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Assessment of Cadmium, Lead, and Arsenic in Beef, Mutton, and Chevon from Hadejia-Nguru Wetlands, Yobe State, Nigeria

[*1]Gashua, M. M., [2]Amshi, S. A., [3]Bello, M., [4]Saidu, S. N. A., [5]Jibril, A. H., [1]Sani, M. and [1]Sa'idu, A. S.

[1]Department of Veterinary Public Health and Preventive Medicine, Faculty of Veterinary Medicine, University of Maiduguri, Nigeria
[2]Department of Pharmaceutical Chemistry, Faculty of Pharmacy, University of Maiduguri, Nigeria
[3]Department of Veterinary Public Health and Preventive Medicine, Faculty of Veterinary Medicine, Ahmadu Bello University Zaria, Nigeria
[4]Department of Veterinary Medicine, Faculty of Veterinary Medicine, Ahmadu Bello University Zaria, Nigeria
[5]Department of Veterinary Public Health and Production, Faculty of Veterinary Medicine, Usmanu Danfodiyo University Sokoto, Nigeria

[*] *Author for Correspondence: mgmuhammad@unimaid.edu.ng*

ABSTRACT

This study was carried out to evaluate the levels of cadmium (Cd), lead (Pb), and arsenic (As) in beef, mutton, and Chevon meant for human consumption in some Local Government Areas (LGAs) of Northern Yobe within the Hadejia-Nguru Wetlands, Nigeria. A total of 31 meat samples were randomly collected from abattoirs, slaughter slabs, and meat vendors comprising 12 (28.7%) from Gashua, 8(25.8%) from Jakusko, and 11 (35.5%) from Nguru LGAs respectively. Both species and sex of the slaughtered animals were noted during sampling. The samples were analyzed using Atomic Absorption Spectrophotometry (AAS) following microwave-assisted digestion. There were 7 (22.6%) beef, 9 (29.0%) mutton, and 15 (48.4%) Chevon samples. The overall concentrations (mean±SEM) of Cd, Pb, and As in the beef, mutton, and Chevon were 1.560±0.43 ppm, 1.047±0.41 ppm, and 0.403±0.14 ppm; 1.330±0.37 ppm, 0.926±0.33 ppm, and 0.167 ±0.07 ppm; and 1.849±0.21 ppm 1.274±0.20 ppm, and 0.734±0.38 ppm respectively. There is no statistically significant difference ($p>0.05$) in heavy metals burden among the LGA nor the meat types nonetheless, all the mean values were above the regulatory limits. The overall sex-specific mean concentrations for Cd, Pb, and As were 1.544±0.26, 1.030±0.26 and 0.170 ±0.63 in males and 1.659±0.22, 1.149±0.19 and 0.589±0.24 in females respectively. The mean concentrations of Cd and Pb in the studied meat are above the maximum residue limits. There is a need to identify the sources of Cd and Pb in the studied meat, also human studies are essential to determine the possible implications of consuming meat from the area.

Key words: Heavy metal residue; Human; Meat; Yobe

INTRODUCTION

Meat is a highly nutritious food rich in protein, minerals (such as zinc and iron), amino acids, and vitamins, particularly Vitamin B complex (Biesalski, 2005; Decker and Park, 2010). The nutritional value of meat depends on its chemical composition which is determined by the quality of nutrients consumed by the animal. The presence of toxic metals in agricultural soil is an important medium through which the latter get into animals after being taken up by plants which constitute the main component of ruminant's diet (Alengebawy *et al.*, 2021; Rashid *et al.*, 2023). Animals fed with these plants tend to accumulate toxic metals in their tissues which invariably affect the quality of products obtained from such animals which can also easily get transferred to human consumers thereby predisposing them to various health hazards (Demirezen and Uruc, 2006; Li *et al.*, 2015).

Heavy metal refers to any naturally occurring metal or metalloid with an atomic density greater than 3.5 g/cm3 (Duffus, 2002), or 5 times or more, greater than water (Vamerali *et al.,* 2010; WHO, 2010). They include copper (Cu), cadmium (Cd), chromium (Cr), cobalt (Co), zinc (Zn), iron (Fe), nickel (Ni), mercury (Hg), lead (Pb), arsenic (As), silver (Ag), and platinum group elements (Ali and Khan, 2018). However, the term toxic metal is used to specifically refer to Cd, Hg, Pb, and As all of which are listed by the WHO under the 10 chemicals of major public health concern (WHO, 2010; Jaishankar *et al.,* 2014; ATSDR, 2017).

Although, some heavy metals known as micronutrients such as Zn, Cu, Mn, Ni, and some species of Cr have been reported to be of bio-importance to plants and animals when present in low concentrations (Arif *et al.*, 2016), some others including Cd, Pb and methylated forms of Hg have no known bio-importance in human biochemistry and physiology and their consumption even at very low concentrations can be toxic (Pandey *et al.*, 2016; Balali-Mood *et al.*, 2021). Moreover, even those considered to be of bio-importance, their dietary intake has to be maintained at regulatory limits, otherwise excesses can lead to toxicity (Pandey *et al*., 2016).

Some communities in Northern Yobe, located within the Hadejia-Nguru Wetlands, have been under considerate environmental pollution threat due to downstream effects. The wetlands are recharged mainly by Hadejia, and to a lesser extent, Jama'are Rivers (Olalekan *et al.*, 2014). There were reports of reckless deposition of industrial and municipal wastes into the source of River Hadejia at the industrial sites of Kano City located upstream (Innocent *et al.*, 2016a; 2016b). There are also wide-scale rain-fed and irrigation agricultural activities upstream and within the wetlands with the resultant deposition of abusive levels of agrochemicals including pesticides and chemical fertilizers into the basin's water system (Bichi *et al.*, 2015). The situation was reported as being capable of not only affecting the ecological biodiversity but also the health of the basin's populace (KYBP, 2006; Bichi *et al.*, 2015; Yakasai *et al.*, 2017). This this study was carried out to assess the occurrence of some toxic heavy metals in the meat of ruminants meant for human consumption from the study area.

MATERIALS AND METHODS

The Study Area

The Yobe quota of the HNWs lies on the Latitude 10°22′E and Longitude 12°46′N covering a catchment area of about 3,500 km^2 which includes the Nguru lake and the Marma Channel complex made up of two rivers, the Hadejia and the Jama'are (Ayeni *et al.*, 2019). The wetlands have formed around and immediately upstream of the confluence of the Hadejia and Jama'are rivers that together form the Yobe River (Fig. 1). The area has multiple river channels and a complex pattern of permanently and seasonally flooded and dry lands. The wetlands support extensive wet-season rice farming, flood-recession agriculture, and dry-season irrigation. The floodplain also supports large numbers of fishing communities, most of whom also farm. The area is grazed by very substantial numbers of Fulani livestock, particularly cattle, which are brought in from both the Northern and Southern parts of the country in the dry season (Blench, 1995; 2013). The area is dominated by Hausa, Fulani, Kanuri, and Bade ethnic groups with a population capacity of about 1,500,000 people (Haladu and Bello, 2014; Birdlife International, 2015).

Study Design

Cross-sectional study was conducted using cluster and systematic sampling techniques. Meat of cattle, sheep, and goats slaughtered for human consumption from abattoirs, slaughter slabs, and meat vendors in communities within HNWs constituted the target population.

Sampling Protocol

Clustering of the study area

The study area was divided into 3 distinct geographical clusters based on the tributaries of River Yobe. The 'Jakusko cluster' presented by (X) are communities found along River Jama'are, the Nguru cluster represented by (Y) are communities along River Hadejia, and the Gashua cluster represented by (Z) are the communities located along River Yobe after the confluence of Hadejia and Jama'are Rivers (Fig. 1). The communities of the Jakusko cluster include Kurkushe, Damasa, Gwayo, Gogaram, Adiya, Gapiwa, Yim, Amshi, Dachia and Kazir. Communities Nguru cluster are Wachakal, Nguru, Madamuwa, Tagama, Tagali, Gabarwa, Dala, Dagona, Murza, Jigawa, Azam, Alagarno and Mainiya, whereas communities in the Gashua cluster include Azam Kura, Azbak, Usur, Gashua, Tarja, Lamarbago, Guyik, Dakalam, Tajuwa, Jawa and Masaba (Fig. 1).

Selection of communities

Three communitieswere randomly selected (using random numbers) from each cluster as follows Amshi, Dachia, and Yim from the Jakusko Cluster, Alagarno, Azam, and Nguru from the Nguru Cluster and Gashua, Jawa, and Tajuwa from Gashua cluster.

Selection of sampling sites

Samples of beef, mutton, and chevon were collected from abattoirs, slaughter slabs, or meat vendors. Unless otherwise not possible, all samples were collected from abattoirs but in the absence of an abattoir, the samples were collected from slaughter slabs. Samples were only collected from meat vendors where collection from abattoirs or slaughter slabs was practically not possible. The exact point of sample purchase was selected randomly. Where possible, all the samples of beef, mutton, and chevon were purchased from a single person, and information on the sex of the slaughtered animal was collected.

Sample Size Determination

Since the population size is not known, the sample size was calculated based on the following formula:

$$n = \frac{z^2 p(1-p)}{d^2}$$

Where,
n = sample size
z = statistic for the level of confidence (95% CI)
P = expected prevalence (prevalence from previous studies) and
d = allowable error (5%)

Sample size calculation

The prevalence reported by Odoh *et al.* (2016) was used, where he got 100% prevalence for heavy metals in beef, mutton, and chevon in Southern Kaduna, Nigeria. Since 100% prevalence will amount to 0 samples, 99% prevalence was used to calculate sample size (Naing *et al.,* 2006).

Therefore,

$$n = \frac{(1.96)^2 \ X \ 0.99 \ X \ (1-0.99)}{(0.05)^2} = 15$$

Thus, a minimum of 15 samples were required across the study area. However, the sample size was increased to increase precision.

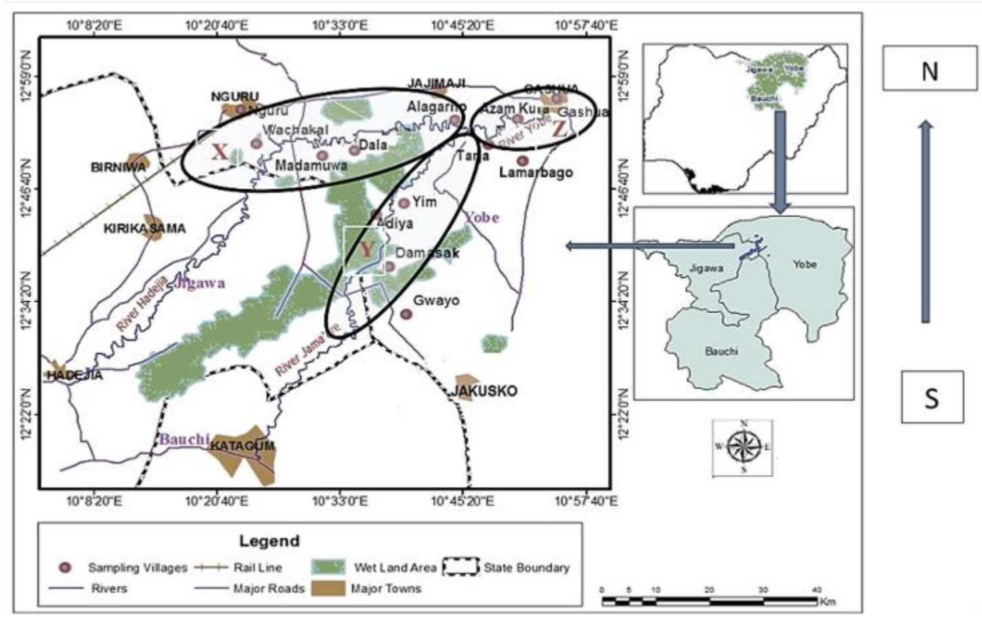

Figure 1: Map of Hadejia-Nguru Wetlands Showing the Sampled Villages (Source: modified from Ayeni *et al.*, 2019)

Samples collection

An approximate 200g sample each of beef, mutton, and chevon was purchased per sampling unit comprising portions from the thigh, brachial, and intercostal muscles. Each sample was placed in a polythene bag, labeled, and transported in an ice-packed container to the chemistry laboratory, at Yobe State University where it was stored at -20^{o}C until analysis.

Laboratory Investigations

Sample preparation

All samples were thawed at room temperature and washed with deionized water to remove physical particles and then an equal portion from each of the composited parts (thigh, brachial, and intercostal muscles) was pooled together to obtain a 20g subsample which were cut into small pieces using a clean ceramic knife. The samples were placed in a hot oven (Model 30GC lab oven) to dry at 100^{o}C. The samples were then ground into fine powder using a ceramic mortar after which they were placed in labelled polyethylene bags and kept at room temperature until acid digestion.

Sample digestion

About 200mg of each sample was weighed into a thoroughly clean plastic container (microwave tube) and 6ml of 65% HNO_3 and 2ml of 30% H_2O_2 were added and allowed to stand for 6 hours. The plastic container (microwave tube) was then covered and placed into a microwave digester (Master 40 serial No: 40G106M) and digested. The digestion was carried out at a temperature of 75^{o}C for 10 min and then ramped at 10^{0}C per min to 95^{0}C and held for 30 min. The digestion was followed by cooling to room temperature in the microwave (AOAC, 1995).

Determination of metal contents by AAS

Preparation of calibration curve

Calibration curves were prepared to determine the concentration of the metals in the sample solution. The instrument was calibrated using a series of working standards. The working standard solutions of each metal were prepared from standard solutions of their respective metals and their respective absorbance were taken using the AAS. A calibration curve for each metal ion to be analyzed was prepared by plotting the absorbance as a function of metal ion standard concentration (Uddin *et al*., 2014).

Elemental Analysis of Samples by Atomic Absorption Spectrophotometry

The instrument was calibrated with stock solutions of the prepared standards before analysis. The accuracy and validity of the analytical method were established through internal QC procedures using spiked samples. A known concentration of each of the elements of interest (1.5µg/l each of Cd, Pb, and As) was analyzed five times by the machine, and the results obtained were used to calculate the precision of the machine using the following formula:

$$\frac{S}{X} X \; 100$$

Where
S = Standard Deviation
X = Mean

The precision which is the repeatability or reproducibility of individual measurement, expressed as the relative standard deviation or coefficient of variation of the instrument should not exceed 10% which signifies high precision (WHO, 1996).

The concentration of the metal ions in the sample was determined by reading their absorbance and comparing it to the standard calibration curve. Three replicate determinations were carried out on each sample and the metals were determined by absorption/concentration mode. The same analytical procedure was employed for the determination of elements in digested blank solutions and for the spiked samples.

Data Analysis

Data were presented using descriptive statistics in the form of charts and tables. Heavy metal concentrations were presented as mean SEM (mean±SEM) per species, sex, and per location. The concentrations were compared among beef, mutton, and Chevon using one-way Analysis of Variance (ANOVA). mean±SEM concentrations of metals in meat were correlated with location using Pearson's correlation coefficient. Variations of metal levels between sexes were compared using a student's t-test. All data analyses were carried out using SPSS 20 software and $p < 0.05$ were considered significant.

RESULTS

Concentrations of Cd, Pb, and As in Beef, Mutton, and Chevon in Hadejia-Nguru Wetlands, Yobe State

Out of the 31 meat samples, 7 (22.6%) were beef, 9 (29%) mutton and 15 (48.4%) chevon. The mean (±SEM) concentrations of Cd, Pb, and As in beef were 1.560±0.43 ppm, 1.047±0.41 ppm and 0.403±0.14 ppm respectively (Table 1). The mean (±SEM) concentrations of Cd, Pb, and As in mutton were 1.330±0.37 ppm, 0.926±0.33 ppm, and 0.167±0.07 ppm respectively (Table 1) whereas, those of chevon were 1.849±0.21 ppm, 1.274±0.20 ppm and 0.734±0.38 ppm for Cd, Pb and As respectively (Table 1). All the mean concentrations of the heavy metals have passed their corresponding regulatory concentrations of 0.05 ppm, 0.1 ppm, and 0.1 ppm respectively (Table 1). There was no statistically significant difference in mean concentrations of the heavy metals between the different meat types.

Concentrations of Cd, Pb, and As in Beef, Mutton, and Chevon by Sex in Hadejia-Nguru Wetlands, Yobe State

A total of 7 beef samples were collected comprising 6 cows and 1 bull. The mean (±SEM) Concentrations of Cd and As Cd, Pb, and As in the cow's meat were 1.750±0.46 ppm, 1.221±0.43 ppm and 0.470±0.14 ppm respectively (Table 2). The mean (±SEM) concentration of Cd in the bull meat was 0.42 ppm but both Pb and As were not detected in the bull meat (Table 2). There was no statistically significant difference in heavy metal concentration between cows and bulls. The mean (±SEM) Concentrations of Cd in the bull meat and those of Cd, Pb, and As in the cow meat were above the regulatory concentrations (Table 2).

Nine mutton samples were collected, 1 ram and 8 ewes with mean (±SEM) Concentrations of Cd, Pb, and As at 2.46 ppm, 1.88 ppm, and 0.366 ppm; 1.189±0.39 ppm, 0.807±0.34 ppm and 0.142±0.07 ppm for male and female meat respectively (Table 2). All the samples contain the studied metals at concentrations higher than the regulatory limits.

Table 1: Mean (±SEM) Concentrations of Cd, Pb and As in Beef, Mutton and Chevon in Hadejia-Nguru Wetlands, Yobe State

Type of Meat	N (%)	Cd (ppm)	Pb (ppm)	As (ppm)
Beef	7 (22.6)	1.560±0.43	1.047±0.41	0.403±0.14
Mutton	9 (29)	1.330±0.37	0.926±0.33	0.167±0.07
Chevon	15 (48.4)	1.849±0.21	1.274±0.20	0.734±0.38
Total	31	1.633±0.18	1.122±0.16	0.495±0.19
	MAC	*0.05	*0.1	*0.1ppm
	p-value	*0.457*	*0.642*	*0.438*

MAC- Maximum Acceptable Concentration; *CODEX, 2017

Table 2: Mean (±SEM) Concentrations of Cd, Pb and As in Beef, Mutton and Chevon Based on Sex in Hadejia-Nguru Wetlands, Yobe State

Spp.	Sex	No.	Heavy metal conc. (ppm)		
			Cd	Pb	As
Beef	Male	1	0.42	0	0
	Female	6	1.750±0.46	1.221±0.43	0.470±0.14
	Total	7	1.085±0.46	1.221±0.43	0.470±0.14
		p-value	*0.322*	*0.335*	*0.271*
Mutton	Male	1	2.46	1.88	0.366
	Female	8	1.189±0.39	0.807±0.34	0.142±0.07
	Total	9	1.824±0.38	1.344±0.33	0.254±0.07
		p-value	*0.308*	*0.333*	*0.321*
Chevon	Male	5	1.586±0.02	1.066±0.22	0.165±0.07
	Female	10	1.980±0.30	1.378±0.28	1.019±0.55
	Total	15	1.783±0.03	1.222±0.25	0.592±0.31
		p-value	*0.119*	*0.202*	*0.208*

MAC – {Cd (0.05); Pb (0.1); As (0.1) (CODEX, 2017)}

A total of 15 chevon samples were collected, 5 males and 10 females. The mean (±SEM) Concentrations of Cd, Pb, and As in chevon were 1.586±0.02 ppm, 1.066±0.22 ppm, and 0.165±0.07 ppm for male and 1.980±0.30 ppm, 1.378±0.28 ppm and 1.019±0.55 ppm for female respectively (Table 2). All the mean values are above the CODEX acceptable concentrations. However, there was no statistically significant difference in concentrations of Cd, Pb, and As between the sexes (Table 2).

Comparison of Mean (±SEM) Concentrations of Cd, Pb, and As amongst Gashua, Jakusko, and Nguru Clusters Hadejia-Nguru Wetlands, Yobe State

Out of the 31 analyzed meat samples, 12 (38.7%) were from Gashua, 8 (25.8%) from Jakusko and 11 (35.5%) from Nguru Clusters. The total mean (±SEM) concentrations of Cd, Pb, and As from the study areas were 1.633 (±0.18) ppm, 1.122 (±0.16) ppm, and 0.495 (±0.19) ppm respectively (Table 3). The total mean (±SEM) concentrations of Cd in meat samples from Gashua, Jakusko, and Nguru Clusters were 1.864 (±0.26) ppm, 1.955 (±0.37) ppm and 1.147 (±0.27) ppm respectively (Table 3). The total mean (±SEM) concentrations of Pb in the samples were 1.344 (±0.26) ppm, 1.365 (±0.32) ppm, and 0.702 (±0.22) ppm respectively whereas for As it was 0.836 (±0.47) ppm in Gashua, 0.356 (±0.11) ppm in Jakusko and 0.223 (±0.05) ppm in Nguru Clusters (Table 3). All the mean concentrations of the heavy metals have passed their corresponding regulatory concentrations of 0.05 ppm, 0.1 ppm, and 0.1 ppm respectively as regulated by the CODEX Commission, (2017) (Table 3) There was no statistically significant difference in mean concentrations of the heavy metals between the different clusters.

Table 3: Comparison of Mean (±SEM) Concentrations of Cd, Pb, and As amongst Gashua, Jakusko and Nguru Clusters Hadejia-Nguru Wetlands, Yobe State

Location	N (%)	Cd (ppm)	Pb (ppm)	As (ppm)
Gashua	12 (38.7)	1.864±0.26	1.344±0.26	0.837±0.47
Jakusko	8 (25.5)	1.955±0.37	1.365±0.32	0.356±0.11
Nguru	11 (35.5)	1.147±0.27	0.702±0.22	0.223±0.05
Total	31	1.633±0.18	1.122±0.16	0.495±0.19
	MAC	*0.05ppm	*0.1ppm	*0.1ppm
	p-value	*0.117*	*0.146*	*0.353*

MAC- Maximum Acceptable Concentration; *CODEX, 2017

DISCUSSION

This study has found significant concentrations of Cd, Pb, and As in samples of fresh beef, mutton, and chevon collected from the Hadejia-Nguru Wetlands, Yobe State where almost all the samples showed varying concentrations of the studied heavy metals. The findings strongly suggest widespread contamination of the environment with Cd, Pb, and As supporting the earlier findings of the National Agency for Food Drugs Administration and Control in 2006, Uduak and Hassan (2007), Egwu *et al.* (2018) and Amshi *et al.* (2019) which reported heavy metals in water, dust storms and in the wetlands soil in the study area. In another study, Gashua *et al.* (2018a) reported varying concentrations of Cd in the blood of goats raised in the area. Similar levels of heavy metals were reported in fresh fish in the area by Shaibu and Audu, (2018) and Gashua *et al.* (2018b).

The lower mean concentration of As recorded in this study compared to Cd and Pb may be suggestive of the fact that, either there is generally lower As pollution in the area or that the element is being utilized by the animals after ingestion. In plants and animals, As usually combines with carbon and hydrogen to form organic arsenic compounds whereas in the environment, As combines with oxygen, chlorine, and sulfur to form inorganic arsenic compounds (ATSDR, 2007). Ingesting very high levels of Arsenic can result in death. Exposure to lower levels can cause nausea and vomiting, decreased production of red and white blood cells, abnormal heart rhythm, damage to blood vessels, and a sensation of “pins and needles” in hands and feet. Ingesting or breathing low levels of inorganic arsenic for a long time can cause a darkening of the skin and the appearance of small “corns” or “warts” on palms, soles, and torso (ATSDR, 2007). Almost nothing is known regarding the health effects of organic arsenic compounds in humans. However, studies in animals show that some simple organic arsenic compounds are less toxic than inorganic forms (ATSDR, 2007). Ingestion of methyl and dimethyl Arsenic compounds can cause diarrhea and damage to the kidneys (ATSDR, 2007).

On the other hand, Cd and Pb have no known biological function and are not readily excreted by the system, as such their occurrence even at trace levels may lead to accumulation in the tissues (Hashemi, 2018). High concentrations of Cd and Pb in meat samples from the study area suggest high exposure to these elements either through contaminated feed, pasture, or drinking water. Diet is the most common route of exposure to most environmental contaminants (Kaplan *et al.*, 2011). Chevon appeared to have higher concentrations of all the analyzed heavy metals followed by beef and then mutton. This can be due to the nature of feeding by goats since they can graze/nibble very low grasses. Not only that, they go for grazing more widely than cattle and sheep as reported by Kaltungo (2013). Furthermore, Sheep tend to graze mostly within villages and towns while goats are hardier and more difficult to be controlled in terms of grazing (Kaltungo, 2013). Thus, there is every chance that goats could have higher exposure potentials than cattle and sheep in terms of grazing on countryside feeding.

Hadejia-Nguru Wetlands is not an industrialized area and there is no known report of any form of mining activity throughout the wetlands. The exact source of these heavy metals is therefore unclear. However, the floodplain has been under intense pressure due to the downstream effect of Challawa Gorge and Tiga Dams, both in the upstream Kano, where extensive rain-fed and dry-season agricultural activities are being practiced (KYBP, 2006; Bichi *et al.*, 2015). Similarly, the widespread Hadejia Valley Irrigation Program is another source of pollution concern to the wetlands. These extensive agricultural practices warrant the application of large quantities of chemical fertilizers and pesticides on the fields and crops. The Government's efforts in encouraging crop farmers to adopt modern farming have made many farmers use herbicides for clearing their farmlands at the beginning of the rainy season in preparation for mechanized farming through the use of work-oxen traction and insecticides on crops for vegetables among others. There is also the use of inorganic fertilizers from approved and unofficial sources, some of which are locally made by individuals or groups through the use of stones from uncertified sources all in efforts to supply fertilizers where the Government has not reached the crop farmers' expectations. Such applications may result in the increase of heavy metals in the environment particularly Cd, Pb, and As (OECD 1994; Atafar *et al.*, 2010; Guan *et al.*, 2019; Reboredo *et al.*, 2019).

The widespread nature of this problem as noted in the three clusters may suggest the possible occurrence of these heavy metals naturally in the study area. It may also the possible these metals may be originating from the headwater region in Plateau State, underlain by the basement complex rock, which is one of the main sources of water to the Komadugu Yobe Basin where the study area is located (KYBP, 2006). Furthermore, chemicals in drainage waters from processing industries and urban wastes in Kano municipality which lies in the upstream part of the study area may contribute to the sources of water pollution in the HNWs. Thus, the pasture and waters from these sources may get their way to animals and therefore the demonstration of these heavy metals in the animals under the study. Other workers earlier have made similar suggestions (Rossipal *et al.*, 2000; and Frodello *et al.*, 2002).

Conclusion

It can be concluded from this study that, Cd, Pb, and As are present in beef, mutton, and chevon meant for human consumption across the Yobe quota of the HNWs at concentrations likely to pose health risks to habitual consumers of meat in the area. There is a need for public enlightenment on the dangers of indiscriminate use of agricultural chemicals and also the disposal of untreated municipal and industrial wastes along the river bank or any kind of environment. Further research is needed in the area to identify the possible sources of these heavy metals to control their emissions into the environment.

Conflict of Interest

The authors have no conflict of interest to declare.

Author Contribution

GMM conceptualized the work and wrote the draft manuscript; ASA collected samples and conducted laboratory analysis; BM and SSNA supervised the work; JAH, SM and SAS conducted the statistical analysis. All authors have read and approved the final manuscript,

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