Evaluation of Heavy Metals, Dissolved Organic Phosphorus (DOP) and Nitrogen (DON) in three Wetlands of Northern Nigeria

Yusuf, S., Audu, A. A. and Waziri, M.

Department of Pure and Industrial Chemistry, Bayero University, P. M. B. 3011, Kano, Nigeria
Department of Chemistry, Federal University, Gashua.

Email: sayzay37@yahoo.com

ABSTRACT

The concentrations of some heavy metals, dissolved organic phosphorus (DOP) and dissolved organic nitrogen (DON) were seasonally determined in water samples from 35 sites from three wetlands areas. The water samples were digested with concentrated trioxonitrate (V) acid at 85 °C for 2 hours on a hot plate and the metal levels were determined using atomic absorption spectrophotometer. The following ranges of values were obtained, copper (Cu) (0.00349±0.001 to 0.0750±0.04 mg/l), lead (Pb) (0.194±0.074 to 0.870±0.001 mg/l), cadmium (Cd) (0.00448±0.0003 to 0.0198±0.0001 mg/l), chromium (Cr) (0.000 to 0.0469±0.001 mg/l), zinc (Zn) (0.00849±0.0001 to 0.144±0.003 mg/l) and nickel (Ni) (0.0042±0.0006 to 0.0454±0.0015 mg/l). Generally, the metal concentrations increased in the dry but decreased in wet season. Pearson correlation coefficient, analysis of variance, Tukey’s test, principal component analysis (PCA) and cluster analysis (CA) were used to assess the data and it was observed that Pb has the highest mean concentration. When the metals levels were graduated, they were found to be in the order of Pb>Cd > Cu > Zn > Ni in the wet season but the order changed in the dry season as Pb>Cu > Zn > Ni > Cd > Cr. The Pb and Cd concentrations in all the sites were higher than the WHO and NAFDAC guidelines, indicating that the wetlands water samples are unsafe for human consumption, thus relying on these wetlands as sources of food would have serious public health implications. Principal Component analysis (PCA) and Cluster analysis (CA), were used to analyse the relevance of different heavy metals and identify their major sources. The results showed three factors for the heavy metals variability (71.4% of the total variance) that Zn and Cu, were dominated by principal component 1 (PC1), Cd and Pb were associated with high values in the second component whereas Cr and Ni are higher in the third component. PCA and (CA) for the sampling sites showed that industrial wastewater, runoff from farmlands and atmospheric depositions were the major sources of heavy metals particularly Pb, Cd, Cr, Zn and Cu in these wetlands. The average values for DON and DOP ranged from 10.7±2.28 to 71.1±14.9 mg/l and 0.46±0.229 to 1.84±1.39 mg/l respectively in the wetlands. There is no significant difference in DON and DOP concentration in both the dry and the wet seasons. High concentrations of DOP and DON in wetlands have been implicated for high yield of agricultural produce of the farmlands around the wetlands.

Keywords: Wetlands, water samples, heavy metals, DOP, DON.

INTRODUCTION

The rapid increase in the development of industry, urbanization and agricultural activities has been threatening the ecological health of wetlands [1]. A number of studies on heavy metals in wetlands have been carried out in different part of the world [2, 3, 4, 5], including wetlands of marsh [6], lake [7, 8, 9], river [10, 11], and coastal area [12, 13]. Other studies have investigated heavy metals deposited in the sediments, with regard to their chemical forms, as well as horizontal and vertical distributions in different periods [14, 15]. The evaluation of heavy metals ecological risks [16, 17] and their accumulations in the wetland water bodies as well as animals and plants have been carried out [18, 19]. Other previous studies focused mainly on man made wetlands [20, 21]. Moreover, the molecular composition of dissolved organic matter (DOM), collected from Baturiya, Nguru, Matara-Uku, Jebba and Lokoja wetlands of the Northern Nigeria were characterized using Fourier Transform Infra–Red (FTIR) and Gas Chromatography-Mass Spectrometry (GC-MS). [22]. This study focused on the molecular characteristics of the wetland ponds, therefore, distributions of heavy metals in natural wetlands ponds need to be explored further [23, 24]. Wastewater treatment plants significantly control the discharge of heavy metals into water bodies, but in the West African region where these treatment plants are basically not
adequate, untreated industrial and urban sewage are frequently discharged into water canals and find their way to wetlands [25]. While it is accepted that the dissolved reactive phosphorus (DRP) fraction is the most available form of phosphorus in aquatic ecosystems, there is growing interest in the transport, transformation and bioavailability of dissolved organic phosphorus (DOP) [26, 27, 28, 29, 30]. Due to low mineral matter content and high organic matter content, a large proportion of phosphorus in wetlands is stored in organic forms [31]. Sources of such organic phosphorus in wetlands include herbicides, pesticides, fungicides, algae and runoff from farms.

Dissolved organic nitrogen (DON) is a complex mixture that is primarily composed of amino acids, amino sugars, amides, peptides and heterocyclic-N compounds [32]. Their primary sources include agricultural fertilizers, wastewater discharges, forest litter, and excretion of algae products in eutrophic water [32]. Chlorination and chloramination of DON not only produces regulated compounds such as trihalomethanes (THMs) and haloacetic acids (HAAs) but also nitrosamines, halonitromethanes, and haloacetonitriles [33, 34]. Toxicity tests have indicated that these compounds are carcinogenic or mutagenic [33, 34, 35]. During the past few decades, many studies have described the occurrence and fate of DON in marine and freshwater ecosystems [36]. Seasonal changes in DON concentration has been previously documented in Mer Bleue bog, Ontario, Canada [37], and forested landscapes in North Carolina [37, 38]. Principal component analysis (PCA) and Cluster Analysis (CA) were conducted in this study to enable us identify the relationships between the different metals and their corresponding origins. It has been observed that PCA and CA could provide identification for association of heavy metals and give some information about the origin of the contamination [39]. The aim of this study is to determine the concentration of heavy metals, dissolved phosphorus (DOP) and dissolved organic nitrogen (DON), and assess their distribution as well as their seasonal variation among three wetlands of Northern Nigeria.

**The Study Area**

The Lokoja and Jebba wetlands (Figure 1) are part of the Lower Kaduna-Middle Niger wetlands which are located on the extensive floodplain of the mid-section of River Niger (in Nigeria) and the lower course of one of its main tributary, River Kaduna. The wetlands extend from Jebba (9°00′N 4°50′E) to Baro (8°35′N 6°25′E) along the Niger, and from Wuya Bridge on the River Kaduna, along the Jebba – Bida (9°00′N 6°00′E) road downstream to Pategi (8°45′N 5°37′E) on the south bank of the Niger. The Hadejia-Nguru wetlands (Fig. 1) are located between latitudes 12°15′N and 12°55′N, and between longitudes 10°E and 11°E in the sudan savanna of Nigeria and are designated as a Ramsar site by the Ramsar Convention; it is presently the only Ramsar site in Nigeria [40, 41]. Baturiya wetland (Figure 1) occupies an estimated area of 3500 square kilometers and is located between latitude 12°31′N and longitudes 010°29′E [41, 42]. In Jebba wetland samples were collected from sites J1, J2, J3, J4, J5, J6 and J7, in Matara-Uku wetland samples were collected from sites M1, M2, M3, M4, M5, M6 and M7, while in Baturiya wetland sites BR1, BR2, BR3, BR4, BR5, BR6 and BR7 were sampled. Likewise, in Lokoja wetlands sites LA1, LA2, LA3, LA4, LA5, LA6 and LA7 were also sampled. Similarly, samples were also collected from sites N1, N2, N3, N4, N5, N6 and N7 in Nguru wetland.

![Figure 1: Nigeria Map Showing the Wetlands](image)

**Material and Methods**

All chemicals used are of analytical reagent grade and solutions prepared using distilled-deionised water.

**Sampling and sample pre-treatment**

Water samples were collected in 1000 cm$^3$ and 500 cm$^3$ white, low-density polyethylene bottles from 35 sites spread across five sampling locations at 200 m apart. The water samples were collected by immersing the sample containers nozzle down 0.5 m below water surface and slowly allowing it to fill up. The samples used for heavy metals analysis were in 1000 cm$^3$ flasks and were acidified using 3.0 cm$^3$ of 1:1 trioxonitrate (V) acid and water. The samples for DOP and DON analyses were collected in 500 cm$^3$ flask and used as collected Samplings were carried out during the earlier part of the dry and the wet season. All the samples were appropriately labelled and transported to the laboratory. The samples were then filtered.
using 0.7 µm GF/F glass fiber filter and then stored in a fridge at 4 °C.

**Sample digestion for Heavy Metals**

500 cm³ of the filtered water sample in a 1000 cm³ was placed on a hot plate and evaporated to about 50 cm³. It was allowed to cool and transferred into a 250 cm³ beaker. 5 cm³ of concentrated HNO₃ was added and the resulting solution was heated at 85 °C until a clear solution was obtained [43]. The digested sample was allowed to cool, then transferred into a 100 cm³ volumetric flask and made up to mark with deionised water. This solution was then used for the heavy metals analysis using Atomic Absorption Spectrophotometer (AAS).

**Metal Determination**

The absorbance values of Pb, Cu, Cd, Cr, Zn and Ni in the water samples were taken using Agilent, varian AA240FS Atomic Absorption Spectrophotometer (AAS) at their individual absorption lines. Instrumental calibration was carried out prior to metal determinations by taking the absorbance values of the standard solutions prepared for the different metals. Calibration curves for the different metals were plotted using the results obtained. The water samples were aspirated into the spectrophotometer and the absorbance reading recorded. The same procedure was used for the blank and standard solutions. The concentrations of metals were extrapolated from the calibration curves.

**Conductivity, Total Dissolved Solidand pH Measurements**

Conductivity of the water samples were measured using a calibrated BDS-11C digital conductivity meter. The meter was standardised using a 0.01 M KCl solution which had a conductivity reading of 1412 µS/cm at 25 °C. It was switched on and allowed to warm for about 15 minutes. The electrode was then immersed into the water sample and the reading was taken when a stable value was obtained [44], the mode was then adjusted and reading of the Total Dissolved Solid (TDS) was recorded. The pH was measured at the sampling sites using a portable wagetzl international potasest pH meter. The meter was calibrated by dipping the tip of the electrode in a sample of pH 7.0 buffer (HI 7007P) at ambient temperature, the reading was allowed to stabilised and the pH 7.0 trimmer adjusted until the reading displayed 7.0. The electrode was rinsed with water and dipped into a sample of pH 10.01 buffer solution (HI 7001P), the reading allowed to stabilize and the pH 10 trimmer adjusted to a reading of 10.0. The standardized meter was switched on and allowed to warm for about 15 minutes. The electrode was then immersed into the water sample and the measurement was taken when a stable value was obtained. The electrode was rinsed with deionised water before taken each reading [44].

**Procedure for phosphate determination**

30 cm³ of the sample was pipetted into a 50 cm³ calibrated flask with the addition of 8 cm³ of the mixed reagentand mixed thoroughly. The solution was allowed to stand for 20 minutes for optimum colour formation, thereafter, the absorbance of the sample was measured using 755S UV-VIS spectrophotometer at 880 nm and reagent blank was used as the reference solution, [45]. Dissolved organic phosphorus (DOP) was calculated by subtracting the hydrolysable Phosphorus from total dissolved phosphorus (TDP).

**Procedure for nitrate determination**

5 cm³ of the digested sample was pipetted into a 50 cm³ volumetric flask and 10 cm³ of 0.5 M NaOH solution and 10 cm³ of the reducing reagent were added and heated for 15 minutes at 52 °C. 10 cm³ of 0.0581 M acidic sulphanilamide solution was added, shaken thoroughly for 5 minutes for the diazotization reaction to go to completion. Thereafter, 10 cm³N -(1-Napthyl) ethylenediamine dihydrochloride solution was added to form an azo dye and the contents were diluted to 50 cm³ with water. The absorbance of the pink coloured dye solution was measured using 755S UV-VIS spectrophotometer at 540 nm against the corresponding reagent blank [45]. DON was calculated by subtracting the sum of the inorganic nitrogen species (NO₃⁻, NO₂⁻ and NH₄⁺) from total dissolved nitrogen (TDN).

**Procedure for NH₄⁺-N Determination**

25 cm³ of the sample was transferred into a 50 cm³ Erlenmeyer flask, with the addition of 1 cm³ phenol solution, 1 cm³ sodium nitroprusside solution and 2.5 cm³ oxidising solution (100 cm³ alkaline citrate and 25 cm³ sodium hypochlorite), the resulting solution was thoroughly mixed after each addition. The samples were covered with plastic wrap and kept in the dark at ambient temperature for 1 h [46]. The absorbance was measured at 640 nm against the reagent blank.

**Data analysis**

Statistical analysis of data was performed using Microsoft Office Excel and the Statistical Package for Social Science (SPSS 20.0 for Windows, SPSS Inc., IL, U.S.A.). Tukey's test was used to determine pair wise differences among different sample sites at the
level of \( p \leq 0.05 \). Correlations among metal concentrations, DOP and DON in the water samples were evaluated using Pearson correlation coefficients. Both Principal Component Analysis (PCA) and Cluster Analysis (CA) were conducted to investigate associations of different sample sites and assess the major sources of metals in the wetlands.

**Results and Discussion**

The variations of pH for all the water samples were between the ranges of 7.6 to 9.0 which were within the World Health Organization standards [47]. The pH values recorded in Jebba and Baturiya are significantly greater than those obtained in Matara-Uku, Nguru and Lokoja during the dry season whereas the value obtained in Nguru is significantly higher than those recorded in Jebba, Baturiya, Lokoja and Matara-Uku wetlands during the wet season. Total Dissolved Solid (TDS) values varied from 50.8 to 119 mg/L, which were below the permissible limits for surface water (300 mg/L). The highest value was obtained at Nguru wetland and this was attributed to the used of refuse dump as manure and runoff from farm lands around the vicinity of the wetland. The concentrations of TDS in Nguru and Baturiya were significantly greater than those recorded in Jebba, Lokoja and Matara-Uku during the dry season. In the wet season, it was observed that the level of TDS in Nguru was significantly greater than those of Jebba, Baturiya, Lokoja and Matara-Uku. WHO normal range for electrical conductivity (EC), of water is 400-600 \( \mu \text{S/cm} \). In all the collected water samples, values of electrical conductivity were recorded below the normal range. Nguru has the highest value of electrical conductivity among the wetlands. Though, there is no significant difference between the values recorded for Nguru and Baturiya, their values were significantly higher than those recorded for Jebba, Lokoja and Matara-Uku during the dry season. Similarly, the value obtained for Nguru wetland during the wet season is significantly greater than those recorded from the other sites of the wetlands at \( p \leq 0.05 \). When the Pearson correlation was conducted, it was observed that conductivity is strongly positively correlated to Total Dissolved Solid (TDS) at a significance level of 0.01 (2-tailed). However, pH values obtained were not correlated to electrical conductivity and TDS both in the dry and the wet seasons. Fig. 2 shows the levels of pH, EC and TDS in the wetlands, with a high electrical conductivity.

**Figure 2: Variation of pH, Electrical Conductivity and Total Dissolved Solid**

The mean values of DOP in water samples range from 0.464±0.229 to 1.84±1.39 mg/l (Figures 3 and 4). The highest concentration of DOP (1.84 mg/l) was found in the sample collected from Matara-Uku during the dry season while the lowest level of DOP (0.464 mg/l) was detected in the sample obtained from Jebba wetland during the dry season. The statistical analysis showed that there is a significant difference among the DOP concentrations from the various sites. The DOP levels were greater than the permissible limit of 0.03 mg/l defined by [47]. The T-test conducted revealed that there was no significant difference between the levels of DOP in the wet and dry seasons at \( p \leq 0.05 \). When the Turkey’s test was applied, it was observed that the difference between the mean concentrations of DOP in Matara-Uku and those of Jebba & Nguru are all greater than the Least Significant Difference, LSD, indicating that the mean concentration of DOP in Jebba and Nguru, are significantly lower than those recorded in Matara-Uku during the dry season (Figure 3). There was no significant difference in the levels of DOP during the wet season (Figure 4), at \( p < 0.05 \), but the concentration decreases in the following sequence during the dry season; Matara-Uku > Baturiya > Lokoja > Nguru > Jebba (Figure 3), and in the wet season Lokoja > Baturiya > Jebba > Nguru > Matara-Uku (Figure 4). The extensive use of organophosphorus insecticides and wastewaters from residential homes entering into the wetlands during the wet season may have led to the high DOP concentration observed in the wet season [48], while the low value recorded during the dry season may be due to adsorption of DOP onto clay and precipitation as calcium and aluminium phosphates [49, 50].
The mean value of DON, range from 10.7±2.28 to 71.1±14.9 mg/l (Figures 5 and 6). The highest concentration of DON was found in the sample collected from Jebba while the lowest level of DON was detected in the sample obtained from Baturiya wetland during the dry season (Figure 5). The statistical analysis showed that there is a significant difference among the DON concentration from the various sites and their mean values were greater than the permissible limit of 1 mg/l set by WHO [47]. When the Turkey’s test was applied, it was observed that the difference between the mean concentrations of DON, in Jebba and those of Baturiya, Lokoja, Matara-Uku and Nguru wetlands were all greater than the Least Significant Difference, LSD during the dry season (Figure 5). There was no significant difference in the levels of DON during the wet season (Figure 6) at p<0.05. The high level of DON recorded was attributed to the wash offs from surrounding farmlands, nitrogen-based fertilizers used and the inflow of wastewater from homes [32].
of 0.931, 0.821 and 0.831 with Cr, Zn and Cu respectively at a significance level of 0.05 (2-tailed). Similarly, Pb correlated strongly with Ni, Zn and Cu at 0.935, 0.966 and 0.961 respectively with a significance level of 0.05 (2-tailed). In the dry season Cd is positively correlated to Pb and Zn while Pb also has strong positive correlation with Zn, while Ni showed a positive correlation of 0.947 with Zn at a significance level of 0.01 (2-tailed). This indicates that metals with strong positive correlation have similar source of pollution.

Tukey’s test revealed that the levels of Cd in Matara-Uku and Nguru (Figure 7), were statistically not significant, but were significantly different from the levels of Cd in Lokoja, Jebba and Baturiya (Figure 7), in the dry season. It also revealed that there were no significant difference between levels of Cd among Lokoja, Jebba and Baturiya wetlands at p<0.05. The mean concentration of Pb showed no significant difference at p<0.05 for all the sites analysed during the dry season, though those recorded at Jebba and Nguru wetlands differ significantly at p<0.05 during the wet season.

Chromium was not detected during the dry season and the levels do not differ significantly at p<0.05 in all the sites studied during the wet season. Similarly, there were no significant differences in the levels of Ni among the different sites studied during the dry and wet seasons. One-way ANOVA revealed that there is no significant difference in the levels of Zn at P<0.05 among the different sites in both seasons. The concentration of Cu in site Nguru (Figure 7), is significantly higher than those recorded for the other sites during the dry season at p<0.05. While, the levels of Cu in Lokoja is significantly different from those obtained from Nguru, Jebba, Matara-Uku and Baturiya wetlands (Figure 7), during the dry season. Similarly, the mean concentration of copper in Nguru and Baturiya differ significantly from that recorded in Matara-Uku (Figure 8), at p<0.05 during the wet season.

The metal with the highest mean concentration was Pb, with its level ranging from 0.194±0.015 to 0.870±0.035 mg/l. The level of Pb is 87 times higher than the permissible limit at the upper limit and 19.4 folds in the lower limit. This high concentration may be attributed to runoff from farm lands, atmospheric deposition, and use of refuse waste from dump site as manure as well as leakage from water pumps used for irrigation. However, it has been reported elsewhere that significant amount of Cu, Cr, Pb and Zn were atmospherically deposited [52]. Therefore, it can be inferred that these metals were deposited in the wetlands by strong atmospheric storm.

When compared with other wetlands water, the water samples in this study contain higher concentrations of Pb, Cd, Ni, Cu, Zn and Cr [53, 54], but in agreement with heavy metals concentrations reported by [18]. The levels of Pb and Cd in all of the samples collected exceeded the permissible limit of 0.01 and 0.003 mg/l respectively. Lead (Pb) has been implicated in cot deaths and still births [55], while Lower exposures
to cadmium may result in kidney damage and Cd may be a contributing factor in some forms of cancer in human [56]. The results of PCA showed the levels of Cr, Zn, Cu, Cd, Pb and Ni are dominated by three principal components (Table 1) which accounted for 71.4% of the total variance observed during the wet season and by two principal components (Table 2) which accounted for 50.2% of the total variance observed during the dry season. As shown in Table 1, Component 1 is accounted for by the metals of Zn and Cu and these two metals contributed 26.85% of observed variance. Zn could be from tyre wear along the road, pesticides, fertilizer, fungicides used in farmlands, construction materials used as building materials and copper comes from fertilizers, pesticides, herbicides, fungicides, copper brake pads, fungicides used in farmlands and municipal wastewater discharges. Therefore, Component 1 was mainly controlled by atmospheric deposition and run off s from farmlands. Cd and Pb are associated with high values in the second component and contributed 24.33% of the variance observed (Table 1). Cadmium mainly comes from manufacturing industrial processes and emission from automobile exhaust. Similarly, the third component during the wet season, accounts for 20.23% of the variance observed and is characterized by high levels of Cr and Ni. In the dry season (Table 2), Component 1 describes the general contamination of the wetland ponds with heavy metals. It accounts for 29.07% of the variance observed and is dominated by high levels of Pb, Ni, and Cu. Lead (Pb), nickel (Ni), and copper (Cu) are associated with high values in the first component and the contribution of these elements, especially Cu and Ni, to the contamination of the wetland pond is considerable. The metallurgical industry and combustion of fossil fuels, particularly coal and gasoline are main sources of lead, cadmium, nickel and zinc in water bodies. Large amounts of these elements go into wetland ponds along with municipal wastewater [24]. However, the high correlations between these metals and their high contributions to the first component showed that, the contamination of wetland ponds is due to the wastewater discharged and runoff from farmlands into the wetlands.

<table>
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<tr>
<th>Rotated Component Matrix for heavy metals in PCA during the wet season</th>
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<tbody>
<tr>
<td><strong>Rotated Component Matrix</strong></td>
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<tr>
<td><strong>components</strong></td>
</tr>
<tr>
<td>1                      2                      3</td>
</tr>
<tr>
<td>Cd                    0.085                0.824                -0.193</td>
</tr>
<tr>
<td>Pb                    0.026                0.834                0.201</td>
</tr>
<tr>
<td>Cr                    0.404                0.216                0.713</td>
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<tr>
<td>Ni                    0.156                -0.135               0.862</td>
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<tr>
<td>Zn                    0.849                0.031                0.064</td>
</tr>
<tr>
<td>Cu                    0.811                0.063                -0.089</td>
</tr>
<tr>
<td>% of variance         26.847               24.331               20.622</td>
</tr>
<tr>
<td>Cumulative %          26.847               51.178               71.406</td>
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</tbody>
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<th>Rotated Component Matrix for heavy metals in PCA during the dry season</th>
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<tr>
<td><strong>Rotated Component Matrix</strong></td>
</tr>
<tr>
<td><strong>components</strong></td>
</tr>
<tr>
<td>1                      2</td>
</tr>
<tr>
<td>Cd                    0.400                0.478</td>
</tr>
<tr>
<td>Pb                    0.573                0.152</td>
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<tr>
<td>Ni                    0.698                0.027</td>
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<tr>
<td>Zn                    0.132                0.902</td>
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<tr>
<td>Cu                    0.638                -0.143</td>
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<tr>
<td>% of variance         29.07                21.177</td>
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<tr>
<td>Cumulative %          29.07                50.247</td>
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These associated data showed that these metals are from similar sources [57, 58]. The Cluster Analysis (CA), Figures 9 and 10 showed that the sampling sites were classified into three clusters using a criteria value of distance between 0.4 and 0.5. The sampling sites of cluster A (Figure 9), locate J1, BR1, M2, LA6, M1, N6, J5, BR4, LA2, BR6, J6, BR2, BR5 and LA5 wetlands which are located in areas where untreated wastewater is discharged into the wetlands and runoff from farm lands around the wetlands are also emptied into them.
The results of PCA and CA indicated that the accumulations of metals in these wetlands are mainly caused by anthropogenic activities. The results are in consistent with the findings reported by [59], that the increase in trace metals in River Challawa may mainly come from anthropogenic sources of rapid development of industry. One may conclude that, anthropogenic activities and atmospheric deposition are the major sources of heavy metals contamination of these wetlands and to protect our environment there is a need for stringent policy to prevent anthropogenic pollution.

**Conclusion**

The concentrations of heavy metals, DON and DOP varied among the water samples collected from the three wetlands in Northern Nigeria. Whereas the trend of metals was in the order Pb > Cr > Zn > Cu > Cd > Ni in the wet season but the order changed in the dry season as Pb > Cu > Zn > Ni > Cd > Cr. The Pb and Cd concentrations in all the sites of the wetland were higher than the WHO and NAFDAC guidelines, indicating that they wetlands water samples are unsafe for human consumption, thus relying on these wetlands as sources of food would have serious public health implications. There is no significant difference in DON and DOP concentration in both the dry and the wet seasons; though their concentrations are higher than the permissible limit. According to PCA and CA, the metal accumulations of Zn; Pb and Cd, Ni and Cu originated from similar sources and anthropogenic activities and atmospheric deposition have seriously contributed to the contamination of the wetlands of Northern Nigeria.

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