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# Physico-chemical parameters, heavy-metals and soil particle distribution of Liverpool axis of Badagry Creek, Lagos, South-western Nigeria

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## Abstract

Heavy metal pollution is a serious issue of concern worldwide because it can bioaccumulate in aquatic organisms and transferred through the food chain to harm humans. Information on the heavy metal pollution of aquatic ecosystems is essential to protect life. Therefore, this study was undertaken to determine the physico-chemical parameters of surface water, soil particle distribution (SPD) and heavy metals in two shellfish species in Liverpool axis of Badagry Creek, Lagos State, Nigeria. Twelve physico-chemical parameters and four heavy metals were studied using standard methods. The results showed that maximum temperature was 31.0±1.00˚C; turbidity, 118.00±50.90NTU; dissolved oxygen (DO), 13.3±3.8mg/l; dissolved carbon dioxide (COD), 67.7±19.1mg/l; total hardness, 173.0±63.1mg/l; conductivity, 39.2±12.2µS/cm and chloride was 2.0±0.7mg/l. Water quality parameters showed significant spatial variations ($p<0.05$) among sample stations. Pearson's correction matrices revealed high correlation of DO with nitrate ($r = 0.61$), total hardness ($r=0.62$) and COD ($r=0.52$) at $p<0.05$. The heavy metal concentrations (mg/kg) in the shellfishes, *Callinectes pallidus* and *Farfantepenaeus notialis* were: lead, 0.05±0.05 and 0.04±0.02; copper, 2.03±0.17 and 0.84±0.18; zinc, 3.51±0.44 and 1.99±0.2 and cadmium, 0.02±0.02 and 0.03±0.04 respectively. These levels were not above the WHO standards (for heavy metals in fish and shell fish). The sediment particle distribution (SPD) showed that Liverpool Jetty had 19.05% coarse sand and 43.91% fine sand, while Apapa Jetty had the highest amount of clay 45.29% in the environment. Heavy metals in shellfishes were above the WHO standards.

## Introduction

The water quality of water bodies changes with season and geographic area, even when there is no pollution. Suitability of water for fish and humans depend on the extent the water is influenced by urbanization and pollution, and the health of the water body (Saliu *et al* 2001; Akintola *et al* 2009 and Ogungbile *et al* 2017). Physico-chemical parameters influencing the aquatic environment are temperature, pH, salinity, dissolved oxygen, carbon dioxide, turbidity and total hardness, amongst others. These parameters influence the growth and survival of organisms.

Nigeria as a developing nation and Lagos metropolis located along the coastal region are experiencing rapid industrial growth (Uttinger 2005). The rapid urbanization and industrialization of cities and improper environmental planning has resulted in the discharge of sewage and industrial wastes into nearby water bodies, thereby affecting water quality. The importance of physico-chemical studies cannot be overemphasized as it provides vital information about the quality of water bodies. The presence of heavy toxic metals in environment matrices is one of the major concerns of pollution control and environmental agencies in most parts of the world. Their presence in aquatic ecosystem mainly due to anthropogenic influences has far-reaching implications directly on the resident biota and indirectly on man. The level of these metals in the environment has increased tremendously during the past decades as a result of human inputs and activities.

Wang *et al* (2008) reported that soil particle size distribution has a great influence on soil hydraulic properties such as water retention characteristics, saturated and unsaturated hydraulic conductivities, bulk density, permeability and porosity due to geological, chemical and biological processes. Soil particle size distribution has a good relationship with changes in soil structure, which is affected by management practices and erosion. Therefore, characterizing changes in the soil particle distribution is an inevitable issue in the environment. Sediments are important sinks for pollutants, particularly, heavy metals and they play a significant role in re-mobilization of contaminants in aquatic ecosystems when certain conditions prevail (Zeng *et al* 2010). Therefore, it is important to evaluate the level of metals contamination of sediments and interactions with the water body.

There paucity of recent information on the physicochemical parameters Badagry Creeks, Nigeria.

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However, available studies such as Akintola *et al* (2011), Lawson (2011) and Ogungbile *et al* (2017) show that some parts of the creek are highly polluted and that the water quality of the creeks influenced by pollution from the surrounding environment, season and intrusions of ocean waters. Saliu (2006) reported that the hydro-chemistry of Ogbe Creek, Lagos was strongly influenced by seasonal flood.

Aquatic organisms are directly exposed to the heavy metals that dissolved in water or are present in sediments. Some heavy metals are carcinogenic, mutagenic and teratogenic depending on the species, concentration, dose and exposure time (Ngo *et al* 2011). Heavy metals could harm fish by impairment of the nervous system or bioaccumulate in aquatic food chain and transferred to humans, which poses serious health risk.

The Liverpool axis of the Badagry Creek is socioeconomically important but there is dearth of information on its ecology despite several anthropogenic activities around it. Therefore, this study aims to provide vital information on the water quality, levels of heavy metals in shellfishes (shrimp and crab) and the soil particle distribution of the creek in order to evaluate the level of pollution of the creek. Information from this study will guide policy makers to reduce pollution of the ecosystem.

## Materials and methods

Study area

Liverpool axis of Badagry Creek lies approximately between latitude: 6º26´N, longitude: 3°21´E (Figure 1). It is a brackish water lagoon system and where the Badagry Creek opens into Gulf of Guinea of the Atlantic Ocean. Liverpool Jetty (Station 1, SS1) is situated close to industries and surrounded by some villages, where most of the industries discharge their wastes treated or non-treated into the water body; Snake-island (Station 2, SS2) is more of mangrove island and Station 3 (SS3) is a fisherman's village called Apapa Jetty. The jetty is polluted through deposition of particulates, organics, carbon gases and transportation activities. However, during the rainy season, runoffs bring into the lagoon lots of wastes such as oil and grease, pesticides, and domestic wastes.

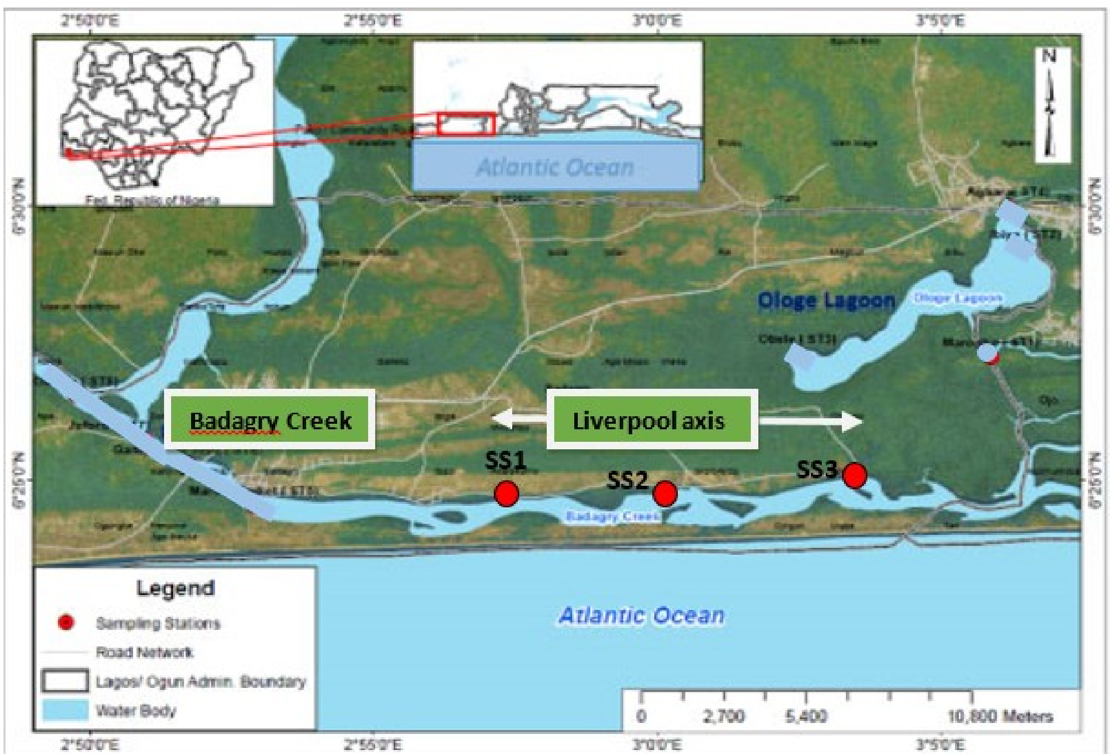


Figure 1: Map of Lagos State, showing Liverpool axis in Badagry Creek with sampling stations: SS1, SS2 and SS3 (Insert is the Map of Nigeria) (Modified from clinmedjournls.org)

Sample collection

Samples for physico-chemical and soil analyses were collected from the three stations (SS1, SS2 and SS3) monthly from May 2019 to April 2020. Samples were collected in triplicates. Surface water samples were collected directly in 2.0 litre polyethylene bottles from about 20cm below the surface water.

Physico-chemical parameters

Temperature and pH were measured *in situ* using standard mercury thermometer and pocket pH meter 197i. Water samples for the analysis of electrical conductivity, turbidity, total hardness, dissolved oxygen, chloride, sodium, nitrate and nitrite and heavy metals were collected in 2 litre plastic containers and screw capped. Water samples were analysed in the laboratory using standard methods by APHA (1998). Heavy metals; iron (Fe), zinc (Zn), cadmium (Cd), lead (Pb) and copper (Cu) were determined using atomic absorption spectrophotometer (AAS – 721(D) 2015 model).

Sediment particle size distribution

The sediment samples were collected from each station using the Ekman grab and kept cool in sealed nylon, labelled appropriately and were analysed based on the United State Department of Agriculture (USDA) and International Society of Soil Science (ISSS) protocol (Uttinger *et al* 2020). Sieve size for various soil ranges: silt/clay < 0.12mm, fine sands, 0.12mm-0.5mm, sand, 0.5–2.mm and gravel, 2.0-4.75mm were used to sieve the sediments.

Data analysis

The mean and standard deviations of collected data were calculated and results graphed using MS Excel. Student's t-test, Analysis of Variance (ANOVA), Duncan multiple range test (DMRT), least significant difference (LSD) and Pearson's correlation were carried out using SPSS version 20 at 95% level of confidence ($p<0.05$).

## Results

Temporal variations of physico-chemical parameters of water in Liverpool axis of Badagry Creek, Lagos

The results of physico-chemical parameters for three stations are presented in Table 1. Temperature differed significantly between months with the highest (31.0±1.0°C) and lowest (24.0±2.6ºC) values observed in May and December, 2019, respectively (Figure 2). Dissolved oxygen was highest in October (27.3±13.9mg/l) but lowest in August (2.6±1.2mg/l). Carbon dioxide also varied significantly between months with the highest (73.9±25.12mg/l) value in October and lowest value in November (16.4±8.5mg/l). Mean turbidity was highest in February (118.0±50.9NTU) and lowest in October (34.0±8.3NTU). Salinity ranged from 2.7‰ to 31.13‰ and pH varied between 6.2±1.5 and 7.2±1.8. Total hardness was the most varied parameter during the study, values ranged from 1.02±0.7mg/l to 173.0±6.2mg/l (Figure 4).

The mean temperature for both wet and dry seasons were 28.0±0.5°C and 28.0±2.3°C, respectively. Turbidity was 61.5±9.4NTU in wet season and 100.5±14.5NTU in dry season. Dissolved oxygen was lower in dry season (5.7±3.8mg/l) compared to wet season (6.12±3.59mg/l). The pH was 7.55±0.97 in wet season and 6.95±0.5 in dry season. Nitrites, nitrates and ammonia were generally lower in wet season (0.33±0.46, 0.73±0.36 and 0.73±0.36 mg/l) compared with dry season (0.08±0.2, 2.8±2.9 and 2.9±2.7 mg/l respectively).

Spatial variations in water quality parameters in Liverpool axis of Badagry Creek

The results of the spatial variations of physical and chemical parameters from the sampling stations compared with water quality standards established by the Federal Ministry of Environment (FME) and Lagos State Environmental Protection Authority (LASEPA) are presented in Table 2. Water temperature values were significantly different between Liverpool Jetty (SS1), Snake Island (SS2) and Apapa Jetty (SS3). The range of values for temperature in the three stations (27.6-28.7ºC) were within the FME limits (<35ºC). The pH values ranged from 6.7-7.2. Carbon dioxide ranged from 31.5-67.4(mg/l), the highest values were recorded in Liverpool Jetty. Salinity varied between 12.8-13.7‰ throughout the period of study. Mean dissolved oxygen (DO) at 5.3, 8.1 and 8.1mg/l in SS1, SS2 and SS3 respectively were higher than the FME limits (5mg/l). Apapa Jetty and Snake Island had higher values for total hardness with 118.6±85.0 mg/l, but all the sampling stations had relatively similar values for conductivity.

**Table 1:** Temporal variations of physico-chemical parameters in Liverpool axis of Badagry Creek

| Physico-chemical parameters | Wet season Min | Max | Mean | SD | Dry season Min | Max | Mean | SD | WHO Limit |
|---|---|---|---|---|---|---|---|---|---|
| Temperature (°C) | 27.00 | 31.00 | 28.60 | 0.50 | 24.0 | 31.00 | 28.00 | 2.30 | 25.00 |
| Turbidity (NTU) | 47.60 | 75.30 | 61.50 | 9.4 0 | 78.5 | 118.00 | 100.50 | 14.50 | 5.00 |
| Dissolved oxygen (mg/l) | 2.64 | 13.00 | 6.120 | 3.59 | 2.70 | 13.30 | 5.70 | 3.80 | 3.50 |
| Carbon dioxide (mg/l) | 24.9 | 67.70 | 45.60 | 19.10 | 16.4 | 69.10 | 36.10 | 18.50 | <10 |
| Salinity (‰) | 2.70 | 31.10 | 12.90 | 9.63 | 8.60 | 23.20 | 14.20 | 6.00 | 0-40 |
| pH | 6.46 | 8.70 | 7.550 | 0.97 | 6.20 | 7.60 | 6.95 | 0.50 | 6.5-8.5 |
| Nitrite (mg/l) | 0.00 | 1.02 | 0.330 | 0.46 | 0.00 | 0.40 | 0.08 | 0.20 | <1.0 |
| Nitrate (mg/l) | 0.00 | 1.40 | 0.73 | 0.36 | 0.60 | 7.00 | 2.80 | 2.90 | 50 |
| Ammonia (mg/l) | 0.28 | 1.40 | 0.73 | 0.36 | 0.60 | 7.00 | 2.90 | 2.70 | 0-0.50 |
| Total hardness (mg/l) | 1.02 | 173.00 | 68.10 | 63.10 | 59.30 | 164.00 | 127.1 | 35.80 | 40-400 |
| Conductivity (µS/cm) | 5.33 | 13.80 | 11.10 | 3.31 | 6.30 | 39.20 | 21.05 | 12.20 | 500 |
| Chloride (mg/l) | 0.03 | 0.09 | 0.04 | 0.02 | 0.0 | 2.00 | 0.40 | 0.70 | 250 |

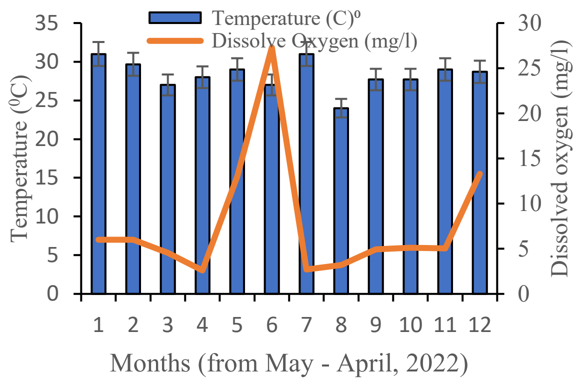


**Figure 2.** Temporal mean values of temperature and dissolved oxygen in Liverpool axis of Badagry creek, Lagos

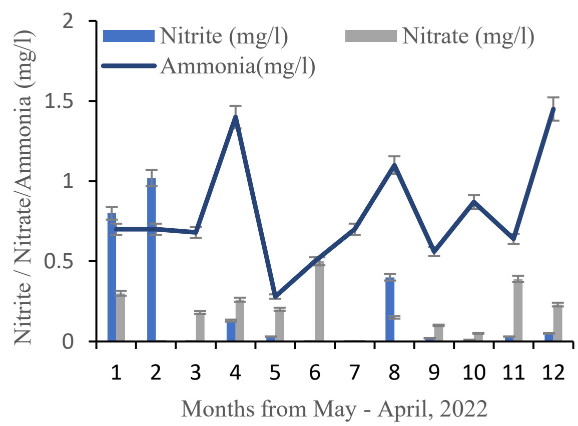


**Figure 3.** Temporal mean values of Nitrite, Nitrate and Ammonia in Liverpool axis of Badagry Creek, Lagos

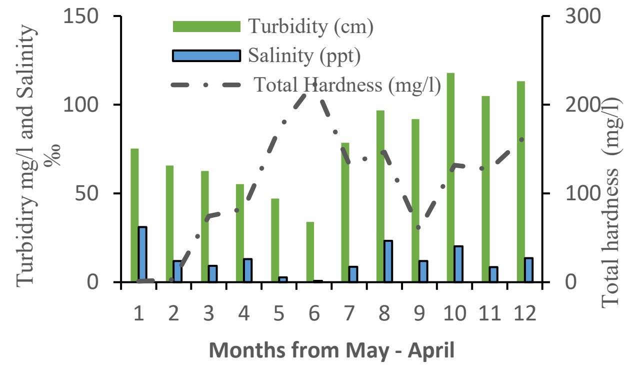


**Figure 4.** Temporal mean values of turbidity and total hardness in Liverpool axis of Badagry Creek, Lagos

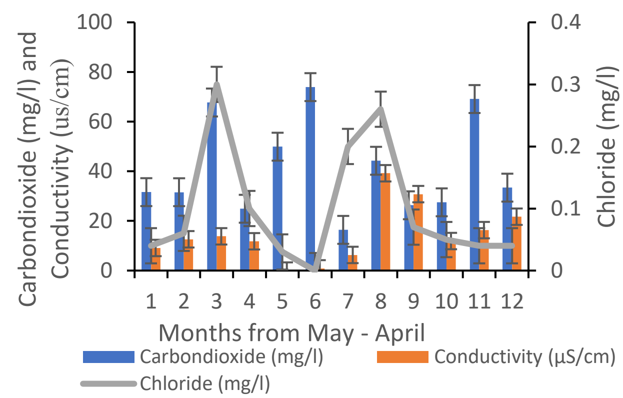


**Figure 5.** Temporal mean values of Carbon dioxide, Conductivity and Chloride in Liverpool axis of Badagry Creek, Lagos

**Table 2**: Spatial mean variations of water quality parameters, Liverpool axis of Badagry Creek

| .Physiochemical parameters | Liverpool Jetty (Station 1) | Snake Island (Station 2) | Apapa Jetty (Station 3) | LASEPA/ FME Limit |
|---|---|---|---|---|
| Temperature (˚C) | 27.6 ± 3.6 | 28.6±1.9 | 28.6±1.9 | 25-35˚C |
| Turbidity (NTU) | 53.0 ± 23.7 | 84.9±30.5 | 84.9±30.5 | 10NTU |
| Dissolved Oxygen (mg/l) | 5.3 ±4.7 | 8.1±9.0 | 8.1±9.0 | 5mg/l |
| Carbon dioxide (mg/l) | 67.4 ±38.7 | 31.5±13.6 | 31.5±13.6 | <10 |
| Salinity (‰) | 12.8 ±7.7 | 13.7±8.5 | 13.7±8.5 | NS |
| pH | 6.7 ±1.9 | 7.2±0.6 | 7.2±0.6 | 6-8 |
| Nitrite (mg/l) | 0.1 ±0.3 | 0.4±0.8 | 0.4±0.8 | 10mg/l |
| Nitrate (mg/l) | 0.2 ±0.4 | 0.3±0.3 | 0.3±0.3 | 10mg/l |
| Ammonia (mg/l) | 1.2 ±0.7 | 0.6±0.4 | 0.6±0.4 | 0.2mg/l |
| Total hardness (mg/l) | 75.5 ±50.2 | 118.6±85.0 | 118.6±85.0 | |
| Conductivity (µS/cm) | 15.0 ±10.8 | 14.4±10.0 | 14.4±10.0 | |
| Chloride | 0.1 ±0.1 | 0.1±0.1 | 0.1±0.1 | 250 |

Note: NS = not specified

Correlation between physico-chemical parameters

The correlation matrix is shown in Table 3. Temperature correlated negatively and significantly ($p<0.05$) with most of the parameters, especially conductivity ($r=-0.59$). Turbidity had the highest correlation value ($r=0.58$) with conductivity. Dissolved oxygen correlated significantly with total hardness ($r=0.62$) and nitrate ($r=0.61$) at $p<0.05$. Carbon dioxide correlated significantly with nitrate ($r=0.68$). Salinity correlated poorly with other parameters.

**Table 3**: Pearson's correlation matrix for water quality parameters from Liverpool axis of Badagry Creek

| Parameters | Temp. | Turb. | DO | $CO_2$ | Salinity | pH | Nitrite | Nitrate | $HN^3$ | Total hard. | Cond. | $Cl^{-1}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temperature | 1.0 | | | | | | | | | | | |
| Turbidity | -0.07 | 1.0 | | | | | | | | | | |
| DO | -0.09 | -0.45 | 1.0 | | | | | | | | | |
| $CO_2$ | -0.37 | -0.32 | 0.52 | 1.0 | | | | | | | | |
| Salinity | 0.02 | 0.48 | -0.49 | -0.44 | 1.0 | | | | | | | |
| pH | -0.52 | -0.16 | 0.24 | 0.54 | 0.04 | 1.0 | | | | | | |
| Nitrite | 0.25 | -0.17 | -0.16 | -0.22 | 0.47 | 0.01 | 1.0 | | | | | |
| Nitrate | -0.11 | -0.32 | 0.61* | 0.68* | -0.14 | 0.12 | -0.18 | 1.0 | | | | |
| Ammonia | -0.25 | 0.41 | -0.26 | -0.37 | 0.36 | -0.08 | -0.10 | -0.06 | 1.0 | | | |
| Total hardness | -0.38 | -0.05 | 0.62* | 0.41 | -0.54 | 0.04 | -0.63* | 0.36 | 0.01 | 1.0 | | |
| Conductivity | -0.59* | 0.58* | -0.42 | -0.16 | 0.38 | 0.07 | 0.02 | -0.26 | 0.39 | -0.12 | 1.0 | |
| Chloride | -0.40 | 0.04 | -0.52 | 0.02 | 0.11 | 0.40 | -0.11 | -0.39 | 0.18 | -0.12 | 0.38 | 1.0 |

**Note:** *means values are significantly different at p-value =0.05, Turb. = Turbidity, DO = Dissolved oxygen, $CO_2$ = Carbon dioxide, pH = hydrogen ion concentration, $HN_3$ = ammonia, Cond. = Conductivity and $Cl^{-1}$ = Chloride.

Monthly variations of heavy metals concentration in crab (*Callinectes pallidus*) and prawn (*Farfantepenaeus notialis*) from Liverpool axis of Badagry Creek

Heavy metals concentrations in *C. pallidus* and *F. notialis* from Liverpool axis of Badagry Creek are shown in Tables 4. While the monthly variations were shown in Figures 6 and 7. Among the metals in the crab, copper was lowest in August (1.74mg/kg) and highest in October (2.27mg/kg), the mean copper value was 2.03±0.17mg/kg. Zinc was lowest in August with 2.69m/kg and highest in December (3.91mg/kg). Mean zinc value of 3.51±0.44) was above WHO permissible limit in fish (0.5 – 0.6mg/kg) (WHO, 1985). Lead (0.05) and cadmium (0.02mg/kg) concentrations were lower than other metals studied in the crabs. In the prawns, copper was lowest in October (0.64 mg/kg), and highest in January with 1.01mg/kg. Zinc was lowest also in October (1.17mg/kg) and highest in August with 2.16mg/kg. Lead was lowest November with 0.02mg/kg and highest in December (0.07mg/kg). However, cadmium was lowest in August, September and November, 2022 with 0.01mg/kg and highest in December with 0.08mg/kg. The mean heavy metals values were less than the WHO standard limits (0.5mg/kg for lead and cadmium, and 5.0mg/kg for zinc).

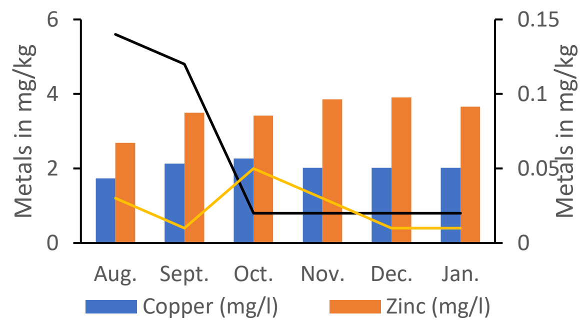


**Figure 6.** Monthly trends of heavy metals concentration in Crabs

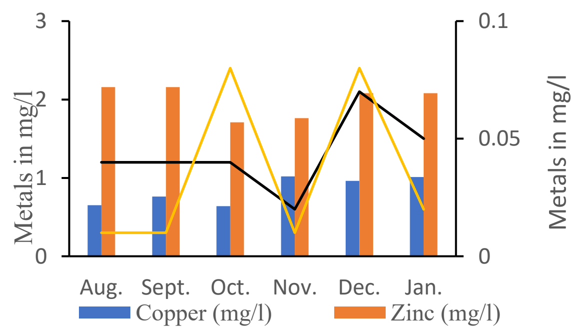


**Figure 7.** Monthly trends of heavy metals concentration in prawns

Table 4: Mean heavy metals concentration in *Callinectes pallidus and Farfantepenaeus notialis* from Liverpool axis of Badagry Creek

| Heavy metals (mg/kg) | *Callinectes pallidus* | *Penaeus notialis* | WHO Limits (mg/kg) |
|---|---|---|---|
| Copper | 2.03±0.17 | 0.84±0.18 | 0.5 |
| Zinc | 3.51±0.44 | 1.99±0.20 | 5.0 |
| Lead | 0.05±0.05 | 0.04±0.02 | 0.5 |
| Cadmium | 0.02±0.02 | 0.03±0.04 | 0.5 |

Sediment particle sizes distribution

The summary of the particle sizes distributions (PSD) of sediment samples from Liverpool axis of Badagry Creek, Lagos is shown in Table 5, which elucidated the percentage (%) contents of coarse sand, fine and silt/clay. Figure 8 shows the same contents of PSD in mm and depict the geometric appearance. The analysis of sediment particle sizes in Liverpool Jetty (SS1) had 19.05% of coarse sand, 43.91% of fine sand, and 36.74% of clay/silt. Samples from Snake Island (SS2) had 16.87% of coarse sand, 51.78% of fine sands and 28.14% of silt/clay. While Apapa Jetty (SS3) had 16.91% of coarse sand, 30.64% of fine sand and 45.29% of silt/clay.

Table 5: Mean values from sieve analysis for the sediment samples from Liverpool axis of Badagry creek, Lagos Nigeria

| S/N | Sieve Sizes | PSD in (SS1) | % PSD SS1 | PSD (SS2) | % PSD SS2 | PSD (SS3) | % PSD SS3 | |
|---|---|---|---|---|---|---|---|---|
| **1** | 2.0 | 0.9 | 0.28 | 1.3 | 1.87 | 2.0 | 2.84 | Sandy |
| **2** | 1.4 | 2.3 | 3.27 | 1.7 | 2.44 | 0.9 | 1.28 | |
| **3** | 1.0 | 1.6 | 2.27 | 2.2 | 0.03 | 1.5 | 2.13 | |
| **4** | 0.11 | 3.4 | 4.84 | 4.0 | 5.76 | 3.7 | 5.26 | |
| **5** | 0.5 | 5.9 | 8.39 | 4.7 | 6.77 | 3.8 | 5.40 | |
| Sum | | | **19.05** | | **16.87** | | **16.91** | |
| **6** | 0.35 | 6.4 | 9.10 | 5.4 | 7.78 | 5.0 | 7.1 1 | Fine sand |
| **7** | 0.25 | 8.3 | 0.11 | 7.4 | 10.7 | 3.7 | 5.26 | |
| **8** | 0.18 | 11.1 | 15.7 | 8.0 | 11.5 | 4.7 | 6.68 | |
| **9** | 0.12 | 13.4 | 19.0 | 15.1 | 21.8 | 13.2 | 18.7 | |
| Sum | | | **43.91** | | **51.78** | | **30.64** | |
| **10** | 0.09 | 10.2 | 14.5 | 13.6 | 19.5 | 22.5 | 32.0 | Silt/ Clay |
| **11** | 0.06 | 6.5 | 9.24 | 5.6 | 8.07 | 8.0 | 11.3 | |
| **12** | 0.04 | 0.4 | 13.0 | 0.4 | 0.57 | 1.4 | 1.99 | |
| Sum | | | **36.74** | | **28.14** | | **45.29** | |

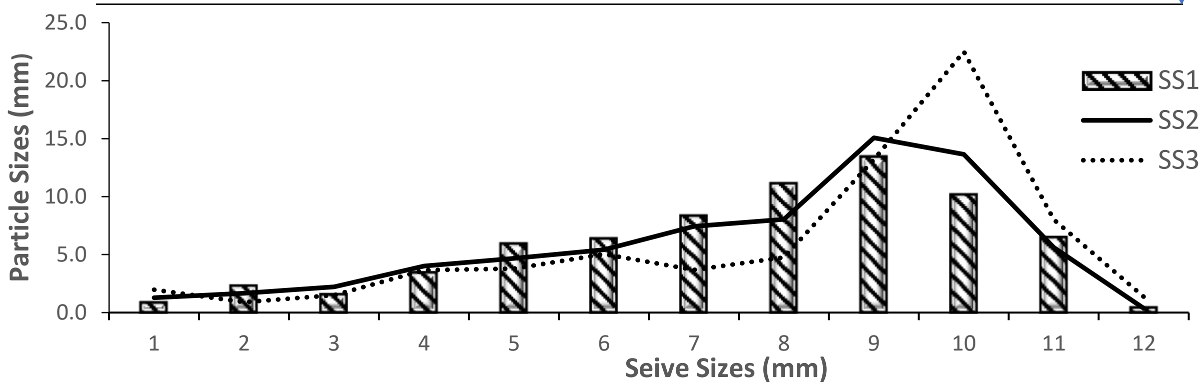


Figure 8. Particle sizes distribution for the three sample stations in Liverpool axis of Badagry Creek, Lagos

## Discussion

Physicochemical parameters and heavy metals in water, sediments and some shell-fish samples from Liverpool axis, of Badagry creeks were studied between May, 2020 and April, 2022. The results showed that dissolved oxygen was lowest in August which is the peak of rainy season, during which organic compounds and pollutants are washed into the creek from different sources. Adeboyejo (2009) reported that the onset of rainfall leads to introduction of biodegradable and non-biodegradable contaminants which was evident in the drop of dissolved oxygen in August and November, resulting in a change of the water quality. Mean DO values were above the WHO standard limits (3.5 mg/l) for water in all the stations (WHO 1985). As reported by Temesgen and Seyoum, (2018), low DO values reported might be due to degradation of organic pollutants from anthropogenic activities. Among the physico-chemical parameters studied that are within local and international permissible limits are turbidity (34.08-118.01 NTU), salinity (0.7-31.13‰), pH (6.2-8.8), nitrite (0.0-0.83mg/l), nitrate (0.0-0.39mg/l), and chloride (0.0-0.3mg/l).

The temporal variations in the physico-chemical parameters in water showed clear differences between months. Higher mean concentration of ammonia was recorded in the dry season (2.7mg/l), but lower in the wet season with (0.73mg/l) throughout the study period. However, the results show higher ammonia levels than the WHO recommended limit (0-0.5mg/l). Rout *et al* (2016) reported higher ammonia levels (35.18 mg/l) from Ogun

River and attributed the results to high concentration of farming activities around the vicinity of the river. They also noted higher concentration of ammonia during dry season than wet season. Higher concentration of carbon dioxide recorded in the wet season than the dry season and also far exceeds the WHO limits High carbon dioxide are derived from biodegradation of waste from domestic, agricultural and industrial sources.

Spatial variations of water quality parameters in Liverpool axis of Badagry Creek showed that DO, the most important parameter in natural surface water system for determining the health of aquatic ecosystem (Yang *et al* 2007) was stable (5.3-8.1mg/l) in the three sampling stations studied. Carbon dioxide concentrations was higher in Liverpool Jetty (SS1) than in Snake Island (SS2) and Apapa Jetty (SS3). This station is the most humanly impacted station with more water transportation, domestic and industrial wastes that visibly ends up the Liverpool Jetty. However, it had the least turbidity concentration, when compared with other stations. Amongst the parameters that remained spatially stable are salinity, nitrite, nitrate, conductivity and chloride throughout the sampling stations. The most spatially varied parameter is total hardness which ranged from 75.5-118.6 mg/l. This variation could be attributed to the fact that the study area is a deep brackish water system with multiple sediment particle distribution (SPD). The pH was slightly acidic in Liverpool Jetty, but neutral in the other stations; this is similar to the report of Samuel *et al* (2007). Nitrate levels were low in the present study in all stations (0.1-0.4mg/l), similar levels of low nitrate values were also reported by Amare *et al* (2017) in the upper Blue Nile basin of Ethiopia.

The Pearson correlation matrix of the 12 physico-chemical parameters analyzed shows that 6 out of 67 correlated coefficients are most significant. There were strong and positive correlations between: conductivity and turbidity, DO and nitrate, total hardness and DO. The correlation of all analyzed variables were affected simultaneously spatially and seasonally, similar to the report of Temesgen and Seyoum, (2018). A significant negative correlation exists between total hardness and nitrite, total hardness and salinity, chloride and DO.

Concentration of heavy metals in the study shows that among the metals examined in the crab (*C. pallidus*) copper was not significantly different throughout the study period. The concentrations of the metals were less than WHO standard limits for fish and shell fishes. Zinc is an indispensable trace element not only for humans, but also for all organisms, and it is a component of proteins as well as a great number of enzymes (Plum *et al* 2010). High level of zinc leads to phyto-toxicity, reproduction problem, and brain disorder (USEPA 1999). In this study, the highest value of zinc observed in the prawn was in January and lowest value in October; this is similar to the values reported in African catfish, *Clarias gariepinus* from River Nile, Egypt (0.12 -0.69ppm) by Osaman and Kloas (2010).

The significance of Particle Sizes Distribution (PSD) is that, soil has the tendency to filter out wastes, contaminant/pollutants before it gets to the water table due to the physical properties that controls the permeability of the particle sizes. Factors that influence the interconnectivity between the soil particles include: particle shape, density and PSD. Based on the United State Department of Agriculture (USDA) and International Society of Soil Science (ISSS) classification for PSD distribution, Liverpool Jetty had more coarse sand than the other stations; Snake Island had more fine sand than other stations while Apapa Jetty had more silt/clay than the other two stations. Generally, there were more fine sand and silt/clay in sediments of the sampling stations which showed their increased or higher ability to retain heavy metals due to retention; thus, making them to be available for bioaccumulation particularly in aquatic benthic community (that more susceptible) after sedimentation and precipitation.

## Conclusion

The water quality showed significant temporal and spatial variations in the physico-chemical parameters studied. Heavy metals in the shell fishes studied were less than WHO permissible limit. Sediment particle sizes of Apapa Jetty had highest amount of clay/silt. Liverpool Jetty had more coarse sand than the other stations due to anthropogenic activities. Industries at the Liverpool axis of Badagry Creek should adequately treat their effluents before discharging them into the water. Regular monitoring and control measures should be embarked upon by environmental protection agencies in order to protect the study area.

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