

HYDROCHEMISTRY AND HEAVY METAL DISTRIBUTION IN SURFACE WATERS AND SEDIMENTS FROM THE LAGOS LAGOON COMPLEX

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ABSTRACT

Industrial wastes constitute a major source of heavy metal contamination in coastal waters. This study was carried out to assess the hydrochemistry and heavy metal distribution in surface water and sediments from selected sites in the Lagos lagoon complex. Water and sediment samples were collected monthly between June and November 2021 from five sampling stations, and analysed in the laboratory following standard methods. The result showed that heavy metal concentration in water was lower than WHO standards. The metals, arsenic, iron, and nickel exhibited significant ($P < 0.05$) spatial variation in sediments. The highest and lowest concentrations of arsenic and nickel in sediments were observed at Badagry and Langbasa respectively; while Fe was highest in Langbasa and lowest in Badagry. The highest and lowest values for all physicochemical water parameters were recorded at Bayeku and Badagry respectively, except turbidity and carbon dioxide. Conductivity, total dissolved solids, turbidity and total hardness at Bayeku and Langbasa exceeded WHO standard. The findings from this study emphasise the need for regular monitoring of the Lagos Lagoon Complex.

Keywords: Marine Pollutants, Sediment contamination, Water quality

INTRODUCTION

The concerns about heavy metal accumulation and its deleterious consequences in aquatic organisms and humans via the food chain have led to increasingly significant monitoring programs and studies on heavy metals in aquatic environmental samples (Otchere, 2003). Heavy metal pollution constitutes one of the most pressing environmental issues, as it can cause environmental toxicity and adversely affect human health (Chaturvedi *et al.*, 2018). Heavy metals are known to be non-biodegradable and persistent and also have high bioaccumulation properties (Varol *et al.*, 2017). Moreover, they have the potential to be harmful even at low levels of exposure (Hu, 2002).

Physicochemical parameters of water are very vital in determining the quality of water found in an aquatic ecosystem. They are also dependent on the depth of the aquatic system (Maurya *et al.*, 2019). It has been reported that environmental factors such as water temperature and pH affect the rate of uptake and accumulation of metals in fish (Olaiifa *et al.*, 2004).

Heavy metals may enter the aquatic ecosystems from natural processes and also through discharges from various anthropogenic processes such as industrial, agricultural, mining, and metallurgical activities, wastewater and runoffs (Hickley *et al.*, 2004; França *et al.*, 2005). According to Dural *et al.* (2007), heavy metals are naturally found in aquatic ecosystems, but anthropogenic deposits raise their

levels, causing environmental issues in coastal zones and rivers. Natural sources of heavy metals include volcanic activity, metal corrosion, metal evaporation from soil and water, sediment re-suspension, soil erosion, and geological weathering (Brady and Duncan, 1994).

Heavy metals can be transferred through the food chain as aquatic organisms bioaccumulate these pollutants upon contact with contaminated water and sediments (Soltani *et al.*, 2019). According to Wang and Rainbow (2005), sediments serve as sinks for a variety of pollutants, including heavy metals, and these pollutants may be assimilated by benthic organisms. Prolonged uptake of heavy metals through seafood may potentially cause damage to organs and tissues (Gwimbi *et al.*, 2020); and may also result in mutagenesis, teratogenesis, carcinogenesis, and deformation (Ghasemidehkordi *et al.*, 2018).

The Lagos lagoon complex is a network of several lagoons (comprising of Badagry, Yewa, Iyagbe, Ologe, Lagos, Epe, Lekki, Kuramo, and Mahin Lagoons) which stretches from the Republic of Benin to Nigeria (Hill and Webb, 1958; Uduma-Olugu and Oduwaye, 2010). These lagoons contribute immensely to socio-economic growth through recreational, fishing, sand dredging, and aquacultural activities. The Lagos lagoon complex receives a huge amount of waste including industrial, domestic, and agricultural effluents (Oyewo and Don-Pedro, 2003). Therefore, the objectives of this study are to assess the water

chemistry and distribution of heavy metals in surface waters and sediments from the Lagos Lagoon complex.

MATERIALS AND METHODS

Study Area

Five sampling stations were selected for the study based on their accessibility, proximity to an industrial establishment and human activities, as

well as suitability for a future survey. These sampling stations comprise three sampling points in the Badagry Lagoon and two sampling points each from the Lagos Lagoon (Figure 1). The Badagry and Lagos Lagoons are part of the Lagos lagoon complex. They are key commercial lagoons for fishing and are prone to industrial waste pollution. The names and coordinates of the sampling stations are shown in Table 1.

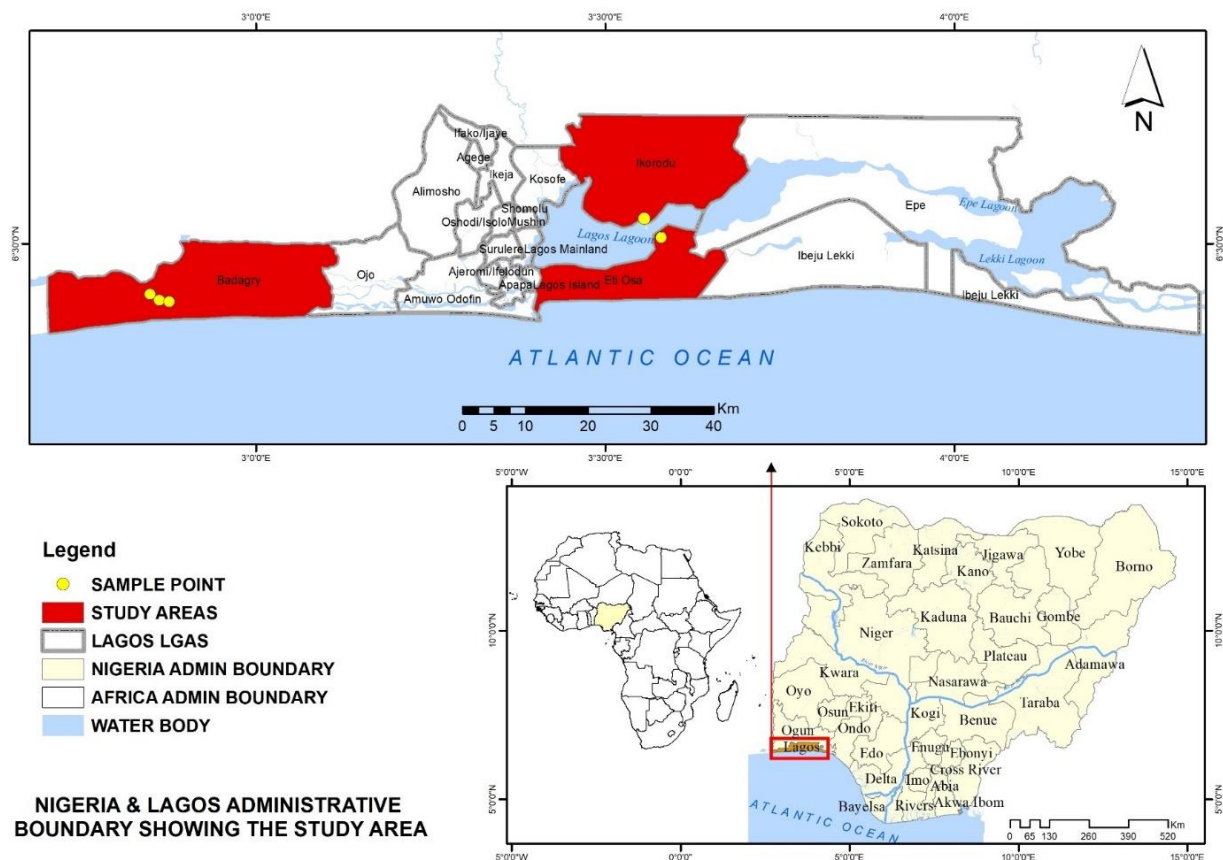


Figure 1: Map of the Study Area

Table 1: Coordinates of the Sampling Stations

Station No	Station Name	Lagoon	Longitude	Latitude
1	Iyeke	Badagry	2.861353	6.418612
2	Marina	Badagry	2.875303	6.416725
3	Afowo	Badagry	2.847808	6.427558
4	Langbasa, Eti-Osa	Lagos	3.579808	6.50956
5	Bayeku, Ikorodu	Lagos	3.5562	6.53532

Collection of Samples

Surface water and sediment samples were collected monthly between June to November 2021 (6 months) from each sampling station. The water samples were collected in 2-liter plastic containers washed with nitric acid to remove contaminants. While sediment samples were collected using a hand auger and carefully placed into labelled polythene

bags. Samples were stored immediately in a cooler, and transported to the laboratory for analysis.

Analysis of Water Chemistry

Physicochemical parameters of water samples were measured. Temperature and pH were determined *in situ* using a mercury-in-glass thermometer and a pH electrode (IONIX PC-50) of multi parameter test

meter respectively. While dissolved oxygen, total alkalinity, CO₂, total acidity, salinity, and total hardness were determined by titration according to Boyd (1981). All other parameters were determined according to the methods described by American Public Health Association (APHA, 1998). Biochemical oxygen demand (BOD) was determined by measuring the amount of dissolved oxygen (DO) before and after 5 days of incubating of 60ml aliquots of the samples in the dark at 20°C. Chemical oxygen demand (COD) was determined by a closed reflux, colorimetric method, in which 2ml of the sample was digested with dichromate/sulfuric acid COD reagent, in a reactor (Grant QBD 2) at 150°C for 2hours. The mixture was then cooled to room temperature, and the COD of the test solution determined at 420nm using a spectrophotometer (HACH DR 3900). Total suspended solids (TSS) was determined by gravimetric method. While turbidity was determined using the nephelometric method. Conductivity in microsiemens per centimetre (µS/cm) was measured using YSI conductivity/DO/temperature meter Model 85.

Digestion of Sediment Samples

Sediment samples were oven-dried to constant weight at 105°C, ground to powder using a mortar, and sieved through a 2 mm mesh screen to remove coarse materials. Then, 1g of the sample was digested in 10ml of aqua regia (a mixture of hydrochloric acid (HCl) and nitric acid (HNO₃) in ratio 3:1) and 5ml of H₂O₂. The samples were heated in a fume chamber until a colourless liquid was obtained. It was filtered hot with Whatman filter paper and made up to mark with distilled water in 100 ml volumetric flask.

Heavy Metal Determination

Eight heavy metals (Zinc, Lead, Copper, Iron, Arsenic, Chromium, Nickel, and Cadmium) were analysed in water and fish samples according to Türkmen *et al.* (2009). The analysis was done using Inductively Coupled Plasma-Atomic Emission Spectrometer (ICP-AES) Varian Liberty Series II (operating conditions: RF power, 1000W; plasma gas flow, 12L/min; torch configuration, radial; nebulizer, V-groove; spray chamber, double-pass cylindrical; detector, photomultiplier). Standard solutions were prepared by diluting stock solutions

(Merck, multi-element standard) and the latter were used for system calibration and control of analytical accuracy. All samples were run in batches composed of two spiked samples, a standard calibration curve, one duplicate, and blanks. Method accuracy and precision were validated by analysing (n=6) dogfish muscle (DORM-2, National Research Council, Canada) as a certified reference material. The recovery rate (% mean recovery±S.E.) was also analysed (n=6) according to Zrnčić *et al.* (2013). The correlation between the analytical and certified values was strong. The analytical procedure had good precision, which was calculated as the relative standard deviation (RSD) and the values obtained ranged from 5 and 9%. The analysis of the standard solution had a precision value that was better than 5%. Each of the analyses was repeated twice, and the results obtained were reported as the average. Heavy metal concentration was expressed as mg/kg dry weight.

Statistical Analysis

The data were statistically analysed using SPSS (Statistical Package for the Social Sciences 22.0). The means and standard error of the heavy metal concentrations in samples were analysed. Multivariate post hoc Duncan multiple range tests and Pearson correlation coefficient were employed to examine the significant differences at p<0.05 for each metal across different seasons and lagoons.

RESULTS

Table 2 shows the mean concentrations of the physicochemical parameters measured in surface water samples from the sampling stations. The result revealed that there were significant (p<0.05) variations in some of the water quality variables across the sampling stations. The highest and lowest values for all physicochemical parameters were recorded at Bayeku and Badagry respectively, except turbidity and carbon dioxide. The highest values for turbidity (17.59±25.45 NTU) and CO₂ (69.215±9.63 mg/L) were recorded in Langbasa and the lowest values (turbidity, 3.8±1.7 NTU; CO₂, 21.0±7.9 mg/L) were observed in Badagry. Few of the parameters (electrical conductivity, total dissolved solids, turbidity, and total hardness) measured exceeded the limits set by the World Health Organisation (WHO), especially in Bayeku and Langbasa (WHO, 2017).

Table 2: Physicochemical Parameters of Surface Water from Badagry and Lagos Lagoons

Parameters	Badagry	Bayeku	Langbasa	WHO Standard (2017)
Temperature (°C)	25.1±0.1 ^a	25.7±1.14 ^a	25.1±0.08 ^a	30°C
pH (at 25°C)	6.6±0.1 ^a	6.31±0.61 ^a	6.24±0.48 ^a	6.5-8.5
Electrical Conductivity (uS/cm)	152.7±10.2 ^a	10882±12434 ^b	6768±3142 ^c	400
Total Dissolved Solids (mg/L)	110.8±6.5 ^a	10218±8801 ^b	4431±2857 ^c	<600

Salinity (ppt)	0.1±0.0 ^a	6.19±7.05 ^b	4.1±1.32 ^b	NS
Total Suspended Solids (mg/L)	7.5±3.5 ^a	10.25±10.14 ^a	13.5±9.47 ^a	NS
Turbidity (NTU)	3.8±1.7 ^a	8.125±6.82 ^a	17.59±25.45 ^b	5.0
Acidity (mg/L, CaCO ₃)	20.2±1.8 ^a	109.75±76.66 ^b	25.78±8.48 ^a	NS
Alkalinity (mg/L, CaCO ₃)	34.5±10.2 ^a	53.15±16.51 ^a	42.175±9.63 ^a	NS
Carbon dioxide (mg/L, CO ₂)	21.0±7.9 ^a	53.15±16.51 ^b	69.215±9.63 ^b	NS
Dissolved oxygen (mg/L)	6.2±2.3 ^a	2.575±1.76 ^a	4.45±0.67 ^a	>2
Biochemical oxygen demand (mg/L)	4.0±1.1 ^a	17.5±19.07 ^b	6±4.69 ^a	50
Chemical oxygen demand (mg/L)	6.5±1.3 ^a	43.25±47.12 ^b	19±22.06 ^c	NS
Total hardness (mg/L, CaCO ₃)	50.4±10.4 ^a	1809±239 ^b	817±295 ^c	100-300

*NS = Not specified. Values in the same row and with the same superscript are not significantly different (p>0.05). All values are expressed as mean±SD

Table 3 shows the mean concentrations of heavy metals in water samples from the study. The concentrations of heavy metals in all the water

samples were below WHO (2008) guidelines for drinking water quality, and these values did not vary significantly (p>0.05) among the sampling stations.

Table 3: Mean Concentration of Heavy Metals in Water from Badagry and Lagos Lagoons

Heavy Metals (mg/L)	Badagry	Bayeku	Langbasa	WHO (2008)
Arsenic	ND	0.002±0.001	ND	0.01
Cadmium	0.001±0.001 ^a	0.002±0.001 ^a	0.002±0.001 ^a	0.003
Chromium	0.03±0.01 ^a	0.01±0.01 ^a	0.02±0.02 ^a	0.05
Copper	0.01±0.01 ^a	0.01±0.01 ^a	0.02±0.01 ^a	2.0
Iron	0.09±0.01 ^a	0.21±0.19 ^a	0.14±0.04 ^a	0.3
Lead	0.002±0.001 ^a	0.001±0.0001 ^a	0.002±0.001 ^a	0.01
Nickel	0.003±0.001 ^a	0.003±0.001 ^a	0.003±0.001 ^a	0.07
Zinc	0.15±0.09 ^a	0.16±0.12 ^a	1.04±1.09 ^a	3.0

*ND = Not Detected. Values in the same row and with the same superscript are not significantly different (p>0.05). All values are expressed as mean±SD

Table 4 highlights the mean concentrations of heavy metals in the sediment samples collected from the sampling stations. Only arsenic, iron, and nickel exhibited significant (p<0.05) spatial variation. The highest (As, 1.69±1.58 mg/kg; Ni, 3.47 mg/kg) and lowest (As, 0.11±0.49 mg/kg; 0.63±0.37 mg/kg)

concentrations of As and Ni in the sediments of the sampling stations occurred at Badagry and Langbasa respectively. The highest concentration of Fe (41991±10694 mg/kg) in sediment was recorded in Langbasa while the lowest (5917±698 mg/kg) was obtained in Badagry.

Table 4: Mean Concentration of Heavy Metals in Sediment from Badagry and Lagos Lagoons

Heavy metals (mg/kg)	Badagry	Bayeku	Langbasa
Arsenic	1.69±1.58 ^a	1.11±0.10 ^a	0.11±0.49 ^b
Cadmium	5.90±0.73 ^a	6.55±2.61 ^a	7.89±2.27 ^a
Chromium	34.76±30.66 ^a	18.01±6.73 ^a	51.67±13.34 ^a
Copper	5.17±0.42 ^a	3.05±2.00 ^a	5.42±1.28 ^a
Iron	5917±698 ^a	20447±3106 ^b	41991±10694 ^b
Lead	5.09±4.25 ^a	6.74±1.92 ^a	9.37±0.880 ^a
Nickel	3.47±3.44 ^a	1.053±0.409 ^a	0.63±0.37 ^b
Zn	1344.9±282.84 ^a	1381.675±282.84 ^a	1632.58±550.17 ^a

Values in the same row and with the same superscript are not significantly (p>0.05) different. All values are expressed as mean±S.D

DISCUSSION

Hydrochemistry of the Study Area

The physicochemical properties of water usually reveal the status, productivity, and sustainability of water bodies (Akintola *et al.*, 2011). Oyewo and Don-Pedro (2003) reported that variability of water quality influences the toxic levels of heavy metals in estuarine organisms as it affects the physical and chemical composition of the ecosystem. The result of the physicochemical parameters of surface water measured in this study as shown in Table 2, reveals that the mean temperature of the sampling stations was within the WHO standard (30°C) for the existence and development of aquatic life (WHO, 2017). This also conforms with the result of the study by Lawson (2011) on swamps in Lagos.

Conductivity is a measure of water's ability to conduct electrical current and is also an indicator of dissolved ions or solutes such as metals present in the water. In this study, the conductivity values obtained at both Bayeku and Langbasa were above the limit suggested by WHO (2017) for the survival of aquatic organisms in water and also varied significantly ($P < 0.05$) across all sampling stations. The high level of conductivity at Bayeku and Langbasa may be due to effluent discharged into this water from industries. A study by Ewa *et al.* (2011) lends credence to this assumption, where a higher mean conductivity level in Omoku Creek was also recorded due to industrial effluent discharged into the creek.

The result in Table 2 also showed that the mean TDS level recorded in Badagry falls within the standard threshold (< 600 mg/L) for the sustenance of aquatic organisms as recommended by WHO (2017). However, TDS values from Bayeku and Langbasa were above the permissible limits. When TDS levels exceed 1000 mg/L, the water is generally considered unfit for human consumption (Lawson, 2011). Lawson (2011) recorded a very high average TDS value of 836.78 mg/L for Lagos swamps which was attributed to organic sources such as leaves, silt, plankton and industrial waste, and sewage. Increased TDS could also indicate the presence of toxic minerals that can cause scaling of pipes and corrosion.

No significant difference ($P > 0.05$) in pH levels was observed in this study. The pH levels recorded were within WHO limits (6.5-8.5) for aquatic life protection, survival, and development, and also agrees with previous studies (Onuoha, 2002). Anoxia occurs when the environment's dissolved oxygen levels drop to the point where aquatic life can no longer survive. Low DO indicates a high organic matter content and, as a result, a fast rate of decomposition. The DO levels observed in this study were within the acceptable limit (WHO,

2017). The values of turbidity measured at Bayeku and Langbasa were higher than the recommended standard, while that from Badagry was below the WHO limits (WHO, 2017). Davies (2009) and Alagoa and Aleleye-Wokoma (2012) found a temporal fluctuation in turbidity in Woji-Okpoka and Taylor Creeks, respectively. Also, Ewa *et al.* (2011) found a high mean turbidity of 29.3 NTU in Omoku Creek.

The BOD values recorded at Badagry, Bayeku, and Langbasa were within the permissible limits of 50mg/L recommended by WHO (2017). BOD represents the amount of oxygen required for the biological decomposition of organic matter under aerobic conditions (Ewa *et al.*, 2011). The alkalinity of a water body is a measure of its capacity to neutralize acids to a designated pH (APHA, 1998). The Alkalinity recorded in this study ranged from 34.5–53 mg/L. This is lower than that reported by Adesalu *et al.* (2010) who observed a high alkalinity range of 490–1190 mg/L at Ajegunle Creek and 70–1681.20 mg/L at Tomara Creek. The salinity recorded in this study ranged from 0.1-6.19 ppt. Olomukoro *et al.* (2009) reported a low salinity range of 0.17 to 1.11 ppt for Ekpan Creek, while Ewa *et al.* (2011) reported a high range of 18.7 to 20.8 ppt for Omoku Creek. According to Sharipova (2005), salinity affects the distribution patterns and relative abundance of organisms.

The extreme water quality parameters recorded in this study at Langbasa and Bayeku could be due to excessive influx of wastes resulting from industrial and other human activities occurring in those areas. There is need for environmental regulatory bodies to enforce appropriate and sustainable waste management and disposal regulations and standards in these areas to improve the health status of the water body.

Concentration of Heavy Metals in Surface Water

In this present study, the concentration of various heavy metals obtained from all sampled stations (Table 3) was considerably low and did not exceed the WHO guidelines for drinking water quality (WHO, 2008). Huang *et al.* (2020) reported that heavy metals quickly settle into sediment after entering a water body. This may be responsible for their low detection in water samples from this study. A similar study by Nubi *et al.* (2024) also reported that the concentration of heavy metals in the surface water of the Lagos lagoon was within permissible limits, except lead and cadmium. A low concentration of heavy metals was also observed in Badagry lagoon by Femi *et al.* (2021). However, regular assessment of heavy metal concentrations in water from the Lagos lagoon complex is crucial to ensure the safety of the water for aquatic organisms and humans.

Concentration of Heavy Metals in Sediments

The mean concentrations of iron and zinc in sediment samples from this study (Table 4) were high across all sampled stations, despite their low concentrations in surface water samples. According to Algul and Beyhan (2020), the concentration of heavy metals is usually higher in sediment than in water. Sediment acts as the main repository for materials that are released into the marine environment (Okeke and Nkwoji, 2024). Therefore, sediment analysis allows contaminants that are absorbed by particulate matter, which escape detection by water analysis to be identified. Oguzie (1996) quoted in Defew *et al.* (2004) showed that the bioavailability of even a minute fraction of the total sediment metal assumes considerable importance. This is especially true for burrowing and filter-feeding organisms. Hence, there is a need to further assess the concentration of heavy metals in biota from this study area to ascertain the risks posed by their presence in sediment.

CONCLUSION

This study indicates that a low concentration of heavy metals was observed in surface water; although, some of the physicochemical parameters of water measured were above recommended standards. Moreover, a high amount of heavy metals was observed in sediments, with iron and zinc having the highest concentrations in the study. The findings from this study highlight the need for continuous biomonitoring of the Lagos lagoon complex to evaluate the levels of other heavy metals and pollutants in not only water and sediment but also in biota, including locations that were not covered in this research.

AUTHORS CONTRIBUTION

OJK designed the study, collected and analysed the data, and wrote the original draft; EGO analysed the data, reviewed and edited the original draft, and prepared the manuscript for publication; JAN analysed the data and reviewed the manuscript. All authors approved the manuscript for submission.

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