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Spatio-temporal variations in water and sediment parameters of Abule Agege, Abule Eledu, Ogbe, creeks adjoining Lagos Lagoon, Nigeria

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Lagos lagoon is known to be highly contaminated due to the increase in human population, industries and influx of contaminants from adjoining creeks. The degree of this contamination can be affected by the seasonal variations in time and space. The spatio-temporal variations in the hydrochemistry and sediments parameters of three (3) Lagos lagoon's creeks were investigated for six months (June, 2016 to November, 2016). Sub-surface water and sediments were collected with a 1 dm^3 water sampler and Van-veen grab, respectively and analyzed. Water temperature, pH, dissolved oxygen and conductivity of the water samples and pH, nutrients (nitrate and phosphate), total organic matter (TOM) and total organic content (TOC), alkalinity, acidity and particle size of the sediment samples were analyzed. The physico-chemical parameters in the water and sediment from the sampled creeks showed none significant differences (P>0.05). The study showed an increasing level of parameters' rates analyzed, indicating increased contaminants in Abule Eledu and Ogbe creeks. Water temperature maintained a relatively uniform temperature with dissolved oxygen values range of 1.6 to 3.1 mg/L. Conductivity was higher in June to August while high prevalence of nutrients was observed in October and November. Abule Agege and Abule Eledu recorded TOM and TOC that were above 15 mg/kg in June to August while alkalinity and acidity were high in October (6.63 mg/kg) and November (7.72 mg/kg) in the study creeks. The sediment particles size of the creeks ranged from clay, muddy and sandy substratum signifying that they were macrobenthic specific. The increase of the parameters' concentration indicates that the three creeks are highly impacted by anthropogenic stressors, dependent on the source of pollution occurring at the sites as well as controlled by seasonal variations. Continuous monitoring is required to be done to prevent future heavy metal pollution and total degradation in the water's quality of the Lagos lagoon's creeks.

Key words: Physico-chemical characteristics, sediments, creeks pollution, seasonal variation, Lagos lagoon.

INTRODUCTION

Nigerian aquatic systems are subjected to pollution pressures associated with urbanization and population growth (Edokpayi et al*.,* 2000; Nkwoji et al*.,* 2010). The effort to transform Lagos into a mega city has led to its rapid urbanization, high influx of humans and likewise volumes of wastes generated (Nkwoji et al., 2010) and have been seen as a threat to the aquatic systems. The pollution status of aquatic systems is generally

attributed to the direct discharge of waste (domestic and industrial) and the contribution from rivers, creeks and drainage canals that empty into larger waters like Lagoon at different points. Abule Agege, Abule Eledu, and Ogbe creeks are in South-western Nigeria and they empty into the Lagos lagoon. Over the years, the water bodies are the primary dump resources for disposal of waste, especially effluents from domestics and industries. These effluents from industries have an unlimited toxic influence on the pollution of the water body, as they can alter the physical, chemical and biological nature of the receiving water body (Sangodoyin, 1991; Adekunle and Eniola, 2008). Creeks provide most important aquatic links between storm water run-offs from land and saline estuaries and lagoons. They may originate as storm water channels or creeklets drain into coastal rivers or directly into estuaries or lagoons (Nwankwo et al., 2003).

Important macro-nutrients such as nitrogen and phosphorus are continuously being interchanged between sediment and overlying water (Abowei and Sikoki, 2005). Water and sediments play significant roles in the aquatic ecosystem and the biosphere. They serve as food and habitat to many marine organisms (such as benthic macro invertebrate), some of which support viable fisheries and whose metabolic activities contribute to aquatic productivity (Edokpayi and Nkwoji, 2007; Holme, 2001). It is also the major site for organic matter decomposition which is largely carried out by bacteria. Nevertheless, sediment serves as reservoir for pollutants and therefore a potential source of pollutants to water column, organisms and ultimately human consumers of those organisms. Contaminated sediment can cause lethal and sub-lethal effect in benthic and other sediment associated organisms (Edokpayi and Nkwoji, 2007). Oschwald (1997) stated that sediment input impacts stream communities through a variety of direct and indirect processes which includes reduced light penetration, smothering, habitat reduction, and introduction of absorbed pollutant (pesticides, metals, nutrients). Also, McLusky and Elliott (1997) stated that the physico-chemical parameters of the sediment such as dissolved oxygen, pH and organic carbon can also influence the occurrence and abundance of species distributed in them.

The presence of contaminants decrease the quality and uses to which water and sediments may be deployed as well as serve as a major factor controlling the state of health in both cultured and wild fishes and other aquatic organisms (Macer, 2000). The resultant effect includes the adverse biological consequences on the coastal aquatic environment, the general health of aquatic life, the maintenance of a hitherto viable artisanal commercial fisheries and the safety of humans occupationally exposed to the pollution (Nkwoji et al., 2010).

Lagos lagoon system experiences two seasonal trends, the dry season (November-April) and the wet season (May-October). Hence, the creeks adjoining the Lagos lagoon is prone to have environmental gradients all through the year. The aim of this research is to evaluate the spatio-temporal variation and the impacts of anthropogenic activities on the sediment and water of creeks around Lagos Lagoon, Nigeria.

Description of study sites

Abule Agege creek (Station A) with coordinates 3°24.024'E and 6°30.864'N is situated on the north-eastern side of the University of Lagos between the Faculty of Engineering and Science. The region is a brackish water creek and is typically shallow, tidal and sheltered (Emmanuel and Onyema, 2007). A study by Nwankwo (1996) stated that the creek is subjected to tidal fluctuations of Lagos Lagoon. Abule Eledu (Station B) which is located about 500 m from Abule Agege is an isolated freshwater swamp that is part of a creeklet, which empties into Lagos Lagoon. The station has a coordinate of 3°23.914'E and 6°31.413'N. The width of the creek is about 20 m and an average depth of about 0.5 m. Ogbe creek (Station C) is located about 1 km from Abule Agege on a swampy creek, which flows south-west through the Lagos metropolis and University of Lagos before emptying into the lagoon. Ogbe creek is non tidal and experience flooding in the wet season as a result of surface runoff (Nwankwo and Akinsoji, 1992). The stream channel width is about 30 m with an average flow velocity of 0.5 cmS^{-1} (Edokpayi and Ayorinde, 2009). The station has a coordinate of 3°23.527'E and 6°30.627'N.

MATERIALS AND METHODS

Collection of samples

The study adopted both field and laboratory based procedures to generate the data required. Surface water for physical, chemical and sediments analysis was collected monthly at three sampling stations from the period of June to November, 2016 between 08:00 am and 11:00 pm.

Sub-surface water samples were collected with a 1 dm^3 water sampler, stored in 1-L water bottles and analyzed in the laboratory for pH and conductivity using a multi-meter water checker (Horiba U-10). Surface water temperature was measured *in situ* using mercury-in-glass thermometers. Separate water samples were collected in 250-ml dissolved oxygen bottles at each station for dissolved oxygen and estimated using iodometric Winkler's method.

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Sediment samples were collected using a Van-veen grab (wt. 25 kg; ht. 20 cm). The grab affixed with a rope was lowered gently into the water until it got to the bottom of the water. It was then hauled and the contents emptied into a bowl. A portion of the sediment sample was collected and kept into a nylon bag that was appropriately labeled with dates and stored in a deep freezer prior to sediment analysis in the laboratory (Nkwoji et al., 2011).

Sediment sample analysis

Two grammes of the sediment were weighed in a beaker into 20 ml of distilled water and allowed to stand for 30 min. Another 30 ml of distilled water was added to the sample and made to 50-ml final volume. 20 ml was removed for acidity and alkalinity while the remaining 30 ml was digested with 5 ml HNO_3 on hot plate heated for 30 min in a fume cupboard. The digest was diluted with 80 ml distilled water and was filtered with No. 1 filter paper (IAEA, 2003).

Particle size analysis

Determination of the particle size was by wet screening method (IAEA, 2003). An accurately weighed 25 g of sample of oven-dried sediment from each station was pre-heated with distilled water containing a sequestering agent (Sodium hexameters phosphate) for two days until all lumps were broken. The sample was sieved through a 63-µm sieve to separate the sediment into sand, silt and clay fractions. The retained material on the sieve was dried to a constant weight at 80°C and agitated on a mechanical shaker for 15 min. Any remaining silt/clay fraction passed through the sieve. The percentage of silt-clay fraction was calculated by subtracting the weight of the fraction retained on the sieve after shaking from the initial weight of the oven-dried sediment sample (IAEA, 2003).

Statistical analysis

Data analysis of the physical and chemical parameters of water and sediments were statistically analyzed for their mean and variance using the Statistical Package for Social Science (SPSS) and was tested at a level ($p>0.05$) for significance. The mean values of each parameters were compared among the three study creeks using bar chat and analysis of variance (ANOVA).

RESULTS

Data on the water and sediment characteristics of the sample sites are presented in Tables 1 and 2, respectively. The physico-chemical parameters in the water and sediment showed that there was no significant differences ($P>0.05$) among the study stations.

Water analysis

The graph of the seasonal variation in the physicochemical parameters is illustrated in Figure 1. The water pH concentrations ranged between 6.5 - 7.20 with slight changes across the months. Recorded values for water temperature varied by 1°C with maximum value of 26°C and minimum of 25°C. Conductivity of the sample sites was ≥ 0.44 mS/cm. Abule Agege (7.67 mS/cm) and Abule Eledu (8.18 mS/cm) creeks recorded conductivity to be highest in June but reduced exponentially to 0.5 and 0.44 mS/cm in November, respectively. Conductivity in Ogbe creek declined in August and September and increased in October and November. The dissolved oxygen concentrations in water were above 1.6 mg/l all through the sample months and sites. There was a rise and fall in DO from June – November. In Abule Agege Creek, the DO increased exponentially from 1.7, 2.0, 2.4, 3.0 mg/L in June to September but dropped in October (2.4 mg/L) and increased again in November (3.0 mg/L). In contrast, Abule Eledu recorded dissolved oxygen of 1.6 mg/L in June but rose to 2.5 mg/L in July. However, DO was dropped in August to 2.1 mg/l. September recorded highest DO concentrations of 3.8 mg/L but dropped in October to 1.8 mg/l and increased again to 2.4 mg/L in November. Also, dissolved oxygen in Ogbe Creek increased exponentially from June to August, declined but maintained a constant value of 1.6 mg/l in September and October and rose to 2.0 mg/L in November.

Sediment characteristics

The seasonal variations of sediment characteristics are shown in Figures 2 to 6. Abule Agege Creek recorded sediment pH concentrations ≥6.0 in June to November. However, all the sample months were alkaline (≤6.4) except in October (6.63) and November (7.2). October and November recorded highest values of acidity and alkalinity. Nitrate concentrations were low in September (17.2 mg/kg) but ≥25.2 mg/kg in other months. Phosphate concentrations from June to August recorded ≤ 1 and ≥ 15.1 mg/kg in September to November. Total organic matter and total organic carbon were low in September and October but high in the other months.

On the other hand, Abule Eledu Creek had pH values that were slightly neutral in the sample months except in October that recorded pH of 6.4. October and November also recorded highest values of acidity and alkalinity like the one observed in Abule Agege Creek. Nitrate concentrations were high in August (25.2 mg/kg) but dropped to 19.8 mg/kg in September and increased in October (41 mg/kg). Phosphorus concentration were highest in October (14.4 mg/kg) and November (18.9 mglkg) but was ≤3.3 mg/kg in the other months. TOC was ≤3.89≥10.8% while TOM was ≤6.80≥18.6%. TOC and TOM were highest in August and lowest in October.

Consequently, pH of sediment from Ogbe Creek showed slight neutral conditions ≤6.8≥7.18 in the months except in September and October that had 6.5 and 6.4 respectively. Just like the other sample stations, October and November recorded highest values of acidity and alkalinity. The creek recorded increasing levels of nitrates across the months with highest in October (38.2 mg/kg) and November (43.8 mg/kg). Phosphorus concentrations

Table 1. Monthly variation in physicochemical paraments of water at the sample sites.

Parameter	June			July			August			September			October			November		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
pH at 25^{oC}	6.7	6.9	7.2	6.8	6.6	7	6.7	6.8	6.9	6.8	6.7	6.5	7.2	7.1	6.8	6.6	6.6	6.9
Water temperature	26	26	25	25	25.2	26	25	25	25	25	25	25	25	26	26	26	26	26
Conductivity (ms/cm)	7.67	8.18	0.85	5.22	3.15	0.91	2.71	1.18	0.8	0.6	0.48	0.6	0.55	0.44	0.86	0.5	0.44	0.99
DO (mg/L)	1.7	1.6	2.3	2.0	2.5	3.1	2.4	2.1	3.0	3.0	3.8	1.6	2.4	1.8	1.6	3.0	2.4	2.0

Table 2. Monthly variation in the sediment characteristics at the sample sites.

Parameter		June			July			August			September			October			November		
		A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
pH (1:1Sediment)		6.43	6.88	7.18	6.4	6.6	7	6.7	6.4	7.1	6.63	6.8	6.5	6.0	6.4	6.5	7.2	7.1	6.8
Alkalinity (mg/kg)		81	82	60.5	80	85	50	82	79	71	90	83	79	1380	1410	1500	120	1370	1190
Acidity(mg/kg)		110	106.5	73	112	105	70	110	108	66	135	132	117	230	180	210	1350	140	200
Nitrate(mg/kg)		24.5	16.1	13.75	23	16.5	13.5	25.2	15.7	14	17.2	19.8	15	64.7	41	38.2	50.6	39.1	43.8
Phosphate(mg/kg)		0.53	1.23	0.91	0.2	0.9	0.7	0.85	1.55	1.12	15.1	3.3	5.7	32.7	14.4	20.7	16.3	18.9	10.7
TOC (%)		11	9.45	6	11.1	10.4	6.2	10.8	8.5	5.8	3.47	6.79	4.25	5.21	3.89	4.03	6.04	5.93	3.12
TOM (%)		18.85	16.25	10.3	19.1	17.9	10.7	18.6	14.6	9.9	5.97	11.68	7.31	8.96	6.80	6.93	10.39	10.20	5.37
Particle size(%)	Clay	58	58	58	50	52	40	47.2	57.5	53.5	65	32	44	59	36.9	42.9	38.1	33.2	18.7
	Silt	35	36	34	41	45	55	44.2	38.8	42.1	45.7	42	30	39.8	60.1	55.0	59.3	64.9	42.9
	Sand	7	6	8	9	3	5	8.6	3.7	4.4	7.1	3.5	2.6	1.2	3.0	2.1	2.6	1.9	8.4

A= Abule Agege creek,**B =** Abule Eledu creek,**C=** Ogbe creek.

in June to August was <1.2 mg/kg but higher from September to November and highest in October with values of 20.7 mg/kg. In contrast to other sample stations, June to August recorded the highest values in TOC (>5 mg/kg) and TOM (>9 mg/kg) whereas November recorded the least concentrations of TOC and TOM.

The following sediment particle size were observed in the sample stations. Abule Agege Creek had a clay-muddy substratum; Abule Eledu Creek had a muddy substratum while Ogbe Creek is a sandy substratum. The sediment particle size in the sediment from the sample locations showed that there was no significant differences (P>0.05).

DISCUSSION

The majority of the water chemistry and sediment characteristics studied can be assigned to influences from early dry season and peak rainy season. Irrespective of the season, results of the present study recorded relatively uniform water temperatures that correlate with the studies of Nkwoji et al. (2010, 2011) which was attributed to the conventional nature of the parameters in the creeks. The low water temperatures across the months and sample stations was due to the effect of low insulation, increase in suspended particles and the dilution effects of flood waters. The slight variation in the values of water temperature (25-26°C) may be linked with the shallowness of the creeks and regular tidal motions, which ensured the complete mixing of the water. This observation agrees with Ajao (1990). The increasing values of conductivity in Ogbe Creek depict it as a fresh

Figure 1. Map showing the sampling stations.

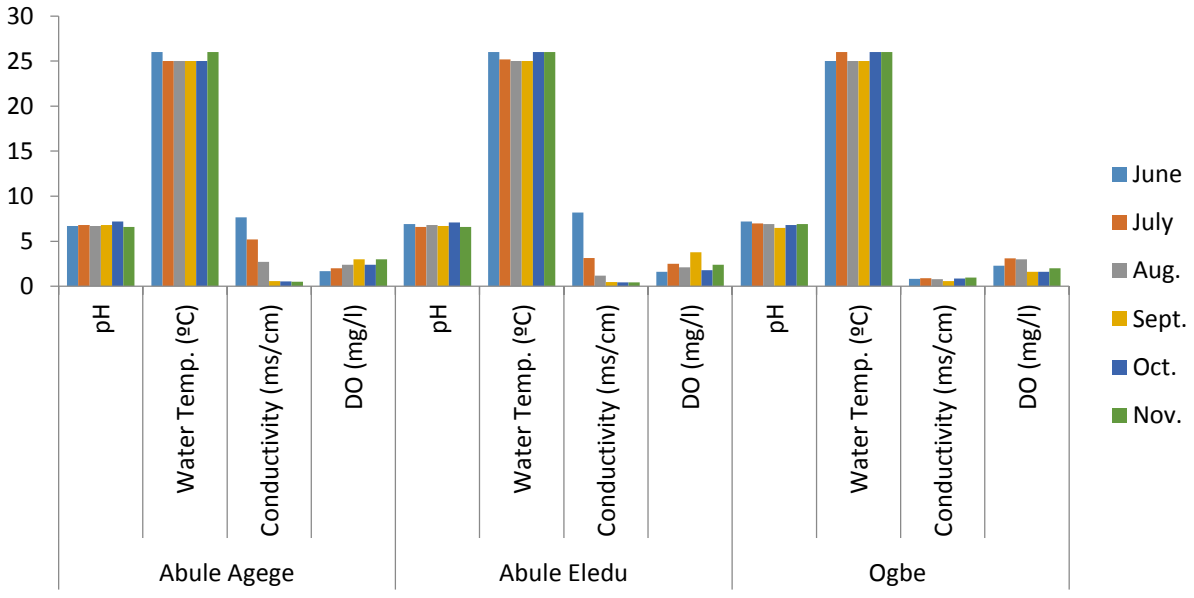

Figure 2. Seasonal variationof the physicochemical parameters in water at Abule Agege Creek, Abule Eledu Creek and Ogbe Creek.

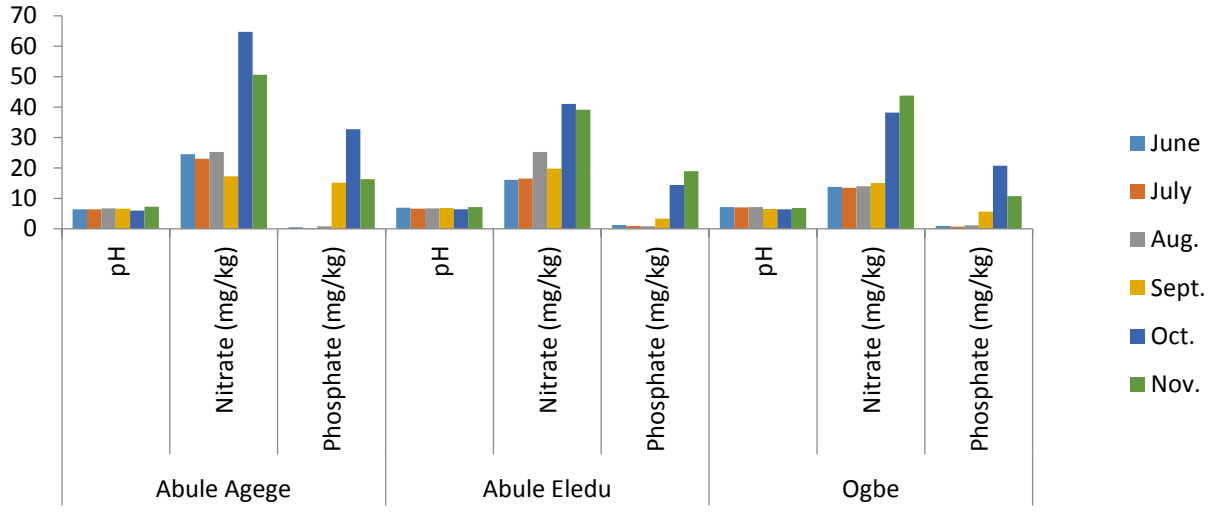

Figure 3. Seasonal variationof pH, Nitrates, and Phosphates in Sediments from Abule Agege Creek, Abule Eledu Creek and Ogbe Creek.

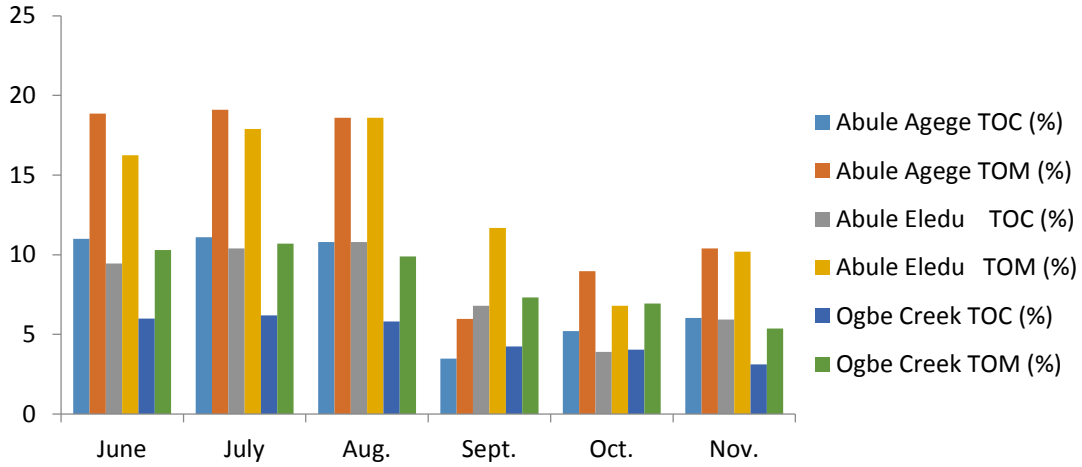

Figure 4. Seasonal variation of TOC and TOM in Sediments from Abule Agege Creek, Abule Eledu Creek and Ogbe Creek.

water ecosystem.

Optimal pH range for sustainable aquatic life is pH 6.5 - 8.2 (Murdock et al*.*, 2001). Most aquatic organisms are known to be affected by pH due to their metabolic activities that are pH dependent (Wang et al., 2002). The pH value recorded across the months was slightly acidic to neutral (pH≥6.5≤7.2). The results indicated slightly acidic pH levels in Ogbe Creek during the rainy season and could be attributed to the mechanic workshops located close to creek. The observed acidity pH in this study agrees with the reports of Abowei and Sikoki (2005) that water with little change in pH are generally more conductive to aquatic life.

Dissolved oxygen (DO) values range of 1.6 mg/kg - 3.1 mg/L was recorded during the period of study. This was however lower than the W.H.O standard of 5 mg/L. This low dissolved oxygen was attributed to be as a result of the discharge of organic wastes and nutrient inputs from sewages and agricultural run-off that find its way into the water body through erosion (Olowu et al., 2010). The low level and decline of dissolved oxygen in the study stations depicted a high level of organic pollution which resulted to biodegradations by biotic microorganism (Nkwoji et al., 2010). Seasonal variations observed in DO concentrations with higher values in rainy season could be due to increased aeration because of rainfall (Adeyemo et al*.*, 2008). Ayoade et al*.* (2006) reported that DO concentration at Asejire Lake reached its peak at the height of rainy season. Even though the studied creeks recorded low DO concentration; the lower DO in

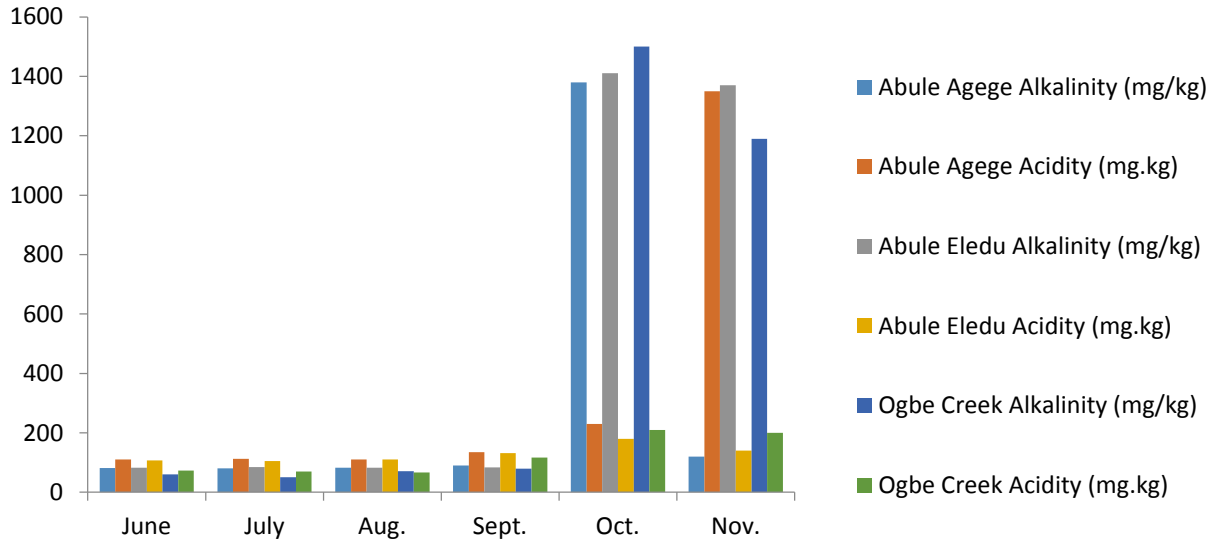

Figure 5. Seasonal variation of alkalinity and acidity in sediments from Abule Agege Creek, Abule Eledu Creek and Ogbe Creek.

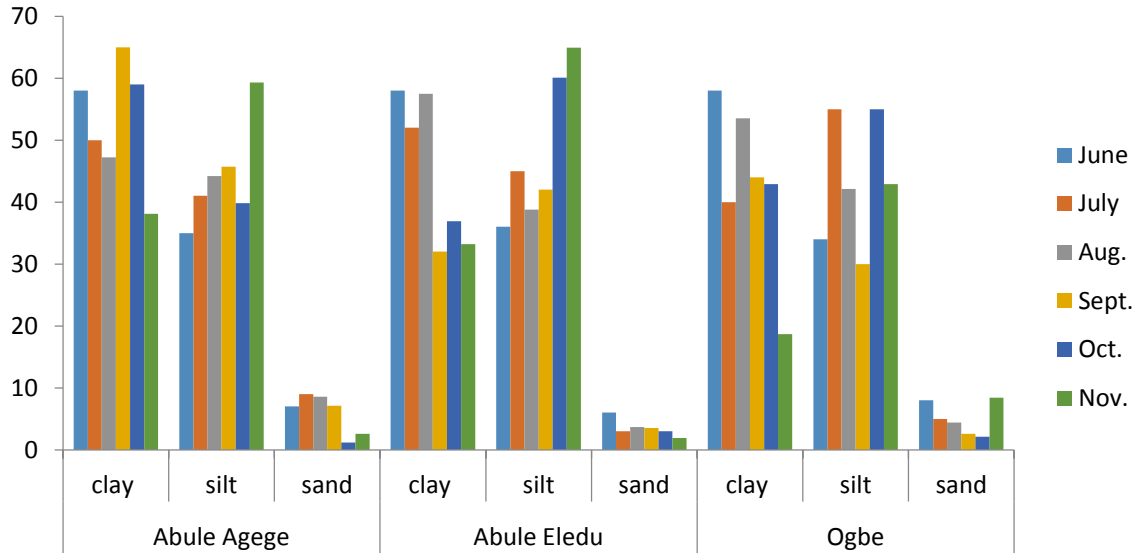

Figure 6. Seasonal variation in the particle size of sediments from Abule Agege Creek, Abule Eledu Creek and Ogbe Creek.

Ogbe Creek specifically implied that the creek was more polluted than Abule Agege and Abule Eledu Creeks. Domestic, agricultural, effluent and waste discharge into creeks are usual practice in Lagos and are the main reasons for the high pollution of the creeks.

The influx of contaminants coming from domestic and industrial effluents, urban storm, and agricultural run-offs into the study locations led to the changes in the environmental conditions of the creeks thereby resulting in the increase in alkalinity, acidity, nutrients, TOC, TOM, and pH of the sediment characteristics. This correlated with the works of Ajao and Fagade (1990) that also recorded changes in the ecological biota and sediment characteristics which were as a result of these stressors.

The sample sites had high concentrations of nitrates higher than 20 mg/kg. The study locations showed limited concentrations of phosphates as compared with that of nitrates. The increase in nutrients of the study sites can be attributed to the increase in anthropogenic activities (Edokpayi and Ayorinde, 2009; Edokpayi et al., 2010).

Excess nitrate in sediment is considered as pollutant (Odiete, 1999). Increase in the sediment nutrient can be attributed to differences in sediment nutrient input from the drainage systems of the various locations. The mean phosphate concentration recorded is 8.10 mg/kg. This compares favorably to the range value of 0.29 - 244 mg/kg obtained by Braide et al. (2004) and Ezekiel et al. (2011) which recorded 13.43 mg/kg. Phosphate and nitrate were exceptionally high in October and November and can be attributed to the ability of the creek to accumulate nutrients from different anthropogenic sources during this period. This phosphates and nitrates are the key limiting nutrients for eutrophication, and results show high nutrient load which will make the biota to be productive, destruction of the creeks, decay and sedimentation as well as nutrient enrichment (Adeyemo, 2003). High Levels of both phosphate and nitrate can lead to eutrophication, which increases growth of algae and eventually decreases dissolved oxygen levels in the creeks (Murdoch et al., 2001).

Total organic content/matter in the sediments of the study locations indicate the presence of contaminants in the creeks coming from anthropogenic activities. Ogbe Creek remained the only creek with reoccurring low concentrations in the parameters studied. This is an indication of increasing human activities and a perturbed creek. The mean organic carbon content of the study is 6.77% while organic matter is 11.66%. The results of the study are higher compared to Sombreiro River which ranged between 2.02 and 4.134% with a mean of 2.68% (Ezekiel et al., 2011) and also below the mean value of 1.02% obtained from Lake Kariba by Mclachlan and Mclachla (1971). TOC and TOM were recorded to be highest between June and August. The level of total organic matter decomposition may be attributed for the variation in total organic carbon content. The difference in the organic content of the sample locations are attributed to the differences in deposition of organic matter at the various locations.

The Abule Agege Creek (Station A) has pH values that range between 6.0 and 7.20. This disagreed with the report of Brown and Kola-Banjo (1998) on the same creek during the late months of dry season and beginning of rainy season where an acidic pH between 5.0 and 6.6 was recorded. The mean value of the sediment pH obtained in this study can be compared favorably with the report of Braide et al. (2004) who reported alkaline range of 6.9 - 7.8 from the freshwater stream of Minichida Stream, Niger Delta.

The increase in acidity and alkalinity in the creeks in October and November with highest in Abule Eledu and Ogbe Creeks may be attributed to the fact that Abule Eledu Creek and Ogbe Creek are in urban location characterized by anthropogenic input, land drainage pollution and anthropogenic sediment accumulation arising from the presence of automobile workshops photographic workshops and other commercial activities, mechanic workshops, wash back of the spoils and chemical wastes from auto-mechanic and car wash shops at the bank of the creeks (Braide et al., 2004).

Conclusion

The deterioration in the physico-chemical quality and increase in the nutrient level observed in this study is alarming and has been attributed to the accumulation of organic matter, contaminants and pollution going on at the time of research. The increase in phosphate and nitrates depict an environmentally stressed ecosystem which resulted in the low values of dissolved oxygen concentrations. Seasonal variations also contributed to the high levels of concentrations in the parameters studied with alkalinity, acidity, phosphates and nitrates having higher concentrations in October and November. It can be deduced that different study stations differed with the level of concentrations due to the type of anthropogenic stressors occurring in the stations. Water and sediments serve as a source of food and habitat to substratum species and man hence, periodic monitoring and preventive measures are necessary to save the creeks from eutrophication and total degradation. Further studies are therefore needed to be carried out especially on the effect of anthropogenic impacts and seasonal variations on the substratum species.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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