Analysis of Sediments from Some Dams in Katsina State, Nigeria

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Authors’ contributions

This work is a part of Ph.D thesis by author FBS, carried out the study under the supervision of author AAA. All authors read and approved the final manuscript.

ABSTRACT

Aims: To investigate the levels of some physicochemical parameters in sediments collected from seven dams in Katsina State and establish possible explanations for the observed trends.

Study Design: It is an analytical Study.

Place and Duration of the study: The study was carried out in some selected local governments in Katsina State between September 2010 to September 2012.

Methodology: The pH, conductivity and concentration of some metals in the sediments collected from seven different dams spread across Katsina State were determined. pH was determined in a sediment/water slurry using a calibrated pH meter, conductivity was determined using the saturated paste method with a calibrated conductivity meter and the concentration of some selected metals was determined using Atomic Absorption Spectrometer. Samples were collected in the rainy season, harmattan and dry seasons for two years. The average result was used in the final analysis and the result for the three seasons were statistically analysed using ANOVA.

Result: It was found that Zn, Fe, and Cr had the highest concentrations in all the seasons studied with most of the values being higher than the maximum recommended values by EPA. ANOVA showed a significant difference in the concentration of all the metals in the different seasons studied, with only Fe (P=.17) showing no significant difference between the seasons. The concentration of Pb was found to be above the maximum permissible limit in harmattan. This can be due to the
relatively lower pH values in harmattan and the contributions from harmattan dust deposited.

**Conclusion:** It was concluded that apart from the numerous natural factors, human activities contribute to the variations in metal concentrations in the sediments. Regular monitoring was suggested in order to ensure the healthy growth of the inhabitants.

**Keywords:** Analysis; sediments; dams; Katsina State.

**1. INTRODUCTION**

Sediments are minerals or organic materials situated beneath an aqueous layer. They are integral and inseparable parts of the aquatic environment because they help to determine the overall assessment of heavy metals in water vis-à-vis aquatic life and survivability [1]. Sediments form a natural filter system in the material cycles of water. They are important habitat as well as a main nutrient source for aquatic organisms [2]. They are also significant in the assessment of the quality of aquatic systems because natural freshwater from lakes and dams have been center of important cultural developments since the earliest days of civilization [3].

Heavy metals contamination in aquatic environment is of critical concern, due to toxicity of metals and accumulation in aquatic habitats [4]. It was further observed that being non-biodegradable they can be concentrated along the food chain, producing their toxic effect at points far away from the source of pollution [4].

Seven major dams spread across Katsina State were selected for this study. The dams are Ajiwa, Malumfashi and Gwaigwaye dams with a height of 12 meters each, Zobe whose height is 18.9 meters, Jibia which is 23.5 meters high, Dutsinma and Mairuwa dams. The selected dams provide a large percentage of the population in Katsina State with water. Irrigation farming, fishing and other agricultural activities are also carried out around the dams. The study was conducted to ascertain the quality of the sediments since it can help in determining the quality of water, aquatic animals, the soil and the plants grown around the dams. Also, sediment testing reflects the long-term quality situation independent of current inputs [2]. This is because sediments serve as sink for metals and other contaminants of low solubility and low degree of degradability. It is hoped that the result of this study will provide information on the quality of the sediments and guide potential remediation and other management decisions.

**2. MATERIAL AND METHODS**

**2.1 Study Area**

Katsina State is located in Northern Nigeria and lies between latitude 11°02’ and 13°13’, longitude 6°05’ and 9°20’ with an area of 24,192 km². It is bounded in the east by Kano and Jigawa States, in the west by Zamfara, State, in the North by Niger Republic.

The State is one of the few states in Nigeria where crops are grown all year round. This is because apart from normal farming during the rainy season, dry season farming is done along river banks and around the numerous dams in the State [5]. Fig. 1 shows the administrative map of Katsina state.
2.2 Materials

Analar grade reagents were used throughout the study. Deionised water was used for all solution preparations. All glasswares and plastic containers were washed thoroughly with detergent solutions, rinsed with tap water and then with deionised water before drying.

2.3 Sample Collection

Sediment samples were collected from seven dams spread across Katsina State between September 2010 to September 2012 in the rainy season, harmattan and dry seasons. The selected dams are Ajiwa(AJI), Dutsinma(DTM), Zobe(ZOB), Jibia(JIB), Malumfashi(MLF), Mairuwa(MAI), and Gwaigwaye(GWA) dams. The samples were collected using grab method with plastic spatula from the surface sediment (2-20 cm), from five points situated in the east, west, north, south, and midpoint in each of the seven dams, immediately placed in pre-cleaned 500 cm$^3$ polythene containers and transported to the laboratory. They were air dried, ground to fine powder in a porcelain mortar and pestle, sieved using a 0.2mm mesh sieve and kept in clean, labeled polythene containers before analysis. The average reading was used in the analysis of result. Fig. 2 is the map of Katsina state showing the locations of the dams used in this study.
2.4 Digestion of Sediments

3g of the dried, ground, and sieved sediments was placed in a clean 250cm$^3$ beaker. 20cm$^3$ aqua-regia was added to the sample. It was left for the reaction to subside and then the beaker was covered with a watch glass, placed on a hotplate and heated at 120°C until a yellow-brown coloration was formed. The solution was allowed to cool before filtering using ashless filter paper into a 100cm$^3$ volumetric flask and the filtrate made up to the mark with deionised water. A blank sample was prepared using the same procedure but with the samples replaced with deionised water.

2.5 pH Determination

pH was determined in a sediment/water slurry using a calibrated pH meter (HANNA model 209). 5g of the sample was weighed in a 250 cm$^3$ beaker, 5cm$^3$ of deionised water was added followed by a drop of 1.0 moldm$^{-3}$ CaCl$_2$ solution. The excess salt masks the effects of differential soluble salt concentrations in individual samples. It was stirred vigorously and allowed to stand for 30 minutes with occasional stirring. The electrodes were then placed in the slurry, swirled carefully and the pH value read [6].

2.6 Conductivity Measurement

The conductivity was determined using the saturated paste method with a conductivity meter (EC 215 model). The conductivity meter was calibrated with a 0.01M KCl solution.
which has a conductivity of 1412 µS/cm at 25°C. 250 g of the sample was weighed into a 250cm³ beaker and then deionised water was added to it while stirring with a spatula until it was saturated. It was allowed to stand for one hour and rechecked for saturation. The saturated paste was transferred to a filter funnel and filtered using a suction pump. The conductivity of the extract was determined by placing the electrode into it and read when a stable value was obtained [7].

2.7 Determination of Metal Distribution

Metal concentrations in the sediments were determined using a Buck Scientific VGP 210 Atomic Absorption Spectrophotometer. The absorbances of the solutions were obtained and the concentrations determined using the formula, \( y = mx \), in the calibration curves.

Where,
- \( y \) = absorbance
- \( m \) = slope and
- \( x \) = concentration.

Concentration = absorbance/slope \( (i) \)

Concentration of sediments = \( \frac{\text{Concentration}(i) \times \text{volume of digest(100cm}^3)}{\text{weight of sample (g)}} \)

2.8 Standard Solutions

Varying concentrations of standard solutions were prepared for each of the metals determined in this study. The absorbance of the metal in each standard solution was obtained using Atomic Absorption Spectrophotometer, and calibration curves prepared for each metal. The calibration curves were used generating the concentrations of metals in the samples as shown in 2.7 above.

3. RESULTS AND DISCUSSION

3.1 pH

Fig. 3 shows the mean pH values in sediments. The pH values ranged from 6.87± 1.02 to 7.26± 0.70 in the rainy season, 4.87± 0.73 to 6.48± 0.38 in harmattan and 6.24±1.12 to 7.26±1.58 in the dry season. It could be observed from the result in this study that all the values in the rainy season and most in the dry season were around 7 (neutral). The values were slightly acidic in harmattan. They were generally highest in the dry season. But, Ajiwa and Dutsinma had the highest values in the rainy season. pH variation in sediments influences the release or adsorption of each metal into sediment fraction [8]. It was also observed that high pH lowers desorption of metals and possesses high buffering capacity against acidic conditions that may be created as a result of waste accumulation [8]. But, it was pointed out in a study that a particular problem associated with acidification is the solubilisation of some metals when the pH falls below 4.5 [4]. This may be the reason why in this study the influence of pH in metal concentration was not clear in the rainy and dry seasons as none of the values is below 4.5. The higher metal concentrations in the rainy season might also be due to the higher amount of particles washed into water bodies in the rainy season that eventually settle down and contribute to the metal content. The low pH values in DTM (5.40), ZOB(4.87) and MLF(5.52) might have contributed to the lower
concentrations of Cu, Ni, Mn and Cr in the dams in harmattan when compared to dry season. Cd was also lower in ZOB and MLF, and Co in DTM in harmattan. Higher concentrations of Pb were obtained in the dams in harmattan when compared to other seasons, which may be explained by the low pH in the season. It was observed in a study that low pH influences the sorption of Pb by organic fraction in sediments [8]. The harmattan dust deposited might also have contributed to the relatively high concentration of Pb. The concentrations of Mn showed a significant positive correlation (0.795) with pH in harmattan at $P=0.05$ level.

![Fig. 3. Mean pH values in sediments](image)

**Fig. 3. Mean pH values in sediments**

*RS= Rainy season, H= Harmattan, DS= Dry season*

*Mean±Standard Deviations for seven dams in the three seasons*

### 3.2 Conductivity

Fig. 4 shows the mean conductivity values in sediments. The conductivity values showed no particular trend in seasonal variations. Ajiwa, Mairuwa and Gwaigwaye dams had the highest conductivity values in the dry season, Dutsinma, Jibia and Malumfashi dams in harmattan, and Zobe dam in the rainy season. Generally, the conductivity values were higher in Mairuwa dam when compared to Jibia and Ajiwa dams. This may be due to the clayey nature of its sediments while Jibia and Ajiwa are sandy in nature, as fine-grained clay particles with more surface area usually contained more metals than coarse grained sand. Also, clayey sediments usually contain high levels of organic matter and are likely to contain higher concentration of heavy metals when compared to sandy sediments whose organic matter content is usually low. The dams used in this study are in different locations of the state with different soil types and varying levels and types of activities carried out around them. This might have influenced the type of ions in the sediments and consequently their conductivities. The differences in conductivities may also be because different salts in water have a different ability to conduct electricity due to differences in charge, size/weight and mobility of different ions in solution. Also, as solutions becomes more concentrated, the proximity of the ions to each other depresses their activity and consequently their ability to transmit current, although the physical amount of dissolved solids is not affected [9]. So, the exact contribution of individual ions is difficult to determine due to interactions between the ions. It is therefore difficult to work out the conductivity of a particular salt mix. Moreover, only a few metals were determined in this study and the contributions of other ions cannot be overruled.
Fig. 4. Mean conductivity values in sediments (µScm⁻¹)

RS= Rainy season, H= Harmattan, DS= Dry season
Mean±Standard Deviations for seven dams in the three seasons

3.3 Concentration of Metals in Sediments

Figs. 5, 6 and 7 show the concentrations of metals in the sediments in the rainy season, harmattan and dry seasons respectively. The concentrations of metals were generally highest in the rainy season and lowest in the dry season. The concentrations of Fe were higher than the Environmental Protection Agency’s (EPA) guideline value of 1.88mg/kg in all the dams in the three seasons studied. Zn was higher than the recommended 9.80mg/kg all the dams in the rainy season, in all dams except Jibia and Malumfashi in harmattan, and in all the dams except in Jibia, Malumfashi and Gwaigwayne in the dry season. Fe has been found to occur at high concentrations in Nigerian soils [3,10]. Zn has also been identified as one of the commonest elements in the earth’s crust [11]. This might be an explanation for the high values obtained in all the seasons. Cr had higher values than EPA’s maximum recommended value 3.63mg/kg in all the dams except Ajiwa in the rainy season, in all but Ajiwa and Malumfashi dams in harmattan, it was also higher than the recommended value in all the dams in the dry season. Cd was higher than the recommended 0.583mg/kg in all the dams except Ajiwa in the rainy season, in all dams except Jibia and Malumfashi in harmattan and in all the dams in the dry season. The values for all the other metals were however within the recommended EPA value. Pb was higher than the guideline value in all the dams except Ajiwa in harmattan but it was within the recommended value in the other seasons. All the metals studied had values that were within their various Consensus Based Sediment Threshold Effect Concentrations with the only exception being Cd which was within the recommended level only in Jibia, Gwaigwayne and Mairuwa dams. Zn, Cd and Pb are transported atmospherically as particles through anthropogenic activities [12], which can increase their concentrations in the sediments. Also, fine grained clay particles with more surface area contained more metals than coarse grained sand, just as sediments containing high levels of organic matter are likely to contain higher concentration of heavy metals when compared to sediments lacking organic matter [13].
This is evident in this study as the concentration of most metals are relatively low in Jibia and Ajiwa dams whose sediments are sandy in nature. A statistical analysis using ANOVA indicated significant differences in the concentration of all the metals except in Fe ($P = .17$) in the different seasons. This can be an indication that Fe might be coming from the same source while other metals come from different anthropogenic sources in the different seasons. The irregularities observed suggest that several factors may influence the concentration of metals in the sediments. These factors include pH, types of soils or rocks present along the water bodies, location of the dams and activities carried out around the dams. Their sources may include nature of the area, industrial waste discharges, municipal and domestic wastes, agricultural inputs, storm water run-off and atmospheric sources such as the harmattan dust.

Fig. 5. Mean concentrations of metals in sediments in the rainy season (mg/kg)
AJI= Ajiwa, DTM=Dutsinma, ZOB= Zobe, JIB= Jibia, MLF=Malumfashi, MAI=Mairuwa, GWA=Gwaigwaye

Fig. 6. Mean concentrations of metals in sediments in Harmattan (mg/kg)
**Fig. 7. Mean concentrations of metals in sediments in the dry season (mg/kg)**

**Table 1. Guideline levels of metals in sediment described in literature (mg/kg)**

|        | Cu   | Ni   | Mn   | Fe    | Cd   | Zn    | Pb    | Cr   |
|--------|------|------|------|-------|------|-------|-------|------|
| CBSTEC | 32   | 23   | 460  | 20,000| 0.99 | 120   | 36    | 43   |
| EPA    | 2.8  | 9.3  | 1.88 | 0.583 | 9.80 | 3.70  | 3.63  |
| NOAA   | 2.5  | 4.0  | 0.18 | 0.10- | 3.80 | 1.70  | 1.30  |
| Present Study | | | | | | | | |
| Rainy season | 0.574- | 1.624- | 3.303- | 5.677- | 0.243- | 14.142- | 1.574- | 3.472- |
| Harmattan | 1.175 | 6.878 | 6.156 | 11.473 | 0.660 | 19.949 | 3.148 | 11.111 |
| Dry season | 0.160- | 0.265- | 1.201- | 6.522- | 0.556- | 8.839- | 2.222- | 2.315- |
|          | 0.481 | 3.175 | 2.853 | 16.425 | 1.181 | 16.162 | 5.566 | 6.019 |
|          | 0.240- | 1.323- | 1.817- | 5.314- | 0.764- | 5.555- | 0.833- | 4.630- |
|          | 0.374 | 2.910 | 3.303 | 8.454 | 2.014 | 14.647 | 2.167 | 7.871 |

CBSTEC: Consensus Based Sediment Threshold Effect Concentration (dry weight)

**4. CONCLUSION**

Zn, Fe and Cr had the highest concentrations in all the seasons in this study. A statistical analysis showed a significant difference in the concentration of all the metals except Fe in the different seasons studied. This might be an indication that the concentration of the metals are influenced by the different human activities carried out around the dams. The high concentration of Pb in harmattan might be as a result of the relatively low pH in the season, as low pH is known to influence the sorption of Pb by organic fraction in sediments. It can be concluded that apart from natural factors, human activities carried out around the dams do contribute to the concentration of metals in the sediment samples studied. It is therefore important that the concentration of metals in sediments are regularly monitored as the result gives information on their sources, distribution as well as the quality of the water, soil, aquatic animals and the plants grown around the dams. Activities that can introduce pollutants into water bodies should be discouraged as the pollutants have the ability to get into the food chains causing detrimental effects on the consumers.
COMPETING INTERESTS

Authors have declared that no competing interests exist.

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DEFINITIONS, ACRONYMS, ABBREVIATIONS

AJI     Ajiwa
ANOVA  Analysis of variance
DS     Dry season
DTM   Dutsinma
EPA    Environmental Protection Agency
GWA   Gwaigwaye
H     Harmattan
JIB    Jibia
MAI    Mairuwa
MLF   Malumfashi
pH    Hydrogen Potential
RS    Rainy season
ZOB   Zobe
Cd   Cadmium
Co   Cobalt
Cr   Chromium
Cu   Copper
Fe   Iron
Mn   Manganese
Ni   Nickel
Pb   Lead
Zn   Zinc
## APPENDIX

### Calibration Curves

| Element | Concentration (Concn.) | Absorbance (Abs.) |
|---------|-------------------------|------------------|
| **Cd**  | 2                       | 0.074            |
|         | 1                       | 0.036            |
|         | 0.5                     | 0.019            |
|         | 0.1                     | 0.003            |
|         | 0                       | 0                |

![Cd Calibration Curve]

\[ y = 0.036x \]
\[ R^2 = 0.999 \]

| Element | Concentration (Concn.) | Absorbance (Abs.) |
|---------|-------------------------|------------------|
| **Cr**  | 2                       | 0.07             |
|         | 1                       | 0.036            |
|         | 0.5                     | 0.017            |
|         | 0.1                     | 0.001            |
|         | 0                       | 0                |

![Cr Calibration Curve]

\[ y = 0.035x \]
\[ R^2 = 0.997 \]

| Element | Concentration (Concn.) | Absorbance (Abs.) |
|---------|-------------------------|------------------|
| **Cu**  | 2                       | 0.041            |
|         | 1                       | 0.021            |
|         | 0.5                     | 0.011            |
|         | 0.1                     | 0.001            |
|         | 0                       | 0                |

![Cu Calibration Curve]

\[ y = 0.020x \]
\[ R^2 = 0.998 \]
| Concentration ppm | Mn Abs. | Ni Abs. |
|-------------------|--------|--------|
| 0                 | 0      | 0      |
| 0.1               | 0.002  | 0.002  |
| 0.5               | 0.013  | 0.011  |
| 1                 | 0.027  | 0.023  |
| 2                 | 0.055  | 0.043  |

**Mn**

\[ y = 0.027x \]

\[ R^2 = 0.999 \]

**Ni**

\[ y = 0.021x \]

\[ R^2 = 0.998 \]
### Pb

| Concentration ppm | Abs.  |
|-------------------|-------|
| 2                 | 0.059 |
| 1                 | 0.031 |
| 0.5               | 0.015 |
| 0.1               | 0.003 |
| 0                 | 0     |

### Zn

| Concentration ppm | Abs.  |
|-------------------|-------|
| 2                 | 0.045 |
| 1                 | 0.022 |
| 0.5               | 0.012 |
| 0.1               | 0.002 |
| 0                 | 0     |

### Fe

| Concentration ppm | Abs.  |
|-------------------|-------|
| 2                 | 0.024 |
| 1                 | 0.013 |
| 0.5               | 0.007 |
| 0.1               | 0.001 |
| 0                 | 0     |

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