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Exposure to Heavy Metals in Nigeria through Land, Water and Fish

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ABSTRACT

Background: *Heavy metals cause some health problems such as anemia, kidney failure, neurological damage, loss of memory, and loss of appetite in the human system. The main objectives of the study are to analyze and determine the concentration of heavy metals (As, Cd, Cr, Cu, and Pb) in soil, drinking water, and fish samples in Nigeria.*

Material and Methods: *Soil, water, and fish samples were randomly taken from different regions in Nigeria. The heavy metals analysis of all the samples was carried out using Atomic Absorption Spectrometry in the Center for Dryland Agriculture, Bayero University, Kano, Kano State, Nigeria.*

Results: *These heavy metals were at different levels of contamination, and some are above the maximum permissible limit. It could be said that they are the contributors to the kidney problem of the population of studies.*

Conclusions: *The root cause of chronic kidney disease is related to those metals as their levels were higher in some of the samples than the maximum permissible limit of the local and international standards.*

Key words: Heavy metals, Soil, Water, fish, Chronic kidney disease

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INTRODUCTION

The Heavy Metals are well known for causing the worst environmental and health problems by virtue of their bioaccumulation through the food chain. It also causes problems; anemia, kidney failure, neurological damage, loss of memory and loss of appetite in the human system [1]. Nutritional exposure to heavy metals has been tagged as a health threat to humans via the ingestion of polluted food. The heavy metals do exist in the environment; water, soil and foods and animals, as a contaminant from anthropogenic activities [2]. This is transferred to agricultural products accumulated in the soil. The fractions of these heavy metals in the soil are also a threat to humans [3] because they are not removed from the environment easily and subsequently end up in the food chain. Water and food are essential to life. Fish is one of the important classes of food rich in protein and healthier than red meat. But recent research shows the accumulation ability of fish to heavy metals was the worst [4].

Exposure to heavy metals such as arsenic, mercury, lead, chromium, copper and cadmium in drinking water and food can cause cancer, cardiovascular disease, diabetes, neurodevelopmental and reproductive abnormalities among others [5]. For example, cadmium often accumulates mainly in the proximal tubules of the kidney, causing renal dysfunction after chronic exposure in the environment [2].

Most end-stage kidney disease patients receiving hemodialysis in Maiduguri were residents of farming communities along the banks of river Komadugu-Yobe in Northeastern Nigeria while at least 85% of people with cases of kidney ailment at Yobe State teaching hospital are from Gashua [5]. This issue has been attracting attention, not only from governments but also the public, who are becoming increasingly concerned about the possible health risks associated with the level of heavy metals in the human food chain [6].

Chronic kidney disease is becoming increasingly common worldwide [7]. High cases of renal failure have been terminating lives and putting many at risk in the town of Gashua. The rate of kidney disease is rapidly increasing in Gashua with the main cause suspected to be a result of ingestion of heavy metals via food or water [7]. Research revealed that in just 10 months, about 467 renal cases were recorded in medical facilities across Gashua. 80% and 85% of people with cases of kidney ailment at Federal Medical Centre Nguru and Yobe State

Teaching Hospital respectively are from Gashua [8]. The research is aimed at determining the concentrations of selected heavy metals in drinking water, soil and fish samples collected from different locations in Gashua, Yobe State with a view of tracing the probable root cause of CKD in the area.

Objectives of the study are to: (1) Obtain a random sample of water, soil, and fish from five places in Gashua, Yobe State, Nigeria, (2) Analyze and determine the concentration of the heavy metals (As, Cd, Cr, Cu and Pb) in these samples, (3) Draw an inference about the root cause of chronic kidney disease as either related or unrelated.

MATERIAL AND METHODS

Sample collection

The source of the water samples was borehole water. Five different sampling sites were chosen for collecting the water and the soil samples. These are Federal University Gashua, Sabon Gari, Local Government Education Authority, Tasha and Takari. As for the fish sampling, three different species of fish samples were collected in River Yobe at the Gashua. The coordinates of the location on Google Map were also captured accordingly.

The random sampling technique was adopted for this research. The water samples were carefully collected in a plastic bottle previously washed with detergents and rinsed with tap and distilled water. The samples were stored in the laboratory refrigerator prior to the analysis [9].

In the soil sampling, the soil surface was swept to remove the top surface debris and dirt prior to the sampling. They were collected at various surface levels (0-10 cm in depth) and transferred into a clean plastic bottle. The sampling was done in triplicate for accuracy. The samples were air-dried for one week and pulverized with porcelain pestle and mortar. The resulting sample was sieved via a 0.5 mm sieve and then kept in a clean crucible for further analysis.

Three different species of common fish in Gashua sourced from river Yobe were selected namely *Clarias gariepinus* (catfish), *Chrysichthys nigrodigitatus* (Mudfish) and *Alestes nurse* (Africanischer). All the fish samples were stored in a cold condition and transported to the laboratory. Before the analysis, the fish samples were labelled individually. The length (cm), breath (cm) and weight (g) of all the fish samples were measured accordingly [10].

Atomic absorption spectroscopic technique

The heavy metals analysis of all the samples was carried out using Atomic Absorption Spectrometry (AAS) model MY17380004 in the Center for Dryland Agriculture, Bayero University, Kano, Kano State, Nigeria. AAS is the most common and reliable technique for environmental analysis of metals and metalloids in samples [6] whereby several extracting solutions were used to determine extractable heavy metals in the soils, water, and food samples [11]. The concentration of the metal ions present in the samples (fish, water, and soil) was determined by reading their absorbance [12].

Analysis of data

Analysis of Variance (ANOVA) for Correlation matrices of the results was conducted using statistical analysis for google spreadsheet software called "XLMiner analysis ToolPak" to obtain the Variance, P - values and to summarize the correlations between all the heavy metals in the dataset.

RESULTS

Table 1 contains the mean concentration of the heavy metal concentration in various soil samples. The concentrations were in mg/kg and are compared with the international standard values of WHO and USEPA.

The highest mean concentration of Cd was recorded in the soil sample collected from FUGA, with a concentration of 76.01 mg/kg. This concentration is very much higher in contrast to the maximum permissible limit (0.5mg/kg). The lowest recorded concentration was 0.01 mg/kg in Sabon Gari.

The highest mean concentration of Cu was recorded in the soil sample obtained from Takari (S3) with the value 0.12 mg/kg while the lowest was recorded in the sample collected from Sabon Gari with the concentration of 0.01 mg/kg. Both concentrations of Cu in the samples were below the WHO permissible limit of 1 - 12 mg/kg.

The highest concentration of Arsenic in the soil was found in the sample collected from FUGA with an average concentration value of 0.82 mg/kg. This is almost two times higher than the WHO maximum permissible limit (0.39 mg/kg). The lowest concentration was recorded in

Table 1: Heavy metal concentration in various soil samples.

Sample Label (mg/kg)	Cd	Cu	As	Pb	Cr
Sample S1	0.01	0.01	0.01	0.09	0.02
Sample S2	0.4	0.03	0.1	0.25	0.05
Sample S3	0.14	0.12	0.07	0.25	0.12
Sample S4	76.01	0.09	0.82	0.06	0.16
Sample S5	0.02	0	0.03	0.11	0
Sample SB	0	0	0	0	0
MPL a	0.02 - 0.5	1.00 - 12.00	0.39b	0.3-10	0.002 - 0.2

a WHO [13,14]; b USEPA [15]

S1, S2, S3, S4, and S5 were sample labels collected from Sabon Gari, LEA, Takari, FUGA and Tasha respectively. SB is the blank samples for the soil.

the soil sample collected from Sabongari (soil sample - S1) with a concentration of 0.01 mg/kg.

Furthermore, the analysis of the samples showed that the Pb concentration of 0.25 mg//kg, from Takari, was the highest, while the lowest concentration (0.09 mg/kg) was recorded in soil sample S4; FUGA. Both levels were below the WHO threshold limit of 10 mg/kg.

As for the Cr, the maximum mean concentration of 0.16 mg/kg was recorded from the soil sample collected from FUGA. This concentration is within the WHO standard (0.002-0.2 mg/kg). The lowest concentration was recorded from the soil sample collected in Sabon Gari (0.02 mg/kg).

The soil blank (SB) was prepared by using the same reagents following the same digestion procedure but now without any sample inside. After getting the results, the concentration of the blank was subtracted from the samples to obtain the real value concentration. Hence the blank concentrations were recorded 0.00 mg/kg.

From the analysis of the result single-factor ANOVA showed that the concentrations of heavy metal in various soil samples were not significant.

Table 2 contains the average concentration of heavy metals in various water samples in mg/Liter. These heavy metals are Cd, Cu, As, Pb and Cr.

From the analysis, the highest average concentration (0.133 mg/L) of Cd was recorded from a water sample collected at Sabon Gari. The lowest detected value was 0.047 mg/L from the sample collected at Takari. Both the highest and the lowest recorded values were above the WHO maximum permissible limit (0.003 mg/L).

As for the Cu, the highest and the lowest recorded concentration were 0.09 mg/L at Tasha and 0.01 mg/L at Sabon Gari. These values were lower than the WHO standard value of 1.00 mg/L.

Furthermore, higher concentrations of Arsenic (concentration above the WHO standard; 0.01 mg/L) were detected in three water samples but not detected in the one collected at FUGA. The highest and the lowest values were 0.05 mg/L from Bayan Gidan Sarki and 0.007 mg/L at Sabon Gari.

In addition, the concentration of Pb (0.04 mg/L) which is higher than the WHO standard (0.10 mg/L) was detected from the water samples collected in FUGA and it is the highest while the lowest being 0.003 mg/L detected from the sample of Sabon Gari.

Cr was not detected in all the water samples except one; that from Tasha, with a concentration of 0.01 mg/L. This was lower than the WHO standard of 0.05 mg/L.

All the heavy metals were detected in the collected water samples but Cd which is not detected in the water sample collected from Tasha and FUGA. Arsenic is also not detected in the FUGA sample, Pb in Takari and Bayan Gidan Sarki and Cr in all but Tasha.

Table 3 shows the average concentration of the various metals in the fish samples and species. From the table, the highest concentrations of Cd, Cu, As, Pb and Cr were 0.08 mg/kg, 0.28 mg/kg, 0.01 mg/kg, 0.15 mg/kg and 0.16 mg/kg respectively. Based on the analysis, all the heavy metals concentrations were below the WHO/FAO

Table 2: Average Concentration of the HMs in various water samples.

Solution Label (mg/kg)	Cd	Cu	As	Pb	Cr
Sample W1	0	0.057	0	0.043	0
Sample W2	0	0.09	0.045	0.015	0.01
Sample W3	0.09	0.05	0.053	0	0
Sample W4	0.133	0.03	0.037	0.003	0
Sample W5	0.047	0.04	0.007	0	0
Sample WB	0	0	0	0	0
MPL a	0.003	1	0.01	0.01	0.05
a WHO [13]					
W1: FUGA, W2: Tasha, W3: Sabon Gari, W4: Bayan Gidan Sarki, W5: Takari					

Table 3: Concentration of the heavy metals in various fish samples.

Samples label	Cd	Cu	As	Pb	Cr
Sample F1 (mg/kg)	0.01	0.22	0	0.03	0.16
Sample F2 (mg/kg)	0	0.16	0	0.15	0
Sample F4 (mg/kg)	0	0.28	0.01	0.05	0
Sample F3 (mg/kg)	0	0.19	0.01	0.05	0
Sample F5 (mg/kg)	0	0.19	0	0	0.03
Sample F6 (mg/kg)	0.08	0.02	0	0	0
Sample FB (mg/kg)	0	0	0	0	0
WHO/FAOa (mg/kg)	0.05	30	1.4	0.5	1
NAFDACb (mg/kg)	1	20	20	2	-
aSource: WHO/FAO [16]; bSource: NAFDAC [17]					
F2, F1 and F3 were *Clarias gariepinus* (Catfish), *Chrysichthys nigrodigitatus* (Mudfish) and *Alestes nurse* (Africanische) respectively, collected at LEA.					
F4, F5 and F6 were *Clarias gariepinus* (Catfish), *Chrysichthys nigrodigitatus* (Mudfish) and *Alestes nurse* (Africanische) respectively, collected at Dabar Musa.					

and NAFDAC standards. From the analysis of the result using ANOVA; the concentration of the heavy metal in various fish samples was significant ($P<0.05$).

DISCUSSION

Cadmium

Cadmium is one of the major contaminants nowadays. It is a toxic often found in soil and groundwater [18]. The concentration of the Cadmium in the soil of one of the sampling points is much higher (76.01 mg/kg) than the WHO MPL (0.5 mg/kg). Furthermore, the highest recorded concentration of water from the samples was 0.13 mg/L. This is above the WHO threshold value of 0.003 mg/L [13]. Even the lowest recorded value is higher than MPL.

The rapid growth of the population and modernization has resulted in an increased waste generation which contains various pollutants especially heavy metals such as cadmium [18]. The elevated concentration of the Cadmium of the samples, especially the water could be the reason for the chronic kidney disease of the people of the Gashua Local Government Area of the State. Toxic effects of cadmium on humans include both chronic and acute disorders such as testicular atrophy, hypertension, damage to kidneys and bones, anemia, itai-itai, and so on [18].

The kidney is one of the organs in the body that suffers most from the toxic effect of Cadmium due to its absorption function [19]. The metal has a high affinity for metallothionein and sulfhydryl groups of albumins. Absorption of cadmium by the gastrointestinal tract causes the excretion of the metal through the fecal route which in turn ends up in the kidney [19]. Cadmium can be accumulated with metallothioneins; an uptake of 3.0–330.0 mg/day is deadly and 1.5–9.0 mg/day is lethal to humans [10].

Copper (Cu)

Copper toxicity can be traced to its ability to accept and donate electrons in oxidation. Its bioavailability in water is more than in other environmental media especially in food or diet due to its solubility function and the types of complexes it forms [18]. Dietary exposure to several heavy metals such as copper has been identified as a threat to human health. They get into the human system through the consumption of contaminated food and drinks like fish and water [20].

The copper was detected in almost all the soil samples but that of 'Tasha'. None of the concentrations is above the WHO standard (1.00 mg/kg - 12.00 mg/kg). The copper level is below the standard of WHO in the soil, and in all the water and the fish species analyzed.

Various research showed that anthropogenic waste and agrochemicals could be the reason for soil, water and fish pollution by Cu [20].

Arsenic (As)

Higher concentrations of Arsenic were detected in the three water sampling points. These recorded concentrations were above the WHO standard (0.01 mg/L). Furthermore, the level of As in the soil samples was also much higher than the WHO standard. For example, one of the samples is having 0.82 mg/kg which is almost twice times higher than the WHO maximum permissible limit (0.39 mg/kg).

The higher As concentration in the soil might be attributed to anthropogenic activities such as treatment from the fertilizers and arsenic-related pesticides (Ali et al., 2016) as the people of Gashua are known for farming. All the heavy metals concentrations in the fish samples were below the WHO/FAO and NAFDAC standards. But this does not mean they are totally free from those metals. Adverse health effects of heavy metals such as arsenic (As) have been extensively studied and are clearly associated with renal damage and chronic kidney disease [7].

Lead (Pb)

According to Malik, et al. as mentioned by Edet, et al. "Lead (Pb) has no beneficial role in living organisms; rather toxic at certain concentrations". Long-term exposure can affect the kidney [18]. This research unveiled that the concentration of Pb has exceeded the threshold standard in the water samples. 0.043 mg/kg concentration was recorded from the water samples collected in FUGA. This value considerably surpassed the WHO allowable level (0.01 mg/L).

The contamination of the said metal could be due to leaded paint waste, improper Pb-waste disposals such as Pb-acid battery breaking, and Mining among others [18]. Furthermore, from the analysis of the other samples; soil and the fish, even though the level of Pb is below the MPL, the result showed that both of them were at certain levels of contamination. Research has shown that Pb, as a toxic heavy metal, usually accumulates more in the Kidney compared to the other body organs due to its possessing of metal-binding protein.

Chromium (Cr)

Cr is one of the metals rarely found in the Earth's crust. It is characterized by silver-grey colour and occurs only in compounds [18]. The severe and prolonged exposure to Cr can cause abnormalities such as renal damage, hypertension, skeletal malformation in the fetus, testicular atrophy [18] cardiovascular and kidney diseases among others [20].

Based on the discussions, it is obvious that the high level of these toxic heavy metals (Cd, Cu, As, Pb and Cr) might be responsible for the CKD. This is in line with the studies conducted by Amsh, et al. on the analysis of heavy metals on the vegetables cultivated on contaminated soil and analysis of heavy metals in irrigation water of Gashau town respectively [6,7]. The authors found that the level of heavy metals was above the WHO standard. Most of the patients with CKD are farmers and herders who are residents of Gashua, Nguru, Bursary and Geidam. People of Gashau are known for the high activity of irrigation and rice farming. They commonly use chemicals such as pesticides, herbicides, and fertilizers. These substances eventually might end up contaminating the soil, water, and fish [5]. Heavy metal is well known for its environmental damage. It is quite difficult to remove heavy metals from the body [21,22]. Several health problems were associated with the metal due to its bioaccumulation through the food chain, causing serious damage to the body and its organs. The kidney is the foremost target organ of heavy metal toxicity due to its capacity to reabsorb and accumulate divalent metals.

CONCLUSIONS AND RECOMMENDATIONS

Nowadays, there has been a rising incidence of chronic kidney disease among patients who have no known risk factors. Research has shown that over 1.1 million patients are having chronic kidney disease with the final stage requiring cure via dialysis, and this number is increasing at a rate of 7 % per year. The disease can remain hidden until a late stage when the cure can only be done via dialysis and kidney transplant. This has led investigators to evaluate the role of environmental, socioeconomic as well as occupational factors in the development of kidney diseases. One of the major known causes so far is the heavy metal within the environment. The toxic heavy metals currently do exist in the ecosystem as a pollutant. The fractions of these heavy metals in the soil are also a threat to the water, plants, or animals because they are not removed from the environment easily and subsequently, can end up in the food chain.

Research has shown that at least 85% of people with cases of kidney ailment at Yobe State teaching hospital are from Gashua. This issue is attracting attention from the government, public, and Non-Governmental Organizations. They increasingly show concern about the possible health risks associated with the level of heavy metals in the human food chain.

The research aimed at analyzing the concentrations of selected heavy metals in drinking water, soil and fish samples collected from different locations in Gashua, Yobe State, with a view of tracing the probable root cause of chronic kidney disease in the area. These samples were analyzed and determined the concentration of the heavy metals (As, Cd, Cr, Cu and Pb). Finally, inference has been drawn that the root cause of chronic kidney disease is related to those metals as their levels were higher in some of the samples than the maximum permissible limit of the local and international standards.

Several studies and experimental evidence suggested that exposure to an abnormal concentration of Cd, Pb, As, Cu and Cr in the soil, water, and food may cause renal problems. This research has found that these heavy metals were at different levels of contamination, and some are above the maximum permissible limit. It could be said that they are the contributors to the kidney problem of the population of studies.

RECOMMENDATIONS

Hence the government and NGO should look into the matter to find a lasting solution to the problem for the betterment of the people of Gashua and Yobe State at large. Here are some recommendations.

- ✓ There is a need to provide a dialysis centre close to the victims of the CKD, precisely at Gashua LGA.
- ✓ The Government should build a modern water treatment plant in Gashau as none is available at the time of this research, to curtail or purify the water from these contaminants.
- ✓ The level of Cd in FUGA soil samples is critically above the MPL. Intensive further study should also be done on the soil from that place.
- ✓ Public awareness should be done about how to use agrochemicals, fertilizers and herbicides effectively to avoid water pollution.
- ✓ Nowadays, there is a remediation process of mitigating metal contaminated soil like the one demonstrated by “GII in situ via electrochemical remediation of metal-contaminated soils at several sites in Europe”. This can be applied to reduce the level of heavy metals in the soil especially at some strategic and public places across the Gashau town of Yobe State.
- ✓ There is a need to expand the heavy metal analysis to other rural areas of Gashau L.G.A and other Local Governments of Yobe State.

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