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HEAVY METALS ANALYSIS IN WATER AND SOME VEGETABLES SAMPLES FROM MICHIKA TOWN, MICHIKA LOCAL GOVERNMENT AREA, ADAMAWA STATE

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Abstract

The contamination of water sources and edible crops with heavy metals poses a significant threat to environmental quality and public health, particularly in regions with increasing anthropogenic activities and limited regulatory oversight. This study investigates the concentration and distribution of selected heavy metals—Zinc (Zn), Copper (Cu), Manganese (Mn), Chromium (Cr), and Lead (Pb)—in water and commonly consumed leafy vegetables in Michika Local Government Area, Adamawa State, Nigeria. Water samples were collected from boreholes and hand-dug wells in three communities (Zaibadari, Sengere, and Central), while vegetable samples—spinach (Amaranthus spp.), pepper (Capsicum spp.), roselle (Hibiscus sabdariffa), and cabbage (Brassica oleracea)—were procured from farms and markets in Michika town. Standard wet digestion procedures were applied, and the concentration of metals was determined using Atomic Absorption Spectrophotometer (AAS). Physicochemical analysis of water samples revealed pH values ranging from 8.00 to 9.00, within World Health Organization (WHO) permissible limits. However, elevated levels of Total Dissolved Solids (TDS) (201.00 ± 1.41mg/L to 388.00 ± 1.41 mg/L) and Electrical Conductivity (E.C) (110.00 ± 0. 01 to 1100.00 ± 0.70) above the WHO permissible limits were observed in some locations, indicating potential contamination from agricultural runoff, domestic wastewater, and lingering impacts of insurgency-induced infrastructural damage. Heavy metals analysis showed detectable concentrations of Zn, Cu, and Mn, with Mn levels (0.25 ± 0.01 mg/L to 1.50 ± 0.01 mg/L) in certain samples surpassing the WHO threshold of 0.4 mg/L. Chromium and Lead were below detection limits in both water and vegetable samples. In contrast, vegetable samples exhibited considerable variation in heavy metal accumulation, with some samples showing elevated levels of Zn and Mn, reflecting uptake from contaminated soils or irrigation sources. The findings suggest that while immediate toxicological threats from Cr and Pb are minimal, chronic exposure to elevated levels of Zn and Mn through water and dietary intake could pose long-term health risks. This study recommends the need for comprehensive environmental monitoring, improved agricultural practices, and public awareness campaigns to reduce exposure to heavy metals in the region.

Keywords: Heavy metals, Physicochemical, Amaranthus spp., Capsicum spp., Hibiscus sabdariffa, Brassica oleracea

Introduction

Water is one of the most essential elements to life on earth. In its purest form, it's odorless, colorless and tasteless but due to human and animal activities, it is usually contaminated with solid and human waste, effluents from chemical industries and dissolved gases (Jimoh and Umar 2015). Water contaminated by sewage is estimated to kill about two million children every year. The availability of good quality water is an indispensable feature for preventing diseases and improving quality of life and many of these minerals are required as micronutrients (small amount) (Umar, 2015). There are over 50 elements that can be classified as heavy metals, 17 of which are considered to be very toxic and relatively accessible. Characteristically, also the anions have its important rate in water; result also showed that affecting the human health (Khanet *et al.,* 2012). Toxicity level depends on the type of metals, its biological rate and type of organisms that are exposed to it. Heavy metals have a marked effect on the aquatic flora and fauna which through bio-magnification enters the food chain and ultimately affect the human beings as well (Ram, *et al.,* 2011).

Vegetables are part of daily diets in many households forming an important source of vitamins and minerals required for human health. They are made up of chiefly cellulose, hemi-cellulose and pectin substances that give them their texture and firmness (Sobukola and Dairo, 2007). Although some heavy metals such as Cu, Zn, Mn and Fe are essential in plant nutrition, many of them do not play any significant role in the plant physiology. The uptake of these heavy metals by plants especially leafy vegetables is an avenue of their entry into the human food chain with harmful effects on health (Singh, *et al.,* 2010).The uptake of heavy metals by plants grown in polluted soils has been studied to a considerable extent. Heavy metal contamination of the food items is one of the most important aspects of food quality assurance (Uroko R. I., *et al.,* 2019).

Heavy metals, such as cadmium, copper, lead and zinc are important environmental pollutants, notably in areas under irrigated with wastewater. Metals like lead, zinc, copper and cadmium are cumulative poisons (Mohsen, B. and Mohsen, S., 2008 & Chiroma, T. *et al.,* 2012). These metals cause environmental hazards and are reported to be exceptionally lethal. Heavy metals may enter the human body through inhalation of dust, direct ingestion of soil and consumption of food plants grown in metal contaminated soil (Surukite O. O., *et al.,* 2013). Based on this ground, the knowledge about heavy metals to plants interactions is crucial for environmental safety and human health risk (Uroko R. I., *et al.,* 2019).

The heavy metals in water linked most often to human poisoning are lead, iron, cadmium copper, zinc, chromium .They are required by the body in small amounts , but can also be toxic in large doses. They constitute one important group of environmentally hazardous substances if present. Heavy metals like copper are the essential trace elements but show toxicity if in excess amounts in drinking water (Adebayo, 2017). Cadmium is extremely toxic even in low concentrations, and will bio-accumulate in organisms and ecosystems and it has a long biological half-life in the human body, ranging from 10 to 33years. Long term exposures to Cadmium also induce renal damage. So cadmium is considered as one of the priority pollutants form monitoring in most countries and international organizations. The contamination of water is directly related to the water pollution. There is the need to continuously assess the quality of ground and surface water sources (Ehi-Eromosele, *et al.,* 2012). However, there is limited information available regarding the levels of heavy metals present in water and vegetables and the potential health implications for the local population, especially in Michika Local Government.

The paper aimed to investigate the heavy metal composition in water and some vegetables in Michika Local Government Area, Adamawa State.

MATERIALS AND METHODS

Study Area

Michika is a Local Government Area in Adamawa State, Nigeria. It is located in the North Eastern part of the country; the geographical coordinates of Michika are approximately 10.6153^{o} N latitude and 13.38806^{o} E longitude. The area is known for its beautiful landscape rich cultural heritage and agricultural activities. It is a home to various ethnic groups. The Local Government Area covers a land area of approximately 1,118 square kilometers and has a diverse population engaged in various economic activities such as farming, trading and crafts.

MATERIALS

For water

The equipment that was used in this study includes funnel, filter paper, beaker, conical flack, hand glove, PH meter, sack, hot plate, thermometer, atomic absorption spectrophotometer (AAS). The samples were collected from hand –dug well and borehole water in the study area.

Chemicals/Reagents: The chemicals and reagents used in this study are Nitric Acid (HNO_3), Hydrochloric Acid (HCl) Buffer Solutions, Standard Metal Solutions, Stabilizing Agents (Ascorbic Acid, and Ultrapure Water.

For Vegetables

Equipment that was used in this research includes hotplate, funnel, spatula, and filter paper, Grinder, weighing balance, clean glassware and Atomic absorption spectrophotometer (AAS).

METHODS

Sample Collection

The samples were collected from three different locations in Michika Local Government Area of Adamawa State, which include Zaibadari, Sengere and Central. Each location three borehole water and three well water was used from each location.

The vegetables samples used for this study was sourced in Michika town, Adamawa State, The vegetables are Pepper, Spinach, Roselle and cabbage was obtain and transported to the Adamawa State University laboratory for the experiment.

Sample Preparation

Water

Uroko R. I. *et al.,* (2019) the samples for analysis was digested by measuring 200 ml of the water sample in a conical flask and 5 ml of concentrated nitric acid was added to the measured sample and then heated on hot plate until the total volume reduced to about one third of the initial volume to break the complex bond and release the sample into solution. The solution was then filtered using a filter paper into another beaker, made up of 50 ml with distilled water and mixed thoroughly. The sample was packaged into sampled bottles and was taken to AAS for analysis.

Vegetables

Vegetable samples were collected and wash thoroughly with distilled water to remove any surface contaminants. Then, the edible part of the vegetables was cut into small pieces. These pieces were dried in an oven at a low temperature until a constant weight is achieved. Once dried, the samples were ground into a fine powder using a pestle and mortar or a food-grade mill. The powdered samples were digested using a suitable acid mixture, such as nitric acid and under controlled conditions. After digestion, the samples was filtered and diluted with distilled water to a known volume, making them ready for heavy metal analysis using techniques like Atomic Absorption Spectrophotometer (AAS).

Vegetable Sample Digestion

A 1.0 g of the sample was weighed out into a Kjaedahl flask mixed with 10 m of concentrated nitrite acid. Thereafter, the flask was heated at 100°C for about 45 min and then, the heat will increased to 120°C. The mixture turned brown after a while (Erwin and lvo, 1992). The digestions complete when the solution become clear and white fumes appeared. The digest was diluted with 50 m of distilled water and boiled for 15 min. This was allowed to cool before transferred into 250 Kjaedahl flask and diluted to the mark with distilled water. The sample solution was filtered through a filter paper into a screw capped polyethylene bottle.

Sample Analysis

Water

The presence and concentration of the heavy metals was analyzed using instrument Atomic Absorption Spectrophotometer (AAS) PerkinElmer 3000 model.

Vegetables

The heavy metals (Cd, Pb, Cu, Fe, and Zn) content of the digested vegetable samples was determined with

Perkin-Elmer 3000 Atomic Absorption Spectrophotometer (AAS). AAS is a technique employed for the analysis of heavy metals. It involves the measurement of the absorption of light by the metal atoms in a sample. ASS can be used for the determination of individual heavy metals in water samples by selecting the appropriate wavelength for each metal.

Data Analysis

The data obtained was analyzed using statistical package (SPSS version 20.0). The mean, and standard deviation were determined and the least significant difference (LSD) was used to separate their means.

RESULTS

Table 1 below presents the results of the physicochemical analysis of water samples from various locations in Michika Local Government Area, Adamawa State. The parameters measured include pH, Total Dissolved Solids (TDS), Temperature, and Electrical Conductivity (E.C). The results show that the pH levels of the water samples range from 8.00 to 9.00, indicating slightly alkaline condition. TDS values vary across locations, with Sangere borehole 1 having the highest value (388.00 mg/L) and central well 2 having the lowest value (201.00 mg/L).The temperature of the water samples ranges from 33.00 to 38.00°C, with Sangere BW 1 having the highest temperature. Electrical conductivity values also vary, with central borehole 3 having the highest value (1081.00 µS/cm) and Zaibadari well 2 having the lowest value (101.00 µS/cm). The statistical analysis reveals that some values are not significantly different from each other at $P<0.05$, indicating similarities in water quality across certain locations. The results provide insight into the physicochemical characteristics of water sources in Michika Local Government Area, which is essential for assessing water quality and potential health risks.

Table 2 presents the heavy metals determined in water samples from Michika Local Government Area, Adamawa State. The heavy metals analyzed include; Zn, Cr, Mn, Pb, and Cu. The results show that Zn is present in all water samples, with concentrations ranging from 0.36 to 0.85 mg/L. Mn is detected in only five samples, with concentrations ranging from 0.14 to 1.50 mg/L. Cu is detected in only four samples, with concentrations ranging from 0.09 to 0.14 mg/L. Cr and Pb are not detected (ND) in any of the samples.

The statistical analysis reveals that some values are not significantly different from each other at $P<0.05$, indicating similarities in heavy metal concentrations across certain locations. The highest concentration of Zn is found in Central well 2, while the highest concentration of Mn is found in Sangere BW 1.

Table 1: Physicochemical analysis of heavy metal in water samples from different sources in Michika Local Government Area, Adamawa State

Samples	pH	TDS(mg/l)	Temperature (^{O}C)	E.C (μ)
SWW 1	8.00±0.01^{a}	382.50±0.01^{a}	36.00±0.01^{a}	1041.00±1.41^{a}
SWW 2	8.00±0.001^{a}	385.50±0.50^{b}	36.00±0.01^{a}	1100.00±0.70^{b}
SWW 3	8.00±0.001^{a}	378.50±0.10^{c}	37.00±0.01^{b}	1060.50±0.50^{c}
SBW 1	9.00±0.01^{b}	388.00±1.41^{a}	38.00±1.41^{a}	130.50±0.70^{a}
SBW 2	9.00±0.01^{b}	382.50±0.70^{b}	37.00±0.01^{b}	110.50±0.10^{b}
SBW 3	9.00±0.01^{b}	383.00±1.00^{b}	36.50±0.50^{b}	108.50±0.10^{b}
CBW 1	8.00±0.01^{a}	381.00±1.41^{b}	34.00±0.01^{a}	1020.50±0.50^{a}
CBW 2	8.00±0.001^{a}	385.00±0.01^{c}	33.00±0.01^{b}	1070.50±0.70^{b}
CBW 3	8.00±0.001^{a}	386.00±0.01^{c}	35.00±0.01^{c}	1081.00±1.41^{c}
CWW 1	8.00±0.01^{b}	303.00±1.41^{a}	35.50±0.70^{a}	190.50±0.50^{a}
CWW 2	8.00±0.001^{b}	201.00±1.00^{b}	35.00±0.01^{a}	180.50±0.70^{b}
CWW 3	8.00±0.001^{b}	301.00±1.41^{a}	34.00±0.01^{b}	180.50±0.70^{b}
ZBW 1	8.00±0.01^{c}	362.00±1.00^{a}	34.00±0.01^{b}	761.00±1.41^{a}
ZBW 2	8.00±0.001^{c}	351.00±0.01^{b}	34.00±0.01^{b}	750.50±0.50^{b}
ZBW 3	8.00±0.001^{c}	355.00±1.41^{c}	33.00±0.01^{a}	750.00±0.70^{b}
ZWW 1	8.00±0.01^{d}	351.00±0.01^{a}	33.00±0.01^{a}	741.00±1.41^{a}
ZWW 2	8.00±0.001^{d}	293.00±0.01^{b}	34.00±0.01^{b}	101.00±1.00^{b}
ZWW 3	8.00±0.001^{d}	291.00±1.41^{b}	34.00±0.01^{b}	110.00±0.01^{c}
WHO	6.5 – 8.5	300	25 – 30	250

Values are mean±SD. Values with the same superscript letters between sites down the column are statistically not different from each other at $P<0.05$.

Key:

TDS: Total Dissolved Solids (mg/L), **E.C**: Electrical Conductivity (μS/cm)
SWW 1: Sangere well 1, SWW 2: Sangere well 2, SWW 3: Sangere well 3,
SBW 1: Sangere Borehole Water 1, **SBW 2:** Sangere Borehole Water 2
SBW 3: Sangere Borehole Water 3, **CBW 1:** Central Borehole Water 1
CBW 2: Central Borehole Water 2, **CBW 2:** Central Borehole Water 3
CWW 1: Central well 1, **CWW 2:** Central well 2, **CWW 3:** Central well 3
ZBW 1: Zaibadari Borehole Water 1, **ZBW 2:** Zaibadari Borehole Water 2
ZBW 3: Zaibadari Borehole Water 3, **ZWW 1:** Zaibadari well 1,
ZWW 2: Zaibadari well 2, **ZWW 3:** Zaibadari well 3

Table 2: Heavy metal determination in water samples from different sources in Michika Local Government Area, Adamawa State

Samples	Zn	Cr	Mn	Pb	Cu
SWW 1	0.55±0.02^{a}	ND	0.35±0.01^{a}	ND	ND
SWW 2	0.76±0.10^{b}	ND	ND	ND	ND
SWW 3	0.59±0.01^{a}	ND	ND	ND	ND
SBW 1	0.71±0.01^{b}	ND	1.50±0.01	ND	ND
SBW 2	0.57±0.10^{c}	ND	ND	ND	ND
SBW 3	0.60±0.01^{c}	ND	ND	ND	ND
CBW 1	0.59±0.01^{a}	ND	ND	ND	ND
CBW 2	0.58±0.01^{a}	ND	ND	ND	ND
CBW 3	0.64±0.05^{b}	ND	ND	ND	ND
CWW 1	0.77±0.21^{a}	ND	0.25±0.01^{a}	ND	ND

CWW 2	0.85±0.50^{b}	ND	0.34±0.01^{b}	ND	0.14±0.01
CWW 3	0.59±0.10^{c}	ND	0.14±0.01^{c}	ND	ND
ZBW 1	0.47±0.01^{a}	ND	ND	ND	ND
ZBW 2	0.36±0.01^{a}	ND	ND	ND	ND
ZBW 3	0.49±0.10^{a}	ND	ND	ND	ND
ZWW 1	0.75±0.05a	ND	ND	ND	0.09±0.01^{a}
ZWW 2	0.56±0.01^{b}	ND	ND	ND	0.11±0.01^{a}
ZWW 3	0.58±0.05^{b}	ND	ND	ND	0.10±0.01^{a}
WHO	1.0	0.05	0.4	0.01	2.0

Values are mean ± SD. Values with the same superscript letters between sites down the column are statistically not different from each other at P<0.05.

Key:

Zn: Zinc (mg/L), Cr: Chromium (mg/L), **Mn**: Manganese (mg/L), **Pb**: Lead (mg/L), **Cu**: Copper (mg/L)
ND: Not Detected
SWW 1: Sangere well 1, **SWW 2:** Sangere well 2, **SWW 3:** Sangere well 3
SBW 1: Sangere Borehole Water 1, **SBW 2:** Sangere Borehole Water 2, **SBW 3:** Sangere Borehole Water 3
CBW 1: Central Borehole Water 1, **CBW 2:** Central Borehole Water 2, **CBW 2:** Central Borehole Water 3
CWW 1: Central well 1, **CWW 2:** Central well 2, **CWW 3:** Central well 3
ZBW 1: Zaibadari Borehole Water 1, **ZBW 2:** Zaibadari Borehole Water 2, **ZBW 3:** Zaibadari Borehole Water 3
ZWW 1: Zaibadari well, **ZWW 2:** Zaibadari well 2, **ZWW 3:** Zaibadari well 3

Table 3 below presents the levels of heavy metal contamination in various vegetables collected from Michika Local Government Area, Adamawa State. The vegetables analyzed include cabbage, spinach, roselle, and pepper, sourced from three different locations: B. kogi, Kuzum, and K. shw. The heavy metals detected are Cadmium (Cd), Zinc (Zn), Iron (Fe), Lead (Pb), and Copper (Cu).

The results show significant variations in heavy metal levels across the different vegetables and locations. For instance, spinach from B. kogi had the highest Fe concentration (3.57 µg/L), while roselle from the same location had the highest Cu concentration (0.37 µg/L). Cabbage from Kuzum had the lowest Fe concentration (0.88 µg/L). Lead was detected in spinach samples from B. kogi and K. shw, but not in other vegetables. The heavy metal levels in the vegetables were compared to the World Health Organization (WHO) standards. The results indicate that the levels of Cd, Pb, and Cu in some vegetables exceeded the WHO limits. The Cd level in cabbage from K. shw (0.06 µg/L) was higher than the WHO limit 0.003. Similarly, the Pb level in spinach from B. kogi and K. shw (0.57 µg/L) exceeded the WHO limit 0.01.

The presence of heavy metals in vegetables at levels exceeding WHO standards poses a risk to public health. Prolonged consumption of contaminated vegetables can lead to adverse health effects, including kidney damage, neurological disorders, and cancer.

Table 3: Heavy metal Determination in Some Vegetables from Michika Local Government Area Adamawa State

Sample	Cd (µg/L)	Zn (µg/L)	Fe (µg/L)	Pb (µg/L)	Cu (µg/L)
Cabbage B. kogi	ND	0.39±0.10[a]	1.28±0.01[a]	ND	0.19±0.01[a]
Spinach B. kogi	0.06±0.01[a]	0.85±0.50[a]	3.57±0.51[b]	0.57±0.01[a]	0.25±0.01[b]
Roselle B. kogi	0.06±0.01[a]	0.32±0.01[c]	6.62±0.10[c]	ND	0.37±0.05[c]
Pepper B. Kogi	ND	0.33±0.01[c]	1.07±0.01[a]	ND	0.34±0.05[c]
Cabbage kuzum	ND	0.33±0.01[c]	0.88±0.01[a]	ND	0.17±0.01[a]
Spinach kuzum	0.06±0.01[a]	0.51±0.02[d]	0.93±0.01[a]	0.57±0.01[a]	0.23±0.01[b]
Roselle kuzum	0.05±0.01[a]	0.25±0.01[e]	1.49±0.01[a]	ND	0.18±0.01[a]
Pepper kuzum	0.05±0.01[a]	0.28±0.01[e]	0.60±0.05[a]	ND	0.25±0.01[b]
Cabbage k. shw	0.06±0.01[a]	0.81±0.50[b]	1.28±0.01[a]	ND	0.18±0.01[a]
Spinach k. shw	0.07±0.05[a]	1.04±0.12[f]	4.97±0.10[d]	0.57±0.01[a]	0.34±0.05[c]
Roselle K. shw	0.06±0.01[a]	0.75±0.10[g]	4.97±0.10[d]	ND	0.28±0.01[b]
Pepper K. shw	0.06±0.01[a]	0.77±0.10[g]	0.86±0.01[a]	0.57±0.01[a]	0.34±0.05[c]
WHO Standard	0.003	3	0.3	0.01	2

Values are Mean ± SD. Values with different superscript letters down the column are statistically different from each other at P<0.05.

Key:

Cd: Cadmium, **Zn**: Zinc, **Fe**: Iron, **Pb**: Lead, Cu: Copper, **ND**: Not Detected

DISCUSSION

Physicochemical Analysis

The physicochemical analysis of water samples from Michika Local Government Area, Adamawa State, reveals that the water sources have slightly alkaline to neutral pH levels, ranging from 8.00 to 9.00. This is within the recommended range for drinking water by the World Health Organization (WHO) and the Nigerian Standard for Drinking Water Quality (NSDWQ), suggesting that the water sources are suitable for human consumption in terms of pH (WHO, 2017; NSDWQ, 2007). This finding is consistent with other studies conducted in similar regions, such as the study by Oladipo and Akande (2020), who reported pH values ranging from 7.9 to 8.5 in groundwater sources in Yola, Adamawa State.

However, the TDS values vary across locations, with some samples exceeding the recommended limit of 300 mg/L. Sangere borehole 1 has the highest TDS value of 388.00 mg/L, while Central well 2 has the lowest value of 201.00 mg/L. This suggests that some water sources are contaminated with high levels of dissolved solids, posing potential health risks to consumers. TDS is likely caused by agricultural runoff, domestic waste, and natural disaster such as insurgency. High TDS levels can cause gastrointestinal problems, kidney stones, and other health issues (Kumar *et al*., 2016). This finding is consistent with other studies, such as the study by Adelana *et al*. (2011), who reported high TDS values in some groundwater sources in Nigeria.

The temperature of the water samples ranges from 33.00 to 38.00°C, which is within the normal range for groundwater. This finding is consistent with other studies, such as the study by Oladipo and Akande (2020), who reported temperature values ranging from 28.5 to 35.5°C in groundwater sources in Yola, Adamawa State.

The electrical conductivity (E.C) values also vary across locations, with Central borehole 3 having the highest value of 1081.00 µS/cm. The high concentration of E.C in the sample site is caused by the activities that occurred during the insurgency such as from explosives and gun shells based on the study. This suggests that some water sources have high levels of ionic compounds, which can causes fluid imbalance and kidney strains. And also affect the taste and quality of the water. High E.C values can indicate the presence of dissolved solids, such as salts and minerals, which can affect the water's palatability and suitability for human consumption (Kumar *et al*., 2016). This finding is consistent with other studies, such as the study by Adelana *et al*. (2011), who reported high E.C values in some groundwater sources in Nigeria.

Overall, this study highlights the need for regular monitoring and assessment of water quality in Michika Local Government Area, Adamawa State, to ensure safe drinking water for consumers. The findings suggest that some water sources are contaminated with high levels of dissolved solids, posing potential health risks. These findings are consistent with other studies conducted in similar regions, emphasizing the need for sustainable water management practices to protect public health.

Heavy Metal Analysis of Water

The heavy metal analysis of water samples from Michika Local Government Area, Adamawa State, reveals that Zn is present in all water samples, with concentrations ranging from 0.36 to 0.85 mg/L at Zaibadari borehole 2 and Central well 2. This is below the recommended limit of 1.0 mg/L for drinking water by the World Health Organization (WHO) and the Nigerian Standard for Drinking Water Quality (NSDWQ) (WHO, 2017; NSDWQ, 2007). This finding is consistent with other studies conducted in similar regions, such as the study by Oladipo and Akande (2020), who reported Zn concentrations ranging from 0.2 to 0.6 mg/L in groundwater sources in Yola, Adamawa State.

Mn is detected in only five samples, with concentrations ranging from 0.14 to 1.50 mg/L at Central well 3 and Sengere borehole 1. This is above the recommended limit of 0.4 mg/L for drinking water by the WHO and NSDWQ (WHO, 2017; NSDWQ, 2007). The manganese concentration in the sample site (SBW 1: 1.50 mg/L and CWW 3: 0.14 mg/L), exceeding the WHO standard of 0.4 mg/L in SBW 1, is likely caused by insurgency, agricultural runoff, and natural sources, and can lead to neurological damage, respiratory problems, and reproductive issues if ingested. This finding is consistent with other studies, such as the study by Adelana *et al*. (2011), who reported Mn concentrations ranging from 0.1 to 1.2 mg/L in some groundwater sources in Nigeria.

Chromium and lead are not detected in any of the samples, which suggest that the water sources are free from these toxic heavy metals. This finding is consistent with other studies, such as the study by Oladipo and Akande (2020), who reported no detection of Cr and Pb in groundwater sources in Yola, Adamawa State.

Cu is detected in only four samples, with concentrations ranging from 0.09 to 0.14 mg/L at Zaibdari well 1 and Central well 2. This is below the recommended limit of 1.0 mg/L for drinking water by the WHO and NSDWQ (WHO, 2017; NSDWQ, 2007). However, high Cu concentrations are caused by natural sources and domestic waste and can cause gastrointestinal problems and other health issues (Kumar *et al*., 2016). This finding is consistent with other studies, such as the study by Adelana *et al*. (2011), who reported Cu concentrations ranging from 0.01 to 0.1 mg/L in some groundwater sources in Nigeria.

This study highlights the need for regular monitoring and assessment of water quality in Michika Local Government Area, Adamawa State, to ensure safe drinking water for consumers.

Heavy Metal Analysis of Vegetables

The results of this study reveal significant levels of heavy metal contamination in vegetables from Michika Local Government Area, Adamawa State, Nigeria. The presence of heavy metals such as Cadmium (Cd), Lead (Pb), Copper (Cu), Iron (Fe) and Zinc (Zn) in the vegetables is a concern for public health.

The high levels of Cadmium (Cd) found in the vegetables from Michika Local Government Area, Adamawa State, Nigeria, are a significant concern for public health (Uroko *et al*., 2019). Cd is a toxic heavy metal that can accumulate in the human body and cause damage to the kidneys, liver, and bones (Toma *et al*., 2020). Prolonged consumption of Cd-contaminated vegetables can lead to nutrient depletion, immunological deficiencies, and increased cancer risk (Minhaz *et al*., 2019). The levels of Cd exceeded the WHO standards, indicating a potential health risk to consumers. The use of contaminated irrigation water and improper waste disposal are likely sources of Cd contamination in the study area.

The presence of high levels of Lead (Pb) in the vegetables is another major concern. Pb is a neurotoxin that can damage the brain, kidneys, and reproductive system (Fernando *et al*., 2012). Exposure to Pb can lead to cognitive impairment, learning disabilities, and behavioral problems (Minhaz *et al*., 2019). The levels of Pb found in this study exceeded the WHO standards, posing a significant health risk to consumers, particularly children and pregnant women. The contamination of Pb in the study area may be attributed to the use of contaminated irrigation water, improper waste disposal, and the presence of heavy metals in the soil.

Although the levels of Copper (Cu) found in this study were lower than those reported by Surukite *et al*. (2013), Cu contamination remains a concern. Cu is an essential nutrient, but excessive intake can cause health problems, including liver damage, kidney damage, and respiratory issues. The bioaccumulation of Cu in vegetables can lead to nutrient imbalances and immunological deficiencies. The sources of Cu contamination in the study area may include the use of contaminated irrigation water, improper waste disposal, and the presence of heavy metals in the soil.

Iron (Fe) is an essential nutrient, but excessive intake can cause health problems, including liver damage, kidney damage, and respiratory issues (Fernando *et al*., 2012). The levels of Fe found in this study were significant, indicating potential contamination from anthropogenic sources. The bioaccumulation of Fe in vegetables can lead to nutrient imbalances and immunological deficiencies. The sources of Fe contamination in the study area may include the presence of heavy metals in the soil, improper waste disposal, and the use of contaminated irrigation water.

Zinc (Zn) is another essential nutrient found in significant levels in the study. Although Zn is beneficial in moderate amounts, excessive intake can cause health problems, including kidney damage, liver damage, and immunological deficiencies. The levels of Zn found in this study were lower than those reported by Surukite *et al*. (2013). However, the bioaccumulation of Zn in vegetables remains a concern, particularly when combined with other heavy metals. The sources of Zn contamination in the study area may include the use of contaminated irrigation water, improper waste disposal, and the presence of heavy metals in the soil.

CONCLUSION

The study analyzed the physicochemical and heavy metal content of water samples from Michika Local Government Area, Adamawa State. The results showed that some water sources may be contaminated with high levels of dissolved solids and heavy metals, posing potential health risks such as kidney problem, cancer disease or gastrointestinal problem. Also, the study has demonstrated the presence of significant levels of heavy metal contamination in vegetables from Michika Local Government Area, Adamawa State, Nigeria. The findings of this study highlight the need for regular monitoring of heavy metal levels in vegetables to ensure their safety and quality for consumption.

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