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Evaluation of Water Quality and Heavy Metal Concentration across Two Connecting Tropical Lagoons in Lagos, Nigeria

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Abstract

Ologe and Badagry Lagoons are important tropical lagoons in Lagos, Nigeria. The water quality and heavy metal concentration were studied for a period of 2 years (Aug. 2016 to Jul. 2018) using standard methods. The least temperature obtained was 28.70±0.05 °C in Ologe Lagoon during the wet season and the maximum recorded was 29.41±0.08 in in Badagry Lagoon during the dry season. During the wet season (May- October) the temperature was steady and similar between the two connecting tropical lagoons. The salinity values vary at different stations in both Lagoon, 0.06 to 0.44 % in Ologe Lagoon and 0.08 to 0.28 % in Badagry Lagoon. Badagry Lagoon showed significant higher values in conductivity, total dissolved solid, chemical oxygen demand, biological oxygen demand, total suspended solid and total hardness across seasons. Heavy metal results showed that except for lead (0.25±0.10 mg/L), Ologe Lagoon had higher concentrations of all examined heavy metals (Zinc, copper, iron, chromium, lead, cadmium, manganese and cobalt) than Badagry Lagoon across season. Furthermore, cadmium, manganese and cobalt were not detected in Badagry Lagoon across season. The two studied connecting Lagoons especially Ologe Lagoon is exposed to dramatic deterioration in its water quality due to different wastes that discharge into the water body. These lagoons are clearly polluted by metals for various utilizations. As a result, the study suggests enforcing the controls on waste discharged into lagoons.

Key words: Badagry lagoon, heavy metals, Ologe lagoon, Physico-chemical parameters.

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INTRODUCTION

Coastal waters are one of the nation's most important natural resources, valued for their ecological richness as well as for the many human activities they support (Mack and Micacchion, 2006). As the interface between terrestrial environments and the open ocean, coastal waters encompass many unique habitats, such as estuaries, coastal wetlands, seagrass, meadows, coral reefs, mangrove and kelp forests, and upwelling areas. Coastal waters support many fish species for at least part of their life cycle, offering some of the most productive fish habitats in the world and support many other organisms with high public visibility or unique ecological significance (USEPA, 2004).

The physico-chemical properties of water vary depending on location, as well as anthropogenic activities in the catchment area such as irrigation, urbanization, domestic sewage, and so on, resulting in a degradation of water quality (Verma *et al.,* 2012). Temperature, turbidity, nutrients, hardness, alkalinity and dissolved oxygen are some of the important factors that play a vital role for the growth of living organisms in the water body. Water quality indicates the relation of all hydrological properties including physical, chemical and biological properties of the water body. Hence, water quality assessment involves analysis of physico- chemical, biological and microbiological parameters that reflect the biotic and abiotic status of ecosystem (Smitha and Shivashankar, 2013).

Water bodies such as rivers, lakes, dams, and estuaries are continually evolving due to geological age and geochemical characteristics. Metal pollution of the sea is known to be less visible and direct than other types of marine pollution, but with profound impacts on marine ecosystems (Van Sprang and Janssen, 2001). Trace metals occurring in aquatic ecosystems at varying concentrations may be due to biogeochemical cycling and anthropogenic inputs (Moruf and Akinjogunla, 2019). The most potentially harmful of these elements are heavy metals, such as lead, mercury, cadmium etc. In recent decades, heavy metal level in aquatic ecosystems has also increased due to mining, industrial, and agricultural activities (Moruf and Durojaiye, 2020).

Regular water quality monitoring of the water resources is necessary to assess the quality of water for ecosystem health and hygiene, industrial use, agricultural use and domestic use (Poonam *et al*., 2013). The water quality evaluation may be a complicated practice in compound parameters causing numerous concerns in general quality of water (Bharti and Katyal, 2011). Studies on heavy metals levels in benthos, water and sediment of Lagos coastal lagoons have been a major environmental focus especially in the last decades (Moruf and Akinjogunla, 2018; Moruf and Lawal-Are, 2018; Usese *et al.*, 2019; Lawal-Are *et al*., 2019a; Afolayan *et al.*, 2020; Sanni *et al.*, 2020). Water pollution by trace metal ions is one of our most serious environmental problems. Effluents resulting from daily domestic and industrial activities may induce considerable changes in water chemistry. Hence, the aim of this study was to assess the physicochemical parameters and heavy metal indices of two connecting tropical coastal lagoons (Ologe and Badagry) in Southwestern Nigeria, in association with the waste discharged in the area.

MATERIALS AND METHODS

Study Area and Sample Collection

Twelve (12) sampling stations were selected across Ologe and Badagry Lagoons (Fig. 1). The sampling stations were chosen based on an experimental scheme design following ecological settings and human activities in the area. The Ologe and Badagry Lagoons meet several socio-economic needs (aquaculture, fishing, sand dredging and drainage) of the various towns and villages bordering them. Details of surface water sampling location are presented in Table 1. Water samples were collected in one litre capacity plastic bottles, between 9 to 10 am, from all the sampling locations, for a period of 24 months. Each sample collected was analysed for physicochemical parameters.

Analytical Techniques

On each occasion, air and water temperature were determined using an ordinary mercury in-glass thermometer to the nearest 1°C. Transparency was measured with a 20 cm diameter black and white painted Secchi disc while water depth was estimated with a calibrated pole. The pH and dissolved oxygen were measured in-situ using Griffin digital pH meter (model 80) and Graffin digital dissolved oxygen meter (model 40) respectively. Salinity was determined with a refractometer while conductivity was determined with a Philip PW9505 Conductivity meter. In the laboratory, total suspended solids (TSS) were

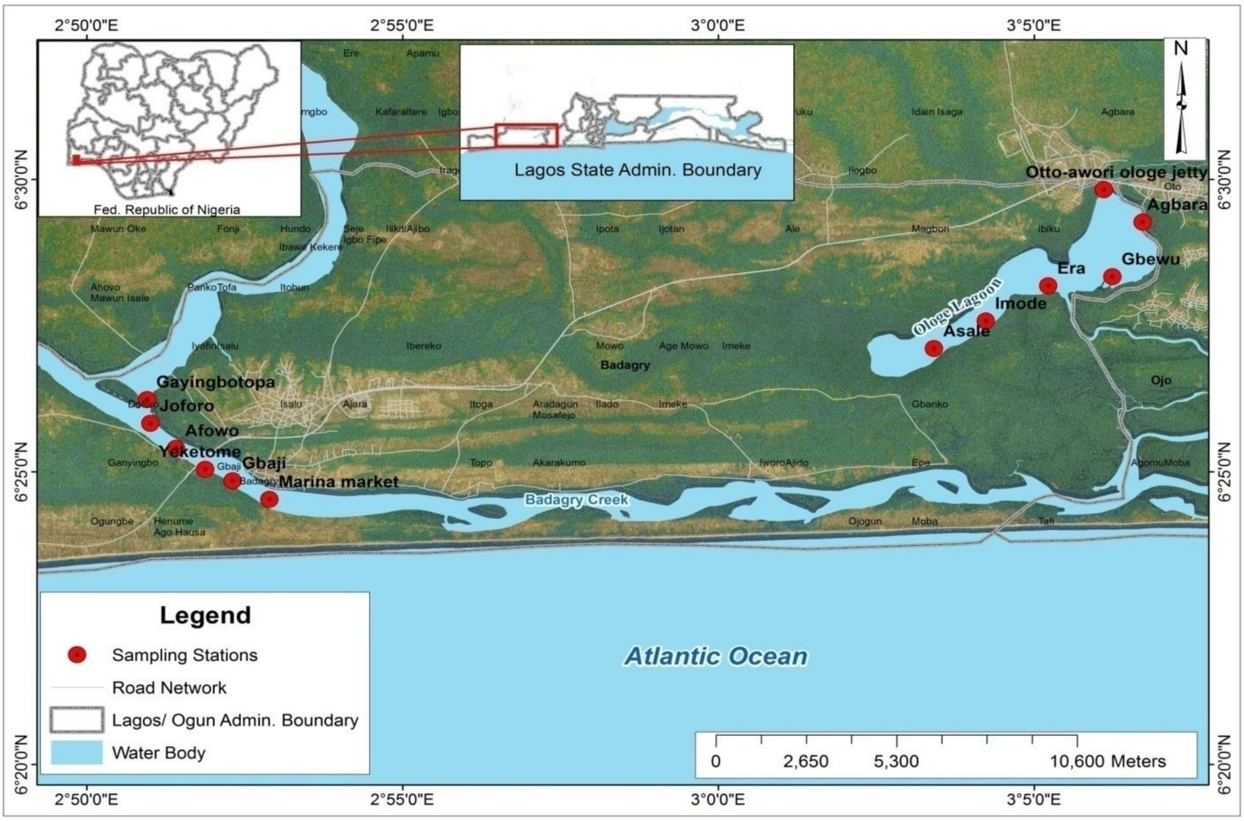

Fig 1. Map indicating sampling stations (Ologe and Badagry Lagoons)

Table 1. GPS coordinates of sampling sites across two connecting tropical lagoons.

S/N	**Ologe Lagoon**		**Badagry Lagoon**	
	Sampling Stations	**GPS**	**Stations**	**GPS**
1	Otto-awori ologe jetty	6°29' 495" N 3°60' 618" E	Gayingbotopa	6°25' 415" N 2°51' 161" E
2	Gbewu	6°29' 231" N 3°60' 621" E	Joforo	6°29' 231" N 2°60' 621" E
3	Era	6°28' 972" N 3°60' 824" E	Afowo	6°25' 672" N 2°50' 809" E
4	Imode	6°28' 838" N 3°60' 907" E	Yeketome	6°25' 179" N 2°51' 61" E
5	Asale	6°28' 679" N 3°60' 930" E	Gbaji	6°25' 075" N 2°51' 819" E
6	Agbara	6°29' 646" N 3°60' 435" E	Marina Market	6°42' 646" N 2°60' 435" E

determined by filtering 500 ml of the sample through pre-weighed filter paper that were subsequently dried in an oven at 105°C for 24 h, cooled and re-weighed while Total Dissolved Solids (TDS) were estimated by evaporating 100 ml of filtrate in a pre-weighed evaporating dish at 100°C. Biochemical Oxygen Demand (BOD) level was estimated after 5-days incubation period using the method described in APHA (1998). Heavy metal contents (Zinc, copper, iron, chromium, lead, cadmium, manganese and cobalt) were determined with an Atomic Absorption Spectrophotometer (model 969) as prescribed by American Public Health Association (APHA, 2005). Each of the water sample was acidified with concentrated nitric acid

(HNO_3) and hydrochloric acid (HCl) successively in a ratio of 3:1 in a beaker. The beaker was swirled and heated gently on an electro thermal heater (200ºC) for 15 minutes until the content was completely digested. The mixture was reduced to a volume of 1 ml, diluted with double distilled water and then filtered through Whatman filter paper (No. 42). The filtrate was transferred to 100 ml volumetric flasks and diluted to the mark with distilled water (100 ml).

Statistical Analysis

Data were subjected to analysis using the Microsoft Excel (2010) descriptive tool. Mean and standard deviations were calculated for each physicochemical and heavy metal parameter. Level of significance was employed at the 95% confidence limit, to check the degree of variability between the measured parameters.

RESULTS AND DISCUSSION

Water Quality of Tropical Lagoons

The mean values and standard deviations of the physicochemical characteristics of Ologe and Badagry lagoons are represented in Table 2. Although temperature has been reported to be less important in governing the distribution of biota in the tropics, it is however important to know that the temperature of the two connecting lagoons varied as the weather changes according to season. The least temperature obtained was 28.70±0.05 °C in Ologe Lagoon during the wet season and the maximum recorded was 29.41±0.08 in in Badagry Lagoon during the dry season. During the wet season (May- October) the temperature was steady and similar between the two connecting tropical lagoons. This fluctuation is therefore due to change in the weather especially during wet season when cloud cover reduces the intensity of the solar radiation. Temperature is an important characteristic that can vary widely; it can be influenced by several variables including geographic location, shading, water body size and depth (Chagas and Suzuki, 2005). The ranges of the pH levels observed in this study are uniform and acidic, with a range of between 6.31±0.10-6.53±0.08 (Ologe Lagoon) and 6.51±0.09-6.65±0.10 (Badagry Lagoon). Most estuarine organisms prefer conditions with pH values ranging from about 6.5 to 8.5 (USEPA, 2006). Water is considered acidic when pH is below 7 and basic when pH is above 7 (William and Robert, 1992).

Relatively very low levels of conductivity were recorded in both lagoons in this study and could be attributed to dilution. The low salinity brings about low conductivity. Onyema *et al.* (2010), has reported conductivity and salinity as associated factors. Conductivity values are < 600 µS/cm grouped as Class I water type while values from 600 to 6,000 µS/cm are under Class II water type and values between 6,000 and 160,000 µS/cm are under Class III water type. The conductivity recorded in this study from both lagoons fall under the Class I.

Total dissolved solids (TDS) varied between 77.17±1.23- 80.31±5.27 mg/L (Ologe Lagoon) and 87.89±3.13 - 96±1.02 mg/L (Badagry Laoon). The Federal Environmental Protection Agency (FEPA) Secondary Regulations advise a maximum contamination level (MCL) of 500 mg/L for TDS. When TDS levels exceed 1000 mg/L it is generally considered unfit for human consumption. A high level of TDS is an indicator of potential threat and warrants further investigation. The TDS recorded in both Lagoons were low and still fall under permissible limits of FEPA. The lower the suspended solids in water, the lower the total dissolved solids. Most often, high levels of TDS are caused by the presence of potassium, chlorides and sodium, and may also be dissolved in the water (Lawson, 2011). Ela (2007) classified water by the amount of TDS per litre: fresh water <1500 mg/L TDS, brackish water 1500 to 5000 mg/L TDS and saline water >5000 mg/L TDS.

The salinity values vary at different stations in both lagoons, 0.13±0.12 to 0.14±0.22 ‰ in Ologe Lagoon and 0.19±0.02 to 0.21±0.02 ‰ in Badagry Lagoon. Salinity remains a vital parameter in the survival of aquatic organisms and renewal of other parameters. It is very essential to note that the very low salinity might be attributed to the rainy season (rain-dependent) because of diluting influence of water precipitations, which greatly reduce the salinity (Adedayo *et al.,* 2012). Also, the distance of the sampling stations to the ocean contribute to the low salinity recorded in this study.

Turbidity recorded varied between 16.10 - 17.96 mg/L in Ologe Lagoon and 23.82 – 24.85 mg/L for Badagry Lagoon. Dissolved oxygen ranged between 4.66±0.05 and 4.91±0.05 mg/L for both lagoons throughout the period of study. Most values recorded except for values above 5.0 mg/L fell below acceptable dissolved oxygen level of 5.0 mg/L for survival, metabolism and physiology of aquatic organisms (Lawson, 2011). The death of many macrobenthic invertebrtaes and appearance of shells could be attributed to the array of low dissolved oxygen recorded in the study stations in both lagoons. Dredging activities were also being carried out in Ologe lagoon and constant and indiscriminate discharge of faeces into Badagry lagoon could also be the cause of low dissolved oxygen recorded. High organic content from human faeces, decayed plant materials and domestic and sawmill wastes that found their ways into the lagoon maybe responsible for low dissolved oxygen. This agrees with the stipulated minimum benchmark level of 5.0mg/l oxygen content for the proper survival of aquatic life (Lawson, 2011). According to United State Environmental Protection Agency (1992), the level of oxygen depletion depends primarily on the quantity of waste added, the size, velocity, turbulence of the stream and the temperature of the water.

Chemical Oxygen Demand was recorded between 31.81±0.66 and 32.92±1.09 mg/L in Ologe Lagoon and between 40.10±1.12 and 43.67±0.51 mg/L in Badagry Lagoon. The Biological Oxygen Demand (BOD) was recorded between 23.64±1.32 and 32.63±1.28 mg/L in Ologe Lagoon and between 38.57±1.35 and 40.89±1.80 mg/L in Badagry Lagoon. Alogoa and Alaleye-Wokoma (2012) reported that BOD values of 1 – 2 mg/L or less represents clean water, 4 – 7 mg/L represents slightly polluted water, and more than 8 mg/L represents severely polluted water. It was also stated that BOD standard for unpolluted water body is greater than 5 mg/L (Bawa *et al* 2007; Lawal-Are *et al*., 2019b).

Badagry Lagoon showed significant higher values in conductivity, total dissolved solid (TDS), chemical oxygen demand (COD), biological oxygen demand (BOD), total suspended solid (TSS) and total hardness across seasons.

Table 2. Physico-chemical parameters of two connecting tropical lagoons (Aug. 2016- Jul. 2018)

Parameter	Ologe		Badagry	
	Dry Season	Wet Season	Dry Season	Wet Season
Water Temp (^{0}C)	29.10±0.01^a	28.70±0.05^a	29.41±0.08^a	29.25±0.01 ^{a}
pH	6.53±0.08^a	6.31±0.10^a	6.51±0.09^a	6.65±0.10^a
Cond. (µS/cm)	162.94±11.13^a	155.82±2.44^a	175.18±6.17^b	192.89±1.99^b
TDS (mg/L)	80.31±5.27^a	77.17±1.23^a	87.89±3.13^b	96±1.02^b
Salinity (‰)	0.14±0.12^a	0.13±0.22^a	0.21±0.02^a	0.19±0.02^a
Turbidity (mg/L)	17.96±2.97^a	16.10±1.05^a	23.82±4.10^a	24.85±1.59^a
DO (mg/L)	4.81±0.05^a	4.91±0.05^a	4.75±0.05^a	4.66±0.05^a
COD (mg/L)	32.92±1.09^a	31.81±0.66^a	40.1±1.12^b	43.67±0.51^b
BOD (mg/L)	23.64±1.32^a	32.63±1.28^a	38.57±1.35^b	40.89±1.80^b
TSS(µS/cm)	78.43±1.03^a	80.17±1.42^a	90.92±1.46^b	109.96±1.65^b
Total Hardness	87.92±5.19^a	87.46±1.66^a	94.78±3.51^b	109.33±1.69^b

Key: TDS= Total Dissolved Solid, DO= Dissolved Oxygen; COD = Chemical Oxygen Demand; BOD= Biological Oxygen Demand; TSS=Total Suspended Solid**; *=** significantly different at $p \lesssim 0.05$.

Heavy Metal Concentration in Tropical Lagoons

Seasonal data on the heavy metal levels in Ologe and Badagry Lagoons are presented in Tables 3 and 4. Except for lead (0.25±0.10 mg/L), Ologe Lagoon had higher concentrations of all examined heavy metals (Zinc, copper, iron, chromium, lead, cadmium, manganese and cobalt) than Badagry Lagoon across season. Furthermore, cadmium, manganese and cobalt were not detected in Badagry Lagoon across seasons. This is similar to the report of Usese *et al*. (2018) on the topical creeks of Lagos Lagoon, where cadmium was below detection limit in Okobaba and site adjoining Abule-Agege Creek. In the present study, zinc, copper and iron levels were significantly higher (P<0.05) in Ologe Lagoon across season while lead concentration was observed to be significantly higher in Badagry Lagoon during dry season.

The concentration of zinc recorded in this study ranged between 0.38 to 1.63 mg/L across lagoons and seasons, being within the recommended standards limits of 0.10 mg/L in seawater (FEPA 2005). Zinc is believed to play a positive role in wound healing. Chromium levels (0.31- 0.66 mg/L) were above the FEPA (2005) standards limits of 0.05 mg/kg for seawater. Apart from its vital role in carbohydrate metabolism (i.e glucose tolerance and glycogen synthesis), trivalent chromium is also believed to play an important role in cholesterol and amino acid metabolism and acts as a cofactor for the hormone insulin. However, high intake beyond the permissible limit is carcinogenic to man and other mammals.

Table 3. Heavy metals in water across two connecting tropical lagoons (Dry Season)

Heavy metal (mg/L)	Ologe Lagoon			Badagry Lagoon			p- value
	Min	Max	Mean±S.Dev.	Min	Max	Mean±S.Dev.	
Zinc	0.66	1.52	1.03±0.36	0.38	0.64	0.53±0.1	0.01*
Copper	0.36	0.89	0.59±0.17	0.27	0.54	0.44±0.11	0.11
Iron	0.42	0.84	0.65±0.14	0.44	0.71	0.55±0.10	0.21
Chromium	0.31	0.63	0.49±0.14	0.36	0.62	0.47±0.09	0.78
Lead	0.1	0.37	0.25±0.10	0.33	0.46	0.39±0.04	0.01*
Cadmium	0	0.09	0.03±0.04	BDL	BDL	BDL	-
Manganese	0.16	0.25	0.19±0.04	BDL	BDL	BDL	-
Cobalt	0.04	0.18	0.11±0.07	BDL	BDL	BDL	-

Key: BDL = Below detection limit; * = Significantly different at P< 0.05

Table 4. Heavy metals in water across two connecting tropical lagoons (Wet Season)

Heavy metal (mg/L)	Ologe Lagoon			Badagry Lagoon			p- value
	Min	Max	Mean± S.Dev.	Min	Max	Mean± S.Dev.	
Zinc	0.82	1.63	1.15±0.31	0.38	0.63	0.50±0.09	0.00*
Copper	0.42	0.76	0.56±0.14	0.27	0.51	0.39±0.10	0.03*
Iron	0.57	0.84	0.69±0.11	0.44	0.65	0.52±0.08	0.01*
Chromium	0.31	0.66	0.48±0.14	0.40	0.58	0.47±0.07	0.88
Lead	0.13	0.37	0.26±0.08	0.23	0.45	0.34±0.08	0.11
Cadmium	0	0.03	0.02±0.01	BDL	BDL	BDL	-
Manganese	0.13	0.22	0.18±0.04	BDL	BDL	BDL	-
Cobalt	0.03	0.17	0.08±0.06	BDL	BDL	BDL	-

Key: BDL = Below detection limit; * = Significantly different at P< 0.05

Conclusion

The water quality of the two studied connecting lagoons, especially Ologe Lagoon, has deteriorated dramatically as a result of various wastes discharged into the water body. Except for lead (0.25±0.10 mg/L), Ologe Lagoon had higher concentrations of all examined heavy metals (Zinc, copper, iron, chromium, lead, cadmium, manganese and cobalt) than Badagry Lagoon across season. Heavy metals have obviously polluted these lagoons. As a result, the study suggests enforcing the controls on waste discharged into lagoons.

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