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Original Research Article

Evaluating the Concentration of Heavy Metals in River Water and Sediment Samples in Gashua Town, Yobe State, Nigeria

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ABSTRACT

This study assessed the concentration of some heavy metals such as Arsenic (As), Cadmium (Cd), Chromium (Cr), Copper (Cu), and Lead (Pd) in river water and sediment samples in Gashua town, Yobe State, Nigeria. An Atomic Absorption Spectroscopy (AAS) machine was used to measure these concentrations during dry and wet seasons. The results show that As was not detected in any of the samples tested in both seasons. The highest concentrations of Cd, Cu, Cr and Pd were 0.012 ± 0.008, 0.245 ± 0.027, 0.044 ± 0.012, and 0.070 ± 0.009 μg mL^{-1} *respectively for dry season, and 0.076 ± 0.034, 0.257 ± 0.023, 0.055 ± 0.005, and 0.092 ± 0.022 μg mL*$^{-1}$ *respectively for the wet season. The sediment samples also showed no trace of As while Cd, Cr, Cu and Pb concentration increased with depth. Among the metals, Cu and Pb were found to be highly concentrated in the sediment but lower than the WHO recommended values. Therefore, there is positive correlation between the sediments and water samples. It is evident that Gashua town could be exposed to the cumulative effects of elevated levels of heavy metals associated with agricultural activities and disposal of domestic sewage around the river. This research will be useful in the management and planning for the protection of this river water and sediment.*

1. INTRODUCTION

Chronic kidney disease (CKD), also known as chronic renal disease, is a condition that is characterized by a gradual loss of kidney function over time which could progressed to kidney failure (Williams *et al.*, 2013). CKD is a quiet disease because it does not have noticeable signs and symptoms that are apparent to the patient at the early stage of the disease. Studies in some parts of Nigeria indicated that 10 people out of every 100 will have CKD, and in some parts, one out of every five people will have CKD at some point in life

(Bamgboye *et al.,* 1993). The rate of CKD prevalence in Nigeria is between 8% and 45% depending on the region and population that was studied (Alebiosu and Ayodele, 2005).

Several environmental risk factors have been recognized globally as probable causes of CKD, namely exposure to heavy metals (Arsenic (As), Cadmium (Cd), chromium (Cr), copper (Cu), and lead (Pb)), agrochemicals, and nephrotoxic substances (Pritchard, 2007). Chronic exposure in drinking water has been reported as a primary cause for CKD in Bangladesh, Taiwan and India (Pritchard, 2007). As, Cd, Cr, Cu, and Pb are some of the heavy metals that occur naturally in the environment. Increased industrial and human activities have contributed significantly to the dispersal of these heavy metals (UNEP, 2010). Most metals are known to have some toxic effect on human health having both acute and chronic effects. As the metals are nephrotoxic (poisonous to kidney) and accumulate in the kidney, the concentrations in kidney cortex are of particular interest (Lentini *et al.*, 2017). However, kidney biopsies from human beings are seldom available because of the risks associated with the procedure, and therefore most of the previous knowledge on metal concentrations in the kidney comes from autopsy studies (Bahemann-Hoffmeister *et al.,* 1988; Waikar and McMahon, 2018).

The contamination of water and sediment by heavy metals is a global environmental issue of concern. It occurs in the environment through various pathways due to natural and anthropogenic activities (Wilson and Pyatt, 2007). The concentration of heavy metals in water sources (river, stream, well and boreholes) has attracted attention from scholars due to its health implications on man. Heavy metals are priority toxic pollutants that severely limit the beneficial use of water for domestic or industrial applications (Nouri *et al.,* 2006). Industries such as ceramic, painting, glass, mining and battery production are considered the main sources of heavy metals in local water streams, which eventually contaminate groundwater with heavy metals (Lokeshwari *et al.,* 2006). Landfill leachate site is another source of heavy metal contamination in groundwater (Sang *et al.,* 2008). Therefore, the study presented here aimed to determine the presence of some heavy metal concentrations in river water and sediment samples in Gashua town and then look at its relationship with chronic kidney disease.

2. MATERIALS AND METHODS

2.1. Description of the Study Area

Gashua is a community in Yobe State, North-Eastern Nigeria with coordinates 12052’5”N and 1102’47”E, and average elevation of about 299 mm (Saleh and Ahmed, 2019). The town is located a few kilometres below the convergence of the Hadejia and Jama’are Rivers downstream of the Hadejia – Nguru Wetlands (Ibrahim *et al.,* 2016). According to the 2006 census, the town has a population of about 12500 (Saleh and Ahmed, 2019)

2.2. Reagents and Chemicals

Laboratory grade reagents and chemicals were used in the study. Deionized water was used for all preparation and dilution purposes throughout the study. Nitric acid, HNO3 (Spectrosol®, England) (69%), Potassium chloride, KCl (0.01 N), Hydrogen peroxide, H_2O_2 (30%) (Spectrosol®, BDH, England) and hydrochloric acid HCl, (36%) were used for sample digestion. Working standards of 1000 ppm was prepared for selected heavy metals (As, Cd, Cr, Cu, and Pb).

2.3. Sample Collection

2.3.1. Water sampling

Representative water samples were collected in February, (2018) for dry season and in August, (2018) for wet season. This was done randomly within 50 m distance. A 50 cm depth was considered in order to exclude the dust materials. And 1Lwater sampling polyethylene bottle were used to collect surface water from the different sites. All sampling bottles were cleaned with detergents before use. During the sampling period, the bottles were rinsed with the river water three times before sample collection. Finally, a composite sample of the water was collected for digestion process. Samples were placed in icebox and transported to the laboratory for the analysis.

2.3.2. Sediment sampling and drying

The sediment samples were collected from Gashua River at the different locations (A to E) and stored in a pre-cleaned polythene bag and air dried for three days at room temperature of 25 °C and then sieved for further digestion process. For determining the relationship between grain size and metal contents, the sediment samples were fractionated into two sizes (fine and coarse) by nest of sieves.

2.4. Digestion of Water Samples

The composite water samples were digested according to United State Environmental Protection Agency, (USEPA 2011). A 50 mL aliquots of well mixed water samples were digested in a beaker covered with a watch glass by adding 1 mL of concentrated (69-72%) trioxonitrate (v) acid (HNO_3) and 2.5 mL of concentrated (30%) HCl. Samples were heated on a hot plate at 90 ^oC. Each of the digested water samples were filtered through Whatman filter paper No. 42 in to a 100 ml volumetric flask.

2.5. Digestion of Sediment Samples

After air drying the sediment samples for 3 days and sieved, samples were ground into smaller particles. Thus, 2 g of the sediment sample was weighed and poured into a beaker where 5 ml of HNO_3 was added together with 2 ml of perchloric acid ($HClO_4$). Thereafter, 5 ml of hydrogen fluoride (HF) was added and the mixture was heated for 1 hour at 160 °C. After the digestion, the sample was allowed to cool and then filtered. The filtrate was then transferred into 100 ml volumetric flask and made up to mark of 100 ml with distilled water. The prepared sample solution was transferred into the pre-cleaned labelled sample bottles in readiness for Atomic Adsorption Spectrometer (AAS) analysis (USEPA 2011).

2.6. Heavy Metal Extraction

After calibration of the instrument, the samples were aspirated into the AAS instrument following standard method (APHA, 1999). The concentrations of As, Cd, Cr, Cu, and Pb in the extracted water and sediment samples were estimated by AAS. The instrument used was fully automated PC-controlled double-beam Buck Scientific Model 210VGP flame atomic absorption spectrometer with fast sequential operation for fast multi element air acetylene flame.

2.7. Statistical Analysis

Analysis of variance (ANOVA) was used to examine the significance level of all parameters measured using Microsoft Office Excel 2007. The level of significance for the t-test and mean comparison was at $p<0.05$.

3. RESULTS AND DISCUSSION

3.1. Heavy Metals Concentrations in Water Samples

The results show that As was not detected in any of the samples tested in both seasons. The mean concentration of Cd in the river water was 0.009±0.005 to 0.012 ± 0.008 and 0.043 ± 0.022 to 0.076 ± 0.034 µg mL^{-1} in dry and wet seasons respectively as presented in Table 1. Higher concentration (0.076 ± 0.034 µg mL^{-1}) of Cd was recorded at point B for wet season. The concentration exceeded the admissible limit (0.05 µg mL^{-1}) set by WHO (2008). The lowest concentration of Cd (0.009±0.005 µg mL^{-1}) was recorded at point A, for dry season. The difference may be due to the high agricultural activity around the river in wet the season. This was similar to a research conducted by Belay and Eshete (2014). It could be possible that the high level of Cd contamination is because of organic fertilizer and environmental pollution in the study area. Previously, studies have shown that the concentration of metals in water bodies were higher than the recommended concentrations (Davies *et al.,* 2009; Rauf *et al.,* 2009; Vicente-Martorell *et al.*, 2009).

Table 1: Concentration of heavy metals in water sample

Dry season concentration (µg mL^{-1})					
Site	As	Cd	Cr	Cu	Pb
A	0.00	0.009±0.005	0.037±0.003	0.245±0.027	0.067±0.011
B	0.00	0.012±0.008	0.044±0.012	0.144±0.012	0.070±0.009
C	0.00	0.011±0.010	0.039±0.007	0.219±0.012	0.067±0.020
Wet season concentration (µg mL^{-1})					
A	0.00	0.052±0.021	0.053±0.003	0.257±0.023	0.086±0.005
B	0.00	0.076±0.034	0.039±0.011	0.238±0.080	0.083±0.014
C	0.00	0.057±0.028	0.055±0.005	0.220±0.012	0.089±0.030
D	0.00	0.038±0.018	0.041±0.008	0.257±0.023	0.092±0.022
E	0.00	0.043±0.022	0.037±0.000	0.232±0.063	0.089±0.028

From Table 1, it was observed that the concentration of Cu in the river ranged from 0.144 ± 0.012 to 0.245 ± 0.027 and 0.220 ± 0.012 to 0.257 ± 0.023 µg mL^{-1} in dry and wet seasons respectively. A higher concentration of Cu was noted (0.257 ± 0.023 µg mL^{-1}) at points D for wet season, and the lowest concentration (0.144 ± 0.012 µg mL^{-1}) at point B for dry season, which is far below the allowable limit set by WHO (2008). The higher level of Cu in the river could be attributed to the water drained via metal scrape yard from nearby the area as described by Chukwu *et al.* (2017).

Furthermore, Table 1 shows that the mean concentration of Cr varies from 0.037 ± 0.003 to 0.044 ± 0.012 and 0.037 ± 0.000 to 0.055 ± 0.005 µg mL^{-1} for dry and wet seasons respectively. The highest concentration of Cr (0.055 ± 0.005 µg mL^{-1}) was observed at point C for wet season, which was found above WHO (2008) standards. The study revealed that the river water is been contaminated with heavy metals, and this might be of artificial origin due mainly to agricultural influx, wastes from farms or sewage via surrounding cultivated lands (Saleh and Ahmad, 2019).

The distribution pattern of Pb concentration in the river sample ranged from 0.067 ± 0.011 to 0.070 ± 0.009 µg mL^{-1} and 0.083 ± 0.014 to 0.092 ± 0.022 µg mL^{-1} in dry and wet season respectively. The concentrations of Pb in this study were below WHO (2008) stipulated standards. The presence of Pb below acceptable limits may not create an upsetting situation for aquatic lives and agricultural practices. The wet season had the highest concentration of Pb, these values could be attributed to the fact that the major sources of Pb in the environment are automobile exhaust, industrial wastewater, wastewater sludge and pesticides Salamatu *et al.* (2019).

It is clear from Table 1 that the concentrations Cd and Cr in water samples of the two seasons were above the permissible limits as stipulated by WHO (2008). This might be an indication of human pollution in the area.

The correlation values of the metals with respect to the seasons showed a positive correlation in the levels of Cd and Cu and a negative correlation for Cr and Pb, while strongly correlated for the sediments as presented in Table 2. These results indicated that there was some original relationship between heavy metals, and revealed probable water and sediment, by heavy metal sources such as anthropogenic and lithogenic (Islam *et al.,* 2016a,b).

Table 2: Water and sediment correlations

Elements	As	Cd	Cr	Cu	Pb
Seasonal variation of water	0.00	0.990343	-0.94771	0.237812	-0.89469
Coarse and fine sediment	0.00	0.974772	0.998259	0.999874	0.999921

3.2. Concentration of Heavy Metals in Sediment Samples

The heavy metal contents were determined in each size fraction (fine and coarse) and presented in Figures 1 and 2 for fine and coarse sediment respectively. As was not found in both sediment samples. The highest concentration of Cd in both sediments was found at point B and the lowest at point A. Thus, with the concentration of Cd at point B above the permissible limit of WHO standards (WHO, 2008). The high level of Cd in sediments at point B could be attributed to the industrial and agricultural discharge around the river. Similarly, concentrations of Cu and Pd were found to be higher at points A and D for fine and coarse sediments respectively.

The results obtained showed that concentration of heavy metals in fine sediment are lower compared to coarse sediments. The essential factors influencing the heavy metal contents in sediments include the physical and chemical properties (grain size, surface to volume ratio, heavy metal contents of the main geochemistry phase), in which grain size is a main control parameters (Salomons, 1984).Some studies have indicated that coarse particles show a similar or even higher heavy metal concentrations than finer ones and the presence of coarse particles are possibly responsible for higher metal content in the coarse size fractions (Tessier, 1982; Singh, 1999).

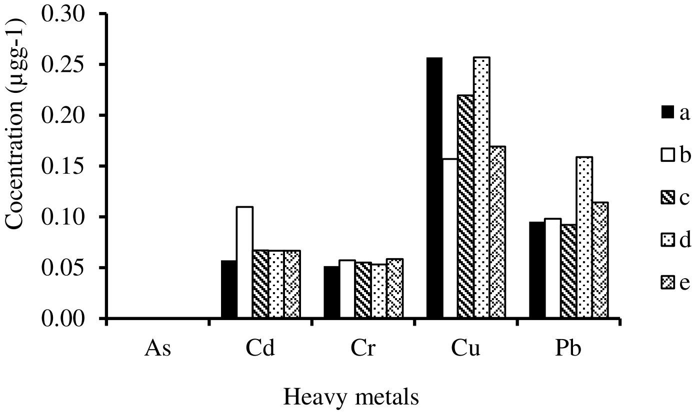

Figure 1: Heavy metal concentration in fine sediment

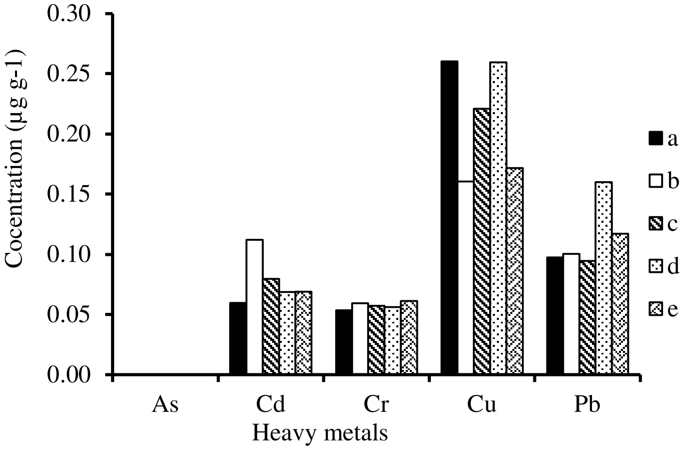

Figure 2: Heavy metal concentration in coarse sediment

3.3. Comparison of Heavy Metals in Sediment and Water

In order to compare the concentrations of As, Cd, Cr, Cu and Pb in the sediment (fine and coarse) and the river water. A paired sample t-test was conducted to determine whether there was any significant difference in the heavy metal concentrations found in water and sediment (fine and coarse).

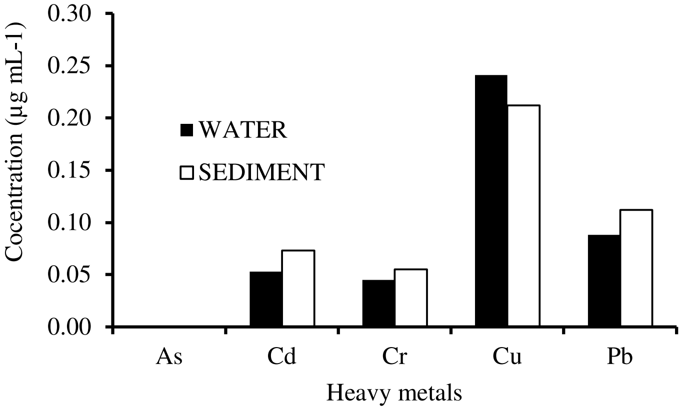

Figure 3: Heavy metal concentration in water and fine sediment

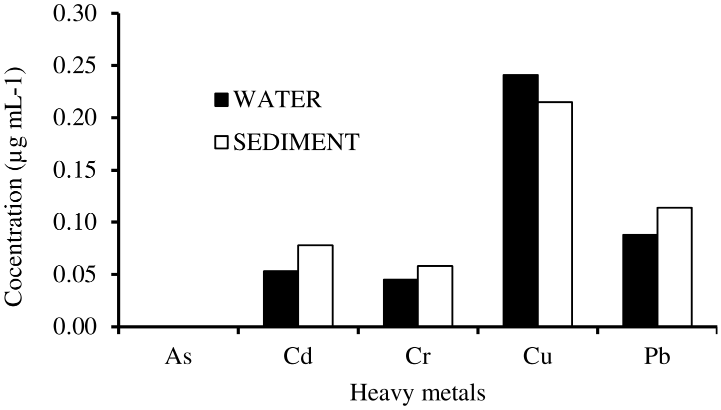

Figure 4: Heavy metal Concentration in water and coarse sediment

The difference in concentration between the fine and coarse sediment for Cd (0.134, 0.075 µg g^{-1}), Pb (0.165, 0.141 µg g^{-1}), Cr (0.055, 0.055 µg g^{-1}), and Cu (0.215, 0.241 µg g^{-1}) are less than the t-test critical value (3.182) at $p \leq 0.05$ and 95% confidence level. This test showed that there was no significant difference in all the concentrations of the metals in water and sediment in both fine and coarse. The analysis show that Cu concentration was high in both sediments and water at fine and coarse followed by the Pb concentration at the sampling points as shown in Figures 3 and 4. In general term, heavy metal concentrations were higher in sediments than in the case of water. This indicates that sediments are better absorber of metals than water (Asmah 2000). Among the metals, Cd and Cr concentrations were lower in water than Pb and Cu concentration. Thus, these concentrations were lower than the recommended value of WHO (2008), and therefore it could not pose risk to the consumers.

4. CONCLUSION

An attempt was made to determine the presence of heavy metals (As, Cd, Cr, Cu and Pb) in river water and sediment samples in Gashua, Yobe State, Nigeria. Metal uptake and accumulation has a direct link with the water and sediment. It was generally observed that heavy metals were more concentrated in the sediment than river water. The measured concentrations of Cu, Pb, Cd and Cr are higher in sediment than water. Seasonal variation was notable, indicating higher concentrations in wet season than in the dry season. However, Cd and Cr concentrations for both seasons were above the permissible limits stipulated by WHO (2008). This might be an indication of human pollution in the area such as agricultural influx, wastes from farms or sewage via surrounding cultivated lands. Heavy metal content determination in different fractions of the sediment collected by points from Gashua river we have discovered the following regularities. Heavy metals accumulate equally on the particles or there is a tendency associated with increasing metal content as far as increasing particle size. Coarse fractions of the sediments most content heavy metals. To confirm observed peculiarities related to metal distribution depending on particle size correlation analysis were used. Water and sediment correlation analysis has shown the existence of high correlation between heavy metals. The values for heavy metals indicate increasing trend from water to sediment. There is need for continuous monitoring of the trace metal concentrations in Gashua river, because the river is serving as source of water for irrigation and fishing for the local inhabitants. However, further research is necessary to make a pathway to reduce the metal pollution level of the Gashua River.

5. ACKNOWLEDGMENT

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6. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

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