

Concentrations and Health Risk Parameters of Heavy Metals in Water Samples from Epe Lagoon in Lagos State, Nigeria

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Abstract

Lagoons are large bodies of water that provide essential economic and ecosystem services such as fishing, erosion protection, transportation, as well as water for domestic, industrial, and agricultural use, among others. Unfortunately, municipal, agricultural, and industrial waste are often dumped in lagoons, polluting the water and predisposing humans and aquatic organisms to environmental and health hazards. This calls for regular monitoring of lagoons worldwide. This study assessed the water quality of Epe lagoon in Lagos State, Nigeria, with regard to heavy metal contamination. Water samples obtained at three settlements (Epe, Ejinrin, and Agbowo) along the lagoon were treated and subjected to heavy metal analysis using standard protocols. The heavy metals analysed were lead (Pb), copper (Cu), nickel (Ni), cadmium (Cd), and chromium (Cr). The chronic daily intake (CDI), chronic dermal contact (CDC), hazard quotients (HQ), heavy metal index (HMI), and probability of cancer risk (PCR) of the heavy metals were also calculated. The results revealed that the water samples from the three locations contained non-permissible levels of Pb, Cu, Ni, Cd, and Cr. The CDI, CDC, and HQ of the heavy metals via ingestion and dermal contact were within the recommended limits, except for Pb. Meanwhile, the HMI and PCR of all the heavy metals exceeded the permissible limits. The results obtained suggest that Epe lagoon's water is contaminated with heavy metals and thus poses health hazards. Consequently, there is a need for heavy metal remediation and control in the lagoon.

Keywords: Chronic daily intakes, Hazard quotient, Heavy metals, Lagoon, Lead

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INTRODUCTION

Lagoons are large bodies of water that provide essential services that help boost the economy and ecology of the areas around them (Davies-Vollum *et al.*, 2019). Lagoon water is utilized for laundry, cooking, farming, and industrial processes. Fishing, shellfish harvesting, salt and sand mining, and maritime transport are among economic activities that take place in lagoons (Yahaya *et al.*, 2022a). Other economic activities offered by lagoons include agriculture, tourism, relaxation, as well as urban development (El Mahrad *et al.*, 2020). Ecological services that coastal lagoons provide include protection from storms, breeding grounds for marine fish, and making sure the marine environment stays alive (Andreea *et al.*, 2022).

Unfortunately, untreated municipal, agricultural, and industrial waste are often dumped in lagoons, polluting the water (Yahaya *et al.*, 2022a). Treated waste, which may contain substances harmful to aquatic organisms and humans, is also released into lagoons (Kumolu-Johnson and Ndimele, 2012). Toxic substances in waste can contaminate water and cause the loss of aquatic organisms, causing adverse effects on people that live near or depend on the lagoon (El Mahrad *et al.*, 2020). The most common group of contaminants in water is heavy metals (Kinuthia *et al.*, 2020). The commonly detected heavy metals in water include arsenic, cadmium, chromium, copper, lead, nickel, and zinc (Yahaya *et al.*, 2019; Moruf and Durojaiye, 2020). Although lagoon heavy metal pollution is less obvious and more direct than other types of pollution, it has far-reaching consequences for the aquatic ecosystem and humans (Okunade *et al.*, 2021). Heavy metals can induce several diseases, such as respiratory and genetic diseases, haematological problems, dermal damage, eye sight problems, and neurological diseases (Yahaya *et al.*, 2019). Considering these health effects, there is a need for periodic monitoring of lagoons' water quality to protect the health of humans and aquatic organisms as well as to keep the lagoon and its ecosystem services functioning.

In Lagos, Nigeria, Epe Lagoon is one of the major lagoons that provides several benefits, including aquaculture, fishing, and bathing. The lagoon is also used to transport people and commodities to nearby towns and villages for socioeconomic activity. However, the lagoon receives enormous municipal, agricultural, and industrial waste. Moreover, human faeces and other domestic waste are deposited in the lagoon indiscriminately. These wastes can potentially pollute the lagoon's water, causing health hazards to aquatic organisms and humans that consume them. It can also endanger the lives of people that use the lagoon's services. Thus, it is important to regularly test the lagoon's water quality in order to provide primary data on the status of the lagoon to agencies in charge of health and the environment in the state. This will go a long way towards protecting the health of humans and aquatic life as well as ensuring the lagoon continues to deliver its services. Few studies have been conducted on the lagoon water in recent years, but their results are inconsistent. Moreover, majority of them did not evaluate the health risks of the lagoon's water. Therefore, this study determined the levels and health risks of heavy metals in water samples obtained from Epe Lagoon.

METHODOLOGY

Description of the Study Area

Epe lagoon is in Epe local government area in Lagos state, Nigeria. The lagoon lies between latitudes 03°50'–04°10'N and longitudes 005°30'–005°40'E (Figure 1). It has a surface area of about 243 km² and is about 180 m deep. The lagoon is sandwiched between Lekki lagoon in the east, where its water is fresh, and Lagos lagoon in the west, where its water is brackish. The vegetation of the area is tropical with a long rainy season, lasting for about 10 months.

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A lot of fishing activities take place on the lagoon, which serves as a source of income for fishermen and fish sellers. The fish are sold in the town and outside the town. The lagoon also serves as a means of transportation in the area. Unfortunately, waste is dumped indiscriminately into the lagoon, polluting it. Toxic substances in the waste can compromise the lagoon's water quality and harm aquatic organisms and humans that eat the aquatic organisms or use the lagoon's services. Thus, it is imperative to assess the quality of the lagoon's water to raise public awareness, especially among agencies in charge of health and the environment.

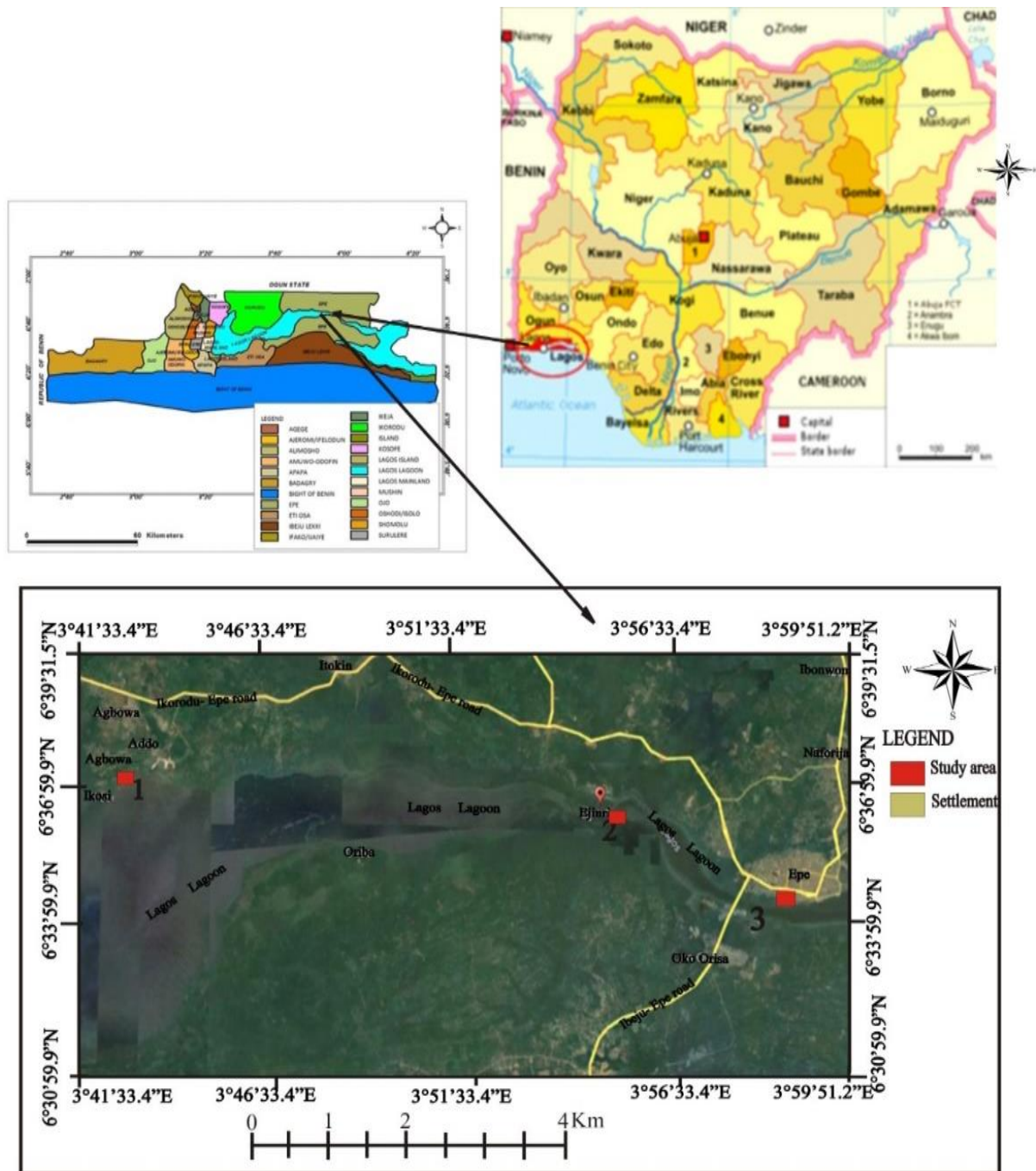


Figure 1: Locations of the study area

Sample Collection

Between February and April 2022, water samples were collected at three locations on the lagoon, namely Epe, Ejinrin, and Agbowo towns, at random every other week. A total of six field trips were conducted, yielding 18 water samples (3 each). The samples were put in clean, disinfected plastic bottles and kept in the lab at 4 °C until the heavy metals were tested.

Heavy metal analysis

The frozen samples from the lab freezer were defrosted at room temperature and mixed vigorously. Thereafter, 100 mL of each sample was digested in a beaker containing baking soda and 5 mL of concentrated HNO₃. The beaker was warmed in a smoke cabinet until the mixture was reduced to 20 mL. More HNO₃ (2 mL) was added simultaneously with heating until the mixture became a clear solution. Splashes of the solution on the wall of the beaker were washed down the beaker with distilled water, after which the solution was filtered through a Whatman filter paper No. 42 into a 100-mL volumetric flask. The filtrate in the flask was topped up to the meniscus with the addition of distilled water. A UNICAM atomic absorption spectrometer (model 969) was used to measure the levels of lead (Pb), copper (Cu), nickel (Ni), cadmium (Cd), and chromium (Cr) in the solution after it had cooled down.

Health risk assessment of the heavy metals

Non-carcinogenic health risk assessment

Equations 1, 2, and 3 were used to estimate the non-carcinogenic risks of daily ingestion of water from the lagoon (Yahaya *et al.*, 2019; Yahaya *et al.*, 2020).

$$CDI \text{ (mg/kg/day)} = \frac{C \times EF \times ED \times IR}{BWT \times AT} \quad (1)$$

$$CDC \text{ (mg/kg/day)} = \frac{C \times Sa \times Pc \times EF \times ED \times Et}{BWT \times AT} \quad (2)$$

$$HQ = \frac{CDI}{RFD} \quad (3)$$

Note: *CDI* stands for chronic daily ingestion; *CDC* is short for chronic dermal contact; *HQ* is hazard quotient; *C* signifies the concentration of heavy metals in water (mg/L); *Ir* (ingestion rate) = 2 litres per day; *EF* (exposure frequency) = 365 days per year; *ED* (exposure duration) = 55 (the average lifespan of resident Nigerians); *Et* (exposure time) = 0.25; *Sa* (the skin surface area) = 28000; *BWT* (average body weight) = 65kg (average body weight of resident Nigerians); *AT* (average time) = 20075 days; *Pc* (dermal permeability coefficient) = 0.004 for Pb, 0.001 for both Cd and Cu, 0.0002 for Ni, and 0.002 for Cr; *RFD* (oral/dermal reference dose (mg/L/day) = 0.0035/0.000525, 0.02/0.0054, 0.0005/0.00001, 0.0003/0.00006, and 0.04/0.012 for oral/dermal *RFD* of Pb, Ni, Cd, Cr and Cu, respectively.

Carcinogenic health risk assessment

The carcinogenic risk of the water samples was calculated from their heavy metal index (*HMI*) and probability of cancer risk (*PCR*) using equations 4 and 5, respectively (Yahaya *et al.*, 2022b).

$$HMI = \frac{Cn}{MPC} \quad (4)$$

$$PCR = CDI \times CSF \quad (5)$$

Note: *Cn* is the concentration of heavy metals (mg/L), *MPC* stands for the maximum permissible concentration of each heavy metal, *CDI* represents the chronic daily intake of heavy metals, and *CSF* means the cancer slope factor (mg/kg/day). The standard *CSFs* for

carcinogenic heavy metals are Pb (0.0085), Cr (0.05), Cd (0.38), and Ni (0.91). The acceptable limit for *HMI* is <2, while the acceptable limit for *PCR* is $\leq 1 \times 10^{-6}$.

Data Analysis

Values were presented as mean \pm standard deviation (SD) using the Excel software version 21. The software was also used to calculate the *CDI*, *CDC*, *HQ*, *HMI*, and *PCR* of the heavy metals.

RESULTS

Levels of Heavy Metals in the Water Samples

Table 1 shows the levels of Pb, Cu, Ni, Cd, and Cr in the water samples obtained from Epe Lagoon. All of the mentioned heavy metals were above the limits set by the World Health Organization (WHO) in all the water samples.

Table 1: Mean levels of heavy metals (mg/L) in water samples from Epe lagoon, Lagos

Location	Pb	Cu	Ni	Cd	Cr
Epe	1.411 \pm 0.05	2.175 \pm 0.17	0.760 \pm 0.02	0.061 \pm 0.010	0.087 \pm 0.00
Ejinrin	2.081 \pm 0.17	1.704 \pm 0.15	0.642 \pm 0.05	0.085 \pm 0.004	0.049 \pm 0.04
Agbowo-Ikosi	1.535 \pm 0.12	2.676 \pm 0.03	0.477 \pm 0.05	0.027 \pm 0.005	0.061 \pm 0.01
WHO (2004)	0.01	0.05	0.07	0.003	0.05

Health Risk of Heavy Metals in the Water Samples

Tables 2, 3, 4, and 5 show the chronic daily intake (*CDI*), chronic dermal contact (*CDC*), hazard quotient (*HQ*), heavy metal index (*HMI*), and probability of cancer risk (*PCR*) of Pb, Cu, Ni, Cd, and Cr in the water samples.

Table 2 shows that in all the locations, the *CDI* and *CDC* of the heavy metals were within the recommended daily intake (*RDI*), with the exception of the *CDC* of Pb. In Table 3, the *HQ* of *CDI* and *CDC* were less than the threshold of 1 in all locations, except for the *HQ* of Pb via *CDC*. With the exception of Cr, the *HMI* of Pb, Cu, Ni, and Cd exceeds the allowable limits in all the locations except for Cr (Table 4). The *PCR* of all the heavy metals was beyond the acceptable limits in all the locations (Table 5).

Table 2: Chronic daily intake (CDI) and chronic dermal contact (CDC) of heavy metals (mg/L) in water samples from Epe Lagoon, Lagos

Location	Pb		Cu		Ni		Cd		Cr	
	CDI	CDC	CDI	CDC	CDI	CDC	CDI	CDC	CDI	CDC
Epe	0.04	0.61	0.07	0.23	0.02	0.01	0.002	0.007	0.003	0.02
Ejinrin	0.06	0.89	0.05	0.18	0.02	0.01	0.003	0.009	0.002	0.01
Agbowo-Ikosi	0.05	0.67	0.08	0.29	0.01	0.01	0.001	0.003	0.002	0.01
RDI	0.21		0.90		0.50		0.06		0.20	

Table 3: Hazard quotient (HQ) of chronic daily intake (CDI) and chronic dermal contact (CDC) with heavy metals in water samples from Epe Lagoon, Lagos

Location	Pb		Cu		Ni		Cd		Cr	
	CDI	CDC	CDI	CDC	CDI	CDC	CDI	CDC	CDI	CDC
Epe	11.43	1161	1.75	19.17	1.00	1.85	4.00	700.0	10.00	33.33
Ejinrin	17.14	1695	1.25	15.00	1.00	1.85	6.00	900.0	6.67	166.67
Agbowo-Ikosi	14.29	1276	2.00	24.17	0.5	1.85	2.00	300.0	6.67	166.70

Table 4: Heavy metal index (HMI) of heavy metals in water samples from Epe Lagoon, Lagos

Locations	Pb	Cu	Ni	Cd	Cr
Epe	141.1	43.50	38.00	20.33	1.09
Ejinrin	208.1	34.08	32.10	28.33	0.98
Agbowo-Ikosi	153.5	53.58	23.85	9.00	1.22
Limits (Charles <i>et al.</i> , 2018)	<2				

Table 5: Probability of cancer risk (PCR) of heavy metals in water samples from Epe Lagoon, Lagos

Locations	Pb	Ni	Cd	Cr
Epe	5.059	0.025	0.005	0.060
Ejinrin	7.529	0.022	0.008	0.040
Agbowo-Ikosi	5.529	0.016	0.003	0.040
Permissible Limits	$\leq 10^{-6}$			

DISCUSSION

This study determined the levels and health risk of heavy metals in water samples from Epe lagoon in Lagos State, Nigeria. This was done to determine the safety of the lagoon's water for the ecosystem and domestic services the lagoon provides. As shown in Table 1, water samples obtained from three selected settlements (Epe, Ejinrin, and Agbowo-ikosi towns) along the lagoon contained non-permissible levels of Pb, Cu, Ni, Cd, and Cr. This implies that ingestion of the water may induce health hazards related to heavy metal toxicity. Pb can bioaccumulate and cause multiple organ damage, especially in children (WHO, 2021). A single high dose of Cu through water can cause vomiting, nausea, abdominal pain, and diarrhea, while persistently taking a high dose can cause chronic diseases involving the liver and kidneys (ATSDR, 2022). Excessive Ni exposure can cause dermatitis, pulmonary fibrosis, respiratory tract cancer, liver damage, as well as cardiovascular and kidney diseases (Dudek-Adamska *et al.*, 2021). Chronic ingestion of Cd can cause cancer and multi-organ damage related to urinary, skeletal, reproductive, respiratory, cardiovascular, and nervous systems (Rahimzadeh *et al.*, 2017). Hexavalent Cr is an established carcinogen, and trivalent Cr can rupture the cell membrane and cause DNA damage (Sawicka *et al.*, 2021; Yahaya *et al.*, 2022a). The results of the current study are consistent with the findings of Olusegun *et al.* (2010), Isibor *et al.* (2020), and Mustapha *et al.* (2021), who separately detected non-permissible levels of some of Zn, Cu, Mn, Fe, Pb, Cr, Ni, and Cd in the Epe lagoon. However, the results contradict those of Olowu *et al.* (2010), who detected permissible levels of selected heavy metals (Zn, Fe, and Ni) in the Epe lagoon. Similarly, Adedeji and Okocha (2011) detected permissible levels of Mn, Cu, Zn, Pb, and Cd in water samples from Epe Lagoon.

The non-carcinogenic health risk assessment of heavy metals in the water samples further proved that the water can induce the health hazards mentioned earlier. Table 2 shows that chronic dermal contact (CDC) with Pb in all the locations exceeded the permissible limits. This indicates that of all the heavy metals, Pb poses a significant risk to consumers, particularly those who use water from the river to bathe or swim in it. Moreover, the hazard quotient (HQ) of the heavy metals via ingestion and dermal contact with water in all the locations was greater than the threshold of 1 (Table 3). This adds to the evidence that the water can pose some health hazards. These hazards may be more significant among consumers who live

above 55 years because the risk assessment was estimated based on the life expectancy of Nigerians, which is 55 years.

The carcinogenic risk assessment of the heavy metals also lends evidence that the water can cause health effects. In all the locations, the heavy metal index (*HMI*) of Pb, Cu, Ni, and Cd was greater than 2, which is the threshold above which a substance or compound can be considered carcinogenic (Table 4). Similarly, the probability of cancer risk (*PCR*) of Pb, Ni, Cd, and Cr in all the locations exceeded the threshold of 10^{-6} , which again proved that daily ingestion of the water may induce cancer. Though Pb is a weak mutagen, it inhibits DNA repair and acts synergistically with other mutagens (Steenland and Boffetta, 2000). High levels of Cr promote cancer development through angiogenesis and by attacking the proteasome, which is actively involved in cancer pathogenesis and survival (Wang *et al.*, 2010). Excessive exposure to Ni promotes carcinogenesis by inducing oxidative stress, inhibiting DNA repair, and disrupting epigenetic mechanisms (Grimsrud and Andersen, 2010). Cd interferes with proteins involved in the cellular response to DNA damage, the deregulation of cell growth as well as resistance to apoptosis (Hartwig, 2013).

CONCLUSION

The results demonstrated that Epe lagoon contained non-permissible levels of Pb, Cu, Ni, Cd, and Cr. The chronic daily intake of these heavy metals was within the tolerable limits. However, the chronic dermal contact with Pb in the lagoon water exceeded the permissible limits. Furthermore, the health hazard, the heavy metal index, and the probability of cancer risk of most of the heavy metals exceeded the permissible limits. Overall, the results suggest that the ecosystem and domestic services rendered by the lagoon could pose some health hazards.

Based on the findings of this study, we recommend that companies that discharge wastewater into the lagoon be required to treat the wastewater before dumping it. Waste control, environmental sanitation, and public enlightenment about the dangers posed by contaminated water are also recommended in the areas. Furthermore, residents should consider water treatment before use. Studies like this one should be done on a regular basis in these areas as well.

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