# Chapter 12
# Metal Burden as Template for Assessing the Quality of Raw Water Sourced from Two Rivers by Lagos State Water Corporation, Nigeria

**Adeleke Adeniyi, Olawale Osifeko, Olabisi Owoade, Yusuf Omotayo, A. Emelia, Aminah Ibrahim, and Raheemot Balogun**

**Abstract** Water and surface sediment samples from three different points of River Owo at Isashi and Ogun River at Akute Odo were collected and quantitatively analyzed for metals burden. The two rivers serve as sources of raw water processed by the Lagos State Water Corporation for domestic and industrial consumption. The levels of lead, cadmium, copper, calcium and zinc in the samples were determined by atomic absorption spectrometry. The results obtained revealed high mean values of calcium in both water and sediment samples. Metals concentration (mg/l) in water samples are within the Nigeria's background values (NBV): ND–0.46 (Pb), ND–0.35 (Cd), ND–0.78 (Cu), 8.47–330.00 (Ca) and ND–1.89 (Zn). However, cadmium and calcium levels in sediment samples exceeded the NBV (μg/g) with ND–2.02 and 0.24–87.50 respectively. Similarly, with the exception of lead and cadmium, all other metals in the water samples are found to be within the World Health Organization (WHO) limit set for drinking water. Correlation coefficient and statistical *t*-test were used to test for statistical significant differences at 95 % confidence level. The levels of cadmium and lead especially in the water samples give cause for concern considering their potential health risk.

## 12.1 Introduction

Lagos is a state surrounded by water and as such it is assumed that water would be easily accessible to the populace. The raw waters in the lagoons surrounding Lagos are not fit for human consumption. The large expanse of freshwater around

A. Adeniyi (✉) • O. Osifeko • O. Owoade • Y. Omotayo • A. Emelia • A. Ibrahim • R. Balogun
Department of Chemistry, Lagos State University, Ojo P.M.B 0001, LASU Post Office, Badagry Expressway, Ojo, Lagos, Nigeria
e-mail: lekeadeniyi@yahoo.com; osifekoo@yahoo.com; owoadeb@yahoo.com; yomi_boyce@yahoo.co; emi_solar@yahoo.com; lekeadeniyi@yahoo.com; adewunmibalogun32@yahoo.com

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Lagos is equally not potable since it does not meet the World Health Organization standards [1].

Changes in any component of the environment may cause discomfort and affect normal life, consequently protection of our environment must be given the highest priority [2]. The river and other water bodies is the ultimate repository of man's wastes [3, 4].

Water is one of the basic requirements for human daily life; the problem of water pollution is increasingly becoming acute as a result of increasing population, urbanization and industrialization [1, 4, 5].

Metals such as cadmium, lead and mercury are known to be toxic with no beneficial effects to man and wildlife [6]. Cadmium and lead are stable and persistent environmental pollutants and are known to exhibit extreme toxicity even at low levels under certain conditions [7]. Meanwhile interests in metals like copper and zinc which are required for metabolic activity in organisms lie in the narrow "window" between their essentiality and toxicity [8]. Calcium is involved in many chemical cycles that take place in water bodies [9]. Contamination with heavy metals may have devastating effect on the ecological balance of the aquatic environment and the diversity of aquatic organism becomes limited [10].

The nature of metals present in rivers depends on ore-bearing deposits in the catchment area, the discharges of human wastes and discharges when the river passes through urban and industrial areas [11, 12].

As a result of adsorption and accumulation, the concentration of metals in bottom sediments is expected to be higher than in the water above and this sometimes can cause secondary pollution problems, therefore bottom sediments are repository of heavy metals [13]. Trace elements are easily influenced by environmental factors such as surface run-off, atmospheric deposition and anthropogenic pollutants. Hence trace metals may be sensitive indicators for monitoring changes in an aquatic environment [14].

There are global concerns that the direct usage of water above permitted limits could cause adverse health effects [15–17]. These concerns are manifested in the significantly large number of freshwater metal contamination studies across different countries. Representative global studies reviewed are from Nigeria, South Africa, USA, India, Bangladesh, Egypt, Turkey, Macedonia, Pakistan and Greece [18–24].

In Lagos State Waterworks fed by the two rivers used for this study, harvested raw water is dosed with alum in the sedimentation tank. It then goes into a filtration bed; calcium hypochlorite is added to the filtered water, allowed to stand for a while before hydrated lime ($Ca(OH)_2$) is used to readjust the pH. The treated water is then released for consumption. It is apparent that this traditional water treatment protocol used by the Water Corporation may not be able to adequately treat raw water with high levels of contaminants. The purpose of this study is to use metal burden as template to assess the quality of raw water sourced from two rivers by the Lagos State Water Corporation, Nigeria. No previous work on these locations has been reported.

## 12.2 Methodology

### *12.2.1 Study Area*

The study areas are the Ogun River at Akute Odo in Ifo Local Government Area of Ogun State and River Owo at Isashi in Ojo Local Government Area of Lagos State, Nigeria (Fig. 12.1). The two rivers are the sources of raw water processed by Iju, Adiyan and Isashi Water Works respectively.

Three sampling stations were established to cover possible impacted areas. The locations of various representative sampling points are: Point A, Entrance point; Point B, Middle point; Point C, Point of raw water collection.

The metals, cadmium, lead, copper, zinc and calcium were selected for this study. Previous studies have implicated these metals as the major contaminants associated with rivers flowing through urban cities and agricultural settlements [9, 18, 25].

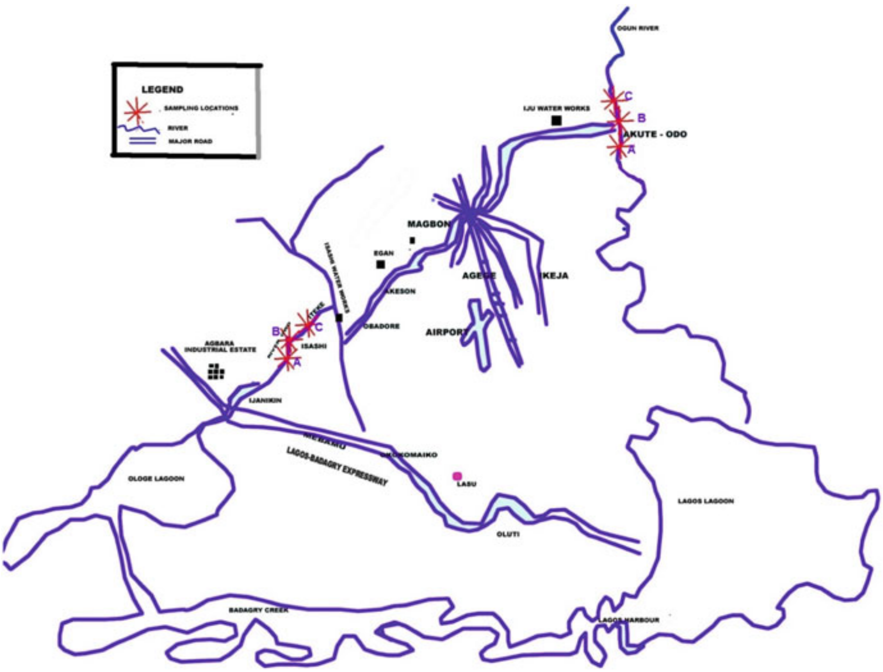


**Fig. 12.1** Sketch map showing sampling locations

### 12.2.2 Sampling and Analyses

Surface water and sediment samples were collected at 2 weeks intervals for a period of 4 months (May – August, 2011).

Water samples were collected using plastic containers while the sediment samples were collected with the help of divers using plastic containers. The pH of the water samples was determined on site. The water samples were then acidified with conc. $HNO_3$ and stored in a refrigerator prior to metal analyses [26].

The sediments samples were air dried and passed through a 2 mm sieve [7]. The pH of the sediment was measured by taking about 5 g of sediment samples and adding 20 ml of distilled water using a Jenway 3505 pH meter.

Analysis of metals was based on the method previously reported for metal analysis by Adeniyi et al. [7]. Five metals, lead (Pb), cadmium (Cd), copper (Cu), calcium (Ca) and zinc (Zn) were determined in an air-acetylene flame using a Buck Scientific 200A Atomic Absorption Spectrophotometer.

### 12.2.3 Data Analysis

Data collected from each parameter were subjected to computation and statistical analysis followed by the correlation coefficients between the metals concentrations in water and the sediments.

## 12.3 Results and Discussion

Tables 12.1 and 12.2 show the mean levels of pH and metals concentration in water and sediment samples collected respectively from River Owo at Isashi and Ogun River at Akute Odo. The water pH value ranges from 6.78 to 7.38, the values falling within the NBV of 5.70–7.79 [7, 27–29]. Similarly, the values are within the WHO limits (6.50–8.50) for drinking water, and 6.1–8.9 reported earlier for Umtata River, South Africa [18, 30]. However, the northern Greece river values of 7.7–8.6 [23] were higher than the values in this study.

Nevertheless, the pH values of the sediment samples are fairly acidic ranging from 5.93 to 6.87. These values pose a threat to aquatic life as decrease in pH aggravates toxicity [7] and this may be attributed to agricultural and industrial activities upstream. The values for this study fall within the reported sediments NBV of 4.02–8.73 [7, 27–29].

The mean metals concentration of sediment samples as captured in Table 12.2 is generally higher than that of water samples (Table 12.1) in the two rivers. This is due to the fact that sediment serves as a bottom sink for all the activities in the aquatic ecosystem [3, 6]. Calcium has the highest levels of the metals determined.

**Table 12.1** Mean levels of pH and metals concentration (mg/l ± SD) in Isashi and Akute Odo water samples

| Sampling location | pH | Pb | Cd | Cu | Ca | Zn |
|---|---|---|---|---|---|---|
| A | 6.94 ± 0.42 | 0.34 ± 0.10 | 0.03 ± 0.01 | 0.02 ± 0.01 | 122.18 ± 39.64 | 0.28 ± 0.12 |
| | (7.28 ± 0.40) | (0.31 ± 0.06) | (0.04 ± 0.01) | (0.08 ± 0.02) | (16.26 ± 16.72) | (0.18 ± 0.06) |
| | 0.23[a] | 0.33[a] | 0.002[a] | 0.01[a] | 0.002[a] | 0.03[a] |
| B | 6.96 ± 0.32 | 0.32 ± 0.08 | 0.03 ± 0.01 | 0.02 ± 0.01 | 133.68 ± 63.61 | 0.27 ± 0.09 |
| | (7.38 ± 0.24) | (0.27 ± 0.05) | (0.04 ± 0.01) | (0.08 ± 0.02) | (8.96 ± 4.10) | (0.18 ± 0.07) |
| | 0.014[a] | 0.17[a] | 0.05[a] | 0.024[a] | 0.01[a] | 0.002[a] |
| C | 6.78 ± 0.13 | 0.31 ± 0.10 | 0.03 ± 0.01 | 0.02 ± 0.01 | 186.30 ± 70.02 | 0.31 ± 0.11 |
| | (7.38 ± 0.17) | (0.33 ± 0.08) | (0.08 ± 0.07) | (0.08 ± 0.02) | (11.03 ± 5.38) | (0.20 ± 0.05) |
| | 0.001[a] | 0.36[a] | 0.13[a] | 0.08 [a] | 0.003[a] | 0.01[a] |
| NBV | 5.70–7.79 | ND – 0.46 | ND – 0.35 | ND – 0.78 | 8.47–330.00 | ND – 1.98 |
| WHO limit | 6.50–8.50 | 0.05 | 0.005 | 5.00 | 75.0–200.0 | 5.00 |

**Notes**: A: Entrance point; B: Middle point; C: Point of raw water collection; Values in parentheses are for Akute Odo samples; [a]*t*-test values; *NBV* Nigeria's background values for some rivers; *WHO* World Health Organization limits for drinking water; *SD* standard deviation; *ND* not detected; $t_{tab}$ at $p = 0.05$ (2.31)

**Table 12.2** Mean levels of pH and metals concentration (μg/g ± SD) in Isashi and Akute Odo sediment samples

| Sampling location | pH | Pb | Cd | Cu | Ca | Zn |
|---|---|---|---|---|---|---|
| A | 6.85 ± 0.39 | 26.16 ± 6.9 | 1.79 ± 0.57 | 182.64 ± 249.57 | 2616.87 ± 2194.29 | 26.29 ± 4.61 |
| | (6.37 ± 0.74) | (11.88 ± 1.90) | (0.66 ± 0.10) | (4.18 ± 2.03) | (23.26 ± 20.98) | (27.27 ± 7.36) |
| | 0.13[a] | 0.01[a] | 0.01[a] | 0.113[a] | 0.04[a] | 0.43[a] |
| B | 6.41 ± 0.62 | 30.23 ± 2.64 | 2.05 ± 0.58 | 123.38 ± 121.82 | 4893.28 ± 4848.68 | 24.95 ± 12.67 |
| | (6.20 ± 0.56) | (14.60 ± 2.91) | (0.84 ± 0.17) | (10.57 ± 6.26) | (51.50 ± 35.87) | (30.71 ± 6.44) |
| | 0.36[a] | 0.0002[a] | 0.013[a] | 0.07[a] | 0.06[a] | 0.28[a] |
| C | 5.93 ± 0.26 | 27.95 ± 7.86 | 1.85 ± 0.47 | 71.82 ± 55.59 | 3835.44 ± 3109.74 | 14.00 ± 8.29 |
| | (6.36 ± 0.59) | (17.10 ± 5.50) | (0.83 ± 0.09) | (6.87 ± 1.74) | (90.38 ± 117.31) | (31.53 ± 4.78) |
| | 0.15[a] | 0.09[a] | 0.01[a] | 0.04[a] | 0.04[a] | 0.01[a] |
| NBV | 4.02–8.73 | ND – 405.0 | ND – 2.02 | ND – 249.5 | 0.24–87.50 | 0.04–429.10 |

**Notes**: A: Entrance point; B: Middle point; C: Point of raw water collection; Values in parentheses are for Akute Odo samples; [a]*t*-test values; *NBV* Nigeria's background values for some rivers; *SD* standard deviation; *ND* not detected; $t_{tab}$ at $p = 0.05$ (2.31)

The trend in metals distribution is of the order of Ca > Pb > Zn > Cd > Cu for water and Ca > Cu > Pb > Zn > Cd for sediments respectively. Similar river sediment and water metal distribution trends have been observed for River Buriganga, Dhaka, Bangladesh and the Cochin estuary and Periyar River, in the southwest coast of India [19, 23].

The concentrations of the metals are higher in River Owo at Isashi when compared with those of Ogun river at Akute Odo water and sediment samples (Tables 12.1 and 12.2). These higher values are not unexpected because of the proximity of Agbara Industrial Estate to River Owo.

All the elements analyzed in the water samples for both rivers are within the NBV. Pb (0.27–0.34 mg/l) and Cd (0.03–0.08 mg/l) exceed the WHO limit of 0.05 and 0.005 mg/l respectively. However, levels of Cu, Ca and Zn are within the WHO limit set for drinking water. The elevated levels of lead and cadmium in the river water samples are of toxicological and ecotoxicological concern. This may result in adverse health effects arising from bioaccumulation in tissues of living organisms [31, 32].

Metals in river water samples reported for rivers outside Nigeria were as follows (mg/l): 0.24–1.11 (Pb), 0.01–0.26 (Cd), 0.10–0.53 (Cu) and 0.07–0.12 (Zn) for Umtata River, South Africa; 1.10–3.90 (Pb), 13.0–51.0 (Cu) and 5.0–142.0 (Zn) for Bindal River, Dehradum, India; 0.14–0.59 (Pb), 0.09–0.24 (Cd), 1.22–2.76 (Cu) and 0.19–0.42 (Zn) for River Buriganga, Dhaka, Bangladesh; <0.005–0.38 (Pb), 0.002–0.003 (Cd), 0.002–0.041 (Cu) and 0.01–0.02 (Zn) for Nile Delta in Egypt; 0.0003–0.0190 (Pb), 0.0001–0.0012 (Cd) and 0.01–0.02 (Zn) for Avsar Dam Lake, Turkey. The values for Pakistan and Greece were as follows (mg/l): 0.01–2.43 (Pb), 0.001–3.129 (Cd), Not detected–3.0 (Cu) and 0.01–0.70 (Zn) for Indus River, Sindh province, Pakistan; 1.0–16.0 (Pb), 0.10–0.60 (Cd), 2.0–7.0 (Cu) and 20.0–157.0 (Zn) in northern Greece rivers. These global values, many of which exceed the WHO limits for drinking water, are an indication of the level of freshwater contamination arising from increasing urbanization and industrialization [15, 18, 20–23, 25, 27, 33]. National, transnational and local authorities must therefore brace up to address the issue of water contamination in a sustainable manner.

Pb, Cu and Zn in River Owo sediment samples are all within the reported NBV (μg/g): ND–405.00 (Pb), ND–249.50 (Cu) and 0.04–429.10 (Zn), whereas Cd (1.79–2.05 μg/g) and Ca (2616.87–4893.28 μg/g) exceed the NBV (μg/g) of ND–2.02 and 0.24–87.50. On the other hand, it is only the levels of Ca (23.26–90.38 μg/g) in Ogun river at Akute Odo sediment samples that exceed the NBV of 0.24–87.50 μg/g.

The global sediment metals background values as captured from earlier studies are: 0.64–2740.0 μg/g (Pb), 0.33–17.26 μg/g (Cd), 13.00–255.82 μg/g (Cu) and 7.5–3050.0 μg/g (Zn). These values along with those of this study reveal substantial global contamination of river sediments [19–22, 24, 34]. The United States Environmental Protection Agency (USEPA) classifies natural sediments with >6 μg/g (Cd), >50 μg/g (Cu) and >60 μg/g (Pb), as being heavily contaminated [12].

**Table 12.3** Correlation coefficients between metals in water and sediment of Isashi and Akute Odo samples

| Sampling location | pH | Pb | Cd | Cu | Ca | Zn |
|---|---|---|---|---|---|---|
| A | $0.78^{ns}$ | $-0.04^{ns}$ | $-0.41^{ns}$ | $-0.59^{ns}$ | $0.59^{ns}$ | $0.59^{ns}$ |
| | $(-0.34)^{ns}$ | $(0.41)^{ns}$ | $(0.69)^{ns}$ | $(-0.32)^{ns}$ | $(-0.56)^{ns}$ | $(-0.70)^{ns}$ |
| B | $-0.31^{ns}$ | $0.52^{ns}$ | $-0.41^{ns}$ | $-0.35^{ns}$ | $-0.39^{ns}$ | 0.84* |
| | $(-0.26)^{ns}$ | $(0.12)^{ns}$ | $(0.29)^{ns}$ | $(-0.48)^{ns}$ | $(0.19)^{ns}$ | $(-0.58)^{ns}$ |
| C | $0.06^{ns}$ | $0.58^{ns}$ | $0.06^{ns}$ | $-0.63^{ns}$ | $0.19^{ns}$ | 0.87* |
| | $(0.17)^{ns}$ | $(0.11)^{ns}$ | $(0.02)^{ns}$ | $(0.23)^{ns}$ | (0.81)* | $(0.41)^{ns}$ |

**Notes**: A: Entrance point; B: Middle point; C: Point of raw water collection; Values in parentheses are for Akute Odo (water vs. sediment) samples; ns, non significant differences at $p = 0.05$; *significant differences at $p = 0.05$, $t_{tab}$ at $p = 0.05$ (0.81)

The statistical *t*-test analysis comparing results obtained from the two rivers (Tables 12.1 and 12.2) reveal non-significant differences at 95 % level of confidence. This shows that the metals burden in the two rivers are not statistically different. Generally, the correlation obtained in the metals concentration (Table 12.3) between the water and sediment samples in both rivers is small and negative giving a non-significant difference at 95 % level of confidence. Coefficients close to zero or negative are indications that the concentration of the metals in the sediment samples is not directly affecting those in the water samples. However, the correlation coefficient of Zn (Isashi) and Ca (Akute Odo) show a significant difference, which reveals that the amount of Zn and Ca in water is directly dependent on the level of contamination of the sediment.

## 12.4 Conclusions

The occurrence of metals (Pb, Cd, Cu, Ca and Zn) at relatively elevated concentrations in water and sediment samples in both rivers give cause for concern. Most probable sources of the contaminants are municipal run-offs, agricultural and industrial activities around the rivers' catchments and the discharge of untreated and partially treated domestic effluents into the river bodies. Lead and cadmium occur at levels which exceed the WHO limit set for drinking water. The Lagos State Water Corporation should be encouraged to improve the method of treating raw water sourced from the two rivers with emphasis on continuous raw water quality monitoring. Metals at elevated levels have been implicated as risk to human health and the "health" of the aquatic system. Direct disposal of effluent from domestic and industrial sources into water bodies should be discouraged by Municipal authorities.

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