ASSESSMENT OF PHYSICOCHEMICAL AND HEAVY METAL CONCENTRATIONS OF SURFACE WATER INCREEKS ADJOINING LAGOS LAGOON, NIGERIA

[1]Okoro, C.U.,[*1,2]Onyena, A.P., [2]Nwosu, A.O.,[3]Chukwueloka, H.E.,[4]Eyo, V.O.
[1]Department of Marine Sciences, Faculty of Science, University of Lagos, Nigeria.
[2]Department of Marine Environment and Pollution Control, Faculty of Marine Environmental Management, Nigeria Maritime University, Okerenkoko, Delta State, Nigeria.
[3]Mathematics Unit, School of Basic Science, Nigeria Maritime University, Okerenkoko, Delta State, Nigeria.
[4]Department of Fisheries and Aquaculture, Faculty of Marine Environmental Management, Nigeria Maritime University, Okerenkoko, Delta State, Nigeria.
Corresponding Author: amarachionyena@gmail.com; +2347038333232.

Abstract

Creeks are potential contamination sinks for heavy metals and pollutants released from domestic, industrial, and other anthropogenic activities. This study assessed the physicochemical characteristics and heavy metal concentrations of surface water of some creeks adjoining Lagos Lagoon, Nigeria. Water samples were collected monthly from three creeks (AbuleAgege, AbuleEledu, and Ogbe) between June and November 2016 within 25cm depth, using hydrobios water sampler and analyzed for pH, Temperature, Conductivity, Total Dissolved Solids (TDS), Total Suspended Solids (TSS), Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Sulphate, Phosphate, Nitrate, Calcium, Iron (Fe), Zinc (Zn), and Lead (Pb); all determined in triplicates. The results revealed that all the physicochemical parameters determined is significant ($P<0.05$) except temperature, TSS and sulphate which showed no significant difference ($P>0.05$)across the three sampling stations. The physicochemical parameters and study months showed a significant interaction ($P<0.05$)for COD in June, August, and October. The parameters studied were within the limits of USEPA and WHO except for DO (1.6-3.8mg/l) which was lower than the WHO recommended 5mg/1 for water quality assessment and Ogbe creek that recorded BOD values >30mg/l from September to November thus depicting a deteriorating creek. The concentrations of Zn, Fe and Pb in the water samples were within the safe limit, but pose potential human and fisheries health implications from continuous usage. The varying concentrations in the creeks were as a result of unregulated anthropogenic activities. Innovative and cost-effective waste management practices are essential to be incorporated into the residential and industrial waste disposal system to curtail the water contamination.

Keywords: *Creeks; Anthropogenic activities; Water quality index; Water pollution; Lagos State.*

1.0 Introduction

Water is a significant substance in nature that is essential for the existence and support for all life forms (WHO, 2006). It occurs in the form of saline (salt) water example oceans, lagoons, seas, and freshwaters which are made up of rivers, streams, lakes, ponds. The quality of life is tied to the accessibility and quality of water. Thus, water quality is correlated to water use and the state of economic development (Walakira and Okot-okumu, 2011).Creeks are "conduits or pipes" that drain water from the mainland and empties into a larger body of water such as lagoon. They are important for their impact on ecological balance and biodiversity (Onyena, 2019). They are vital for the several goods and functions distributed freely to the ecosystem and human habitats which include food storage distribution, retention of sediments and nutrients, aquifer recharge, water quality improvement, aesthetic, and educational benefits (USEPA, 2009). They are critical resources for agriculture, manufacturing, transportation, waste disposal, cultural heritage, and several human activities. Notwithstanding its importance, creeks are the most poorly managed resource in the world (David, 2014). Coastal communities use water for several purposes, including fishing, irrigation, transportation, power generation, recreation, domestic, and industrial purposes (Nkwoji *et al.*, 2016). Nevertheless, the quality of creeks adjoining the Lagos lagoon is degrading due to the diverse anthropogenic activities such as industrialization, urbanization, agricultural activities, transportation, and indiscriminate waste disposal (Nkwoji *et al.*, 2016; Nkwoji *et al.*, 2019; Onyena and Okoro, 2019)which affects their physicochemical properties (Ibanga *et al.*, 2018).

Water pollution resulting from anthropogenic discharge into water bodies is the major problem in the global context (Gaur, 2018;Wato *et al.*, 2020). Water bodies in developing countries like Nigeria, for instance, with increased human populations and industrialization, are the endpoints of effluents discharged from industries (Ibanga *et al.*, 2018; Onyena and Okoro, 2019). In Lagos State, marine pollution especially industrial waste occurs in both rural and urban areas (Oteri and Ayeni, 2016). The state has over 75% of the manufacturing industries that generate effluents discharged into the environment daily (Olawusi-Peters, 2014; Jimoh, 2018). In most rural communities, the predominant source of drinking water is aquatic coastal systems which are usually polluted by organic substances from upstream users who may as well, use water for some agricultural and industrial related activities. These effluents are complex and include various kinds of pollutants including organic, inorganic, microbial contaminants, and other wide-ranging environmental disturbances that threaten the hydrochemistry and faunal characteristics of aquatic ecosystems (Nkwoji *et al.*, 2019; Onyena, 2019). In addition to other ecosystems stressors; industrial wastes are the sources of heavy metal contaminants in aquatic and terrestrial environments as well as groundwater contamination (Mishra *et al.*, 2019; Boateng *et al.*, 2019).

The extent of discharge of the domestic and industrial waste is such that creeks receiving untreated effluent cannot give much dilution required for their survival as good quality water sources which becomes detrimental to safety, human, benthic, cultured, and wild fishes, and other aquatic organisms ((Nkwoji *et al.*, 2016; Nkwoji *et al.*, 2019; Onyena, 2019). Thus, there is a challenge of providing water in adequate quantity and of the essential quality to decrease hazards to human health and conserve the water bodies and the environment. The degradation of creeks will inevitably lead to a loss of some if not all of their functions if left uncontrolled. The research aims to provide data on some heavy metal and physicochemical parameters of water in creeks adjoining Lagos lagoon, thereby complementing the existing data, and providing baseline information for management decisions in the management of similar water bodies.

2.0 Materials And Methods

Study area

The sampling stations investigated consist of three stations (Fig. 1). Station A is AbuleAgege ($3^0$24.024'E and $6^0$30.864'N); a brackish water swamp that is located at the North-Easternside of the University of Lagos between the faculties of Engineering and Sciences. It is influenced by the tidal fluctuations of the Lagos lagoon. The dominant riparian vegetations were Oil palm (*Elaeisguineensis*) and shrubs such as Christmas bush (*Alchorneacordifolia*). Apart from the occasional fishing and abandonment of fish gear suchas nets, this site was devoid of human activities coming from the University. Sampling station B is AbuleEledu ($3^0$23.914'E and $6^0$31.413'N); which is also a brackish water swamp. This site is located on the community road.

The creek is highly perturbed and receives various domestic and industrial effluents from populated urban settlements along its routes. Human activities at the site was high and included direct defecation and dirt dropping at the shoreline. Fishing of mollusksuch as periwinkle (*Tympanotonusfuscatus*) and Blue crab (*Callinectesamnicola*) is the primary occupation of the people that settled there. Sampling station C is Ogbe creek ($3^0$23.527'E and $6^0$30.627'N); a freshwater creek that flows south-west through the Lagos metropolis and the University of Lagos before emptying into the lagoon. The creek is highly disturbed and receives various domestic and industrial effluents from heavily populated urban that settle along the route. The creek's water was stinking and usually murky green to black. The floating aquatic vegetation is dominated by Water hyacinth (*Eichhorniacrassipes*). Human activity at the site was high and included direct defecation and channelling of sewage and other domestic waste into the stream.

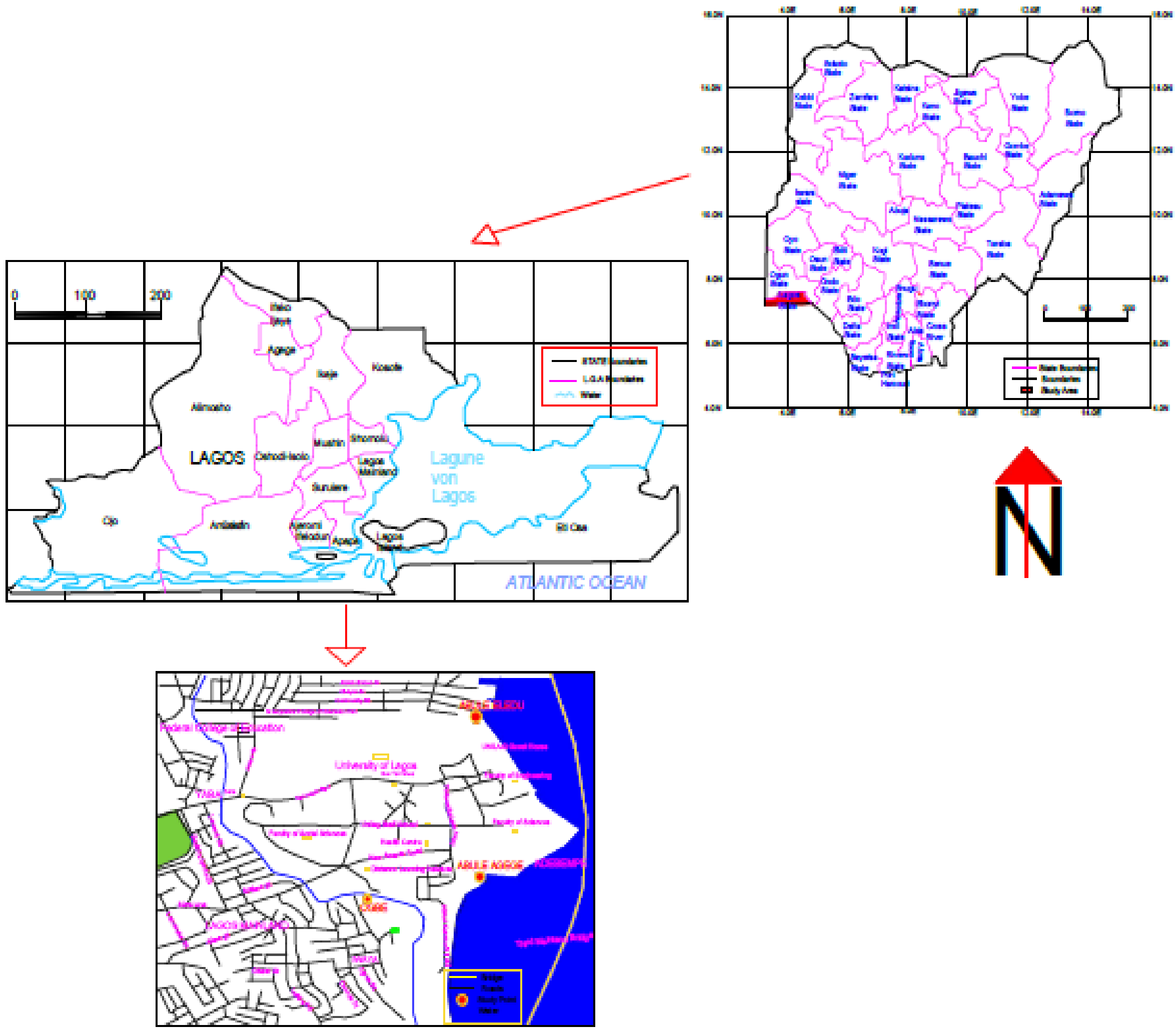

Fig.1. Map of the study area.

Sampling locations and sample collection

The study adopted both field and laboratory-based procedures to generate the data required. Surface water for physical and chemical analysis was collected using hydrobios water sampler at three sampling stations monthly from the period of June 2016 to November 2016. Samples were collected between 08:00 am and 11:00 am on each occasion. After collection, the water samples were tightly covered, labelled, and immediately kept in a vacuum thermos flask filled with crushed ice onboard for preservation. All collected water samples were transported to the laboratory and samples were kept in the refrigerator at $4^{\circ}C$ until analysis. The period between sampling and analysis were kept between the recommended times by standard methods APHA, (2005).

Physicochemical properties and metals concentration of water samples

The physicochemical parameters; pH, Temperature, Conductivity, Total Dissolved Solids (TDS), Total Suspended Solid (TSS), Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Sulphate (SO_4^{2-}), Phosphate (PO_4^{3-}), Nitrate (NO_3^-), Calcium (Ca), Iron (Fe), Zinc (Zn), and Lead (Pb) of the water samples were determined following standard methods by APHA [16]. Water samples for the determination of dissolved oxygen (DO) were collected into a narrow-mouthed glass bottle and fixed immediately on the field with Winkler's reagent. The samples collected were filled to the brim to prevent atmospheric oxygen from the surface of the water. Physical parameters such as pH and water temperature were determined in-situ using HACH pH meter and mercury-in-glass thermometer, respectively.

Statistical analysis

The statistical analysis was carried out using Minitab 18. The descriptive analysis of the physicochemical parameters (PCPs), months, and locations was carried out. The statistical tool used for this research is a 2-factor factorial analysis of variance in a randomized complete block design where the blocks will be the number of the PCPs, then months, locations, and month*location as factors were taken into consideration. A pairwise comparison test was then conducted to check for the most significant parameter. The hypothesis testing used included:

1. H_0: there is no significant difference in the mean of concentrations of the physicochemical parameters of the water samples collected.
2. H_0: there is no significant difference in the mean of concentrations for various months the research was conducted.
3. H_0: there is no significant difference in the mean of concentrations for the different locations the research was conducted.
4. H_0: there are no significant interactions in the mean of concentrations for various months and the mean of concentrations for the different locations the research was conducted

3.0 RESULTS

The results of the physicochemical parameters and heavy metals in water are shown in table 1 below.

Table 1.

Mean and Standard deviation of physicochemical and heavy metals in water from sample locations

	AbuleAgege					AbuleEledu					Ogbe					WHO	USEPA
PARAMETERS	Mean	SD	SE	Max	Min	Mean	SD	SE	Max	Min	Mean	SD	SE	Max	Min		
pH	6.80[a]	0.2	0.1	7.2	6.6	6.78[a]	0.19	0.08	7.1	6.6	6.88[a]	0.2	0.11	7.2	6.5	6.5-8.5	6.5–8.5
Water temperature (ºC)	25.30	0.5	0.2	26	25	25.5	0.5	0.22	26	25	25.5	0.5	0.24	26	25	-	<40.00
Conductivity (mS/cm)	2.88[a]	3.0	1.2	7.67	0.5	2.31[a]	3.06	0.06	8.18	0.437	0.83[a]	0.1	0.01	1	0.6	1	-
DO (mg/L)	2.42[a]	0.5	0.2	3	1.7	2.37[a]	0.78	0.3	3.8	1.6	2.27[a]	0.7	0.42	3.1	1.6	5	-
Total Dissolved Solids (mg/L)	298[a]	90.3	37	429	149	339.07[a]	179.92	33.3	650	176.1	462[a]	73.2	5.11	546.9	330	500	1000
Total Suspended Solids (mg/L)	27.20[a]	6.2	2.5	35	17	17.33[a]	4.97	5.75	24	9	29[a]	17.2	3.06	53	14	500	-
BOD_5 (mg/L)	18.30[a]	7.8	3.2	34	13.2	15.05[a]	4.04	8.22	20.5	10.6	28.5[a]	18.7	1.95	65	15.4	-	28-30
COD (mg/L)	2780[a]	300.6	123	862	25	231.33[a]	300.61	70.7	833	19	284[a]	180.6	31.6	510	92	-	-
Sulphate (mg/L)	85.30	86.6	35	240	16	60.5	88.98	4.11	240	11	33.2	9.1	3.12	46	18	<250	-
Phosphate (mg/L)	1.640[a]	1.5	0.6	4.57	0.44	1.65[a]	1.19	0.36	3.95	0.61	2.35[a]	0.8	0.68	3.8	1.3	250	-
Nitrate (mg/L)	2.63[a]	2.1	0.8	6.6	1.1	1.63[a]	0.92	0.51	3.2	0.7	3.83[a]	2.3	0.1	7.9	1.8	<50	-
Calcium (mg/L)	131.00[a]	116.8	48	242	20.2	85.25[a]	72.38	35.5	170.4	19.4	103[a]	85.6	1.46	221.1	28.9	<1000	-
Iron (mg/L)	1.02[a]	0.7	0.3	2.33	0.42	0.75[a]	0.94	0.4	2.65	0.27	1.68[a]	0.9	0.09	3.1	0.8	0.1	-
Lead (mg/L)	0.05[a]	0	0	0.08	0.01	0.03[a]	0.01	0	0.04	0.021	0.05	0	0	0.1	0	0.01	<l
Zinc (mg/L)	0.03[a]	0	0	0.11	0.01	0.03[a]	0.02	0.01	0.046	0.009	0.03	0	0.01	0	0	-	<l

Note:Same letters indicate means that are significantly different ($P<0.05$)

Hydrochemistry and heavy metals concentrations

Surface water samples were collected, analyzed, and the levels of contaminants estimated. The mean values and standard deviation (Table 1) of the parameters studied were compared with the water quality criteria of the World Health Organization (WHO) and the United States Environmental Protection Agency (USEPA).

pH in the water samples from AbuleAgege creek recorded a mean of 6.80±0.20 while AbuleEledu creek had a mean pH of 6.78±0.19 and Ogbe creek recorded a mean pH of 6.88±0.20. The water temperature had mean values of 25.30±0.50^{0}C in AbuleAgege creek and 25.50±0.50^{0}C in AbuleEledu and Ogbe creeks. The mean value of the conductivity in the water samples recorded 2.88±3.00mS/cm in AbuleAgege creek and 2.31±3.06mS/cm in AbuleEledu Creek. Ogbe creek recorded 0.83±0.10mS/cm.

The Dissolved Oxygen in the water samples had means values of 2.42±0.50mg/l in AbuleAgege creek while 2.37±0.78mg/l in AbuleEledu Creek and 2.27±0.7mg/l in Ogbe creek. Total Dissolved Solids recorded mean values of 298.00 ±90.3mg/l, 339.07±179.92mg/l, 462.00 ±73.20mg/l while Total Suspended Solids recorded 27.20±6.2mg/l, 17.33±4.97mg/l, and 29.00±17.20mg/l in AbuleAgege, AbuleEledu, and Ogbe creeks, respectively. BOD mean values recorded 18.30±7.80mg/l, 15.05±4.04mg/l, and 28.50±18.70mg/l while COD concentration in the water samples had mean values of 278. 00 ±300.60mg/l, 231.33±300.61mg/l, and 284.00±180.60mg/l in AbuleAgege, AbuleEledu, and Ogbe creeks, respectively.

Sulphate concentrations recorded mean values of 85.30±86.60mg/l, 60.50±88.98mg/l and 33.20±9.10mg/l, Nitrate concentrations (2.63±2.10mg/l, 1.63±0.92mg/l and 3.83±2.30 mg/l), Calcium concentrations (131.00±116.80mg/l, 85.25±72.38mg/l and 103.00±85.60mg/l) and Phosphate concentrations (1.64±1.50 mg/l, 1.65±1.19 mg/l, and 2.35±0.80mg/l) in AbuleAgege, AbuleEledu and Ogbe creeks respectively.

Lead concentrations in the water samples have a mean value of 0.05± 0.00mg/l in AbuleAgege, 0.03± 0.00mg/l in AbuleEledu Creek, and 0.05± 0.00mg/l in Ogbe creek. Zinc concentration in water samples have a mean value of 0.03± 0.00mg/l in the three creeks while Iron concentration in water samples have a mean value of 1.02±0.70mg/l in AbuleAgege, 0.75±0.94mg/l in AbuleEledu Creek and 1.68±0.90mg/l in Ogbe creek.

Result of the statistical analysis

Table 2 shows the result of the 2-factor factorial analysis of variance (ANOVA) in a randomized complete block design. For the PCP's (blocks) having a P-value = 0.000 and F = 36.27 with a level of significance of 0.05. Thus, the p-value (0.000) is less than 0.05, which implies that we reject Ho and conclude that there is a significant difference in the PCPs (block). Also, in the mean of concentrations for the various Months (June to November) having a P-value = 0.007 and F = 3.28 (See Table 2), it was evidentthat there is a significant difference in the mean of concentrations in the various months the research was conducted with a significance level of 0.05. Hence Ho was rejected. Furthermore, the mean of concentrations in the different locations with P-value = 0.657 and F = 0.42 showed that there is no significant difference in the mean of concentrations for different locations (AbuleAgege, AbuleEledu and Ogbe creeks) with a significance level of 0.05.

The interaction of the mean of concentration for the various months and the mean of concentration for the three locations having a P-value =0.110 and F = 1.59 with the level significance of 0.05 and p-value (0.110) is less than 0.05; therefore, we do not reject H_o and conclude that there is no significant interaction between the factors.

Table 3 shows that all the coefficients of PCPs (blocks) determined were significant with a significance level of 0.05 except for Temperature, TSS, and sulphate. Also, the concentrations in June and November were significantly different from others.

A pairwise comparison test (Table 4) further revealed that in June*AbuleAgege, and October*AbuleEledu are significantly different from others.

4.0 Discussions

The pH of the aquatic system is a significant indicator of water quality and the degree of pollution. Low pH values or acidic water are known to allow toxic elements and compounds such as heavy metals to become mobile, thus creating conditions that are hostile to aquatic life. The findings of the pH range 6.5 – 7.2 in the study were in line with the studies of Seiyaboh *et al.*, (2016) which reported a mean pH value between 6.78 and 7.10 of Ikoli Creek, Niger Delta.

Temperature is an important ecological factor that influences the distribution of organisms in the aquatic environment. The lower temperature (25-26^{0}C) recorded in the study locations can influence the distribution of biota. The findings compare satisfactorily with Lagos Lagoon waters reported by Nkwoji *et al.*, (2019) (27-30 ºC) and the Igbedi creek Niger Delta (26.1 and 29.8) (Seiyaboh *et al.*, 2013). Electrical conductivity indicates water freshness and the study areas showed high levels of ionic content in the water samples with values ranging between 0.44-8.18ms/cm. AbuleAgege and AbuleEledu creeks recorded mean concentrations >1 ms/cm required WHO standard. This concentration increase in the creeks indicated the level of elevated salts compared to the Ogbe creek that is a freshwater ecosystem.

Dissolved oxygen determines the survival, distribution, behavioural, and physiological of aquatic organisms. The dissolved oxygen ranged from 1.6-3.8mg/l and agrees with Nkwoji *et al.*, (2019) who reported a dissolved oxygen range of 2.1-4.5mg/l. The low dissolved oxygen in the study areas could be attributed to the discharge of organic wastes, nutrient inputs from untreated sewages, decayed plant and animal materials, agricultural run-off, industrial effluents, and domestic effluents flushed into the creeks at different points, thus requiring large quantities of dissolved oxygen for aerobic decomposition (Nkwoji *et al.*, 2019). The type of the water system, tidal flow and aeration can increase the level of DO as reported in Ikoli creek of 5.734 - 7.56 (Seiyaboh *et al.*, 2016).

The Chemical Oxygen Demand (COD) and Biochemical Oxygen Demand values showed that organic matter contents in the study creeks were high. The values of COD ranged from 19 to 862mg/l. The high disparity in dissolved organic matter concentration from one site to another suggests the discharge of sewage containing varying amounts of substances at different points in a given time. The high values of COD (see Fig. 2 and 3) in the study months are a reflection of the level of contamination occurring at the period of research. A measure of the effect of pollution on receiving water and the biologically oxidizable matter for deoxygenating water gives the total Biochemical oxygen demand (Jaiswal *et al.*, 2019). The BOD values (12 – 34 mg/l) recorded in this study were higher than those (0.7 - 12.7mg/l) reported for some Nigerian streams (Seiyaboh *et al.*, 2013; Onojake *et al.*, 2017). Ogbe creek has greater concentrations of BOD than other study locations. This is an indication of the pollution status of creeks and a deteriorating creek. The high BOD could be attributed to the high level of organic substances from the effluent discharge into the lagoon; where the creek receives its influxes mostly occasioned by the rains thus implying the presence of a high concentration of aerobic microbes which acted on the biodegradable wastes and accordingly depleted the optimum dissolved oxygen (Nkwoji *et al.*, 2019). The BOD values recorded in some of the sample locations were not within the WHO 28-30mg/l limit. The high BOD is comparable to those linked with low dissolved oxygen and include physiological stress of aquatic organisms, suffocation, and eventual mortality (Ajibare, 2014).

The Total Dissolved Solids obtained during the study period were high across the creeks (176.1-650mg/l), indicating that solids in this environment were less of suspended solids. The total suspended solids were 9-53mg/l. The graph (Fig 3) shows a high concentration of TDS and COD across the various months.

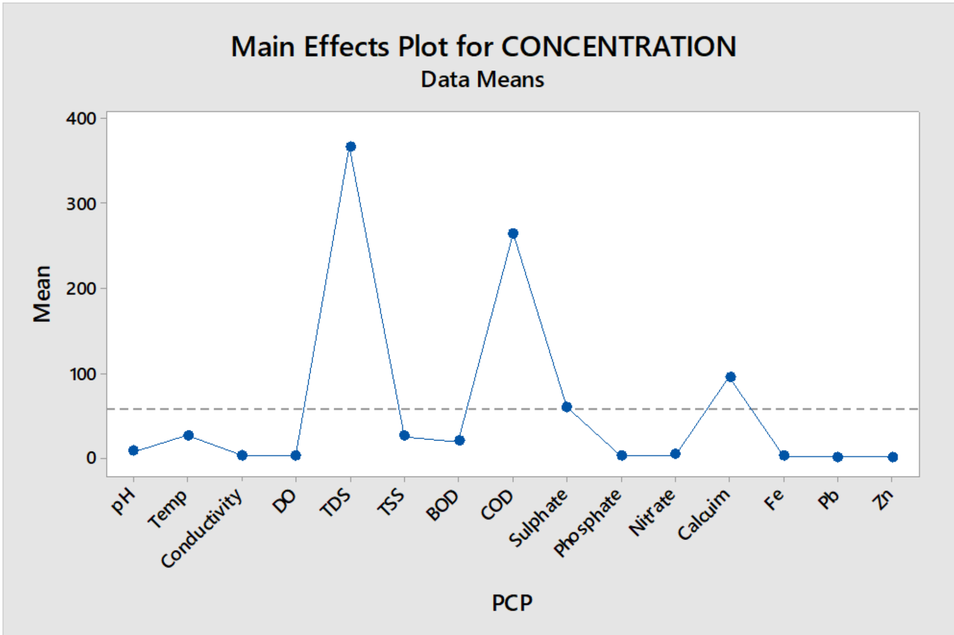

Fig. 2. The Plot for the concentrations of the PCPs studied

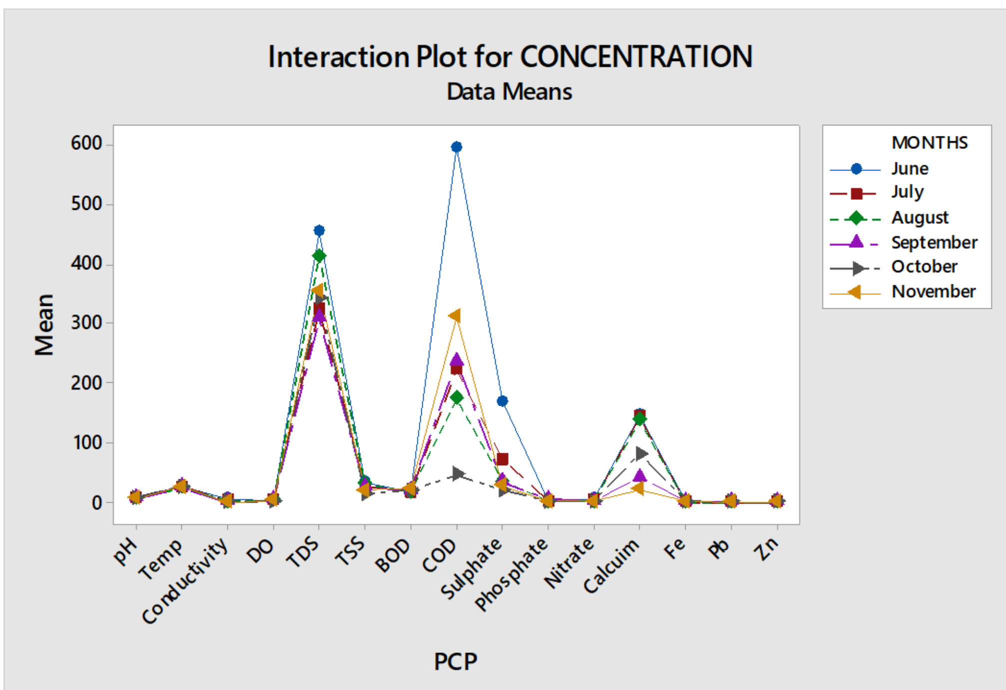

Fig. 3. The PCPs Plot for the studied across the months

This high total dissolved solids, COD, and low dissolved oxygen content (Fig 2 and 3) recorded could indicate the deteriorating water quality and probably from the discharges of industrial and domestic wastes into the creek through influxes from the lagoon, river, and other anthropogenic inputs. This attribution agreed with the studies of Nkwoji *et al.*, (2019) who also observed that land-based pollutants affected the water chemistry and benthic macroinvertebrates community of the Lagos lagoon. Although the TDS values were far less than the United States Environmental Protection Agency in Marine Water and WHO guidelines for water quality and fisheries of 1000mg/l, the TDS concentration was high in AbuleAgege creek compared to other study stations. This explains that the creek contained measurable quantities of organic matters and an increase in dissolved solids in the water.

Nitrogen and Phosphorus are essential elements in the aquatic ecosystem. They occur as nitrate and phosphates. The result of nitrate concentrations from the study ranged from 0.9-7.9mg/l, phosphorus was between 0.44 – 4.57 mg/l. Ogbe creek recorded high values of nutrient concentrations compared to other creeks. Sulphate concentrations recorded a high range of values between 11-240mg/l, while Calcium concentrations ranged between 11.4-242mg/l. The increase in the nutrient concentrations could be a result of the discharge from wastes from the septic systems of the humans living in the surroundings of the sampling locations, agricultural fertilizers and industrial wastes that seeped into the water bodies (Onyena and Okoro, 2019) and also as a result of detergents, dissolved organic and inorganic forms, that attached to sediment particles. The levels of nitrate observed here correspond with the values reported for some Nigerian waters (Edokpayi and Nkwoji, 2007; Onyema *et al.*, 2009).

The creeks recorded heavy metals concentration in the water samples. Concentrations of Iron detected in the water samples (0.27-3.08mg/l) were highest compared to other heavy metals. The high content of iron in the water samples maybe because of the clayey material that forms the river bed which had been exposed as a result of sand mining activities from Lagos lagoon and also be attributed to human activities such as the discharge of untreated sewage and uses industrial materials that contain metals. Olowu *et al.* (2010) reported that iron occurs at high concentration in soils and find its way into the aquatic ecosystem through erosion. Zinc and lead concentrations in the water samples were <1mg/l; an average value far less than the United States Environmental Protection Agency in Marine Water and WHO for drinking water. The result aligns with the findings of Olowu *et al.* (2010) who observed that the concentration of Zinc in water samples collected from Epe and Badagry lagoon is 0.5mg/l and 0.40mg/l, respectively. The New Calabar River Estuary also recorded values <1mg/l (Onojake *et al.*, 2017). In contrast, Addey *et al.*, 2018 observed the concentration of Pb (0.203-2.601 mg/L) and Fe Fe (0.253-1.049 mg/L) which was attributed to the increasing untreated industrial discharge and municipal solid waste disposed of in the area.

The overall study showed an increasing level of concentrations in the study stations across the six months with the highest level recorded in Ogbe creek (Fig. 4) depicting a deteriorating creek.

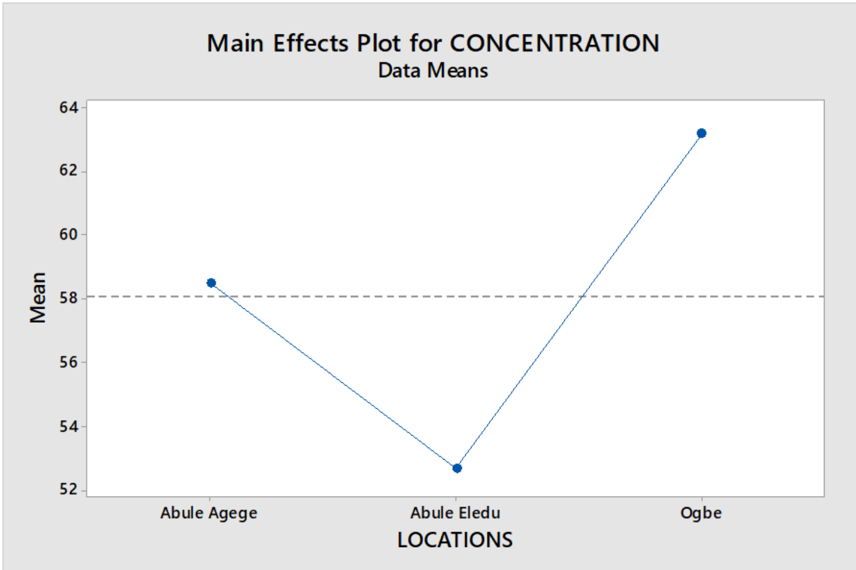

Fig.4. Main effects plot for the concentration of PCPs (Block) in the various location

The elevated concentrations in June and a constant concentration in July to August and a sharp decline in September to November (Fig. 5) illustrate the extent of impacts of different months on the physicochemical properties of the creeks. The concentration of heavy metals in the water was within the safe limit set by WHO and may not pose any health threat as at the time of the study. This, notwithstanding, a prolonged consumption of large amount of fishes with these heavy metals may lead to a potential threat to human health since heavy metals can bioaccumulate, biomagnify and persist.

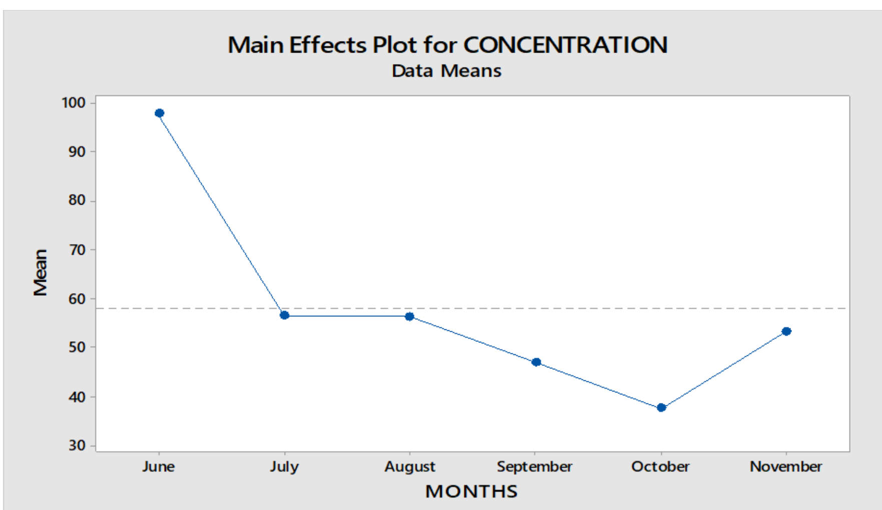

Fig. 5. Main Effects Plot for the concentration of PCPs in the study months

5.0 Conclusion

Most of the physicochemical parameters of water samples studied from all the stations were within the safe limits set by USEPA and WHO. This indicatesthat continuous monitoring of the creeks is needed not to go beyond the stipulated range of acceptability. The water was predominantly burdened with organic wastes from effluents. The BOD and DO were not within safe limits, thus presenting the creeks as environmentally disturbed, deteriorating creeks, and of poor water quality. The heavy metals concentrations (Zn, Fe, Pb) in the water were also below safe limits, despite the presence of different anthropogenic activities in the creeks. Nevertheless, in spite of the low concentrations of the heavy metals, excessive or persistent use of the creeks for fisheries and human use could be risky since heavy metals are highly toxic even at low levels and can bioaccumulate and persist for a long period.

The effluents from anthropogenic activities resulted in poor water quality. The statistical analysis conducted showed that the different concentrations observed in the study are location and months specific. Anthropogenic activities carried out at different times, seasons and areas have individual impacts on the creeks. The study also recommended that proper education and monitoring be carried out promptly in these locations as they are stressed by pollutants generated from domestic, agricultural, and industrial activities for health and sustainable living. Standard waste management practices need to be incorporated into the residential waste disposal system to thwart the leaching of heavy metals to surface and groundwater.

Table 2.
Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
PCP (BLOCK)	14	3018878	215634	36.27	0.000*
MONTHS	5	97464	19493	3.28	0.007*
LOCATION	2	5005	2503	0.42	0.657
MONTHS*LOCATION	10	94471	9447	1.59	0.110
Error	238	1414954	5945		
Total	269	4630772			

Table 3.
Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	58.09	4.69	12.38	0.000*	
Blocks					
pH	-51.3	17.6	-2.92	0.004*	1.87
TEMP	-32.6	17.6	-1.86	0.064	1.87
COND	-56.1	17.6	-3.19	0.002*	1.87
DO	-55.7	17.6	-3.17	0.002*	1.87
TDS	308.1	17.6	17.55	0.000*	1.87

TSS	-33.6	17.6	-1.91	0.057	1.87
BOD	-39.1	17.6	-2.23	0.027*	1.87
COD	206.4	17.6	11.76	0.000*	1.87
Sulphate	1.6	17.6	0.09	0.929	1.87
Phosphate	-56.2	17.6	-3.20	0.002*	1.87
Nitrate	-55.4	17.6	-3.15	0.002*	1.87
Ca	37.1	17.6	2.11	0.036*	1.87
Fe	-56.9	17.6	-3.24	0.001*	1.87
Pb	-58.1	17.6	-3.31	0.001*	1.87
MONTHS					
JUNE	39.9	10.5	3.80	0.000*	1.67
JULY	-1.6	10.5	-0.15	0.880	1.67
AUGUST	-1.7	10.5	-0.16	0.870	1.67
SEPTEMBER	-11.1	10.5	-1.06	0.292	1.67
OCTOBER	-20.6	10.5	-1.97	0.050	1.67
LOCATIONS					
ABULE AGEGE	0.38	6.64	0.06	0.954	1.33
ABULE ELEDU	-5.45	6.64	-0.82	0.412	1.33
M**ONTHS*LOCATION**					
JUNE ABULE AGEGE	26.3	14.8	1.77	0.078	2.22
JUNE ABULE ELEDU	26.9	14.8	1.81	0.071	2.22
JULY ABULE AGEGE	9.2	14.8	0.62	0.536	2.22
JULY ABULE ELEDU	-8.7	14.8	-0.59	0.557	2.22
AUGUST ABULE AGEGE	-13.1	14.8	-0.88	0.377	2.22
AUGUST ABULE ELEDU	14.0	14.8	0.94	0.348	2.22
SEPTEMBER ABULE AGEGE	-5.9	14.8	-0.40	0.692	2.22
SEPTEMBER ABULE ELEDU	-10.7	14.8	-0.72	0.471	2.22
OCTOBER ABULE AGEGE	-8.6	14.8	-0.58	0.564	2.22
OCTOBER ABULE ELEDU	-8.5	14.8	-0.57	0.568	2.22

Note: the p-value with * are the significant

Table 4

Tukey Pairwise Comparisons: MONTHS*LOCATION

Grouping Information Using the Tukey Method and 95% Confidence

MONTHS*LOCATION	N	Mean	Grouping	
JUNE ABULE AGEGE	15	124.610	A	
JUNE ABULE ELEDU	15	119.397	A	B

DECEMBER OGBE	15	79.182	A	B
SEPTEMBER OGBE	15	68.679	A	B
JULY ABULE AGEGE	15	66.097	A	B
AUGUST ABULE ELEDU	15	64.882	A	B
JULY OGBE	15	61.095	A	B
AUGUST OGBE	15	60.599	A	B
OCTOBER OGBE	15	59.585	A	B
JUNE OGBE	15	49.840	A	B
DECEMBER ABULE AGEGE	15	45.718	A	B
AUGUST ABULE AGEGE	15	43.628	A	B
JULY ABULE ELEDU	15	42.336	A	B
SEPTEMBER ABULE AGEGE	15	41.512	A	B
DECEMBER ABULE ELEDU	15	34.828	A	B
SEPTEMBER ABULE ELEDU	15	30.861	A	B
OCTOBER ABULE AGEGE	15	29.275	A	B
OCTOBER ABULE ELEDU	15	23.522		B

Means that do not share a letter are significantly different.

Note: the p-value with * are the significant

Declaration Of Competing Interest

Authors declare no competing interest

Acknowledgements

The authors wish to acknowledge other researchers in the Department of Marine Sciences, University of Lagos, Nigeria for their cooperation. We are particularly grateful to Azmarineberg Environmental Laboratory for their contributions.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

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