ACTA TECHNICA JAURINENSIS

Vol. XX, No. Y, pp. ZZ-ZZ, 2025

10.14513/actatechjaur.00756

Research Article

Comprehensive physico-chemical and heavy-metals profiling of the Epe Lagoon in southwestern Nigeria

Omogbolade Adepitan[1,*], Abidat Fasasi-Aleshinloye[2], Oyeyemi Aforolagba-Balogun[1], Temitope Ladigbolu[1]

[1]Department of Mechanical Engineering, Lead City University, Toll Gate Area Ibadan 200255, Oyo State, Nigeria

[2]Department of Civil Engineering, Lead City University, Toll Gate Area Ibadan 200255, Oyo State, Nigeria

*email: adepitan.omogbolade@lcu.edu.ng

Submitted: 05/10/2024 *Revised: 06/05/2025* *Accepted: 28/05/2025* *Published online: 20/06/2025*

Abstract: This study focuses on surface water around the south-western part of Nigeria. This research examines the types and amounts of chemical and heavy metal pollutants in the lagoon. It also checks if the lagoon water is safe to use for household purposes. This study characterised the physicochemical parameters and heavy metals in one of the major accessible lagoons. Water samples were gathered during two seasons (wet and dry) in 15 different sampling and control areas and examined using accepted standard measures and methodology. The results showed no significant difference statistically ($p>0.005$) at 95% confidence between the obtained results from the sampling areas. The results show a pH range of 7.12 to 8.30 and 7.22 to 8.30, total suspended solids to be 25 to 41 mg/L and 28 to 34.5 mg/L, biochemical oxygen demand to be 0.89 to 2.08 mg/L and 0.01 to 1.61 mg/L, dissolved oxygen, 7.12 to 9.0 mg/L and 3.12 to 3.19 mg/L; chemical oxygen demand, 2.8 to 3.84 mg/L and 3.60 to 4.78 mg/L; copper, 0.01 to 0.19 mg/L and 2.23 to 5.04 mg/L; and cadmium, 0.01 to 0.15below mg/L and 3.61 to 5.32 mg/L for the wet and dry seasons, respectively. Some of the obtained results do not agree with the recommended standard quality of water by the World Health Organisation, as well as the Nigerian Standard for Drinking Water Quality; however, the lagoon is safe for public health, provided proper monitoring of human activities around it is done regularly.

Keywords: Heavy metal; Physico-chemical; Profiling; Water; Lagoon

I. INTRODUCTION

Epe Lagoon, situated in Lagos State, Nigeria, serves as a vital aquatic resource supporting local communities through fishing, agriculture, and recreational activities. However, increasing anthropogenic activities, including industrial discharges, agricultural runoff, and urban waste, have led to significant contamination of the lagoon's water and sediment.

Recent studies have highlighted elevated concentrations of heavy metals such as zinc (Zn), manganese (Mn), iron (Fe), cadmium (Cd), and lead (Pb) in the lagoon's water, sediment, and aquatic organisms [1]. These contaminants pose potential health risks to humans and aquatic life, underscoring the necessity for detailed monitoring and assessment [2].

The bulk of contaminants that enter surface water come from the terrestrial environment; before these pollutants reach the closest body of water, their fate and effects may vary. Since surface water is an important natural resource that is used for a variety of purposes, it is necessary to maintain and monitor its quality [3]. Water pollution is caused by several circumstances, which make it very undesirable for drinking. These elements include industrial activity near the water source, fertiliser loading into an unstable environment, and sewage discharge, which increases oxygen demand. According to [4], waste management practices are poor around the country, especially in a developing region like Epe, where there is no adequate waste disposal management.

In 2011, [23] studied the Seasonal Variation of Heavy Metals in the Sediment and Water of Lagoons in Lagos. It was confirmed that sediments are significant hosts for harmful metals because the metal levels in the sediment were higher than those in the lagoon's surface water. Increased levels of heavy metals in coastal sediments, such as those found in Lagos Lagoon, can be a sign of pollution caused by humans as opposed to natural enrichment from geological weathering. Also, [5] studied the concentrations and health risk parameters of heavy metals in water samples from Epe Lagoon in Lagos State, Nigeria. From the obtained results, it is imperative to conduct ongoing assessments since metals from the lagoon surface water may contribute to animal levels. According to the data, there are health risks associated with the heavy metal contamination of Epe Lagoon's water. As a result, the lagoon requires heavy metal treatment and control.

In general, pollution in every aspect of human life has been a major concern to researchers and a global challenge [6]. In 2019, the World Health Organisation concluded that roughly 2 billion people drink water contaminated with excrement. In Sub-Saharan Africa (including Nigeria), 42% of the population relied on unimproved water sources for drinking, while 72% lacked access to basic sanitation. [7-8]. Because surface water is a precious resource used for a variety of reasons, its quality needs to be maintained and observed because most lagoons in the country are full of polymeric materials such as polyethylene terephthalate (PET), polyamide (nylon), etc., which cause the most blockage in drainages around the major cities in the country [9]. Water bodies possess an inherent capacity to adapt to the introduction of contaminants, employing dilution and organic matter breakdown facilitated by microorganisms. However, this buffering effect is lost when anthropogenic pollutants surpass threshold limits and cause pollution [10,20-21].

One of the main lagoons in Lagos, Nigeria, Epe Lagoon offers several advantages, such as swimming, fishing, and aquaculture. To support socio-economic activity, the lagoon is also used to convey goods and people to neighbouring cities and villages. Nonetheless, a significant amount of industrial, agricultural, and municipal trash is dumped into the lagoon [10]. Furthermore, home waste, including human faeces, is carelessly dumped into the lagoon. These pollutants can contaminate the lagoon, endangering the health of living organisms (aquatic and human). Additionally, it may put the lives of those who utilise the lagoon's services in peril. Therefore, it is crucial to conduct routine water quality tests on the lagoon to give primary data on its condition to state organisations responsible for environmental and public health. This will ensure that the lagoon continues to provide its services and safeguard the health of people and aquatic life. Inconsistent results have been found. A study conducted in 2021 focused on the bioaccumulation of heavy metals in the kidneys of scaly and non-scaly fish species from Epe Lagoon. It found significant concentrations of Cu, Zn, Fe, Pb, and Cd, with some levels surpassing safety thresholds, highlighting the need for monitoring and management of heavy metal pollution in the lagoon [12]. Another study conducted in 2022 assessed the concentrations of heavy metals in water samples from Epe Lagoon to evaluate associated health risks. The findings revealed non-permissible levels of lead (Pb), copper (Cu), nickel (Ni), cadmium (Cd), and chromium (Cr), with health risk indices exceeding recommended limits, underscoring the need for remediation efforts [13-14]. Furthermore, the majority of them failed to assess the water in the lagoon's health dangers, and there is a need to holistically evaluate the current state of the lagoon.

This research aims to provide a comprehensive analysis of the physico-chemical parameters and heavy-metal concentrations in Epe Lagoon. By evaluating the distribution and bioaccumulation of these pollutants, the study seeks to assess their implications for public health and the suitability of lagoon water for domestic and recreational uses. The findings will contribute to informed decision-making and the development of strategies to mitigate pollution and protect this critical ecosystem. The importance of water to every living thing cannot be over-emphasized due to the important roles it plays [15]. This also includes the everyday activities we carry out; apparently, none can be done without the involvement of water. Water as a natural resource is pivotal to human survival and an efficient tool for economic development [16]. It is important to a country's economic survival because it is utilised for transportation, recreation, agriculture, and the production of hydroelectric power [5]. Life is difficult to exist without the availability of water [6, 17]. Water is used for numerous purposes such as bathing, drinking, agricultural, medical, industrial, waste treatment, etc. Large bodies of water called lagoons offer vital functions that support the local economy and environment. Large bodies of water known as lagoons offer a variety of vital environmental and economic services, including transportation, erosion prevention, fishing, and water for residential, commercial, and agricultural purposes. Regrettably, lagoons are frequently contaminated by the disposal of industrial, agricultural, and municipal waste, putting aquatic life and people at risk for environmental and health problems [18]. Lagoon water is used in industrial, agricultural, and washing operations. Lagoons are used for a variety of economic activities, including fishing, shellfish harvesting, salt and sand mining, and maritime transportation [9, 19]. Lagoons also provide opportunities for urban growth, tourism, agriculture, and leisure. Coastal lagoons offer a variety of ecological benefits, such as storm protection, fish breeding sites, and maintaining the health of the marine environment.

Therefore, this study examined the heavy-metal and physicochemical profiling of the Epe lagoon in southwest Nigeria, identified possible sources of pollution, and evaluated the dangers to human and ecological health that are involved. In addition, this study aims to examine important physico-chemical characteristics at different sites and times, such as ph, dissolved oxygen, nutrients, and salinity. Determine the amount and geographic distribution of heavy metals (such as cadmium, lead, and mercury) present in the sediment of water. Also, to analyse the possible hazards to human well-being and the environment that may be connected to the found contamination. Provide useful information to support well-informed strategies for pollution control and water resource management

1. Study Area

Epe Lagoon is a significant coastal water body located in Epe, Lagos State, Nigeria. It serves as a vital hub for the region's fishing industry, with the Oluwo Fish Market, situated along its shores, being the largest in Lagos State. The lagoon's waters support various aquatic species, including tilapia, though some are contaminated with heavy metals, rendering them unsafe for consumption. Beyond its economic importance, the lagoon is surrounded by lush mangrove forests, which play a crucial role in protecting the coastline from erosion and serve as habitats for diverse wildlife. The area is also a focal point for cultural activities, such as the Kayo-Kayo Festival. The geographic position of the research area (Epe Lagoon). Its latitude coordinates are 06° 31.89' N and 06° 33.70' N, while its longitude coordinates are 03° 31.91' E and 04° 03.71' E. Its southern boundary is the Gulf of Guinea; its eastern, northern, and western borders are shared by several agricultural, residential and few industrial settlements within the region. **Fig. 1** shows the map of the lagoon (inserted are maps of Nigeria and Lagos state). The ticked parts are the areas under study, and they are 20 m apart to have a distinct outcome. The lagoon sustains a sizable fishery in Lagos State.

2. Sample Collection

Using accepted practices and procedures, samples of surface water were collected randomly from 15 locations in the study region. The places with the lowest possible level of industrial activity were the control sites. Some samples were taken using a 2-litre polymer container that was rinsed with distilled water and washed in dilute hydrochloric acid to get rid of any contaminants that might have interfered with the qualitative analysis. Dates and sample point numbers were written on the labels of the sample bottles. The containers were repeatedly rinsed using the surface water at the sample collection location. The containers were immersed below the surface to allow overflow into them. In situ measurements were made of variables that change quickly, including conductivity, dissolved oxygen, temperature, turbidity, total dissolved solids, and pH. Separate samples were gathered for heavy metals, biochemical oxygen demand (BOD), and chemical oxygen demand (COD). Heavy metal samples were acidified using concentrated nitric acid to prevent the precipitation of any salt (cation). Using concentrated sulfuric acid, the chemical oxygen demand samples were made more acidic. The American Public Health Association [11] validated modified standard procedures, which were followed in the execution of the *ex-situ* analysis.

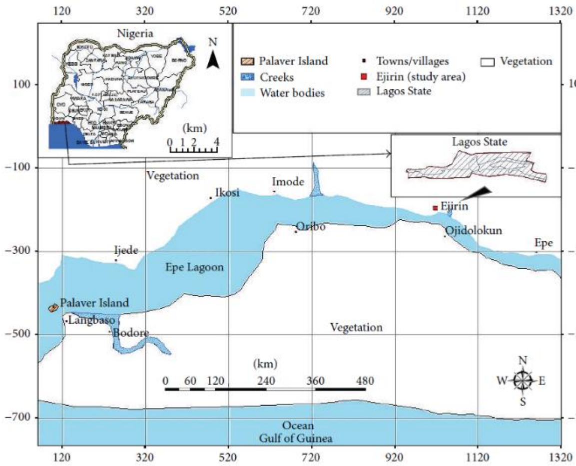

Figure 1. *Map of Epe lagoon with map of Nigeria (Top left) and map of Lagos State (top right)*

3. Laboratory analysis

The standard operating procedures created and approved at the laboratories served as the foundation for the analysis techniques. All of the techniques were followed according to the worldwide best practices shown in **Table 1**, and the specifications and techniques used to achieve these outcomes.

4. Sample analysis

The samples underwent statistical analysis, that is, descriptive statistics and a one-way analysis (ANOVA) were employed in the computation of the importance difference between the sampling areas at a 95% confidence level using SPSS software

II. Results

The physicochemical parameters of the surface water in the Epe lagoon in Lagos State, south-western Nigeria, are shown in **Tables 2** and **3** for the wet season and **Tables 4** and **5** for the dry season. The result gave a summary of the descriptive statistics of the physicochemical parameter and also the statistical difference between the sampling areas at a 95% confidence level. From **Table 3** and **Table**

5, $p>0.05$ shows that at a 95% confidence level, the difference in values obtained at different sampling areas is statistically insignificant, and $p<0.05$ shows that the difference is statistically significant.

Table 1. *The analytical methods for the parameters analysed in this study [11].*

Parametric quantity	*Analytical method of Physico-Chemical*
pH	Electronic method
Total Suspended Solids (TSS),	Gravimetric methods
Conductivity (µ) S/cm	APHA 2510
Turbidity (Nephelometric	Nephelometric method (APHA - 2130)
Total dissolved solids (TDS),	APHA 2540
Anions	
Nitrate, (mg/L)	Cadmium reduction method (ASTM, D3867)
Sulphate, (mg/L)	Turbidity method (APHA-426C)
Inorganics	
Magnesium (mg/L)	APHA-3500
PAHs	Polynuclear aromatic hydrocarbon (APHA 6440)
Metals	Atomic absorption spectrophotometer (AAS), (APHA
Gross organics	
BOD, (mg/L)	5day method (APHA 5210B)
DO, (mg/L)	APHA - 4500-O C
COD (mg/L)	Dichromate method (Reflux) (APHA - 5300 B

Table 2. *Heavy metal analysis of samples from Epe Lagoon during the wet season.*

Sampling region				*Control region*	
Parameter	***Mean ± SD***	***Range***	***P-value, 95%***	***Mean ± SD***	***Range***
Arsenic (Ar) mg/L	<0.005	<0.005	P >0.05	<0.005	-
Barium (Ba), mg/L	<0.005	<0.005	-	<0.005	-
Cadmium (Cd),	0.012 ± 0.003	0.01 - 0.015	P >0.05	0.04 ± 0.03	0.01 - 0.06
Chromium (Cr),	39 ± 5.37	35 – 50	--	30.21 ± 3.47	26.43 - 36.19
Copper (Cu), mg/L	0.09 ± 0.06	0.01 -0.19	P >0.05	0.02 ± 0.02	0.004 - 0.033
Iron (Fe), mg/L	1.23 ± 0.72	0.01 - 2.93	--	7.05 ± 9.77	0.08 - 21.53
Lead (Pb), mg/L	<0.01	<0.01	P >0.05	<0.001	-
Vanadium (V),	<0.001	<0.001	--	-	-
Zinc (Zn), mg/L	1.21 ± 0.25	1.15 - 1.32	P >0.05	0.92 ± 0.45	0.05 - 1.46

Table 3. *Physicochemical parameters of samples collected from Epe Lagoon during the wet season.*

	Sampling region			***Control Region***	
Parameters	***Mean ± SD***	***Range***	***P-value, 95%***	***Mean± SD***	***Range***
pH	7.88 ± 0.21	7.12 - 8.30	P > 0.05	7.42 ± 0.30	7.38 - 8.03
Electrical conductivity, μS/cm	27432 ± 20.87	17932–28305	P >0.05	24145 ± 20.87	16932 - 26305
Total suspended solids (TSS), mg/L	32 ± 4.59	25 – 41	P >0.05	27 ± 12.12	26 - 29
Total dissolved solids (TDS), mg/L	14121 ± 11.30	920 – 1890	P >0.05	11864 ± 4319	900 – 16050
Dissolved Oxygen (DO), mg/L	8.64 ± 3.2	7.12 – 9.0	P >0.05	8.84 ± 3.5	7.92 – 9.20
Biochemical Oxygen demand (BOD), mg/L	1.75 ± 0.54	0.89 – 2.08	P >0.05	1.87 ± 0.53	1.68 - 2.00
Chemical oxygen demand (COD), mg/L	3.40 ± 0.40	2.8 – 3.8	P >0.05	3.15 ± 0.35	3.05 – 3.25
Turbidity, NTU	36.55 ± 2.21	30.05 - 41.06	P >0.05	34.63 ± 3.94	31.23 – 34.12
			Organic (mg/L)		
Polynuclear aromatic hydrocarbon (PAHs)	0.22 ± 0.21	0.05 - 1.06	P >0.05	0.12 ± 0.09	0.05 - 0.26
Benzene toluene ethylbenzene	<0.005	<0.005	--	<0.005	
			Anions(mg/L)		
Sulphate	372 ± 20.9	303 – 781	P >0.05	295 ± 24.0	239.74 - 581.57
Nitrate	0.02 ± 0.01	0.002 - 0.032	P<0.05	0.01 ± 0.005	0.014 - 0.022
			Cations(mg//L)		
Magnesium	34 ± 1.10	32 – 36	P >0.05	28.49 ± 10.36	19.33 - 43.25
Sodium	3886 ± 128	3651 – 4136	P >0.05	3291 ± 198	2234 - 4999

Table 4. *Physicochemical parameters of samples from the Epe Lagoon during the dry season.*

	Sampling region			***Control region***	
Parameter	**Mean ± SD**	**Range**	**P-value, 95%**	**Mean ± SD**	**Range**
pH	7.95 ± 0.22	7.22 - 8.30	P >0.05	7.30 ± 0.31	7.58 - 8.12
Electrical conductivity, µS/cm	27219 ± 2850	18010 - 29920	P >0.05	23740 ± 8596	16150 - 35980
Total suspended solids (TSS), mg/L	37.23 ± 1.30	28 - 34.5	P >0.05	28.75 ± 1.20	25.5 - 30.5
Total dissolved solids (TDS), mg/L	4194 ± 459	3360 - 6911	P >0.05	10864 ± 931	9890 - 12020
Dissolved oxygen (DO), mg/L	2.84 ± 0.44	3.12 - 3.19	P >0.05	2.84 ± 0.67	2.68 - 3.91
Biochemical oxygen demand (BOD), mg/L	1.05 ± 0.54	0.01 - 1.61	P >0.05	0.87 ± 0.53	0.48 - 1.24
Chemical oxygen demand (COD), mg/L	4.23 ± 0.6	3.60 – 4.78	P >0.05	3.0 ± 0.5	2.8 – 3.6
Turbidity, NTU	25.55 ± 0.21	27.50 - 31.06	P >0.05	24.63 ± 0.94	14 - 26
		Organic (mg/L)			
Polynuclear aromatic hydrocarbon (PAHs)	0.22 ± 0.01	0.05 - 1.06	P >0.05	0.10 ± 0.09	0.05 - 0.26
Benzene toluene ethylbenzene	<0.005	<0.005	--	<0.005	
		Anions (mg/L)			
Sulphate	370 ± 20.9	303 - 581	P >0.05	290 ± 24.0	239.74 - 381.57
Nitrate	0.02 ± 0.01	0.002 - 0.032	P <0.05	0.01 ± 0.005	0.014 - 0.022
		Cations (mg//L)			
Magnesium	28 ± 1.10	22 - 33	P >0.05	30.49 ± 9.36	19.33 - 33.25
Sodium	4134 ± 102	2568 - 4236	P >0.05	3271 ± 198	2434 - 4699

Table 5. Heavy metals analysis of samples from Epe Lagoon during the dry season.

	Sampling Region		*P-value*	*Control Region*	
Parameters	***Mean ± S.D***	***Range***	***P-value, 95%***	***Mean ± S.D***	***Range***
Arsenic (Ar), mg/L	<0.005	-	-	<0.005	-
Barium (Ba), mg/L	<0.005	<0.005	-	<0.005	-
Cadmium (Cd), mg/L	4.9 ± 1.15	3.61 - 5.32	P > 0.05	5.53 ± 1.84	4.72 – 9.64
Chromium (Cr), mg/L	<0.006	<0.006	-	<0.006	-
Copper (Cu), mg/L	3.56 ± 0.69	2.23 - 5.04	P > 0.05	3.08 ± 0.92	1.93 - 4.20
Iron (Fe), mg/L	9.54 ± 1.41	8.14 - 11.51	P > 0.05	2.22 ± 0.04	1.17 - 2.26
Lead (Pb), mg/L	0.13 ± 0.05	0.04 - 0.26	P > 0.05	0.12 ± 0.06	0.08 - 0.20
Vanadium (V), mg/L	<0.005	<0.005	-	<0.005	-
Zinc (Zn), mg/L	<0.001	<0.001	-	<0.001	-

1. Physicochemical parameters of Epe Lagoon

The pH levels in the sampling areas ranged from 7.12 to 8.30 during the wet season and 7.22 to 8.30 during the dry season. In comparison, the control area had pH values between 7.38 and 8.03 in the dry season and 7.58 to 8.12 in the wet season. There was no significant difference in pH between the sampling areas ($p > 0.05$). The average pH in the control area was 7.42 ± 0.30, which is lower than the average pH of 7.88 ± 0.21 recorded at the sampling points during the wet season. As shown in **Fig. 2**, the average pH in the sampling areas during the dry season was 7.95 ± 0.22, slightly higher than the control area's pH of 7.30 ± 0.31, shown in **Fig. 3**.

Total suspended solids (TSS) in the sampling areas ranged from 25 to 41 mg/L in the wet season and 28 to 34.5 mg/L in the dry season. In the control areas, TSS ranged from 26 to 29 mg/L during the wet season and 25.5 to 30.5 mg/L during the dry season. There was no significant statistical difference in TSS between the sampling areas ($p > 0.05$). The average TSS in the sampling areas was 32 ± 4.59 mg/L during the wet season, higher than the control area's 27 ± 12.12 mg/L, as shown in Figure 2. Similarly, in the dry season, the sampling areas had a higher average TSS of 37.23 ± 1.30 mg/L compared to 28.75 ± 1.20 mg/L in the control area, as seen in **Fig. 3**.

The turbidity value ranges from 30.05 to 41.06 NTU and 27.50 to 31.06 NTU for the wet season and dry season, respectively. In the control area, turbidities of 31.23 to 34.12 NTU and 14–26 NTU were obtained for the wet season and dry season, respectively. There are no statistically reliable disparities between sampling areas for turbidity values ($p>0.05$) at a 95% confidence interval. The mean turbidity values of 36.55 ± 2.21 and 25.55 ± 0.21 NTU obtained from the sampling area for the wet and dry seasons, respectively, were slightly higher compared to the mean values of 34.63 ± 3.94 and 24.63 ± 0.94 NTU recorded in the control areas in the wet and dry seasons, as seen in **Figs. 2** and **3**.

From **Tables 3** and **4**, the electrical conductivity (EC) at the sampling areas is 17932 to 28305 µs/cm and from 18010 to 29920 µs/cm for the wet season and dry season, respectively. EC results were obtained from a control area range of 16932–26305 µS/cm and 16150–35,980 µS/cm for the wet season and dry season, respectively. The average electrical conductivity results obtained from the sampling area for wet and dry seasons are 27432 ± 20.87 and 27219 ± 2850, respectively. **Figs. 4** and **5** show their relationship, and the results show no statistical difference in sampling areas.

The total dissolved solids (TDS) in the sampling areas ranged from 920 to 1890 mg/L in the wet season and 3360 to 6911 mg/L in the dry season. In the control areas, TDS values ranged from 900 to 16050 mg/L during the wet season and 9890 to 12020 mg/L in the dry season. The average TDS in the sampling areas was 14121 ± 11.30 mg/L (wet season) and 4194 ± 459 mg/L (dry season). In the control areas, the average TDS was 11864 ± 4319 mg/L (wet season) and 10864 ± 931 mg/L (dry season). There was no significant difference in TDS between the sampling areas ($p > 0.05$). **Figs. 4** and **5** illustrate these results.

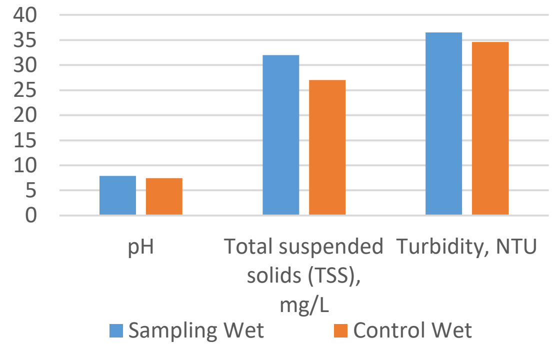

Figure 2. *Average pH, total suspended solids, and turbidity concentration from sampling areas compared to areas in the wet season.*

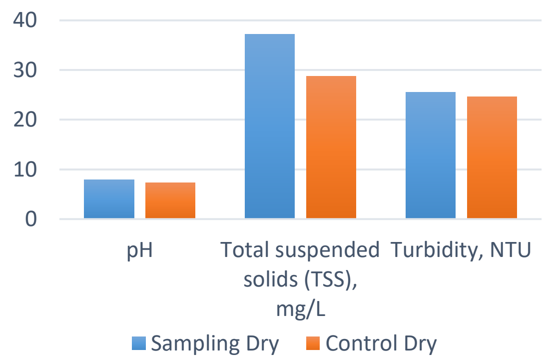

Figure 3. *Average ph, total suspended solids, and turbidity from sampling areas compared to control areas during the dry season.*

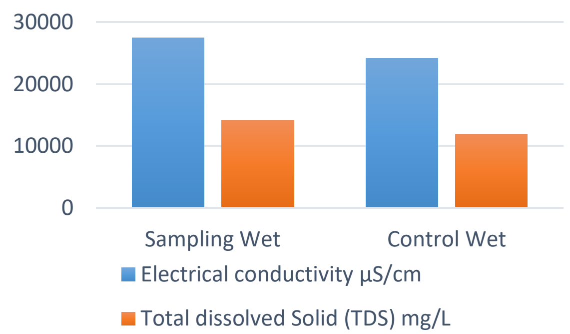

Figure 4. *Electrical Conductivity (EC) and Total Dissolved Solids in the wet season.*

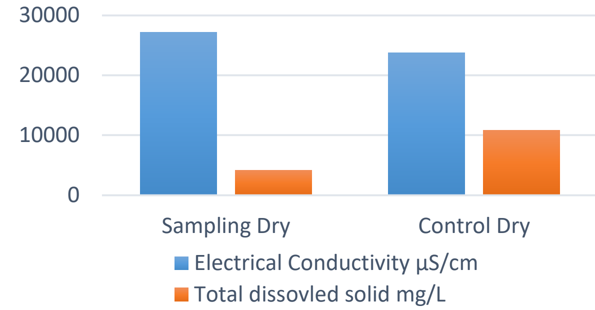

Figure 5. *Electrical Conductivity (EC) and Total Dissolved Solids for the dry season*

Tables 3 and **4** also give the results of the dissolved oxygen (DO) from 7.12 to 9.0 mg/L and 3.12 to 3.19 mg/L for the wet season and dry season, respectively. The control DO ranges are 2.68–3.91 mg/L in the dry season and 7.92–9.20 mg/L in the rainy season, respectively.

All the sampling areas analysed showed no significant difference in DO statistical values ($p>0.05$) at a 95% confidence level. Meanwhile, the average DO values obtained from the sampling areas for the wet season and dry season are 8.64 ± 3.2 mg/L and 2.84 ± 0.44 mg/L, respectively, and for the control wet and dry seasons, they are 8.84 ± 3.5 mg/L and 2.84 ± 0.67 mg/L, respectively. **Figs. 6** and **7** give a bar chart of these results.

Tables 3 and **4** also give the results of the biochemical oxygen demand (BOD) from 0.89 to 2.08 mg/L and 0.01 to 1.61 mg/L for the wet season and dry season, respectively. The range of values of the control BOD obtained for the wet and dry seasons is 1.68–2.00 mg/L and 0.48–1.24 mg/L, respectively. All the sampling areas analysed showed no significant difference in BOD statistical values ($p>0.05$) at a 95% confidence level. Meanwhile, the mean BOD values obtained for the sampling areas for the wet season and dry season are 1.75 ± 0.54 mg/L and 1.05 ± 0.54 mg/L, respectively, and for the control wet season and dry season are 1.87 ± 0.53 mg/L and 0.87 ± 0.53 mg/L, respectively. **Figs. 6** and **7** give a bar chart of these results.

Tables 3 and **4** show that chemical oxygen demand (COD) in the sampling areas ranged from 2.8 to 3.8 mg/L in the wet season and 3.60 to 4.78 mg/L in the dry season. In the control areas, COD ranged from 3.05 to 3.25 mg/L (wet season) and 2.8 to 3.6 mg/L (dry season). There was no significant difference in COD between the sampling areas ($p > 0.05$). The average COD in the sampling areas was 3.40 ± 0.40 mg/L for the wet season and 4.23 ± 0.6 mg/L for the dry season. In the control areas, the averages were 3.15

± 0.35 mg/L (wet season) and 3.0 ± 0.5 mg/L (dry season). **Figs. 6** and **7** show these results as bar charts

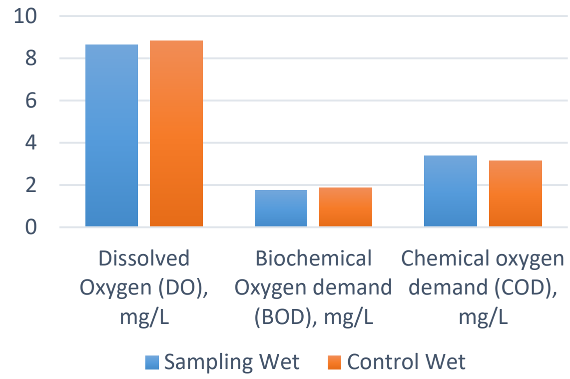

Figure 6. *Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), and Chemical Oxygen Demand (COD) in the wet season*

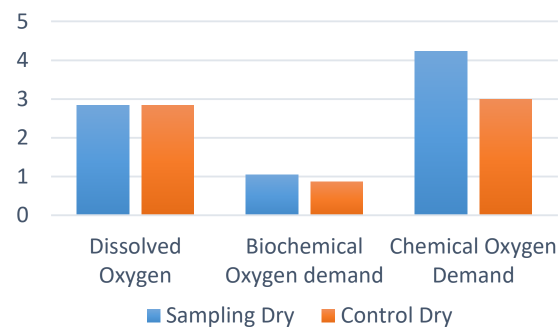

Figure 7. *Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), and Chemical Oxygen Demand (COD) during the dry season.*

Tables 3 and **4** show that the levels of Polynuclear Aromatic Hydrocarbons (PAHs) in the sampling areas ranged from 0.05 to 1.06 mg/L during both the wet and dry seasons. In the control areas, PAH levels ranged from 0.05 to 0.26 mg/L for both seasons. There was no significant difference in PAH levels between the sampling areas ($p > 0.05$). The average PAH values were 0.22 ± 0.01 mg/L in both seasons for the sampling areas, and 0.12 ± 0.09 mg/L (wet) and 0.10 ± 0.09 mg/L (dry) for the control areas. **Figs. 8** and **9** display these results as bar charts.

Tables 3 and **4** also show nitrate levels in the sampling areas ranging from 0.002 to 0.032 mg/L during both the wet and dry seasons. In the control areas, nitrate levels ranged from 0.014 to 0.022 mg/L in both seasons. There was no significant difference in nitrate levels among the sampling areas ($p < 0.05$) at the 95% confidence level. The average nitrate values for the sampling areas during the wet and dry seasons are 0.02 ± 0.01 mg/L and 0.22 ± 0.01 mg/L, respectively, and for the control wet season and dry season are 0.01 ± 0.018 mg/L and 0.016 ± 0.01 mg/L, respectively. **Figs. 8** and **9** give a bar chart of these results.

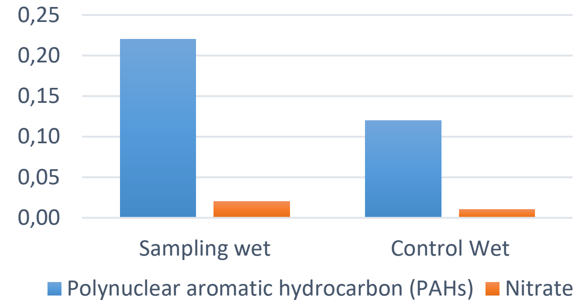

Figure 8. *Polynuclear aromatic hydrocarbon (PAHs) and Nitrate for the wet season.*

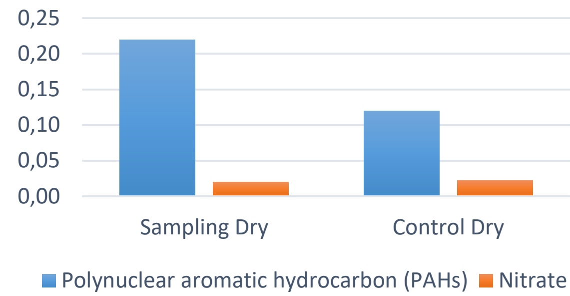

Figure 9. *Polynuclear aromatic hydrocarbon (PAHs) and Nitrate for the dry season*

Tables 3 and **4** also give the results of the sulphate of 303 to 781 mg/L and 239.74 to 581.57mg/L for the dry season and wet season from the sampling area, respectively. The values of the control sulphate obtained for the wet season and dry season are 239.74 to 581.57 mg/L and 239.74 to 381.57 mg/L, respectively. All the sampling areas analysed showed no significant difference in sulphate statistical values ($p>0.05$) at a 95% confidence level. Meanwhile, average sulphate values obtained from the sampling areas for the wet season and dry season are 372 ± 20.9 mg/L and 370 ± 20.9 mg/L, respectively, and for the control wet season and dry season are 295 ± 24.0 mg/L and 295 ± 24.0 mg/L, respectively. **Figs. 10** and **11** give a bar chart of these results.

Tables 3 and **4** show that magnesium levels in the sampling area ranged from 32 to 36 mg/L during the wet season, from 22 to 33 mg/L in the sampling areas, and from 22 to 33 mg/L in the dry season. In the control samples, levels ranged from 19.33 to 43.25 mg/L (wet season) and 19.33 to 33.25 mg/L (dry season). There was no significant difference in magnesium levels between the sampling areas (p >

0.05). The average magnesium levels in the sampling areas were 34 ± 1.10 mg/L (wet season) and 28 ± 1.10 mg/L (dry season). In the control areas, averages were 28.49 ± 10.36 mg/L (wet season) and 30.49 ± 9.36 mg/L (dry season). These values are also shown in **Figs. 10** and **11**.

Tables 3 and **4** also show sodium levels ranging from 3651 to 4136 mg/L (wet season) and 2568 to 4236 mg/L (dry season) in the sampling areas. In the control areas, sodium levels ranged from 2234 to 4999 mg/L (wet season) and 2434 to 4699 mg/L (dry season). Again, there was no significant difference in sodium levels between the sampling areas ($p > 0.05$). The average sodium levels were 3886 ± 128 mg/L (wet season) and 4134 ± 102 mg/L (dry season) in the sampling areas, and 3291 ± 198 mg/L (wet season) and 3391 ± 198 mg/L (dry season) in the control areas. These values are also shown in **Figs. 10** and **11**.

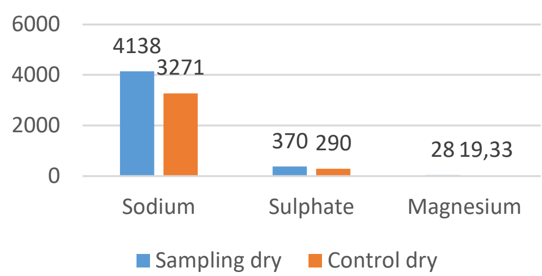

Figure 10. *Sulphate and Sodium for the wet season.*

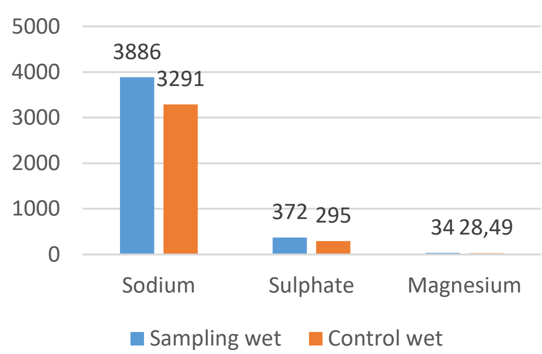

Figure 11. *Sulphate, Sodium and Magnesium for the wet season*

2. Heavy-metal analysis of Epe Lagoon

Tables 2 and **5** also give the results of the Iron (Fe) levels of 0.01 - 2.93 mg/L and 8.14 - 11.51 mg/L for the wet season and dry season of the sampling area, respectively. Ranged values of control Fe obtained for wet and dry seasons are 0.08 - 21.53 mg/L and 1.17 to 2.26 mg/L, respectively. All the sampling areas analysed showed no significant difference in Fe statistical values ($p>0.05$) at a 95% confidence level. Meanwhile, mean Fe values obtained from the sampling areas for wet and dry seasons are 1.23 ± 0.72 mg/L and 9.54 ± 1.41 mg/L, respectively. For control wet season and dry season are 7.05 ± 9.77 mg/L and 2.22 ± 0.04 mg/L, respectively. **Figs. 12** and **13** give a bar chart of these results.

Tables 2 and **5** also give the results of the Chromium (Cr) levels of 35 - 50 mg/L and an average value of 39 ± 5.37 mg/L for the wet season. The control area also has a value of 26.43 to 36.19 mg/L and an average value of 30.21 ± 3.47 for the wet season. All the sampling areas analysed showed no significant difference in Cr statistical values ($p>0.05$) at a 95% confidence level. There were traces of Cr in the control and sampling areas during the dry season. **Figs. 12** and **15** give a bar chart of these results.

Tables 2 and **5** also give the results of the Copper (Cu) levels of 0.01 - 0.19 mg/L and 2.23 - 5.04 mg/L for the wet season and dry season of the sampling area, respectively. Ranged values of control Cu obtained for wet and dry seasons are 0.004 - 0.033 mg/L and 1.93 - 4.20 mg/L, respectively. All the sampling areas analysed showed no significant difference in Cu statistical values ($p >0.05$) at a 95% confidence level. Meanwhile, mean Cu values obtained from the sampling areas for wet and dry seasons are 0.09 ± 0.06 mg/L and 3.56 ± 0.69 mg/L, respectively, for the control wet season and dry season are 0.02 ± 0.02 mg/L and 3.08 ± 0.92 mg/L, respectively. **Figs. 13** and **14** give a bar chart of these results.

Tables 2 and **5** also give the results of the Cadmium (Cd) levels of 0.01 - 0.015 mg/L and 3.61 - 5.32 mg/L for the wet season and dry season of the sampling area, respectively. The values of control Cd obtained for wet and dry seasons are 0.01 - 0.06 mg/L and 4.72 – 9.64 mg/L, respectively. All the sampling areas analysed showed no significant difference in Cd statistical values ($p >0.05$) at a 95% confidence level. Meanwhile, average Cd values obtained from the sampling areas for the wet season and dry season are 0.01 ± 0.003 mg/L and 5.53 ± 1.84 mg/L, respectively. For the control, the concentrations in the wet and dry seasons are 0.012 ± 0.003 mg/L and 4.9 ± 1.15 mg/L, respectively. **Figs. 13** and **14** give a bar chart of these results.

Tables 2 and **5** also give the results of the Lead (Pb) levels of 0.04 - 0.26 mg/L for dry seasons of the sampling area and the mean value of 0.13 ± 0.05. The control area also has a value of 0.08 - 0.20 mg/L and the average value of 0.12 ± 0.06 mg/L. All the sampling areas analysed showed no significant difference in COD statistical values ($p>0.05$) at a 95% confidence level. There were no traces of Pb in the control and sampling areas during the wet season. **Figs. 14** and **15** give a bar chart of these results.

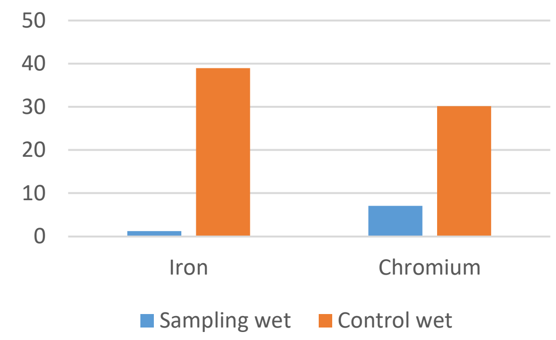

Figure 12. *Iron and Chromium for the wet season*

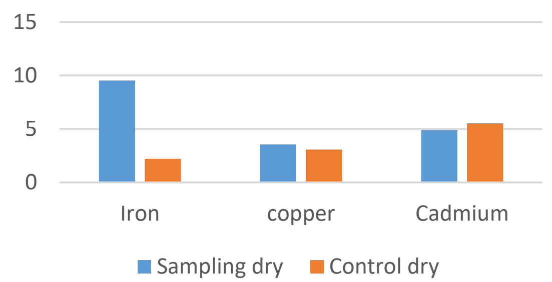

Figure 13. *Iron, Copper, and Cadmium for the dry season*

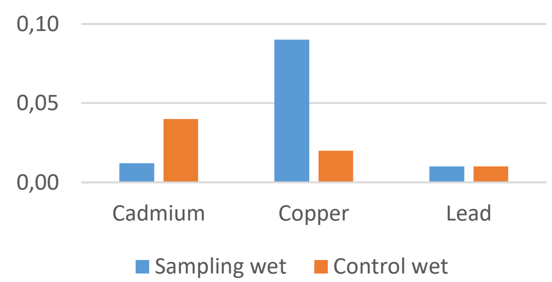

Figure 14. *Cadmium, Copper and Lead for the wet season*

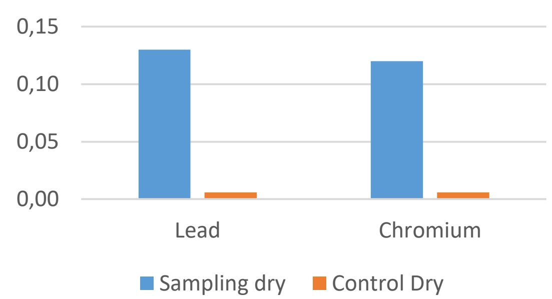

Figure 15. *Lead and Chromium for the dry season*

III. Discussion

1. Physicochemical parameters

According to [9], optimal pH levels for aquatic organisms range from 6.5 to 9. This study found that pH values in both the sampling and control areas fall within this range and also meet WHO standards for drinking water.

High electrical conductivity (EC) in both the sampling and control areas is likely due to seawater intrusion, with even higher values in the dry season from increased evaporation [9]. These EC levels exceed WHO-recommended limits, as noted in **Table 6**.

Total suspended solids (TSS) in the sampling areas were low, with values of 32 mg/L in the wet season and 37.23 mg/L in the dry season, both below the WHO limit of 50 mg/L, as shown in **Table 6**.

Total dissolved solids (TDS) levels in the lagoon were far above the WHO drinking water limit of 500 mg/L in both wet and dry seasons, indicating the water is unsuitable for drinking or domestic use. This is likely due to seawater and freshwater mixing, consistent with previous studies reporting similarly high TDS values [12, 15, 23-26].

The dissolved oxygen (DO) levels in the sampling and control areas were 8.64 and 8.84 mg/L in the wet season, slightly higher than the Nigerian Standard for Drinking Water Quality (NSDWQ) recommendation of 5 mg/L. However, in the dry season, the DO levels were 2.84 mg/L in both the sampling and control areas, which is below the recommended value. Similar low DO levels were reported by [15], [16], and [17], with values as low as 1.21 mg/L in the dry season.

Biochemical oxygen demand (BOD) values in this study were 1.75 mg/L (wet season) and 1.05 mg/L (dry season), suggesting some microbial activity in the area. This also indicates possible pollution by microbes. The low chemical oxygen demand (COD) values suggest fewer chemical activities in the region, which could mean less agricultural runoff, as low COD is often linked to less agricultural activity [17].

Turbidity, which refers to water cloudiness caused by suspended particles, is an important public health indicator. High turbidity values of 36 mg/L (wet season) and 25 mg/L (dry season) were found, well above the NSDWQ and WHO recommendations of 5 mg/L, making the water unsafe to drink. This high turbidity could be due to activities around the lagoon, such as washing and bathing.

The polynuclear aromatic hydrocarbons (PAHs) in the study were 0.22 mg/L for both seasons, which is high compared to the NSDWQ standard of 0.007 mg/L. This suggests that human activities, particularly industrial activities, are contributing to higher PAH levels in the lagoon [16]

Sulphate levels in the sampling areas were higher than the WHO limit of 250 mg/L, with slight seasonal variation. This elevation is likely due to pollution from insecticides and fossil fuel combustion in nearby residential areas. Similar high sulphate values have been reported in previous studies [10, 17, 23-26].

Nitrate levels in both the sampling and control areas were below the recommended limits by NSDWQ (2007) and WHO (2011), likely due to minimal farming activity in the region. Low nitrate levels help prevent increases in the lagoon's biochemical oxygen demand (BOD) [19,21,25]

The study found elevated sodium levels in both the sampling and control areas, exceeding recommended drinking water limits, likely due to seawater intrusion. Magnesium levels were also high, attributed to rock weathering around the lagoon, consistent with previous findings

2. Heavy-metal

Some heavy metals were found in traces, such as Arsenic, Barium, Cadmium, Chromium, and Zinc in the sampling and control areas during the wet seasons, while Arsenic, Barium, and Cadmium were found in traces during dry seasons. These traces can be ascribed to some deteriorating galvanised plumbing rods and some distant industrial waste contamination, or surface water contamination.

Iron (Fe) levels in both the sampling and control areas significantly exceeded the recommended limit of 0.3 mg/L set by the Nigerian Standard for Drinking Water Quality (2007) and the WHO (2011), particularly in the sampling area during the dry season. Similar high concentrations reported in previous studies are attributed to redox reactions occurring within the water body.

According to [19] and [12], the allowable value of lead (Pb) is 0.01 mg/L. The results of lead obtained at the sampling and control areas were below the recommended values for the wet season and above the recommended value of 0.01 mg/L for the dry season. The values obtained from the dry season could be ascribed to the concentration of water obtained by evaporation due to the sun is slightly above the recommended value. This can be attributed to the washing of chromates from the soil surface to the lagoon during the wet season. Also, the value of copper (Cu) obtained in this study during dry seasons does not conform to the World Health Organisation's (2011) advisory limit of 2 mg/L for drinking water (**Table 6**). The value obtained from the sampling site during the wet season conforms to the recommended value by the WHO. This could be attributed to the flow of water from plumbing pipes made from copper and brass in the home. Zinc levels varied by season, with higher concentrations in the wet season (1.21 mg/L) and very low traces in the dry season, all within WHO and NSDWQ limits, indicating minimal industrial discharge and corrosion. However, chromium levels in both sampling and control areas exceeded WHO limits, making the water unsuitable for domestic use due to potential health risks. (2011) recommended limit of 0.05 mg/L as shown in **Table 6**, for drinking water, the values from the wet season are well above the recommended value, and those from the dry season.

IV. Conclusion and Recommendation

1. Conclusion

. The total suspended solids, as well as turbidity, obtained in this study signified a low impact of agricultural activity by humans around this region. DO, and heavy metals excluding Zinc, PAHs, and sulphate, did not conform to the recommended standards by WHO and the Nigerian Standard for Drinking Water Quality. The obtained results may be due to a large amount of human activity around the lagoon, as the lagoon is greatly surrounded by residential houses and many human activities like fishing, washing, swimming, and the like.

However, the EC, Sodium, and TDS obtained in the sampling and control area in this study did not agree with the standards set by WHO and NSDWQ due to their advisory limits; the results were within the confines typical of brackish water. High EC, TDS, and sodium obtained in this paper may be ascribed to seawater inflow. Disparities or differences in results may be due to erosion, which tends to wash the upper soil layer of the lagoon, and also evaporation during dry seasons due to high temperatures in the region.

This study provides a comprehensive and up-to-date physico-chemical and heavy metals profile of the Epe Lagoon, offering critical baseline data for environmental monitoring and management. By identifying elevated concentrations of certain heavy metals and deviations in key water quality parameters, the research highlights potential ecological and public health risks. The findings support evidence-based policymaking for sustainable lagoon management and contribute to the broader understanding of anthropogenic impacts on tropical aquatic ecosystems.

Table 6. *Quality standard drinking water [12] [23].*

Parameter	***WHO (2011)***	***NSDWQ (2007)***
pH	6.5 to 8.5	
Conductivity, µS/cm	1.0×10^3	1.0×10^3
Dissolved oxygen, mg/L	–	5.0
Total dissolved solids (TDS), mg/L	5.0×10^2	5.0×10^2
Turbidity, NTU	5.0	5
Total suspended solids (TSS), mg/L	5.0×10	-
Sulphate, mg/L	2.50×10^2	-
Nitrate, mg/L	5.0×10^{-2}	5.0×10
Sodium, mg/L	2×10^2	2×10^2
Copper, mg/L	2.0	-
Chromium, mg/L	5.0×10^{-2}	-
Iron, mg/L	3.0×10^{-1}	3.0×10^{-1}
Zinc, mg/L	3.0	3.0
Nickel, mg/L	3.0×10^{-2}	–
Cadmium, mg/L	3.0×10^{-3}	–
Lead, mg/L	1.0×10^{-2}	1.0×10^{-2}
Polynuclear Aromatic Hydrocarbons (PAHs), mg/L	–	7.0×10^{-3}

2. Recommendation

Human activities around the lagoon should be monitored; this will help prevent some contaminants from finding their way into the lagoon, thereby improving the lagoon's water quality and environmental safety.

Also, constant study and monitoring of the heavy-metal properties of the lagoon and physicochemical parameters should be done every three months to know the measures or precautions to be taken for better health, societal, and environmental impact on the residents within the environment.

To mitigate contamination in the Epe Lagoon, authorities should enforce stricter regulations on waste disposal, limit agricultural and industrial runoff, and implement routine water quality monitoring. Public awareness campaigns and the development of sustainable land-use practices around the lagoon are also essential to preserve water quality and protect public health.

Acknowledgements

The authors are grateful to the engineering faculty at Lead City University, especially the Department of Mechanical Engineering and Civil Engineering, for the opportunity to carry out the research work.

Author Contributions

O. Adepitan: Conceptualisation, Experiments, Theoretical analysis, and manuscript compilation.
A. Fasasi-Aleshinloye: Experiments, Theoretical analysis, and manuscript compilation.
O. Aforolagba-Balogun: Manuscript compilation and reviewing.
T. Ladigbolu: Revision of manuscript.

Disclosure Statement

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

ORCID

Omogbolade L. Adepitan: http://orcid.org/0009-0007-6939-9207

Abidat O. Fasasi-Aleshinloye: http://orcid.org/0009-0008-6502-4640

REFERENCES

[1] A. M. Mustapha, A.Y. Ugya, Z. Mustapha, Assessment of Heavy Metal Levels in Fish Tissues, Water and Sediment from Epe Lagoon, Lagos, Nigeria. Science World Journal, 16 (4) (2021) pp. 464-469.

[2] A.M. Taiwo, *et al*., Assessment of Water Quality Index and the Probable Human Health Implications of Consuming Packaged Groundwater from Abeokuta and Sagamu, Southwestern Nigeria. Sustainability, 15 (4) (2023) 3566. https://doi.org/10.3390/su15043566

[3] R. Dinrifo, S. Babatunde, Y. Bankole, Q. Demu, Physico-chemical properties of rainwater collected from some Industrial areas of Lagos State, Nigeria. European Journal of Science Research, 41 (3) (2010) pp. 383–390.

[4] M.B. Addisie, T.Y. Gelaye, W.M. Teshome, Households' reluctance to collect potable water from improved sources, Ethiopia. AQUA - Water Infrastructure, Ecosystems and Society, 70 (6) (2021) pp. 868–878. https://doi.org/10.2166/aqua.2021.158

[5] S.A. Ojelabi, et al. Water Quality Assessment of Eleyele Dam, Ibadan, South-Western Nigeria. Civil and Environmental Research. 40 (8) (2018) pp. 52-59.

[6] A.G. Okeniyi, et al. Capacity and Quality Assessment of Awba Dam. Civil and Environmental Research, 11 (2) (2013) pp. 345-353.

[7] O. Aiyelokun, A. Ojelabi, A. Olaniyi, An underground-based Municipal Water Supply System for a Rural Community. Mayfeb Journal of Civil Engineering. 1 (1) (2017) pp. 1-9.

[8] T. Yahaya, et al., Concentrations and health risk parameters of heavy metals in water samples from Epe Lagoon in Lagos State, Nigeria. Dutse Journal of Pure and Applied Sciences, 8 (2b) (2022) pp. 149-157. https://doi.org/10.4314/dujopas.v8i2b.15

[9] O. L. Adepitan, et al. E-Waste Management: The Nigerian Case (Overview). International Journal of Agriculture and Environmental Research, 9 (4) (2023) pp. 650–661. https://doi.org/10.51193/ijaer.2023.9411

[10] M G. Nimota. Morphometric and meristic characteristics of silver catfish Chrysichthys nigrodigitatus (Lacepède, 1803) (Siluriformes: Claroteidae) from Epe Lagoon, Lagos, Southwest Nigeria. Brazilian Journal of Biological Sciences. 5 (2018) pp. 125-131. https://10.21472/bjbs.050913.

[11] D. Okoro, L. C. Diejomaoh, Profiling the surface water around Odeama Community of the Niger Delta area of Nigeria. Journal of Environmental Chemistry and Ecotoxicology, 14 (1) (2022) pp. 9–25. https://doi.org/10.5897/jece2021.0485

[12] R. Eberhard Access to water and sanitation in sub-Saharan Africa. Review Sector Report, Investments, and Key Findings for Infrastructure Future Support to Sector Development. 2019.

[13] O. L. Adepitan, A. O. Fasina. Evaluating the structural performance of waste PET-infused interlocking units versus traditional stone masonry. Engineering and Technology Journal, 43 (4) (2024) pp. 1–10. https://doi.org/10.30684/etj.2024.145504.1656

[14] O. Akinnifesi, et al., Occurrence and Impact of Heavy Metals on Some Water, Land, Flora and Fauna Resources across Southwestern Nigeria. In IntechOpen eBooks. 2021. https://doi.org/10.5772/intechopen.4982

[15] APHA. Standard Methods for the Examination of Water and Wastewater, 21st edn. American Public Health Association, Washington, DC. 2015

[16] World Health Organisation (WHO). National systems to support drinking water: Sanitation and hygiene: Global status report: UN-Water global analysis and assessment of sanitation and drinking water: GLAAS 2019 report

[17] J. Osokpor, E. G. Maju-Oyovwikowhe, Paleodepositional Environment and Sequence Stratigraphy of Miocene Sediments in Well TN-1, Coastal Swamp Depo belt, Niger Delta Basin, Nigeria, Tanzania Journal of Science, 47 (5) (2021) pp. 1530–1545. http://doi.org/10.4314/tjs.v47i5.4

[18] A.O. Adeniyi, et al. Levels of polycyclic aromatic hydrocarbons in water and sediment of Buffalo River estuary, South Africa and their health risk assessment. Environmental Contamination and Toxicology, 76 (2019) pp. 657-669.

[19] O.S, Edori, M. Idomo, B.S.K, Chioma. Physicochemical characteristics of surface water and sediments of Silver River, Southern Ijaw, Bayelsa State, Niger Delta, Nigeria. American Journal of Environmental Science and Engineering, 3 (2) (2019) pp. 39-46.

[20] O. Odigie, J.O. Olomukoro. Physicochemical profiles and water quality indices of surface waters collected from Falcorp Mangrove Swamp, Delta State, Nigeria. Journal of Applied

Science and Environmental Management, 24 (2) (2020) pp. 357-365. https://doi.org/10.4314/jasem.v24i2.23

[21] C. N., Egbinola, A. C. Amanambu. Groundwater contamination in Ibadan, South-West Nigeria. Springer Plus, 3 (1) (2014). https://doi.org/10.1186/2193-1801-3-44

[22] Z. O. Ojekunle, et al., Assessment of physicochemical characteristics of groundwater within selected industrial areas in Ogun State, Nigeria, Environmental Pollutants and Bioavailability, 32 (1) (2020) pp. 100–113. http://doi:10.1080/26395940.2020.1780157.

[23] Nigerian Standard for Drinking Water Quality 2007. Standard Organisation of Nigeria, Abuja, Nigeria

[24] M.S Alam, B. Han, A. Gregg, J. Pichtel, Nitrate and biological oxygen demand changed in a typical Midwest stream in the past two decades. H_2O Open Journal, 3 (1) (2021) pp. 519-537. https://doi.org/10.2166/h2oj.2020.054

[25] H. I. Owamah. Heavy Metals Determination and Assessment in a Petroleum Impacted River in the Niger Delta Region of Nigeria. Journal of Petroleum & Environmental Biotechnology, 4 (1) (2013) pp. 567-578. https://doi.org/10.4172/2157-7463.1000135

[26] K.I., Oshisanya, et al., Seasonal Variation of Heavy Metals in Sediment and Water of Lagos Lagoon. Journal of American Science. 7 (3) (2011) pp. 384-38.