Pollution Status of Heavy Metals in Water and Bottom Sediment of River Delimi in Jos, Nigeria

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Abstract There has been a lot of concern on the rate at which industrial and domestic wastes are discharged into River Delimi in north central Nigeria. This study was an attempt to assess the status of heavy metal pollutants (Cd, Cu, Pb and Zn) in sediment and water from River Delimi in Jos city, with a view to determining its ability to support aquatic life and suitability for use in vegetable crop irrigation. The study was conducted at three major irrigation sites at Gangare (station I), Farin Gada (station II) and main campus of University of Jos (station III) along River Delimi and one control site at Lamingo Dam (station IV) all within Jos city. The total metal contents in water and sediment were determined using Atomic Absorption Spectrophotometer (AAS) after extraction with Conc. HNO_3 and aqua-regia respectively. Results of the study revealed that the total metals content in water and sediment were generally higher at the study compared to the control site. At the study site, the mean Cd concentrations in water at stations I (0.14mg/L), II (0.381mg/L) and III (0.300mg/L), Cu at stations I (0.341mg/L) and II (0.371mg/L) were above the limits of 0.01mg/L and 0.20mg/L for Cd and Cu respectively for irrigation water recommended by FAO. Further analysis on the sediment pollution status using Contamination Factor (CF) revealed that Cd obtained from all the sampling sites showed considerable ($3 \leq CF \leq 6$) contamination while the other metals showed low ($CF < 1$) contamination. The use of Geoaccumulation Index (I-geo) also showed that only Zn at station IV (control site) attained unpolluted status (Class 0) It is recommended among others that measures should be put in place by relevant authorities to regulate the indiscriminate dumping of domestic waste and untreated industrial effluents into the river.

Keywords: heavy metals, pollutants, river delimi, water, sediment

1. Introduction

In natural aquatic ecosystem, heavy metals occur in low concentrations mainly due to weathering of soils and their associated bedrocks. In recent times however there has been an unprecedented increase in the level of these metals due to human activities. The occurrence of such metals in excess of natural load has become a problem of increasing concern not only to environmentalists but also to health practitioners. The concern about heavy metals stems from their persistence in the environment as they are not easily degraded either through biological or chemical means unlike most organic pollutants. The discharge of various metal pollutants in to the aquatic environment as pointed out by [1] could damage the quality of the ecosystem thereby rendering water body unsuitable for its intended uses posing a serious health threat to the immediate population.

The Nigerian inland water bodies have been subjected to various forms of degradation due to pollution. River Delimi in Jos the Plateau State capital of Nigeria is one of such endangered inland water bodies [2]. The river is not considered a source of water for drinking purposes but serves as an important habitat to numerous plant and animal species. It has also been use extensively for vegetable crops irrigation by residents of Jos city. Different kinds of effluents are discharged from domestic and industrial activities into the river as it passes through the city. Earlier studies by [2] revealed that the water in River Delimi is already contaminated with some heavy metals. However, there is a dearth of information on the metals pollution status in river sediment and the relationship between the concentrations of the metal pollutants in sediment and water. This study was therefore aimed at assessing the status of heavy metal pollutants (Cd, Cu, Pb and Zn) in sediment and water from River Delimi in Jos with a view to determining its suitability for use in vegetable crop irrigation as practiced in the city.

2. Materials and Methods

2.1. Study Area

The study was conducted at designated points along River Delimi (study site) and Lamingo Dam (control site) in Jos city as shown in Figure 1.

Jos the capital of Plateau State is located on Lat. 9° 52'59''N and Long 8° 54'26''E in north central Nigeria. The city is about 1250m above sea level. The average monthly temperatures range between 21 and 25°C. The annual rainfall ranges from 2000 – 3250mm between May and September [3].
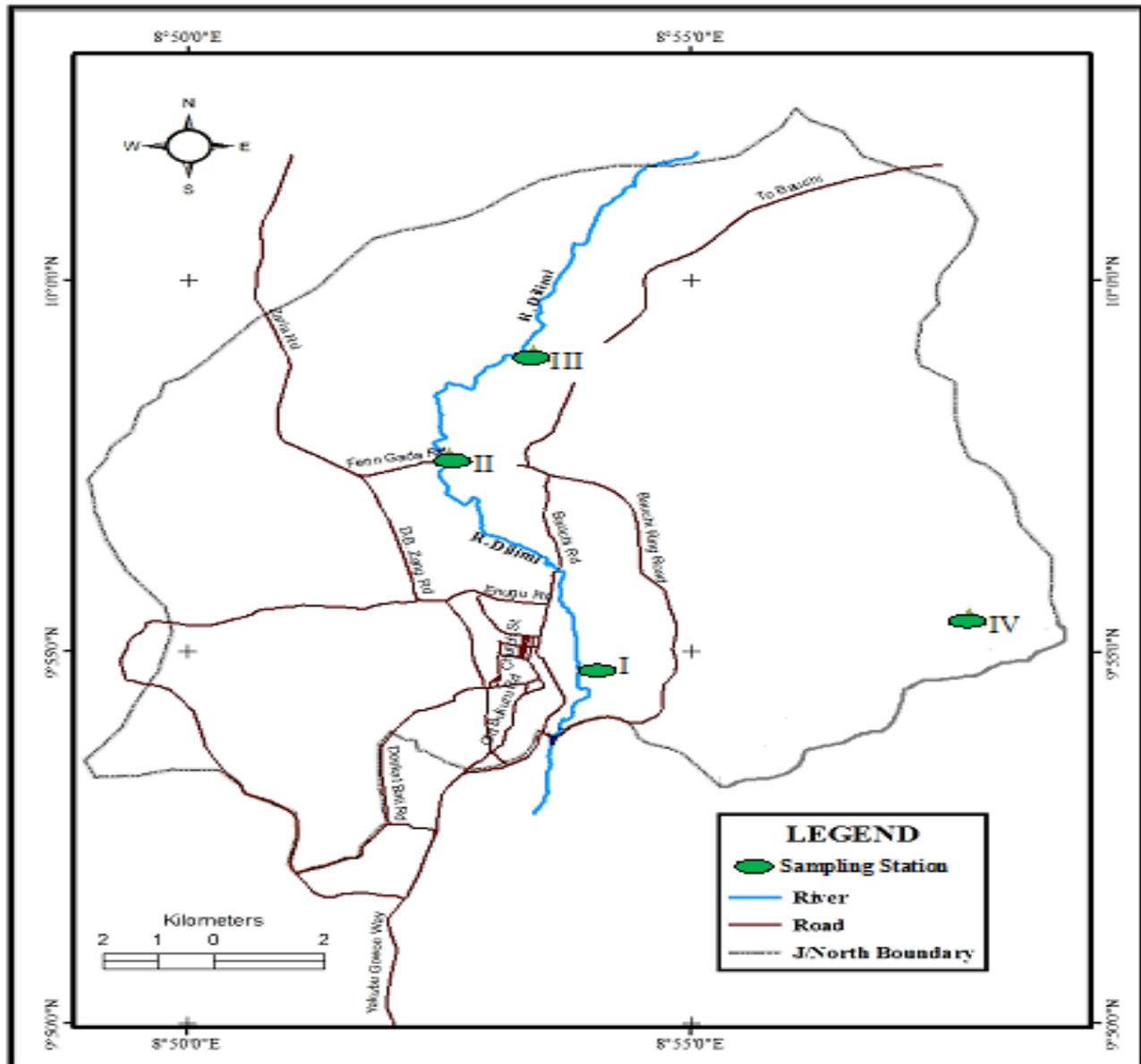
Figure 1. Map of Jos city showing the sampling stations

River Delimi covers a distance of about 15km as it passes through the city. It mainly originates from Delimi village located few a kilometers to the southern outskirts of Jos city. The river responds very quickly to rainfall in its catchments' area. It is therefore characterized by low base flows in dry season and relatively high peak flows in rainy season. The Delimi River is a habitat to many species of plants and animals and serves as the major source of water for vegetable crops irrigation in Jos city.

2.2. Sampling Strategy

Samples of water and sediment were collected from three different sampling stations along the river (study site) as follows: Station I (Gangare); Station II (Farin Gada); Station III (University of Jos main campus) and one control site Station IV (Lamingo Dam) as shown in Figure 1. The samples were collected in the dry season (when irrigation activities are extensively carried out) between the month of January and April in 2009 and 2010.

At each of the sampling stations nine samples each of water and sediment were collected with each sample replicated three times. Water samples were collected at the depth of 30cm below the surface using 1 litre polyethylene bottles with screw caps which were acid washed and rinsed with distilled water prior to the sampling. Samples were acidified with 1.5ml concentrated Nitric acid (HNO_3)/litre of sample, after pH, conductivity and temperature measurements and subsequently transported to the laboratory for analysis. Sediment samples (top 10cm) were collected using soil auger, kept on ice in polythene bag and transported to the laboratory [4].

2.3. Samples Preservation and Pre-treatment

Sediment samples meant for total metal analysis were placed in porcelain crucibles and oven dried at 80°C for 24 hours. The dried samples were grounded using a previously acid washed porcelain mortar and pestle. The samples were then kept in desiccators to attain constant weights before being transferred into air-tight plastic bottles. The sediment samples were sieved with a 200μm sieve before metal analysis. Water samples were kept at low temperature (4°C) before analysis [4].

2.4. Laboratory Analysis

2.4.1. Determination of Temperature, Electrical Conductivity and PH in Water

The temperature values of water samples were recorded using a thermometer while pH and electrical conductivity values were determined using Hand-held pH/Electrical conductivity instrument (ExStik II EC500 model) at point of collection but before preservation with HNO_3.

2.4.2. Determination of Total metal Content in Water

100ml of the water sample was placed in 125ml conical flask and digested with concentrated HNO_3 until a clear solution was obtained (which means the digestion is complete). The solution was filtered after the wall of the flask is washed with distilled water. The filtrate was then transferred into a 50ml volumetric flask diluted to mark with distilled water and mixed thoroughly [5]. A portion of this solution was used for the metal analysis using Atomic Absorption Spectrophotometer (Buck Scientific Model 210 VGP).

2.4.3. Determination of pH and Organic Matter Content in Sediment

Sediment pH was determined using a pH meter after shaking 5g of each sample with 5ml water and allowed to stay overnight. The organic matter content was determined by LOSS ON IGNITION (LOI) using 5g each of soil and sediment samples heated at 450°C for I hr [6].

2.4.4. Determination of Total Metal Content in Sediment

0.5g of the sieved sediment sample was placed into 100ml beaker and moistened with few drops of distilled water. The sample was digested using 5ml of Aqua-regia. The digested sample was cooled and filtered through a Whatman 541 filter paper into 100ml volumetric flask. The filtrate was made up to the mark with distilled water. The volumetric flask was then inverted several times to ensure mixing and homogenization of the solution. The solution was then transferred into a labeled sample bottle and was analyzed for heavy metal content using Buck Scientific model of Atomic Absorption Spectrophotometer (Buck Scientific Model 210 VGP) [7].

2.4.5. Statistical Analysis

Tests for significant difference between means were carried out using the analysis of variance (ANOVA) of the Statistical Package for Social Sciences (SPSS) computer programme. Means were separated using the Tukey test. Test for relationships in metals concentrations were carried out using correlation analysis.

The contamination status of the river sediment was assessed by determining the following

Contamination Factor (CF).

The degree to which sediment is contaminated is often express as Contamination Factor (CF)

$$CF = \frac{Cmetal}{Cbackground\ value}$$

Where C*metal* is the total metal concentration and C*background* represent the average background value of the element in sediment. The geochemical background values in shale of the metals under investigation (Cd = 0.2; Cu = 32; Pb = 20 and Zn = 129) earlier reported by [8] were used as background values.

The CF value could fall into either of the levels of contamination. Where CF < 1 refers to low contamination; $1 \le CF < 3$ indicates moderate contamination; $3 \le CF \le 6$ means considerable (high) contamination and CF > 6 refers to very high contamination [9].

Geo-accumulation Index (I-geo)

Geo-accumulation Index was first used by [10] to assess the level of metal pollution is sediment [11,12]. The index is represented as

$$I - geo = \log 2\left(Cn\,/1.5Bn\right)$$

Where Cn is the concentration of the metal pollutant; Bn is the geochemical background concentration of the pollutant in sediment and 1.5 is the background matrix correction factor due to lithogenic effect. The I-geo consists of seven grades ranging from unpolluted to very highly polluted as follows

I-geo Class Severity of pollution

0	0	Uncontaminated
0-1	1	Uncontaminated to moderately contaminated
1-2	2	Moderately contaminated
2-3	3	Moderately contaminated to highly contaminated
3-4	4	Highly contaminated
4-5	5	Highly to very highly contaminated
>5	6	Very highly contaminated

3. Results

3.1. Water Analysis

The mean values and standard deviations of pH, temperature and electrical conductivity of water samples obtained from the study and control sites are presented in Table 1.

Table 1. The mean values (±SD) of pH, EC (µsm-^{1}) and Temperature (O°C) in water samples obtained from the four sampling stations along River Delimi and Lamingo Dam in Jos city

Station	pH	Temp .(O°C)	EC (µsm^{-1})
I	6.8(±0.06)[b]	26.1(±1.31)[a]	95.8(±7.71)[a]
II	6.8(±0.27)[b]	26.8(±0.61)[a]	95.1(±6.52)[a]
III	6.8(±0.22)[b]	26.6(±1.38)[a]	94.3(±6.74)[a]
IV	7.5(±0.42)[a]	27.6(±0.86)[a]	104.5(±9.79)[a]
Limits	6.5- 8.4*	23-35**	350***

Means followed by same letter within column are not statistically different at 95% level of confidence. *= [13]   ** = [14]; *** = [15]

Table 2. The mean values (±SD) of heavy metal concentrations (mg/L) in water samples obtained from the four sampling stations along River Delimi and Lamingo Dam in Jos city

Station	Cd	Cu	Pb	Zn
I	0.146(±0.04)[a]	0.341(±0.08)[a]	0.933(±0.80)[a]	1.803 (±0.34)[a]
II	0.381(±0.09)[b]	0.371(±0.18)[a]	0.955(±0.61)[a]	1.871(±0.37)[a]
III	0.300(±0.21)[b]	0.190(±0.08)[b]	1.030(±0.91)[a]	1.615(±0.46)[a]
IV	0.006(±0.01)[c]	0.115(±0.02)[b]	0.516(±0.36)[a]	0.951(±0.26)[b]
FAO Limits	0.01	0.20	5.00	2.00

Means followed by same letter within column are not statistically different at 95% level of confidence.

There was a significant difference ($p \leq 0.05$) in the mean pH values of water depending on whether the samples were collected at the study or control site. As such, the mean pH values of 6.8 each recorded at stations I, II and III of the study site were significantly lower than a value of 7.5 recorded at station IV (control site). Statistically no significant difference ($p > 0.05$) was observed in the mean temperature values of water collected at the study site (stations I, II and III) compared to the control site (station IV). The mean temperature values were 26.1°C, 26.8°C, 26.6°C and 27.6°C for stations I, II, III and IV respectively. Similarly, the mean Electrical Conductivity values of 95.8µsm^{-1}, 95.1µsm^{-1}, 94.3µsm^{-1} and 104.6µsm^{-1} recorded in water samples from stations I, II, III and IV respectively were statistically the same ($p > 0.05$). Relatively higher mean value (6µsm^{-1}) was however recorded in the samples collected at station IV (control site).

The mean values and standard deviations of total metal content of water samples obtained from the study and control sites are presented in Table 2.

Difference in sampling stations had a significant influence ($p \leq 0.05$) on the mean Cd concentration in water. The highest mean Cd value 0.146mg/L was observed in water samples from station I, followed by statistically similar values of 0.381mg/L and 0.300mg/L for stations II and III respectively. A significantly much lower mean Cd concentration of 0.006mg/L was however recorded in water samples obtained from station IV of the control site. The water samples collected from stations I and II with similar mean Cu concentrations of 0.341mg/L and 0.371mg/L respectively were statistically similar ($p > 0.05$), but significantly higher ($p \leq 0.05$) than the mean values of 0.190mg/L and 0.115mg/L in samples collected at stations III and IV respectively. Although a relatively lower mean Pb concentration was realized from water samples at station IV (0.516mg/L) compared to what were recorded at stations I (0.933mg/L), II (0.955mg/L) and III (0.030mg/L), the differences are not statistically significant ($p > 0.05$). The mean Zn concentrations in water collected at stations I (1.803mg/L), II (1.871mg/L), III (1.615mg/L) were statistically similar ($p > 0.05$) but significantly higher ($p \leq 0.05$) than a mean value of 0.951mg/L recorded in samples from station IV. At the study site, only the mean Cd concentrations in water at stations I, II and III, Cu at stations I and II were above the limits of 0.01mg/L and 0.20mg/L for Cd and Cu respectively for irrigation water recommended by FAO. The mean Pb and Zn concentrations in the study area were all below the limit recommended by the regulatory authority. At the control site however the concentrations of all the metals were below the recommended limits. The general profile of mean metal content in water for both the study and control areas is Zn > Pb > Cu > Cd.

3.2. Sediment Analysis

The means and standard deviations of pH and organic matter content in sediment samples obtained from the study and control sites are presented in Table 3.

Table 3. The mean values (±SD) of pH and Organic Matter (OM) in sediment samples obtained from the four sampling stations along River Delimi and Lamingo Dam in Jos city

Station	pH	OM
I	6.5(±0.14)[b]	4.5(1.50)[a]
II	6.6(±0.47)[b]	4.6(1.83)[a]
III	6.6(±0.22)[b]	4.1(1.31)[a]
IV	7.3(±0.43)[a]	4.9(0.41)[a]

Means followed by same letter within column are not statistically different at 95% level of confidence.

Data analysis revealed that there was a significant variation in the mean pH values of sediment samples collected at the study sites (stations I, II and III) compared to the control site (station IV). Thus, a significantly higher value of 7.3 was recorded for sediment samples obtained from station IV compared to statistically similar value of 6.5 for station I and 6.6 each for stations II and III. There was no significant variation in the mean OM content in sediments collected from the various sampling stations. The mean values of 4.5%, 4.6%, 4.1% were recorded for samples collected from stations I, II and III respectively (study site), while station IV (control site) had a mean OM value of 4%.

The means and standard deviations of total metal concentrations in sediments obtained from the study and control sites are presented in Table 4.

Table 4. The mean values (±SD) of heavy metals (mg/kg) in sediment obtained from the four sampling stations along River Delimi and Lamingo Dam in Jos city

Station	Cd	Cu	Pb	Zn
I	1.330(±0.39)[a]	3.701(±0.76)[a]	1.840(±1.78)[a]	3.558(±0.54)[a]
II	1.515(±0.35)[a]	3.966(±1.84)[a]	1.673(±1.11)[a]	4.390(±0.38)[a]
III	1.301(±0.37)[a]	1.898(±0.94)[b]	2.053(±1.89)[a]	2.680(±0.48)[b]
IV	0.900(±0.31)[b]	1.983(±0.18)[b]	1.111(±0.79)[a]	2.405(±0.65)[b]
USEPA Limits	0.68	18.70	30.20	124.00

Means followed by same letter within column are not statistically different at 95% level of confidence.

Difference between sampling stations had a significant influence ($p \leq 0.05$) on the mean Cd concentration in sediment. There was a highly significant variation in the Cd content of sediment collected at the study sites compared to the control site. Sediment samples collected at stations I, II and III had statistically similar ($p > 0.05$) mean Cd values of 1.330mg/kg, 1.515mg/kg and 1.301mg/kg respectively. These values were significantly higher ($p \leq 0.05$) than 0.900mg/kg recorded in samples collected at station IV. Significant variation ($p \leq 0.05$) was observed in the mean Cu concentration in sediment obtained from the various sampling stations. The mean Cu concentrations in sediment obtained from stations I (3.701mg/kg) and II (3.966mg/kg) were statistically similar ($p > 0.05$), but significantly higher ($p \leq 0.05$) than 1.898mg/kg and 1.983mg/kg obtained from stations III and IV respectively. No significant variation ($p \geq 0.05$)

was observed in the mean Pb concentrations in sediment samples collected at the various sampling stations in the study as well as the control sites. The mean values of 1.840mg/kg, 1.673mg/kg and 2.053mg/kg recorded in sediment samples obtained respectively at stations I, II, and III and 1.111mg/kg recorded at station IV were all statistically similar ($p > 0.05$). The general profile of mean metal content in sediment for both the study and control areas is Zn > Cu > Pb > Cd except for station III where Pb > Cu.

3.2.1. Sediment Contamination Factor (CF) and Geoaccumulation Index (I-geo)

The CF assessment values for the heavy metals are as presented in Table 5.

Table 5. Contamination Factor (CF) values for heavy metal concentrations in sediment obtained from the four sampling stations along River Delimi and Lamingo Dam in Jos city

Station	Cd	Cu	Pb	Zn
I	6.65	0.12	0.09	0.03
II	7.58	0.12	0.08	0.03
III	6.51	0.06	0.10	0.02
IV	4.50	0.06	0.06	0.02

The highest CF in all the sampling stations were recorded for Cd with the CF values of 6.65, 7.58, 6.51 and 4.50 respectively for stations I, II, III and IV respectively. The least values were however recorded for Zn with CF values of 0.02 each at stations I and II; 0.17 at station III and 0.13 at station IV. It is also worthy of note that station IV compared to other stations recorded the least CF for all the metals (Cd = 4.50, Cu = 0.06, Pb = 0.06 and Zn = 0.02).

The I-geo index values of the metals under investigation are presented in Table 6.

Table 6. Geoaccumulation Index (I-geo) values for heavy metal concentrations in sediment obtained from the four sampling stations along River Delimi and Lamingo Dam in Jos city

Station	Cd	Cu	Pb	Zn
I	1.33	0.02	0.02	0.01
II	1.52	0.02	0.02	0.01
III	1.31	0.01	0.02	0.01
IV	0.90	0.01	0.01	0.00

Generally Cd had the highest I-geo index with the values 1.33, 1.52, 1.31 and 0.90 recorded for stations I, II, III, and IV respectively. On the other hand, the lowest values were obtained for Zn with only 0.01 each recorded for stations I, II and III and no (0.00) value recorded for station IV. The least I-geo index values for all the metals (Cd = 0.90, Cu and Pb = 0.01 each and Zn = 0.00) were recorded at station IV (control site) compared to others (study sites).

3.2.2. Correlation Analysis

The correlation coefficient (r) values determined between irrigation water and sediment collected from the various sampling stations are presented in Table 7.

Statistically significant ($p \leq 0.05$) correlations were obtained between metal concentrations in water and sediment. The r values for these relationships for Cd, Cu, Pb and Zn were 0.421, 0.896, 0.952 and 0.761 respectively. Other significant correlations observed include those of sediment Cd and water Cu (0.457);

sediment Cu and water Zn (0.517) as well as sediment Zn and water Cd (0.584).

Table 7. Correlation coefficient (r) values for heavy metal concentrations in sediment and water obtained from the four sampling stations along River Delimi and Lamingo Dam in Jos city

Heavy metals in sediment	Heavy metals in water			
	Cd	Cu	Pb	Zn
Cd	0.421*	0.457*	-0.092	0.388
Cu	0.290	0.896**	-0.012	0.517**
Pb	0.252	0.157	0.952**	0.207
Zn	0.584**	0.744**	0137	0.761**

**Correlation is significant at the 0.01 level
*Correlation significant at the 0.05 level

4. Discussion

The results of this investigation revealed that the water in River Delimi is slightly acidic while that of Lamingo Dam is slightly alkaline. The pH gives an indication of the balance between the acids and bases in water. The level of pH in solution reflects the solvent power of water, thereby indicating its possible chemical reactions on sediment. Water with a pH outside the normal range (6.5 – 8.4) may contain excess toxic ion(s) posing serious threat to aquatic organisms. It may also bring about nutritional imbalance if used for irrigation purposes. The lower pH values recorded in samples obtained from the study site may be due to dumping of waste materials which release ions into the water. The normal pH range for irrigation water according to and [13] is from 6.5 to 8.4. The pH of water in both study and control sites therefore falls within the limit set by the regulatory authorities for irrigation purposes.

The mean electrical conductivity values in water obtained from all the sampling stations were statistically similar although a relatively higher value ($6\mu sm^{-1}$) was recorded in the samples collected at station IV (control site). Conductivity indicates the presence of dissolved

solids especially electrolytes but does not give information about any specific chemical. The conductivity values from all the areas were far below the maximum limit of 350µsm-[1] recommended by [15]. It can be concluded therefore that the water obtained from Delimi River and Lamingo dam is suitable for irrigation activities as far as electrical conductivity values are concerned.

The highest mean values for all the metals were recovered from water samples at study site while the lowest values were obtained at station IV – the control site. The mean metal content in water obtained in all the sampling stations is however lower than what was previously reported by [16] who found mean values of metals (Cd = 1.00ma/L, Cu = 39.00mg/L, Pb = 33.00mg/L and Zn = 193.00mg/L) in water samples obtained from River Kera in Addis Ababa, Ethiopia due to discharge of industrial and domestic waste. [17] also reported similar higher mean metal concentrations of 0.74mg/L, 19.07mg/L, 6.11 and 160.70mg/L for Cd, Cu, Pb and Zn respectively in water obtained from polluted River Pariyej in India. Dumping of different waste materials such as plastics, electrical and electronic materials, metal scraps, old batteries, spent lubricating oil from nearby mechanic workshops especially at station II (Farin gada) along the Delimi River bank may be responsible for the high level of heavy metals in the river water. The excess levels of these heavy metals especially Cd, and Cu in River Delimi water is a threat to aquatic life. It also means that the water is not suitable for use in irrigation activities. Crops irrigated with water obtained from the river could potentially accumulate these toxic metals.

Significant variations were observed in the mean pH values of sediment collected at the different sampling stations. Thus, a significantly low mean pH value was recorded for sediment samples obtained from study compared to the control sites. A study carried out by [18] also revealed that sediment obtained in the study site of River Anyang, Korea has lower pH values compared to those samples collected at the control site. The low pH (below 7) in sediment collected at the study site indicated that the sediment is acidic. The acidic nature of the sediment at the study site is an indication that the metals can easily be desorbed from the sediment into the water column making them more bioavailable to aquatic life and to crops when the water is used for irrigation purposes. The high pH value (above 7) at the control site means that the metals cannot be easily desorbed from the sediment to the water phase and therefore less bioavailable to biota.

No significant difference was observed in the mean organic matter content in sediments collected from the various sampling stations. However, the relatively higher organic matter content in the sediment at the control station means that the metals are less likely to be released into the water column due to formation of metal-organic matter complex. Organic matter in the sediment is known to play an important role in the adsorption and retention of heavy metals.

The significant positive correlations observed between the heavy metals contents in sediment and water means that the metals in the two environmental media could have common sources. The metals probably originate from either same waste or parent material as the case may be. It was earlier pointed out by [19] that when metals are released into the aquatic environment, they do not always remain in water column but could also be adsorbed onto the sediment. The metals adsorbed to the sediment are however desorbed (remobilized from the sediment) back to the water column due to changes in environmental conditions such as pH and redox potentials. It may be concluded therefore that positive significant correlation in metals concentrations found between sediment and water was because the metals were derived from common sources.

The sediment analysis revealed that the concentrations of all the metals were generally at their maximum in the study site (River Delimi) compared to what were obtained in the control area (Lamingo dam) perhaps due to dumping of domestic and industrial wastes into the river. This corroborates the findings of [20] who collected sediment samples from Yamuna River which passes through Delhi and Agra urban centers and analysed them for concentration and distribution of nine heavy metals and obtained the following results; Chromium (157–817mg/kg), manganese (515–1015mg/ kg), iron (28,700–45,300mg/kg), cobalt (11.7–28.4mg/kg), nickel (40–538mg/kg), copper (40–1204mg/kg), zinc (107–1974mg/kg), lead (22–856mg/kg) and cadmium (0.50–114.8mg/kg). The levels of metals were compared with the average shale concentration and showed exceptionally high values for chromium, nickel, copper, zinc, lead and cadmium in the two urban centers. The author concluded that high levels of these metals were found in sediments obtained from the urban centers because they received domestic and industrial wastes.

The analysis in the investigation indicated that total metal contents in sediment are below the limits recommended by [21]. However, if a more critical analyses using CF categories are used, Cd obtained from all the sampling sites showed considerable ($3 \leq CF \leq 6$) contamination while the other metals showed low ($CF < 1$) contamination.

The I-geo values vary from metal to metal and from site to site. However using the I-geo Index categories as earlier presented, only Zn at station IV (control site) attained unpolluted status (Class 0). On the other hand, Cd at station I, II and III attained moderate contamination status (Class 2), while all other metals in their respective sampling sites had a low to moderate contamination status (Class 1).

5. Conclusion

The result of this investigation generally revealed the presence of all the metals under consideration in water and sediment samples collected from Delimi River. The total metals content in water and sediment were higher at the study compared to the control site. This may not be unconnected with dumping of domestic and industrial wastes into the river. The excess amount of metals especially Cd and Cu recovered in water samples obtained from River Delimi is a threat to aquatic organisms. It also means that the water is not suitable for vegetable crop irrigation (as practiced in the city) because the contaminated water might be a cause of heavy metals toxicities to crops and humans through their entry into food chain.

It is therefore recommended that the Plateau State Environmental Protection Agency and other relevant government agencies should ensure regular monitoring of the river and put in place measures to regulate the indiscriminate dumping of domestic waste and the discharge untreated industrial effluents into the river.

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