (Al-thani et al., 2023; Umar et al., 2023).

Therefore, it is important to constantly monitor levels of heavy metals in environmental components such well fresh water considering its vast roles in the life of residents' communities (such as Almajiri schools). High levels of heavy metals in water could lead to detrimental Effects on the aquatic plants and aquatic animals, the essential components of the biosphere. Moreover, the elevated levels of metals in water could elicit uptake by plants and animals that are taken by humans or other animals. Likewise, intake of

heavy metals polluted water could elicit detrimental effects on humans or other animals as well (Yahaya et al., 2019; Uba et al., 2016). Heavy metals (such as lead, cadmium, and mercury) affect development, cognitive ability, affect brain development, decreased density of memory, reduced the density of dendritic spines in the hippocampus, and affect cognitive development (Balali-mood et al., 2021; Al-thani et al., 2023). The aim of the study was to carry out an analysis of heavy metal content in well water and propel some predictive insights for students well-being in Almajiri schools in Sokoto, Nigeria

Statement of the problem

In Nigeria, there is complaint about the rising increase in environmental pollution or contamination which is due to the diverse array of activities including domestic, industrial, agricultural, medical, technologic application and ultimately causing food poisoning in animals and humans included (Uba et al., 2016). Furthermore, pollution affect everything including plants, pastures, fodder, and drinking water (Umar et al., 2023). Heavy metals are good at making a complex with biomolecules such as DNA, Enzymes, proteins, phospholipids, hormones, and other components in the biological system. In turn, the complex changes the nature of biomolecules by rendering them altered in terms of biochemistry, transport, and signaling of host. The affected body parts could change and become incapacitated or reduced in activities (Njoga et al., 2021; Olagunju et al., 2020). For instance, Pb, Cr, and Cd are reported toxins affecting the liver, kidney, nervous system, and are known carcinogens (Evens et al., 2015; Njoga et al., 2020).

Pb cause abnormal bone formation, affect pregnancy, affect hemoglobin synthesis, damages GIT, damages nervous system, e.t.c. (Witkowska et al., 2021). Cd is toxic at low concentration. It can cause renal dysfunction, lung disease, bone defect, high blood pressure, reproduction defects and other pulmonary outcomes (Witkowska et al., 2021). Hexavalent Chromium is toxic and as well as carcinogenic (Witkowska et al., 2021). Too much Fe can elicit vomiting, nausea, diarrhea, cramps, and abdominal pain (Mafuyai et al., 2020).

Consequently, it is important to monitor the levels of heavy metals in water in our environment. An analysis of well water sample in Kebbi state shows that there might be no risk regarding the concentration of Pb, Zn, Fe, Cr in Kebbi. However, Cd presence in the water is at a level that is harmful (Yahaya et al., 2019). Suleman et al., (2018) conducted an assessment of parameters of Kware Lake, and found that Pb, Zn, were below WHO recommended limit, but Fe is excess. Uba et al., (2016) in their Sokoto study of water, found that, Na, K, Ca, Mg, were within the limits. Thus, heavy metals were not examined therewith. A study of well water collected in Sokoto East from Almajiri schools shows elevated Pb, Cr, and Cd above WHO limits (Sarkingobir et al., 2023). Sarkingobir et al., (2023) examined heavy metals in well water from selected secondary School in Sokoto East and observed that the water contains K, Ca, Mg, Zn, Cu and Fe. Therefore, there is scarcity of information about heavy metals in drinking water in Almajiri schools water, Avery important sources for domestic and agricultural purposes. The analysis of heavy schools, in Sokoto East, Nigeria. Thus, this work is important because of the role of the water for domestic and agricultural purposes and has to be of good quality to safeguard public health. The information obtained in this work, will serve to inform the public about the possible risk of taking the water and risk of pollution at the area. Likewise, the policymakers will be briefed with the baseline data for taking measures, to control pollution and safeguard health through water quality maintenance. Students and Scholars would find a baseline information for further studies regarding the heavy metals in Almajiri Schools in Sokoto. The aim of the study was to carry out an analysis of heavy metal content in well water and propel some predictive insights for students well-being in Almajiri schools in Sokoto, Nigeria.

Almajiri is a word in Hausa language that was borrowed from Arabic word "Almuhajir" the immigrant (for the sake of Islam) (Sarkingobir et al., 2020; Bello et al., 2021). They refer to a system of Quranic education in Hausa land of Nigeria and the likes. Almajiri is the student in Almajiri school. Almajiri school is a system of education in which a child is taken to an Islamic boarding school where he spends years before going back home in most cases (Sokoto et al., 2018). In the past the system was better, and currently the system was bad because the public, parents, and the government are not supporting it (Hiliya et al., 2021; Hiliya et al., 2022; Mohammed et al., 2022). Heavy metals are metals of high density above 5g/cm3 and have tendency to cause toxicity (Rahman etal., 2019; Zhang et al., 2019). Because, the Alamajiri schools suffer challenges including that of poor water, sanitation, and hygiene, it is possible that the rising extent of pollution has led to contamination of Almajiri drinking water at schools (Dalhat et al., 2016; Sarkingobir et al., 2019). A consequent situation that can affect health, and learning of the Almajiri children.

Research Objectives

The research questions made for this study are as follows:

1. What are the concentrations of Ca, Mg, Fe, and Zn determined in well water in Almajiri schools in Sokoto, Nigeria?
2. What are the levels of concentrations of Pb, Hg, Cd determined in well water in Almajiri schools in Sokoto, Nigeria?
3. What are the estimated risks of non-carcinogenic health effect due to the contamination of heavy metals in Almajiri schools drinking water, Sokoto Nigeria?

RESEARCH METHOD

Study Area

The study was carried out in Sokoto state, Nigeria. Sokoto State is located at the extreme Northwest corner of Nigeria, it lies between latitudesm11E and longitude 4N bounded in the East by Zamfara State, in the North by Niger Republic and in the west by Kebbi State. It is within the savannah region with scanty vegetation and shrubs. Two intermit rivers cut across the State i.e. River Sokoto and River Rima with a confluence at Wamakko, move southwest and finally discharge into River Niger (Hamza et al., 2023).

Sample Collection

The sample was collected from Different Almajiri schools in Sokoto East, Nigeria. The sample was collected from different wells in Sokoto East area. The samples collected from schools were labeled A to D.

Preparation

1-litre sterile containers containing sodium thiosulphate (5mg/litre) were used to collect well water samples from different Almajiri schools in Sokoto, Nigeria. 1000ml capacity bottles were used to collect well water samples using local collecting vessel. All water samples were properly covered, 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. Then 5ml of sulfuric acid was added and 2ml of perchloric acid (70% of HCLO4) was added. The preparation was heated to dryness. Then 15ml of water was added, filtered using filter paper into volumetric flask. Filter paper was washed with water, then

diluted with deionized water. The preparation was taken to AAS machine for analysis (Umar et al., 2022).

Principle of Atomic Absorption Spectroscopy

In Atomic Absorption Analysis, the absorption of light uses an instrument called Atomic Absorption Spectrophotometer (AAS). In this process, flame system is generally employed to dissociate element from their chemical bonds. The atoms absorb light at characteristic wavelength chemical bonds. The atoms absorb light at characteristic wavelength when present in their ground state. A mixture of air and acetylene produce a flame which is of a sufficient high temperature to ensure the presence of free atoms of most elements. The use of nitrous oxide in place of air result in a higher temperature and this is necessary for the estimation of certain elements (Umar et al., 2022). The narrow spectral line of the sample necessitates the use of line source as well as high resolution monochrometer. This help to prevent interference from adjacent spectral lines of other species on the sample matrix. AAS in conjugation with flame atomizer was used to determine specific metals in a liquid sample, the availability of a spectrometer equipped with a lamp turret facility the measurement of multiple metals in a sample.

Procedure for Atomic Absorption Spectroscopy (AAS)

The AAS machine was used to determine the presence and concentration in the sample containing the metals analyte aspirated into air-acetylene flame causing evaporation of the solvent and vaporization of free metal atoms. This method is called atomization, a line source (hallow cathode lamp) operating in the Uv-visible spectra region is used to cause electronic excitation of the metal and the absorbance is measured with a conventional Uv-visible dispersive spectrometer with photomultiplier detector (Umar et al., 2022).

Estimation of Human Health Risk

Human Health risk was calculated using different equations shown in this section. EDI=CP×IR×EF×ED/Bw×AT

Where, EDI= Estimated Daily Intake, CP= concentration of metal in water, IR=Ingestion Rate=0.0004kg daily water intake, EF= Frequency of Exposure=365 days, ED= Exposure Duration=20 years, Bw= weight = 30 kg for children AT= 25550 days.

Hazard Quotient (HQ) = EDI/RfD
Where, RfD= Chronic Oral Reference Dose, Zn=0.003, Fe=0.7, Cd: 0.0005, Pb: 0.004, Hg= 0.1
Hazard Index (HI)= Summation of individual HQs
(Olagunju et al., 2020; Tschinkel et al., 2020).

Statistical Analysis of Data

Data generated were statistically analyzed using IBM - SPSS Statistics version 20 computer program. The one-way analysis of variance (ANOVA) test were used to ascertain the levels of metals in Almajiri school drinking water in Sokoto, Nigeria at $P < 0.05$.

FINDINGS AND DISCUSSION

Research questions one: What are the concentrations of Ca, Mg, Fe, and Zn determined in well water in Almajiri schools in Sokoto, Nigeria?

Table 1. Concentrations of Ca, Mg, Fe, and Zn determined in well water in Almajiri schools in Sokoto, Nigeria

School	Zn	Ca	Fe	Mg
A	5.00 ± 0.02	600.1 ± 0.01	5.100 ± 0.3	21.70 ±0.1
B	2.34 ± 0.05	300.1 ±0.5	10.43 ± 0.5	300.0 ± 0.01
C	4.65 ± 0.01	100.1 ±1.4	0.546 ± 0.05	100.1 ± 0.5
D	4.110 ± 0.05	60.10 ±5.1	10.10 ± 0.05	100.1 ± 0.5

Source: Field work 2023

The results for analysis of heavy metal content in well water and predictive insights for students well-being in Almajiri schools in Sokoto, Nigeria was shown in Table 1-5. In Table 1 the concentrations of some metals (namely, zinc, calcium, iron, and magnesium) that are required by the human biological systems (at optimum amount) determined in well water sampled from Almajiri schools in Sokoto, Nigeria were shown. Therein, 60.10 ± 5.1 to 600.1± 0.01, 100.1 ± 0.5 to 600.0 ± 0.02, are the ranges of calcium, and magnesium macroelements determined. The ranges for essential heavy metals zinc, and iron are as follows; 2.34 ± 0.05 to 5.00 ± 0.02 (zinc), and 0.54± 0.05 to 10.43 ± 0.5 (iron) respectively.

Research question two: what are the levels of concentrations of Pb, Hg, Cd determined in well water in Almajiri schools in Sokoto, Nigeria?

Table 2. Concentrations of Pb, Hg, Cd determined in well water in Almajiri schools in Sokoto, Nigeria

School	Pb	Hg	Cd
A	0.005 ± 0.002	2.501 ± 0.01	0.701 ± 0.0001
B	1.0 ± 0.002	0.101 ± 0.002	0.0702 ± 0.002
C	0.00	0.101 ± 0.002	0.001222 ± 0.0004
D	1.06 ± 0.005	0.455 ± 0.005	0.00134 ± 0.0001

Source: Field work 2023

Table 2 shows the concentrations of lead, mercury, and cadmium in well water in Almajiri schools in Sokoto, Nigeria. The ranges for the assessed metals are as follows; lead (0.0 to 1.06 ± 0.005), mercury (0.10 ± 0.002 to 2.501 ± 0.01), and cadmium (0.00122 ±0.0004 to 0.0761 ± 0.0001).

Research question three: What are the estimated risks of non-carcinogenic health effect due to the contamination of heavy metals in Almajiri school drinking water Sokoto Nigeria?

Table 3. Showing EDI for the Concentrations of Zn, Fe, Pb, Hg, Cd determined in well water in Almajiri schools in Sokoto, Nigeria

School	Zn	Fe	Pb	Hg	Cd
A	0.0000191	0.0001943	0.00	9.523809E-5	2.899047E-6
B	8.914286E-5	0.0003973	1.904761 E-7	3.847619E-6	2.674286E-6
C	0.000171	0.000208	0.00	3.847619E-6	4.647619e-8
D	0.0001565	0.0003847	3.847619E-6	1.7333333e-5	5.104761E-8

Table 3 shows the EDI for heavy metals based on the concentrations determined in well water in Almajiri schools from Sokoto, Nigeria. All the values estimated are less than one, and relatively far away from one.

Table 4. Showing HQ for the Concentrations of Zn, Fe, Pb, Hg, Cd determined in well water in Almajiri schools in Sokoto, Nigeria

School	Zn	Fe	Pb	Hg	Cd
A	0.000637	0.000278	0.00	0.0009523	0.000102
B	29.714287E-5	0.000568	4.761904 E-7	3.847619E-5	0.000534
C	0.0057	0.000297	0.00	3.847619E-5	9.295238E-5
D	0.000522	0.000549	0.10095	0.000173	0.000103

Table 4 shows the HQ for the heavy metals in Almajiri well water in Sokoto, Nigeria. All the values are less than one, and 99% are far away from one.

Table 5. Showing HI for the Concentrations of Zn, Fe, Pb, Hg, Cd determined in well water in Almajiri schools in Sokoto, Nigeria

School	HI
A	0.0019663
B	7.729923
C	0.000998
D	0.017697

While, Table 5 shows the HI for the heavy metals determined. The values are in the order of schools B>D>A>C.

Almajiri education is a renown, cultural, and olden system of education in the northern part of Nigeria and many other countries where Muslims live. It is olden and well-entrenched system of education mostly for Muslim children (Maigari, 2017).

However, with the advent of colonialization in Nigeria, the Almajiri education has been abandoned to its fate. The public (including the wards of the students), wealthy, and the government have failed to properly support the Almajiri system. Thus, the students at Almajiri schools in many cases are synonymous to begging, poor environmental hygiene, poor parental care, child labor, vulnerability, poor WASH (water, sanitation, and hygiene) etc (Sughis et al., 2012; Teke et al., 2020; Bello et al., 2021; Sarkingobir et al., 2023). Nevertheless, most of the studies in Sokoto do not assess the quality of drinking water at Almajiri schools that can make or mar the health of the Almajiri (children at very younger age). This study aimed to estimate the possible risks of consuming well water at Almajiri schools in Sokoto, Nigeria. Meanwhile, in Table 2, the calcium determined is a little bit lower than the recommended (daily) dietary allowance (RDA) of the Food and Nutrition Board (USA) and magnesium in school A is above the RDA, magnesium in school B is slightly below the RDA, magnesium in schools C and D are below the RDA (350mg). Thus, the levels in water are of concern (Duruibe et al., 2007; Umar et al., 2022; Wali et al., 2022).

The levels of Fe in Almajiri water as shown in Table 1 are below the RDA recommended by the Food and Nutrition Board (FNB) for children. And that of zinc is equivalent to the RDA set by FNB USA (Duruibe et al., 2007; Mathew et al., 2021; Heng et al., 2022). The levels of cadmium determined in schools C, D are lower than maximum acceptable concentration set by WHO, but above the NAFDAC maximum acceptable concentrations (Duruibe et al., 2007; Farias et al., 2022). In schools A and B mercury is above the levels set by NAFDAC and WHO (Duruibe et al., 2007).

Table 3 shows the EDI for heavy metals in Almajiri school well water in Sokoto, Nigeria. The EDI in all the samples are below 1; therefore, putatively there may be little risk due to the consumption of the individual metals at the observed concentrations. As depicted in Table 4, the HQ for zinc, iron, lead, cadmium, and mercury are below 1, indicating that, there might be little risk. Likewise, in Table 5 the overall risk estimation calculation shows results lower than one in schools A, C, and D; albeit school d and A are reaching the value of one, meaning slight concentration increase could be hazardous. On the other hand, the school B has a value above one, a value that depicts possible risk due to consumption of the four metals present in the well water.

Generally, metals are parts of the environment we live in, and many of them are applicable in adverse array of purposes in human endeavors (Raji et al., 2010; Quds et al., 2021). Many of them are required at optimum amount to be useful to biological system. Therefore, the uncontrollable release of metals from the crust to the immediate human contact has led to increase in intake of essential metals through sources such as water is a great concern (Uba et al., 2016; Rahman et al., 2019; Aved et al., 2021; Seiyaboh et al., 2022). The findings of this study shows concerns pertaining calcium, magnesium, lead, cadmium, iron, mercury, and the least zinc as depicted by estimations of these metals in Almajiri school water. These metals have been found as either little or too much in the observed water in most cases. On the general, low zinc causes anemia; low or excess calcium causes low bone quality; low magnesium affects ATP metabolism. While, lead, cadmium, and mercury are toxic to the body even at low concentration (Bello et al., 2017; Kowalska et al., 2018; Farias et al., 2022).

Some physical effects of cadmium include lung disease, bone defects, nausea, stomach cramp, edema, dyspnea. Lead is an important toxic metal capable of causing dysfunction of kidney, central nervous system, effects of GIT, poor growth and development. Mercury can debilitate the renal and nervous system as well (Saeed et al., 2011; Mahurpawar, 2015; Mathew et al., 2021). Additionally, the heavy metals in Almajiri school water can pose diverse risk to the children's learning capacity, academic performance and cognitive ability. Parable, lead causes central nervous system disorders, and anemia, and neurotoxicity. Mercury causes nervous system disorders through its ability to cross the blood brain bilayer (BBB) easily. Hg also causes memory loss, headache, insomnia, tremors, emotional lability, neuromuscular alterations (Balali-mood et al., 2021; Wikowska et al., 2021). These implied that, the heavy metals consumption in water can affect education of children at least through three ways as follows: 1. Firstly causing sickness or disorders that in turn lead to absenteeism for sickness behavior and poor academic performance 2. Secondly, causing direct effect on nervous system, and on growth and development, that are crucial for learning 3. And ultimately, affecting the academic performance through the earlier mechanisms. It is paramount to ensure the quality of public water at Almajiri schools in Sokoto, Nigeria (Balali-mood et al., 2021).

CONCLUSIONS

The aim of this study was to basically determine (heavy) metals (Cd, Pb, Hg, Fe, Zn) and Ca, Mg. The study also aimed to give an insight about the possibility of effects due to the consumption of the water by Almajiri students. The findings of this study shows concerns pertaining calcium, magnesium, lead, cadmium, iron, mercury, and (the least zinc) as depicted by estimations of these metals in Almajiri school water. Most of the water from the schools either contained excess heavy metals such as Cd, Pb, and Fe or contains low Ca and Mg. Particularly in one of the schools, the analysis shows that, there the population consuming the water are at risk because the HI is extremely above 1. Thus, these metals are not at required levels and effects could manifest in the affected students. Effects on overall health and subsequently on learning and academic capacity of the students.

LIMITATION & FURTHER RESEARCH

Since this study is a survey design, there is need for experimental or case-control or other mote robust methods that will augment the findings of this study.

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