Correlates of Food Contamination by Heavy Metals in Northwest Nigeria

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ABSTRACT

BACKGROUND: The increasing cases of chronic kidney disease is a global public health concern. The potential link between consumption of food contaminated with heavy metals and development of end stage renal disease is becoming an emerging challenge. This study aimed to identify heavy metal contaminants in food and environmental risk factors for development of chronic kidney disease in Nigeria.

METHODS: Cross-sectional survey in 4 high burden local government areas of Jigawa state, northwest Nigeria.

RESULTS: The median age of the respondents was 45 years (interquartile range = 30–80) years. All the households had normal values of cadmium in the food analyzed. The majority of households (97.8%) had elevated mercury levels in analyzed food. Approximately 4.2% of households had increased lead levels. Elevated mercury levels were significantly higher in households that did not cultivate the food they consumed (median = 2.503 mg/kg, $P = .05$), those that did not use fertilizer on their farms (median = 2.522 mg/kg, $P = .02$), and those whose farms were located outside their communities (median = 2.733 mg/kg, $P = .020$). Households that did not use fertilizer on the farm (median = 0.027 mg/kg, $P = .007$), and those that primarily consumed rice (median = 0.023 mg/kg, $P = .005$) had significantly higher lead concentrations.

CONCLUSIONS: We identified high levels of mercury in food samples of the majority of the households studied. Elevated levels of mercury were associated with food cultivation practices and fertilizer use. We recommend future studies that will identify points of food contamination and inform the development of appropriate environmental remediation measures.

KEYWORDS: Heavy metals, food, environmental contamination, Jigawa, Nigeria

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Introduction

Chronic kidney disease (CKD) was reported in 2022 as one of the most common chronic diseases affecting a significant proportion of the world's population.[1] According to the Global Burden of Disease (GBD) study, CKD related mortality is projected to increase by 138% in the next 30 years.[1] In addition, Acute Kidney Injury (AKI) accounts for about 1.7 million deaths globally, with an estimated 5 to 10 million annual cases.[1]

While genetic factors, age, obesity, hypertension, diabetes, proteinuria, dyslipidemia have traditionally been associated with the development and progression of kidney disease, environmental pollution, and climate change are important emerging facilitators of kidney injury.[2] Moreover, a relationship has been observed between exposure to heavy metals and kidney damage among occupationally exposed individuals and in communities where members are exposed to elevated environmental levels of naturally occurring heavy metals, such as lead (Pb), mercury (Hg), and cadmium (Cd).[3] Heavy metal pollution can occur through air, use of agricultural chemicals, contaminated food and crops, cigarettes, gasoline, and contamination of drinking water from agricultural,[4-8] and industrial activities.[4]

These environmental heavy metal contaminants are known to be potentially toxic to many body organs at high and cumulative exposure levels.[4-8] Such exposures can result in acute and chronic kidney disease, neurological disorders, respiratory problems, and cancers, among other health issues.[9] Consequently, recurrent exposure to these metals is a growing global public health challenge.

Heavy metals are important pollutants because they are both poisonous and difficult to break down in nature and can cause many human diseases and disorders.[10] Monitoring, appropriate prevention and removal of the heavy metals are required to enhance the quality of the food and make it safe for human and animals consumption as well as for other essential uses.[10-15] Many anthropogenic sources, such as fossil fuels and solid waste combustion, discharge of industrial waste, and metal mining, have been recognized as the main causes of heavy metal pollution.[11] Heavy metal contamination in the natural environment is recognized as a significant health risk to human health.[10-15] Due to their inertness and inability to be decomposed, heavy metals can enter the food chain through a variety of routes and accumulate toxically in living organisms throughout their lifetimes,[10-15] acute poisoning is unusual. Still, the long-term effects of low-level chronic toxicity from heavy metals, such as bone deterioration, and lung and liver and blood cell damage are dangerous to human health.[10]

The World Health Organization (WHO) and the United States (U.S) Environmental Protection Agency (USEPA) have set the permissible limit of heavy metals in food, therefore, it is of utmost importance to design an efficient system for monitoring and protection of food contamination,[11] there are instrumental technologies in use to determine the levels of heavy metals in food even in ultra-trace amounts such as using the Atomic Absorption Spectrophotometer (AAS).[11]

There is a pressing need for studies to identify the health effects of recurrent and prolonged exposure to HM and other environmental contaminants. The increasing generation and release of these substances as industrial and agricultural wastes, coupled with the fact these substances are not biodegradable, underscored the importance of research that quantifies the levels of these metals in common foods ingested in at-risk communities, which can result in chronic exposure among the general population.[16] Under Nigerian law, environmental protection and prevention of environmental contamination are provided for by the constitution, international treaties, common law, and state and local government laws. However, enforcement and regular monitoring for compliance are not common.[17]

A recent study from northwest Nigeria reported a significant burden of kidney disease requiring renal replacement therapy, with Jigawa State leading in terms of the number of patients managed for kidney diseases during the review period.[18] Notable risk factors identified included hypertension, and diabetes, among other risk factors .[19] Another study to identify missing links for undiagnosed kidney diseases highlighted the importance of searching for potential environmental contaminants in northeast Nigeria including Jigawa State.[20] Ibrahim et al[21] revealed that quality analysis of water samples from Hadejia and Yobe rivers showed high concentrations of lead (Pb) and cadmium (Cd), ranging from 13 to over 150 times beyond acceptable levels. There is a paucity of data on the link between heavy metal food contamination and kidney disease, this study is a significant and unique effort to uncover the potential roles of heavy metal food contamination as a risk factor of kidney disease in Jigawa state.

This study aimed to identify the levels of heavy metals (lead, cadmium, and mercury) in commonly consumed staple foods and the potential environmental factors contributing to food contamination in our study area. We hypothesized that consumption of food contaminated with heavy metals is associated with increasing burden of chronic kidney disease in Jigawa State. The findings of this research could inform policymaking regarding prevention and management of potential environmental contaminants associated with kidney disease in Jigawa state.

Materials and Methods

Study area

Jigawa State is one of the 36 states of Nigeria and is located in the north-western part of the country. The state has an estimated population of over 7 million in 2024 based on the projected population growth.[22] The population is predominantly rural (90%), the economy is largely dominated by informal agricultural activities, with over 80% of the population engaged in animal husbandry and subsistence farming. Other informal sector activities include blacksmithing, leatherwork, tailoring services, auto repairs, metal works, carpentry, tanning, dyeing, food processing, and masonry.

Study design and population

A descriptive, cross-sectional study design was used to study eligible respondents from the 4 local government areas (LGAs) (Dutse, Gumel, Jahun, and Hadejia) identified as having a high burden of kidney disease.[23] A pre-tested interviewer-administered questionnaire was employed .[24] All adults aged 18 years and above residing in the selected settlements for at least 6 months before the survey were eligible for inclusion. We excluded visitors and household members temporarily away or unwell during the survey.

Sample size estimation

The minimum sample size (n) of 361 was calculated using Fisher's formula for a single proportion.[25] The formula parameters included a 95% confidence interval (CI) ($Z = 1.96$), a prevalence rate (p) of 29.8% (0.298) from a previous study, a precision level d of 5% (0.05), an 11% possible non-response rate.[26]

Participants and household selection

We employed a multistage sampling technique: First, 1 rural and 1 urban political ward were randomly selected by simple balloting. Each local government area was allocated 90 households for interview and food sample collection. One rural and 1 urban settlement were then randomly selected from each political ward by simple balloting. Each selected settlement was allocated 45 households. We then conducted a census and numbered the houses in the selected settlements. We determined the sampling interval by dividing the total number of eligible people by the sample size. The first household was selected by simple balloting, and subsequent households were selected using the sampling interval. In each selected household, 1 adult was randomly chosen by simple balloting for the interview. Commonly consumed staple food samples were collected in plastic containers and appropriately numbered.

Data collection

We used a pre-tested interviewer-administered questionnaire consisting of 3 sections for data collection.[18] The sections covered socio-demographics, environmental and farming conditions, and details of the collected food samples. Sixteen nurses, from the general hospitals in the 4 LGAs served as research assistants. They were trained on the study objectives, community entry, research ethics, and food sample collection, packaging, and transportation.

Sample collection, transportation, digestion, and analysis

A total of 361 raw food samples were collected, including cereals (maize, rice, millet, and sorghum) and legumes (cowpea and soybean). Samples were labeled, grounded and sieved using a 100 µm sieve. Each sample was digested with concentrated nitric acid and analyzed using an Atomic Absorption Spectrometer (AAS) for mercury, cadmium and lead.[27]

Quality assurance/quality control

To ensure accuracy, all isotherm tests were repeated 3 times, and metal blanks were used as controls. Glassware was pre-soaked in 5% HNO_3, rinsed with deionized water, and oven-dried.[24] High percent recovery was observed for all metals calibrated between 0.01 and 3.5 mg/l (92%-103%). Measurements were made in triplicate, and mean values were recorded.[27] All instrumental settings were in line with recommendation in the manufacturer's manual book.[27]

Data analysis and measurement of variables

Data were entered into Microsoft Excel and analyzed using IBM SPSS Statistics version 22.0. Quantitative data were presented using the median and interquartile range, while qualitative variables were presented using frequency and percentage. The Kolmogorov-Smirnov test was used to test the normality of Hg, Pb, and Cd levels, which were found to be skewed. The acceptable levels for heavy metals were defined as cadmium ⩽ 0.2, lead ⩽ 0.2, and mercury ⩽ 0.02 mg/kg.[28] The Kruskal-Wallis test was used to compare medians between outcome and independent variables at a 5% significance level.

Ethical approval

Ethical approval was obtained from the Jigawa State Ministry of Health Research Ethics Committee on 4th, April 2022, with approval number JGHREC/2022/086. Written informed consent was obtained from the study participants, and all the principles of research ethics involving human subjects were adhered to throughout the survey. Data were collected from April 30th, 2023 to May 21st, 2023.

Results

Socio-demographic and other characteristics of respondents

The ages of the respondents ranged from 18 to 102 years with a median age of 45 years (interquartile range = 30–80 years). About two-thirds (61.8%) of the respondents were male. Most respondents (80.1%) were married. Slightly more than half of the eligible respondents resided in urban areas within 12 months prior to the survey. There were a few respondents with a known diagnosis of diabetes (5.8%), while less than a quarter were being known as hypertensive (18.0%). More than two-thirds (70.1%) reported cultivating the food consumed by household members, with slightly more than half (51.5%) using fertilizer on their farms to improve yield, mostly utilizing NPK or urea (Table 1).

Heavy metals concentration in the commonly consumed staple food

All households studied had normal values of cadmium in the food analyzed. A few households (4.2%) had elevated lead levels, while the majority (97.8%) had elevated mercury levels, (Table 2). In addition, higher levels of mercury were found in raw food from Jahun and Hadejia LGAs. A significantly higher proportion (60.0%, †0.008) of raw foods collected from Hadejia LGA had higher concentrations of lead (Table 2).

Average heavy metals in the raw foods

The mercury level was significantly higher in the raw food collected from Hadejia LGA (median = 3.084 mg/kg, $P < .001$). Significantly higher mercury levels were found among households with male respondents (median = 2.53 mg/kg, $P < .001$), those with non-formal education (median = 0.468 mg/kg, $P = .02$), and those who were not employed (median = 2.691 mg/kg, $P < .001$). Households with a prior history of kidney disease requiring renal replacement therapy within the last 5 years before the survey had significantly higher concentrations of mercury in their food (median = 2.54 mg/kg, $P = .05$). Elevated mercury levels were also significantly higher among those who do not cultivate the food they consumed (median = 2.503 mg/kg, $P = .05$), do not use fertilizer on the farm (median = 2.522 mg/kg, $P = .02$), and those whose farms were located outside their communities (median = 2.733 mg/kg, $P = .020$; Table 3).

For the Cd levels, significantly higher levels were found in Gumel LGA (median = 0.021 mg/kg, $P < .001$). Households with respondents aged 18 to 24 years had significantly higher cadmium concentrations (median = 0.015 mg/kg, $P = .02$) in

Table 1. Socio-demographic and environmental characteristics of respondents, Jigawa State, Nigeria.

VARIABLE (S)	FREQUENCY, N = 361	PERCENTAGE, %
Age (y)		
<24	35	9.7
⩾24 (Median = 45, Interquartile range = 30,80)	326	90.3
Sex		
Male	223	61.8
Female	138	38.2
Marital status		
Single	61	16.9
Married	289	80.1
Separated/divorced	5	1.4
Widowed	6	1.7
Educational status		
None	19	5.2
Quranic	171	47.4
Primary	41	11.4
Secondary	81	22.4
Tertiary	49	13.6
Place of residence in the last 12 mo		
Urban	178	49.3
Rural	183	50.7
Known diagnosis of hypertension		
Yes	65	18.0
No	296	82.0
Known diagnosis of diabetes		
Yes	21	5.8
No	340	94.2
Cultivate the food consumed		
Yes	253	70.1
No	108	29.9
Sources of additional food supply for the household		
Market	328	90.9
Shop	33	9.1
Use fertilizer for farming		
Yes	186	51.5
No	175	48.5
Name of fertilizer		
NPK/Urea	110	30.5
Manure	38	10.5
NPK and manure	6	1.7
None/not sure	207	57.3
Source of fertilizer		
Domestic animals	30	8.3
Government	27	7.5
Market	106	29.4
Not sure/not applicable	198	54.8
Location of food cultivation		
Locally/around the community	288	79.8
Brought from other states	73	20.2

(Continued)

Table 1. (Continued)

their food. Households whose respondents had Qur'anic education as the highest educational attainment, and those from rural settlements had significantly elevated cadmium levels, (median = 0.014 mg/kg, $P < .001$; Table 4).

We found significantly higher concentrations of lead in Gumel LGA (median = 0.078 mg/kg, $P < .001$) compared to other LGAs. Similarly, households interviewed with no current case of a patient undergoing renal replacement therapy had significantly higher concentrations of lead in food (median = 0.023 mg/kg, $P = .03$). Households who do not use fertilizer on their farms (median = 0.027 mg/kg, $P = .007$), and those with rice as the commonly consumed staple food (median = 0.023 mg/kg, $P = .005$) had significantly higher lead concentrations compared to other reported stable foods (Table 5).

Discussion

Heavy metals pose a significant public health problem due to their role as environmental pollutants. Their recurrent release and exposure, resulting in toxicity, is an increasingly serious issue for nutritional, ecological, environmental, and evolutionary reasons.[29] Recently, there has been growing concern about

Table 2. Distribution of heavy metals in food.

HEAVY METAL	FREQUENCY N = 361	PERCENTAGE (%)			
Cadmium concentration (mg/kg)					
⩽0.2	361	100			
median = 0.013, interquartile range (0.011, 0.012)					
Lead concentration (mg/kg)					
⩽0.2	341	94.5			
>0.2 (median = 0.022, interquartile range (0.01, 0.06))	15	4.2			
Mercury concentration (mg/kg)					
⩽0.02	2	0.6			
>0.02 (median = 2.4, interquartile range (1.3, 3.4))	353	97.8			
DISTRIBUTION OF HEAVY METALS IN FOOD ACROSS THE HIGH BURDEN LGAS					
VARIABLE	LGAS				
	DUTSE	GUMEL	HADEJIA	JAHUN	*P*-VALUE
Mercury (mg/kg)					
⩽0.02	0 (0)	2 (100)	0 (0)	0 (0)	†<.1
>0.02	88 (24.9)	85 (24.1)	90 (25.5)	90 (25.5)	
Lead (mg/kg)					
⩽0.2	90 (26.4)	84 (24.6)	80 (23.5)	87 (25.5)	†.008*
>0.2	0 (0)	3 (20.0)	9 (60.0)	3 (20.0)	

χ^2 = Chi squared, † = Fishers.
*Statistically significant.

environmental contamination by heavy metals due to increased human exposure from their prolonged use in agricultural, industrial, domestic, and technological domains.[30] While the literature has traditionally focused on factors such as diabetes mellitus (DM) or high blood pressure as established risk factors for kidney diseases,[31] researchers are now concerned about the rising number of cases globally and in some states in northern Nigeria, with environmental contamination with heavy metals in food or water being a potential missing link.[20]

The dietary intake of heavy metals through contaminated food can lead to various chronic diseases. The bio-toxic effects of heavy metals depend upon their concentrations in food, their oxidation states, the sources, and the modes of deposition,[9] of the 4 LGAs included in this study with a high burden of kidney diseases, Hadejia and Jahun LGAs have rivers passing through them. Residents near these water bodies are likely involved in swimming, drinking, and irrigation activities, which can be risk factors for contamination, subsequently affecting crops that are consumed by communities in the area. This aligns with findings of contaminated water samples analyzed and reported.[26]

All the households had acceptable levels (⩽0.2 mg/kg) of Cd in food,[20] while 4.2% had elevated levels of lead. This contrasts with a study that reported higher values of cadmium and lead in all food samples studied.[20] This study identified elevated levels of mercury in cereals, with 97.8% households having mercury levels greater than 0.02 mg/kg, which is beyond the healthy acceptable limit for human consumption. This finding is supported by papers that reported heavy metals contamination of food in various parts of Nigeria.[31-34]

The Cd level identified by our study is a good development with regards to human health and agricultural productivity in the study area. Even though plants have complex mechanisms to respond to stress conditions,[35] for example, drought,[36] Cd toxicity in plants, is associated with interference with essential functions, such as food intake and metabolism that can result in damage to plants' cell parts. Cd could also affect the microbial

Table 3. Average mercury levels in raw food by selected variables Jigawa, Nigeria.

VARIABLE(S)	MEDIAN (MG/KG)	*P*-VALUE	VARIABLE (S)	MEDIAN MG/KG	*P*-VALUE
LGA					
Dutse	1.188	<.001*	**Currently have a patient with kidney disease**		
Gumel	3.062		Yes	2.603	.1
Hadejia	3.084		No	2.272	
Jahun	2.553		**Known diabetic**		
Sex			Yes	2.646	.2
Male	2.532	<.001*	No	2.314	
Female	1.789		**Known hypertensive**		
Age group (y)			Yes	2.532	.2
18-24	1.857	.04*	No	2.282	
>24	2.404		**Use fertilizer on the farm**		
Marital status			Yes	2.155	.02*
Single	1.976	.6	No	2.522	
Married/cohabitating	2.413		**Cultivate food consumed**		
Separated/divorced	2.032		Yes	2.299	.05*
Widowed	2.157		No	2.503	
Educational qualification			**Where food is cultivated**		
None	2.413	.02*	Locally around the community	2.261	.02*
Quranic	2.468		Other communities	2.733	
Primary	1.399		**Name of fertilizer**		
Secondary	2.407		Urea/NPK	1.785	.001*
Tertiary	2.253		Manure	2.023	
Place of residence in the last 12 mo			Urea/NPK/manure	1.219	
Urban	2.533	.7	Not applicable	2.64	
Rural	2.189		**Fertilizer Supply source**		
Employment status			Domestic animals	2.093	<.001*
Employed	2.299	<.001*	Government	2.682	
Farmer	2.408		Market	1.466	
Not-employed	2.691		Not applicable	2.623	
Petty trading	1.774		**Commonly consumed staple food**		
Ever had history of kidney disease in the family			Rice	2.106	.1
Yes	2.540	.05*	Millet	2.338	
No	2.252		Maize	2.682	

*Statistically significant.

Table 4. Average cadmium levels in raw food by selected variables, Jigawa, Nigeria.

VARIABLES	MEDIAN MG/KG	*P*-VALUE	VARIABLES	MEDIAN MG/KG	*P*-VALUE
LGA			**Currently have a patient with kidney disease**		
Dutse	0.012	<.001*	Yes	0.013	.9
Gumel	0.021		No	0.013	
Hadejia	0.013		**Known diabetic**		
Jahun	0.013		Yes	0.013	.8
Sex			No	0.013	
Male	0.013	.3	**Known hypertensive**		
Female	0.013		Yes	0.013	.9
Age group (y)			No	0.013	
18-24	0.015	.02*	**Use fertilizer on the farm**		
>24	0.013		Yes	0.013	.3
Marital status			No	0.014	
Single	0.015	.1	**Cultivate food consumed**		
Married/cohabitating	0.013		Yes	0.013	1
Separated/divorced	0.019		No	0.013	
Widowed	0.017		**Where food is cultivated**		
Educational qualification			Locally around the community	288	.01*
None	0.019	.001*	Other communities	108	
Quranic	0.014		**Name of fertilizer**		
Primary	0.012		Urea/NPK	0.013	.8
Secondary	0.013		Manure	0.013	
Tertiary	0.013		Urea/NPK/manure	0.014	
Place of residence in the last 12 mo			Not applicable	0.013	
Urban	0.013	<.001*	**Fertlizer Supply source**		
Rural	0.014		Domestic animals	0.014	.4
Employment status			Government	0.014	
Employed	0.013	.6	Market	0.013	
Farmer	0.013		Not applicable	0.013	
Not-employed	0.014		**Commonly consumed staple food**		
Petty trading	0.013		Rice	0.013	.3
Ever had history of kidney disease in the family			Millet	0.013	
Yes	0.013	.6	Maize	0.015	
No	0.013				

*Statistically significant.

Table 5. Average lead levels in raw food by selected variables.

VARIABLES	MEDIAN MG/KG	*P*-VALUE	VARIABLES	MEDIAN MG/KG	*P*-VALUE
LGA			**Currently have a patient with kidney disease**		
Dutse	0.021	<.001*	Yes	0.011	.03*
Gumel	0.078		No	0.023	
Hadejia	0.027		**Known diabetic**		
Jahun	0.012		Yes	0.009	.1
Sex			No	0.022	
Male	0.019	.1	**Known hypertensive**		
Female	0.026		Yes	0.019	.3
Age group (y)			No	0.023	
18-24	0.026	.9	**Use fertilizer on the farm**		
>24	0.021		Yes	0.019	.007*
Marital status			No	0.027	
Single	0.024	.4	**Cultivate food consumed**		
Married/cohabitating	0.021		Yes	0.021	.2
Separated/divorced	0.042		No	0.024	
Widowed	0.022		**Where food is cultivated**		
Educational qualification			Locally around the community	0.022	.4
None	0.037	.3	Other communities	0.022	
Quranic	0.024		**Name of fertilizer**		
Primary	0.023		Urea/NPK	0.021	.7
Secondary	0.018		Manure	0.021	
Tertiary	0.019		Urea/NPK/manure	0.027	
Place of residence in the last 12 mo			Not applicable	0.023	
Urban	0.021	.7	Fertilizer supply source		
Rural	0.023		**Domestic animals**	0.027	.2
Employment status			Government	0.02	
Employed	0.019	.8	Market	0.021	
Farmer	0.019		**Not applicable**	0.023	
Not-employed	0.021		Commonly consumed staple food		
Petty trading	0.026		Rice	0.023	.005*
Ever had history of kidney disease in the family			Millet	0.019	
Yes	0.018	.2	Maize	0.098	
No	0.023				

*Statistically significant.

communities in soil, resulting alteration in soil fertility and nutrient cycling.[37]

A study conducted in Iran that reported the concentration of Cd in the cultivated rice in the 2 studied cities to be within the range of the national standard of Iran.[38] This finding is in line with our finding of Cd concentration in all the households we studied. Similarly, the study hypothesized potential rice pollution in Champa in Ahvaz to be due to the industrial nature of the city, while in Lordegan it was linked to pollution through use of pesticides, chemical fertilizers, and transportation activities.[38] Further, another study reported Tarom rice to have the maximum reported levels of Cd, but Pakistani rice has the lowest level.[38] These findings are likely linked to the consequences of human activities like fishing, land use through development projects, ecological and environmental pollution.[39] An analytic study revealed a link between urine Cd level and Cd consumed in rice,[40] pointing the role of heavy metals in end organ damage.

Identifying the exact point of food contamination is challenging, as it can occur at any stage from farm to plate. This study highlights areas for future research, such as identifying the use of fertilizer, the type of fertilizer used, and the source of commonly consumed food. The presence of heavy metals in food products is a concern because they are ubiquitous in the environment and can enter the food supply through plants, animals and water sources.[32] Ingesting heavy metals can lead to various adverse health effects, including organ damage, developmental alterations, and cancers.[32]

The elevated levels of heavy metals identified in this study could be a factor in the high burden of kidney diseases in the state, as evidenced by the number of people who reported a case of kidney disease in their household within the last 5 years. It is also possible that the contamination of food originated from the soil across the study areas, which may contain heavy metals, or that contamination occurred during farming, from planting to storage, through the use of pesticides, herbicides, or preservatives. This is supported by the finding of elevated mercury levels among respondents who reported using fertilizer on their farms, which could be a potential source of heavy metals.

We suggest future studies to identify the role of heavy metals in kidney disease, the causal pathway, and the relationship between cumulative exposure to heavy metals and the development of the most commonly recognized risk factors of kidney disease, notably hypertension and diabetes mellitus. This could help us understand whether cumulative exposure to heavy metals facilitates the development of these risk factors, or if the exposure independently results in kidney disease. Future studies can also explore the potential sources of contamination for preventive interventions.

This study provides insight into the pattern of contamination by heavy metals of food samples collected across the sampled households in an area with a reported high prevalence of chronic kidney disease, suggesting that consumption of food containing heavy metals is associated with an increasing burden of kidney disease, in line with our study hypothesis. However, it is limited by focusing on only 3 heavy metals, based on literature findings that highlighted these as the most common contaminants. Another limitation is the cross-sectional nature of the study, which limits any causal inferences.

Conclusions

We found high levels of mercury, low levels of lead and zero levels of contamination of foods commonly consumed in Jigawa state of Nigeria, an area with reported high prevalence of chronic kidney disease. This study is unique and a significant improvement compared to other studies conducted in the areas as it tried to cover a significant number of households to analyze up to 3 essential and toxic heavy metals in the commonly consumed food. We suggest larger spatio-epidemiological studies that can provide more information on distribution of kidney diseases in the area, pinpoint the sources of heavy metal contamination, and inform the development of a holistic preventive strategy.

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Author Contributions

Conceptualization, UMI, MZK methodology, UMI, MZK, MAM, AMJ, MLU, MA formal analysis, UMI writing—original draft preparation, UMI, MZK, MAM, AMB, MLU, MA visualization, UMI, MZK, MAM, AMJ, MLU, MA supervision, UMI, MZK project administration, UMI, MZK All authors have read and agreed to the published version of the manuscript.

Institutional Review Board Statement

Ethical approval was obtained from the Jigawa State Ministry of Health Research Ethics Committee on 4th, April 2022, with approval number of JGHREC/2022/086.

Informed Consent Statement

Written informed consent was obtained from the study participants, and all the principles of research ethics involving human subjects were adhered to throughout the survey. Data were collected from April 30th, 2023 to May 21st, 2023.

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