Distribution Of Heavy Metals in Surface Sediments from Streams and Their Associated Fishponds in Osun State, Nigeria

1Omolara Titilayo Aladesanmi *  
2Femi Kayode Agboola  
3Israel Funsho Adeniyi

1Institute of Ecology and Environmental Studies, Obafemi Awolowo University, Ile-Ife, Nigeria  
2Department of Biochemistry, Obafemi Awolowo University, Ile-Ife, Nigeria  
3Department of Zoology, Obafemi Awolowo University, Ile-Ife, Nigeria

Corresponding Author:  
Omolara Titilayo Aladesanmi  
email: taladesanmi@gmail  
Tel: +234-8035827392

Introduction

Heavy metals in natural waters and their corresponding sediments have become a significant topic of concern for scientists and engineers in various fields associated with water quality, as well as the general public. Heavy metals are serious pollutants because of their toxicity, persistence and non-degradability in the environment.1-4 Direct toxicity to humans and aquatic life and indirect toxicity through accumulation of metals in the aquatic food chain are a focus of concern.5, 6 The presence of heavy metals in aquatic systems originates from the natural interactions between the water, sediments and atmosphere. Concentrations fluctuate as a result of natural hydrodynamic chemical and biological forces. Humans, through industrialization and technology, have developed the capacity to alter these natural interactions to the extent that water bodies and associated aquatic life have been threatened.7 There is now considerable evidence that contaminants such as heavy metals can be taken up and concentrated by sediments and suspended matter in aquatic systems.8 Heavy metals, on entry into water bodies, are partitioned between water, sediments, suspended solids and aquatic biota9 and they tend to accumulate more in sediments than in water and aquatic organisms.10 Sediment quality is a good indicator of pollution in the water column, where it tends to concentrate the heavy metals and other organic pollutants.11 Sediments, a mixture of several components of mineral species as well as organic debris, represent an ultimate sink for heavy metals discharged into the environment.5, 6 Chemical leaching of bedrock, water drainage basins and runoff from banks are the primary sources of heavy metals,12 as well as mining operations, disposal of industrial

Background. Heavy metals in water systems are a human health concern as they can enter the food chain.  
Objectives. Heavy metal and particle size determinations were used to determine the sediment quality of three fishponds in Osun State, Nigeria and their feeder streams.  
Methods. Sediment samples were collected in triplicates from the streams and their associated fishponds and the accumulations of nine heavy metals (lead (Pb), cobalt (Co), cadmium (Cd), chromium (Cr), copper (Cu), nickel (Ni), iron (Fe), manganese (Mg), zinc (Zn)) in the sediment were investigated seasonally. Particle size distribution and textural class of the samples were also determined.  
Results. Metal concentrations recorded in bottom sediment varied widely and exhibited fluctuations among the different ponds and streams, especially in the values of Fe, Cu, Mn, Cr, Zn and Pb. There was a significant difference (p<0.05) in the concentrations of metals across the three investigated locations. The metals in the sediments occurred in the order of Fe>Cu>Ni>Zn>Pb>Cr>Mn>Co in Ilesha, Fe>Cu>Ni>Zn>Mn>Co>Pb>Cr in Osogbo and Zn>Fe>Ni>Mn>Cu>Co>Cr>Pb in Yakoyo. A closely related order of Fe>Mn>Ni>Zn>Cr>Se>Pb>Mo>Cd was observed in River Eku. The selected streams and their associated fishponds were fairly polluted, with the Yah fishpond (Ilesha) having the highest heavy metal pollution compared to Arula fishpond (Osogbo) and Ewuru/Rara fishpond (Yakoyo). The concentrations of accumulated heavy metals depended on the textural class of the sediment.  
Conclusion. Pollution has reached levels hazardous to human health compared to standard limits for aquaculture development. Stream and fishpond sediments should be analyzed at regular intervals as a quality assurance process to ensure that there are no toxic substances in the ponds, leading to possible bio-accumulation and magnification. This will help guarantee the health of the aquatic ecosystem, humans and the environment.  
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wastes and applications of biocides for pests, agricultural activities and other anthropogenic sources. Heavy metals are trapped in sediments in rivers, lakes and reservoirs and their release is a function of the oxidation-reduction state in the water, organic matter content and pH. Polluted sediments, in turn, can act as sources of heavy metals, releasing them into the water and debasing water quality.

Lead is an industrial hazard and is considered to be one of the most dangerous environmental pollutants. Chromium is also a toxic environmental pollutant which can have detrimental effects on plants and animals. 

According to a report on fisheries management in Nigeria, the fish supply in Nigeria is approximately half the demand, hence the need to close the gap between fish demand and fish supply throughout the country, including Osun State. Education and enlightenment programs on omega-3 fatty acids found in Clarias have prompted many farmers in Nigeria to cultivate this fish. As demand for Clarias has increased, more people have joined the ranks of farmers cultivating the fish and many ponds are constructed without consideration of water quality and intrusion by external water sources, e.g. runoff and leachate from wastes. There are several important common denominators to consider when building a pond, irrespective of whether the pond is built by hand for small scale aquaculture or by machines for large scale commercial farming. These include type of wall, basic engineering principles, design and construction criteria for the water outlet, and drainage system and exclusion of predators. The ponds in the study area do not conform to these guidelines; most ponds are recipients of industrial effluents, runoff and leachate from wastes. Growing evidence has revealed that animals raised in water contaminated with leachate from waste gain considerable body weight as a result. Mortality and weight are salient factors considered by most fish farmers in Nigeria. Once the fish do not die and are gaining weight, farmers spend less money on feed. However, this gain comes at the expense of public health.

This study assessed the seasonal heavy metal content of sediment from Arula, Yah and Rara streams and their associated fishponds. These streams are the main branches of River Osun (Ogun-Osun River Basin). There are various anthropogenic activities around the streams and their associated fishponds such as waste disposal and sewage, as well as agricultural practices which may result in pollution of water quality. This pollution eventually settles on the bottom sediment, posing a serious threat to aquatic life and consumers of fish from polluted waters.

**Methods**

A purposive sampling method was used to select three streams with associated fishponds located in Osogbo, Ilesha and Yakoyo, in Osun State, southwestern Nigeria. The capital of Osun State is Osogbo. The state is one of the six states that make up the South West geopolitical zone of Nigeria with a population of 4,137,627. The state covers an area of approximately 14,875 sq km and lies within latitude 6.55° and 8.10° North and longitude 3.55° and 5.05° East. The people of Osun State are mainly farmers, traders, artisans and farmers. The study ponds were selected because they are all earthen fishponds which receive water from natural streams. The selected ponds are located in the state's main

| Abbreviations | Description |
|---------------|-------------|
| Cd            | cadmium     |
| Co            | cobalt      |
| Cr            | chromium    |
| Cu            | copper      |
| Fe            | iron        |
| Mg            | manganese   |
| Ni            | nickel      |
| Pb            | lead        |
| Zn            | zinc        |
cities and fish from these ponds are consumed throughout Osun State. There are dumpsites, block making factories, automobile workshops and various agricultural activities (Figures 5, 6 and 7) going on around these streams, which are potential sources of pollutants in the water bodies. There were fish in the ponds at the time of sampling and sediment temperature and pH were determined on site.

Heavy Metal Determination

Sediment samples 10-15 cm in depth were collected in triplicate at different points using the grab method, both from the fishponds and inflow streams. Sediment samples were air dried, and replicates were thoroughly mixed and passed through a 2 mm mesh sieve to remove roots and stones separately.

The bottom sediments of the selected ponds and their inflow streams were assessed for the presence of the following heavy metals: lead (Pb), chromium (Cr), zinc (Zn), nickel (Ni), cadmium (Cd), copper (Cu), iron (Fe), cobalt (Co), and manganese (Mn), using a PG 990 atomic absorption spectrometer. Five grams (5 g) of the sieved (2 mm) sediment was measured into a 150 mL conical flask. Fifty (50) mL of 0.1 M HCl (hydrochloric acid) was added and the flask was agitated on a shaker for 30 min at 200 rev/min. The content was then filtered into a 50 mL standard flask and made up to mark with 0.1 M HCl for the determination of the metals. The analysis was carried out at Obafemi Awolowo University Centre for Energy Research and Development Laboratory, and reference materials (Standard Reference Material 1643e, trace element in water) and element reference solutions were obtained through the National Institute of Standards and Technology (US and MRS Scientific Limited, UK). All solvent/reagents were of analytical...
grade (SIGMA-Aldrich, USA; BDH Chemicals Ltd., Poole, England; and Merck, Paris, France) and standard quality assurance procedures were followed.\textsuperscript{31,32}

Particle Size Distribution

The particle size distribution of the collected sediment samples was determined using the hydrometer method.\textsuperscript{33} The temperature and hydrometer readings of the blank were first recorded. Fifty grams (50 g) of sediment sample was weighed to ±0.01 g and transferred to a dispersing cup. One hundred milliliters (100 ml) of 5% dispersing solution (50 g of sodium hexametaphosphate, Na$_6$(PO$_3$)$_6$, diluted to 1000 ml with deionized water) was added and the dispersing cup was attached to a mixer to mix the sample for about 60 s. The 100 ml suspension was quantitatively transferred from the dispersing cup into a 1000 ml cylinder filled to the 1000 ml mark with deionized water equilibrated to room temperature. Standard sediment of known particle size content was analyzed with each sediment sample to check for instrument calibration and procedural accuracy. Results were reported as percentages of the mineral fraction, % sand, % silt, and % clay. The sediment textural triangle is shown in Figure 8.

Results

The sediment pH measurements for Ilesha, Oshogbo and Yakoyo streams were 6.67±0.40, 7.23±0.52 and 8.00±0.40, respectively, while the temperatures at the time of sampling were 27.40°C±1.08, 27.75°C±1.18 and 28.00°C±1.30, respectively. The sediment pH for Ilesha, Oshogbo and Yakoyo ponds were 6.87±0.39, 7.34±0.59 and 8.15±0.65, respectively, while the sediment temperatures at the time of sampling were 27.60°C±1.11, 27.90°C±1.25 and 28.30°C±1.30.
Heavy metal contents showed a mass sequence of Fe>Cu>Ni>Zn>Pb>Cr>Mn>Co>Cd (Table 1). Iron had the highest mean concentration (663.51 μg/kg), while Co had the lowest detectable mean (11.63±6.70 μg/kg). The concentration of Cd was below the detectable limit of 0.004 mg/kg. All the investigated heavy metals had higher concentrations in the dry season than in the rainy season. However, only four (Pb, Cr, Co and Mn) out of the nine heavy metals showed significant seasonal differences (p<0.05). The mean Pb concentration recorded in the dry season (96.62±7.32 μg/kg) was significantly higher (p<0.05) than the concentration recorded in the wet season (45.01±7.33 μg/kg). Similarly, Cr, Co and Mn concentrations were significantly higher (p<0.05) in the dry season (39.34±3.18 μg/kg, 18.01±6.05 μg/kg and 36.18±3.06 μg/kg) than in the rainy season (13.2±2.47 μg/kg, 5.2±1.36 μg/kg and 12.1±2.29 μg/kg) (Table 2).

The heavy metal contents in the stream sediment samples were higher than those detected in the pond sediment sample, however, not all differences were significant (p≥0.05). The mean Pb concentration recorded in the dry season (96.62±7.32 μg/kg), Cr (27.50±3.65 μg/kg) and Fe (698.66±94.13 μg/kg) were significantly higher (p<0.05) than the mean values in the pond. There was no Cd detected in any of the samples (less than 4.00 μg/kg). In addition, the silt, clay and sand contents of the sediment were not significantly affected by habitat variation (Table 3).

In the sediment samples from Arula stream and the associated fishpond in Osogbo, the recorded heavy metal concentrations were in the order: Fe>Cu>Ni>Zn>Mn>Co>Pb>Cr>Cd (Table 4). The Fe concentration was the highest, with a range of 383.31 μg/kg to 558.83 μg/kg and mean value of 471.07±43.88 μg/kg, while Cr was the lowest with a mean value of 7.87 μg/kg. The mean values of Cr and Pb were relatively low compared to the other metals. Cadmium was below the detectable limit (4.00 μg/kg) of the equipment used. The sediment samples had mean values of 21.88±1.13% silt, 26.75±2.61% clay and 58.38±4.99% sand, which falls within the textural class of silt clay.

There was a significant difference (p<0.05) between the Mn concentration recorded in the dry season (33.24±2.26 μg/kg) and the wet season (17.64±2.93 μg/kg). In addition,

| Parameter | Minimum | Maximum | Mode | Median | Mean | SEM |
|-----------|---------|---------|------|--------|------|-----|
| Pb        | 45.01   | 98.46   | 63.47| 68.36  | 70.80| 7.33|
| Cr        | 20.61   | 31.93   | 23.44| 25.33  | 26.27| 2.83|
| Co        | 4.23    | 19.03   | 7.93 | 10.40  | 11.63| 3.70|
| Zn        | 65.3    | 97.22   | 73.28| 78.60  | 81.26| 7.98|
| Ni        | 92.65   | 133.65  | 102.9| 109.73 | 113.15| 10.25|
| Mn        | 18.81   | 29.49   | 21.48| 23.26  | 24.15| 2.67|
| Fe        | 496.73  | 830.29  | 580.12| 635.71 | 663.51| 83.39|
| Cu        | 136.32  | 204.08  | 153.26| 164.55 | 170.20| 16.94|
| Cd        | BDL     | BDL     | BDL  | BDL    | BDL  | BDL |
| Silt %    | 15.6    | 23.96   | 17.69| 19.08  | 19.78| 2.09|
| Clay %    | 44.63   | 95.07   | 57.24| 65.65  | 69.85| 12.61|
| Sand %    | 14.33   | 23.33   | 16.58| 18.08  | 18.83| 2.25|
| Textural Class | Silt mud |         |      |        |      |     |

Table 1—Sediment Characteristics of Yah Stream and Associated Fishpond at Ilesha

Abbreviations: BDL, below detectable limit (0.004 mg/kg); PSD, particle size distribution; SEM, standard error of mean.
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| Heavy Metal (μg/kg) | DS Mean ± SE | RS Mean ± SE | F Value | P Value |
|---------------------|--------------|--------------|---------|---------|
| Pb                  | 96.62±7.32   | 45.0±7.33    | 6.17    | 0.01**  |
| Cr                  | 39.34±3.18   | 13.2±2.47    | 5.89    | 0.04*   |
| Co                  | 18.01±6.05   | 5.2±1.36     | 3.84    | 0.03**  |
| Zn                  | 86.51±7.49   | 76.0±8.46    | 6.12    | 0.20    |
| Ni                  | 117.78±9.98  | 108.5±10.53  | 3.69    | 0.11    |
| Mn                  | 36.18±3.06   | 12.1±2.29    | 8.05    | 0.05*   |
| Fe                  | 766.22±85.64 | 560.8±81.14  | 1.26    | 0.06    |
| Cu                  | 176.80±17.60 | 163.6±16.29  | 2.13    | 0.22    |
| Cd                  | BDL          | BDL          |         |         |

**Physicochemical Parameter**

- Silt %: 23.5±1.28 (DS) vs 16.05±0.82 (RS), F Value 5.99, P Value 0.02
- Clay %: 76.1±6.94 (DS) vs 63.6±5.67 (RS), F Value 4.33, P Value 0.07
- Sand %: 15.05±0.97 (DS) vs 22.6±1.29 (RS), F Value 5.14, P Value 0.16

**Table 2—Seasonal Variation in Heavy Metal Concentrations of Sediment from Yah Stream and the Associated Fishpond in Ilesha**

- * Significant (p<0.05); ** Highly significant (p≤0.01); *** Very highly significant (p≤0.001)
- Abbreviations: BDL, below detectable limit (0.004 mg/kg); DS, dry season; PSD, particle size distribution; RS, rainy season; SEM, standard error of mean

| Heavy Metal (μg/kg) | Pond Sediment Mean ± SEM | Stream Sediment Mean ± SEM | F Value | P Value |
|---------------------|---------------------------|---------------------------|---------|---------|
| Pb                  | 66.27±6.67                | 75.33±7.98                | 5.34    | 0.01**  |
| Cr                  | 25.045±2.00               | 27.5±3.65                 | 7.46    | 0.01**  |
| Co                  | 10.08±1.01                | 13.17±6.40                | 2.15    | 0.10    |
| Zn                  | 77.53±7.39                | 84.99±8.56                | 2.75    | 0.12    |
| Ni                  | 109.84±11.77              | 116.47±8.74               | 3.50    | 0.35    |
| Mn                  | 22.17±2.50                | 26.14±2.85                | 3.12    | 0.09    |
| Fe                  | 628.37±72.65              | 698.66±94.13              | 5.55    | 0.04*   |
| Cu                  | 166.49±15.82              | 163.6±16.29               | 2.13    | 0.22    |
| Cd                  | BDL                       | BDL                       |         |         |

**PSD**

- Silt %: 19.35±1.13 (Pond) vs 20.2±0.97 (Stream), F Value 3.11, P Value 0.07
- Clay %: 69.55±6.17 (Pond) vs 70.15±6.44 (Stream), F Value 2.98, P Value 0.29
- Sand %: 20.75±1.17 (Pond) vs 16.9±1.09 (Stream), F Value 4.56, P Value 0.03*

**Table 3—Habitat Variation of the Physicochemical Sediment Characteristics of Yah Stream and Associated Fishpond at Ilesha**

* Significant (p<0.05); ** Highly significant (p≤0.01); *** Very highly significant (p≤0.001)
- Abbreviations: BDL, below detectable limit; SEM, standard error of mean
the Ni concentration recorded in the dry season (96.86±39.21 μg/kg) differed significantly from the value recorded in the wet season (60.12±8.79 μg/kg, p<0.05). The effect of seasonal variation was not significant in the other heavy metals detected in the study. In addition, the mean values of silt (25.30±1.30%) and clay (35.45±1.70) were significantly higher in the dry season than in the rainy season (Table 5).

Concentrations of heavy metals were higher in the Osogbo stream sediment than in the pond. The mean concentration occurred in the order: Fe>Cu>Ni>Zn>Mn>Co>Pb>Cr>Cd. In addition, the particle size distribution (% silt, % clay and % sand) was not affected by habitat variation (Table 6).

Descriptive analysis of the heavy metals showed an order of Zn>Fe>Ni>Mn>Cu>Co>Cr>Pb. The mean concentration of Pb was (4.29±1.76 μg/kg) with a range of 0.77–7.81 μg/kg, while the mean concentration of Zn was (322.80±23.02 μg/kg) with a range of 286.76–378.84 μg/kg. Particle size distribution was in the order: % clay > % sand > % silt. Consequently, the textural class of the sediment was silty mud (Table 7).

Elevated values of all the heavy metals (except Zn) were recorded in the dry season compared to the rainy season. The heavy metals were present in the following order: Fe>Zn>Ni>Mn>Co>Cr>Pb>Cr>Cd in the dry season and Zn>Fe>Ni>Mn>Co>Pb>Cr>Cr in the rainy season. The differences between seasons in metal concentrations (except Pb) were significant. The mean values of Cr (17.04±7.22 μg/kg), Co (17.51±6.61 μg/kg), Ni (94.67±33.64 μg/kg), Mn (80.04±28.58 μg/kg, Fe (176.62±64.46 μg/kg), Cu (68.39±30.11 μg/kg) in the dry season were significantly higher (p<0.05) than in the rainy season (Table 8). On the contrary, the mean concentration of Zn (394.05±8.39 μg/kg) in the dry season was significantly lower (p<0.05) than in the rainy season (120.23±43.39 μg/kg).

In addition, % sand in the dry season (28.10±1.40%) was significantly higher (p<0.05) than in the rainy season (15.50±1.70%). There were no significant differences in the other sediments over the two seasons.

The heavy metals (except Zn) were more dominant in the stream sediment than in the pond sediment and they occurred in the order: Zn>Fe>Ni>Mn>Co>Cr>Pb>Cr>Cd in the pond sediment and Fe>Zn>Ni>Cu>Mn>Co>Cr>Pb>Cr in the stream sediment (Table 9). The mean

| Parameter | Minimum | Maximum | Mode | Median | Mean | SEM |
|-----------|---------|---------|------|--------|------|-----|
| Pb        | 7.59    | 10.55   | 8.33 | 8.82   | 9.07 | 0.74|
| Cr        | 6.89    | 8.85    | 7.38 | 7.71   | 7.87 | 0.49|
| Co        | 14.84   | 19.52   | 16.01| 16.79  | 17.18| 1.17|
| Zn        | 57.125  | 86.405  | 64.45| 69.33  | 71.765| 7.32|
| Ni        | 91.935  | 138.615 | 103.61| 111.39| 115.275| 11.67|
| Mn        | 28.265  | 43.265  | 32.02| 34.52  | 35.765| 3.75|
| Fe        | 383.31  | 558.83  | 427.19| 456.44| 471.07| 43.88|
| Cu        | 141.47  | 207.31  | 157.93| 168.90| 174.39| 16.46|
| Cd        | BDL     | BDL     | BDL  | BDL    | BDL  | BDL|
| Silt %    | 19.62   | 24.14   | 20.75| 21.50  | 21.88| 1.13|
| Clay %    | 21.53   | 31.97   | 24.14| 25.88  | 26.75| 2.61|
| Sand %    | 48.4    | 68.36   | 53.39| 56.72  | 58.38| 4.99|
| Textural Class | Silt Clay |         |     |        |      |     |

Table 4—Physicochemical Sediment Characteristics of Arula Stream and Associated Fish Pond at Osogbo

Abbreviations: BDL, below detectable limit; PSD, particle size distribution; SEM, standard error of mean
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*Significant (p<0.05); ** Highly significant (p≤0.01); *** Very highly significant (p≤0.001)

**Abbreviations:** BDL, below detectable limit; DS, dry season; RS, rainy season; SEM, standard error of mean

#### Table 5— Seasonal Variation of the Heavy Metal Concentration in the Sediment of Arula Stream and Associated Fishpond at Osogbo

| Parameter | DS Mean ± SE | RS Mean ± SE | F Value | P Value |
|-----------|--------------|--------------|---------|---------|
| Pb        | 11.97±0.74   | 8.59±0.74    | 3.45    | 0.72    |
| Cr        | 9.32±0.41    | 7.77±0.58    | 2.31    | 0.12    |
| Co        | 25.82±1.12   | 13.69±1.23   | 6.01    | 0.01**  |
| Zn        | 82.87±7.51   | 78.92±7.13   | 5.66    | 0.09    |
| Ni        | 138.82±12.18 | 118.68±11.17 | 3.57    | 0.23    |
| Mn        | 48.02±3.71   | 35.63±3.78   | 5.66    | 0.19    |
| Fe        | 650.27±43.73 | 358.23±44.03 | 9.20    | 0.001***|
| Cu        | 36.73±16.98  | 344.02±15.94 | 8.98    | 0.001***|
| Cd        | BDL          | BDL          |         |         |

| Parameter | DS Mean ± SE | RS Mean ± SE | F Value | P Value |
|-----------|--------------|--------------|---------|---------|
| PSD       |              |              |         |         |
| Silt %    | 25.30±1.30   | 18.45±0.96   | 3.11    | 0.03*   |
| Clay %    | 35.45±1.70   | 18.05±3.52   | 4.25    | 0.04*   |
| Sand %    | 54.65±4.00   | 62.10±5.97   | 3.23    | 0.76    |

**Table 6—Habitat Variation of the Physicochemical Sediment Characteristics of Arula Stream and Associated Fishpond at Osogbo**

* Significant (p<0.05); ** Highly significant (p≤0.01); *** Very highly significant (p≤0.001)

**Abbreviations:** BDL, below detectable limit; SEM, standard error of mean

| Parameter | Pond Sediment Mean ± SEM | Stream Sediment Mean ± SEM | F Value | P Value |
|-----------|--------------------------|----------------------------|---------|---------|
| Pb        | 9.07±0.71                | 22.97±0.77                 | 6.02    | 0.01**  |
| Cr        | 7.87±0.39                | 18.42±0.60                 | 8.49    | 0.01**  |
| Co        | 17.18±1.05               | 44.64±1.30                 | 4.98    | 0.01**  |
| Zn        | 71.76±6.13               | 180.04±8.50                | 9.06    | 0.01**  |
| Ni        | 115.27±10.59             | 284.44±12.75               | 5.37    | 0.03*   |
| Mn        | 35.76±3.08               | 95.76±4.42                 | 2.18    | 0.16    |
| Fe        | 471.07±41.55             | 1074.85±46.22              | 9.40    | 0.001** |
| Cu        | 174.39±16.47             | 412.71±16.45               | 5.33    | 0.04*   |
| Cd        | BDL                      | BDL                        |         |         |

| Parameter | Pond Sediment Mean ± SEM | Stream Sediment Mean ± SEM | F Value | P Value |
|-----------|--------------------------|-----------------------------|---------|---------|
| PSD       |                          |                             |         |         |
| Silt %    | 23.00±1.25               | 20.75±1.01                  | 4.78    | 1.12    |
| Clay %    | 25.75±1.61               | 27.75±3.61                  | 5.12    | 0.09    |
| Sand %    | 59.85±4.92               | 56.90±5.06                  | 6.13    | 0.12    |

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concentrations of Cr (16.53±2.68 µg/kg), Mn (82.34±14.94 µg/kg) and Cu (87.37±18.45 µg/kg) were significantly higher (p<0.05) in stream sediment than in pond sediment as shown in Table 9. On the contrary, the mean concentration of Zn (443.74±8.41 µg/kg) was significantly higher (p<0.05) in pond sediment than in stream sediment (121.23±23.02 µg/kg). The variation in habitat was not significant for the other heavy metals (Pb, Co, Ni, Fe and Cd).

The mean value of silt in the Ilesha sediment sample was 19.78±2.09%, clay was 69.85±12.61% and sand had a mean value of 18.83±2.25%, therefore the textural class of the sediment was silty mud. Osogbo had mean particle size distribution of 19.78% silt, 69.85% clay and 18.83% sand; while the mean values of the particle size distribution in Yakoyo were in the order: clay>sand>silt. Consequently, the textural class of the sediment was mud. Sediment textural class was silty mud in Ilesha and Yakoyo, while Osogbo sediment fell within a textural class of sandy clay. The sediment texture was also affected by seasonal variation; Ilesha was silty clay during the dry season, but silty mud in the rainy season. Osogbo was silty clay in the dry season, but clay in the rainy season, and Yakoyo was silty mud during the dry season, but silt during the rainy season.

**Discussion**

The environmental implication of sediment contamination by metals lies in the fact that the adsorbed portion of the metals (within the sediment phase) could be released back to the water phase. Generally, the concentration of metals in fishponds gradually accumulates on the sediments (as a function of pH) and in due course gets transferred to fish. Some fishes are bottom feeders which feed on substances at the bottom of the streams and ponds. Sediment is also a repository for all dead organic matter descending through the water column. According to Ademoroti, nearly all metal contents in the aquatic environment reside in water sediments. Metal concentrations recorded in bottom sediment varied widely and exhibited fluctuations among the different ponds and streams, especially in the values of Fe, Cu, Mn, Cr, Zn and Pb. In the present study, there were significant differences (p<0.05) in the metal concentrations across the three investigated locations. The metals in the sediments occurred in the order of Fe>Cu>Ni>Zn>Pb>Cr>Mn>Co (in Ilesha), Fe>Cu>Ni>Zn>Mn>Co>Pb>Cr (in Osogbo) and Zn>Fe>Ni>Mn>Cu>Co>Cr>Pb (in Yakoyo). A closely related order of Mn>Ni>Zn>Cr>Cu>

### Table 7—Heavy Metal Concentration in Sediment of Ewuru/Rara Stream and Associated Fishpond at Yakoyo

| Parameter | Minimum | Maximum | Mode | Median | Mean | SEM |
|-----------|---------|---------|------|--------|------|-----|
| **Heavy Metal (µg/kg)** | | | | | | |
| Pb | 0.77 | 7.81 | 2.53 | 3.70 | 4.29 | 1.76 |
| Cr | 0.64 | 11.36 | 3.32 | 5.11 | 6.00 | 2.68 |
| Co | 1.71 | 17.43 | 5.64 | 8.26 | 9.57 | 3.93 |
| Zn | 286.76 | 378.84 | 309.78 | 325.13 | 332.80 | 23.02 |
| Ni | 18 | 91.08 | 36.27 | 48.45 | 54.54 | 18.27 |
| Mn | 16.87 | 76.63 | 31.81 | 41.77 | 46.75 | 14.94 |
| Fe | 39.75 | 185.83 | 76.27 | 100.62 | 112.79 | 36.52 |
| Cu | 9.37 | 43.77 | 18.12 | 23.75 | 26.87 | 18.45 |
| Cd | BDL | BDL | BDL | BDL | BDL | |
| **PSD** | | | | | | |
| Silt % | 22.05 | 54.85 | 9.15 | 12.02 | 13.45 | 4.30 |
| Clay % | 66.49 | 101.61 | 50.27 | 66.12 | 74.05 | 23.78 |
| Sand % | 18.22 | 35.38 | 15.01 | 19.54 | 21.80 | 6.79 |
| **Textural Class** | Silty mud | | | | | |

Abbreviations: BDL, below detectable limit; SEM, standard error of mean
## Distribution of Heavy Metals in Surface Sediments from Streams and Their Associated Fishponds in Osun State, Nigeria

**Research**

### Table 8—Seasonal Variation of the Heavy Metal Concentrations in Sediment Characteristics of Ewuru/Rara Stream and Associated Fishpond at Yakoyo

| Parameter | DS Mean ± SE | RS Mean ± SE | F Value | P Value |
|-----------|--------------|--------------|---------|---------|
| Pb        | 8.82±3.35    | 4.37±2.67    | 2.89    | 0.11    |
| Cr        | 17.04±7.22   | 2.83±0.65    | 1.27    | 0.04*   |
| Co        | 17.51±6.61   | 5.94±1.45    | 3.02    | 0.03*   |
| Zn        | 120.23±43.39 | 394.05±8.39  | 4.58    | 0.001***|
| Ni        | 94.67±33.64  | 33.48±7.22   | 1.84    | 0.03*   |
| Mn        | 80.04±28.58  | 29.45±5.50   | 0.37    | 0.001***|
| Fe        | 176.62±64.46 | 80.89±15.25  | 2.60    | 0.04*   |
| Cu        | 68.39±30.11  | 15.00±9.44   | 2.89    | 0.04*   |
| Cd        | BDL          | BDL          |         |         |

### Table 9—Habitat Variation in the Heavy Metal Concentration in Sediment Characteristics of Ewuru/Rara Stream and Associated Fishpond at Yakoyo

| Parameter | Pond Mean ± SEM | Stream Mean ± SEM | F Value | P Value |
|-----------|-----------------|-------------------|---------|---------|
| Pb        | 5.72±2.64       | 8.37±1.76         | 3.54    | 0.08    |
| Cr        | 8.00±0.66       | 16.53±2.68        | 7.71    | 0.01**  |
| Co        | 12.76±9.05      | 19.66±3.93        | 3.41    | 0.09    |
| Zn        | 443.74±8.41     | 121.23±23.02      | 7.68    | 0.01**  |
| Ni        | 72.73±7.38      | 92.96±18.27       | 2.34    | 0.13    |
| Mn        | 62.33±5.20      | 82.34±14.94       | 5.41    | 0.03**  |
| Fe        | 150.39±13.80    | 196.22±36.52      | 3.57    | 0.07    |
| Cu        | 35.83±2.87      | 87.37±18.45       | 5.30    | 0.03**  |
| Cd        | BDL             | BDL               |         |         |

| PSD | Pond Mean ± SEM | Stream Mean ± SEM | F Value | P Value |
|-----|-----------------|-------------------|---------|---------|
| Silt % | 13.80±1.25     | 13.10±1.06        | 1.12    | 0.97    |
| Clay % | 72.80±7.02    | 75.30±6.94        | 2.34    | 0.12    |
| Sand % | 22.70±1.79     | 20.90±0.98        | 9.28    | 0.07    |

* Significant (p<0.05); ** Highly significant (p≤0.01); *** Very highly significant (p≤0.001)

Abbreviations: BDL, below detectable limit; DS, dry season; PSD, particle size distribution; RS, rainy season; SEM, standard error of mean
Se>Pb>Mo>Cd was observed in River Eku, Oyo State, which has similar anthropogenic activities (farming, dumpsite, auto mechanic workshops, etc.) around it as the investigated water bodies. Among the metals detected in this study, Fe had the highest concentration in Ilesha (628.37±72.65 µg/kg) and Osogbo (471.07±41.54 µg/kg) in pond and stream sediments, as reported by Nubi. However, Yakoyo had the highest level of Zn (443.74±8.41 µg/kg) in the pond sample and Ni (84.04±7.85 µg/kg) in stream sediment. The Pb concentration was significantly higher in Ilesha than in Osogbo and Yakoyo. The value recorded in Ilesha (70.80±7.33 µg/kg) was higher than the pollution standard limit for aquaculture as shown in Table 10. This could be as a result of dumpsites situated close to the stream. An acidic pH was also recorded for Ilesha sediment and low pH increases metal solubility. This is of concern because previous research on fish from the same pond showed that the fish bioaccumulated metals in their tissues to varying degrees. The sediment characteristic of Ilesha stream is silty mud and this may also be linked to the high concentration observed. Sediments play an important role in elemental cycling in the aquatic environment. They are responsible for transporting a significant proportion of many nutrients and contaminants. They also mediate their uptake, storage, release and transfer between environmental compartments. Heavy metals are more likely to attach to mud surfaces as seen in Ilesha, and these surfaces were therefore expected to have the highest concentration of heavy metals accumulation. Variation in the sediment across the two habitats showed higher levels of most metals in the streams than in the ponds for the three studied locations. This is similar to the trend recorded in the water samples, confirming the stream as a potential source of pollutants to the associated fish pond. Comparing the accumulation of heavy metals in stream and ponds, it may be inferred that the heavy metals in the pond sediments were accumulated from the stream serving the ponds. Heavy metal concentrations were generally higher in the dry season than in the rainy season, as has been previously reported, and this may be a result of slow water currents in the dry season, enabling the particles to settle.

Generally, Yakoyo had the lowest level of most metals (except Zn), as shown in Table 1.

### Conclusion

The present study found that there were high levels of heavy metals in the sampled sediments from Ilesha. Sediments with a textural class of mud tend to accumulate more heavy metals, as observed in Ilesha. Heavy metals pollution has reached levels hazardous to the health of humans compared to standard limits for aquaculture development. In addition, the two other selected streams and their associated fishponds (Osogbo and Yakoyo) were fairly polluted. Stream and fishpond sediments should be analyzed at regular intervals as a quality assurance process to ensure that there are no toxic substances in the ponds leading to possible bioaccumulation and magnification. This will help guarantee the good health of the aquatic ecosystem, humans and the environment.

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