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On the Physico-chemistry and Nutrient Profile in the Lagos Harbour

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Authors' contributions

This work was carried out in collaboration between all authors. Author UJP designed the study and wrote the protocol. Authors PS, OO and NC carried out sampling on the study. Authors FI and FA wrote the draft of the manuscript, formatting of the article, literature searched and made statistical analysis. All authors read and approved the final manuscript.

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ABSTRACT

Physico-chemical and nutrient distribution control lagoon biological productivity, however, focus has been on studies on surface and bottom distribution with little on the vertical profiling of nutrients. Yet it is important to validate physico-chemical properties with nutrients to successfully determine the biological variability and trend of the Lagos harbour. Here, the study was carried out during the rainy season in the months of August, September and October 2014 at surface, 2.6 m and 5.2 m depth to demonstrate quantitatively that variability of nutrients within the Lagos harbour is correlated with physic chemical parameters and depth. Water temperature (°C), pH, Conductivity (μS/cm} and salinity (‰) were measured in-situ. Dissolved oxygen, alkalinity, calcium and magnesium concentration were determined in the laboratory by titremetry, while chloride, sulphate, silicate, nitrate, nitrite and phosphate were determined by colorimetry. The result shows that temperature (23-27°C), pH (7.91-8.68) and dissolved oxygen (6.37-11.20 mg/l) were relatively constant as a result of mixing and the relatively shallow water. Conductivity and salinity were seen to increase down the depth across the months studied. The month of September had the highest

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physico-chemical and nutrient concentrations reflecting impact of decomposition of introduced macrophytes and high tides. Though nutrient variability as a function of depth was shown to have no significant difference $p>0.05$, variations down the depth in the months studied were attributed to factors such as tidal influence, chemical precipitation and decomposition. The result indicated that the dynamic in physical and chemical processes are probably the main variables that determine the instantaneous distribution of nutrients. However, subsequent studies are recommended in deeper areas of the harbour to understand and provide information on biological productivity of Lagoons.

Keywords: Physico chemical parameters; nutrients; depth; Lagos harbour.

1. INTRODUCTION

Coastal lagoons rank among the most productive ecosystems on Earth, and they provide a wide range of ecosystem services and resources. Anthropogenic impacts are escalating in many coastal lagoons worldwide because of increasing population growth and associated land-use alteration in adjoining coastal watersheds. The conversion of natural land covers to agricultural, urban, and industrial development has accelerated loading to streams and rivers that discharge into estuaries, leading to cascading water quality and biotic impacts, impairments, and diminishing recreational and commercial uses. Many coastal lagoons, notably those with restricted circulation, freshwater inflow, low flushing rates, and relatively long water residence times, are particularly susceptible to nutrient enrichment from surface runoff, groundwater, and atmospheric inputs. [1].

The Lagos lagoon is an urbanized estuarine ecosystem, receiving load from a number of important large rivers (Yewa, Ogun, Ona and Oshun) draining more than 103, 626 sq. km of the country. The lagoon is a great expanse of shallow water with depths ranging as low as 0.9 meters in some points and up to 25 meters at the dredged areas [2]. Much greater seasonal changes occur by the influx of fresh water during the rainy periods. The lagoon borders the forest belt and empties directly into the Atlantic Ocean at the harbour. During the rainy season, large volume of fresh water passes through the harbour into the sea. The estimated area of the Lagos lagoon is 150.56 km^2 while the harbour is about 8 km long and leads to the wharf area of Apapa where shipping activities are concentrated. The lagoon is also impacted by industrial, agricultural and municipal activities that keep increasing with the ever growing population of Lagos, the most populated city in the country, presently harbouring not less than 15% of the total population (about 150 million) of Nigeria [3].

To mitigate the impacts of these activities on the aquatic ecosystem, it becomes imperative to implement comprehensive routine monitoring regimes in physico-chemical properties and nutrient status of surface water which is a major factor for distribution of ocean life. There have been several seasonal and spatio-temporal assessments of the surface physico-chemical properties of the harbour waters over time [4,5]. However, there is a dearth in studies of the variations in physico-chemical properties with depth around the harbour, hence the need for this study to assess its variations with depth to elucidate the effects on the aquatic ecosystem around this ecological region.

The aim of this study is to investigate the physico-chemical parameters and nutrient concentrations of the Lagos harbour to understand and determine factors responsible for their variations with depth. This is important because of the diversity in hydrology and chemistry of the Lagoon ecosystem. Our main interest is to emphasize the variation of water parameters with nutrients to depth which will reflect and give vital information on the likely biodiversity of the Lagos harbour.

2. MATERIALS AND METHODS

Lagos Harbour, Nigeria's most important seaport is the first inlet from the Atlantic Ocean beyond the Republic of Benin. The Harbour is one of the three main segments of Lagos Lagoon Complex; other segments are: Metropolitan and the Epe Division Segments. The Lagos harbour (Fig. 1) is located in Lagos state, Nigeria. The 2 km wide harbour receives inland waters from the Lagos Lagoon in the east, and from Badagry Creek in the west. It provides the only opening to the sea for the nine lagoons of South Western Nigeria. Lagos Harbour is a naturally protected basin equipped with docking and other facilities for the loading and unloading of cargo and usually with installations for the refuelling and repair of ships [6].

NIOMR jetty, Latitude (6°25',88°N longitude 3°24 24 42°E) is located in the Commodore channel of the Lagos Harbour with jetty facilities awaiting rehabilitation. Subsistence fishing takes place in this part of the water body by artisanal fishermen [6]. The study took place between August and October 2014, water samples were collected three times weekly at 0, 2.6 and 5.2 meters depth using water sampler, 0.28 m height and 0.1 m diameter in size. Sample collection was done by descending graduated sampler into the water and allowing influx of water at predetermined depth. The physico-chemical parameters analyzed were pH, Salinity (‰), Conductivity (µScm), Alkalinity (mg/l), Temperature (°C) and Dissolved Oxygen (mg/l). Water temperature was taken in-situ with mercury-in-glass thermometer. Dissolved oxygen was determined by fixing with alkaline potassium iodide (KI) reagent and manganous sulphate solution ($MgSO_4$) adopting the Winklers method. Alkalinity was determined by titrating dilute (HCl) against 50ml of water sample using methyl orange indicator [7]. pH, Conductivity and Salinity were measured in-situ with a multi-meter checker (Horiba-U10). Water quality analysis included nitrite (NO2) with the sulfanilamide method, and reduction of nitrate (NO3) to nitrite using a cadmium-copper column. Phosphorus, as soluble reactive phosphorus (SRP) was measured with the mixture of reagents technique; soluble reactive silica (SRSi) was measured using the blue-molybdenum method; Sulphate was determined using barium chloride and chloride by using silver nitrate. Determination of calcium and magnesium were carried out using the titrimetry method with standardized ethylene diamine tetracetic acid (EDTA) [IOC, 1993] [8].

A one way factor analysis of variance (ANOVA) was used to interpret the relationships between the physico-chemical parameters and nutrients with depth. Statistical hypothesis testing was used to determine the significance of the result obtained using 95% confidence interval where $P<0.05$ are considered to be statistically significant [9].

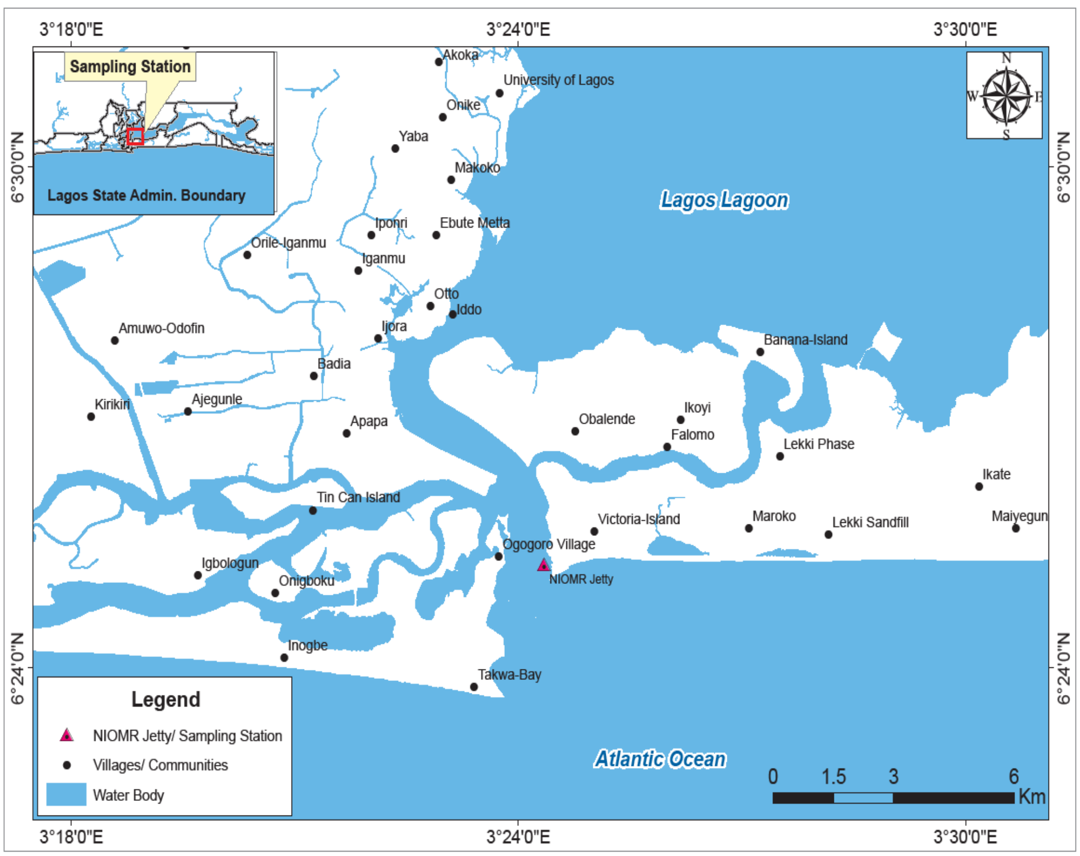

Fig. 1. Map of the study area

3. RESULTS

At the surface, conductivity and salinity in the month of August were 9.94 µS/cm and 5.67‰ while September values were shown to be 21.96 µS/cm and 13.5‰ respectively. The month of August showed low surface temperature relative to 2.6 m and 5.2 m depth. In September and October, it remained relatively constant at an average of 26.39°C (Figs. 3 and 4). Increased pH values with depth were observed in the months studied and ranged from 7.91-8.68. In October, the surface showed neutral value of 7.48±1.19 while at 2.6 m and 5.2 slight alkaline values of 8.65±0.37-8.68±0.39 respectively were recorded (Fig. 3). Dissolved oxygen values recorded at the surface in August, September and October were 7.38, 9.32 and 7.93 mg/l respectively. Values for 2.6 m and 5.2 m depth for the three months were 6.37, 8.36 7.70 mg/l and 7.47, 7.28 and 11.2 mg/l respectively. Alkalinity values recorded for 5.2 m depth was highest for the three months at 78.33, 93.2 and 72.25 mg/l relative to surface and 2.6 m depth for the same period.

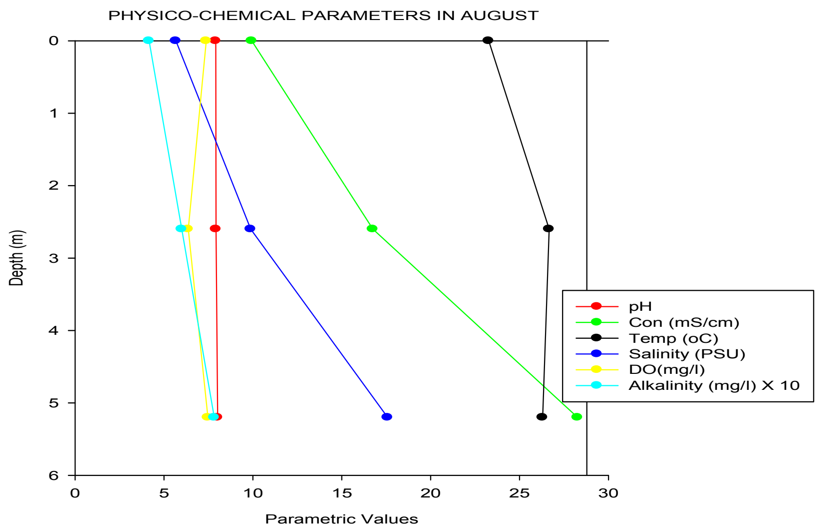

Fig. 2. Mean values of physico-chemical parameters in August

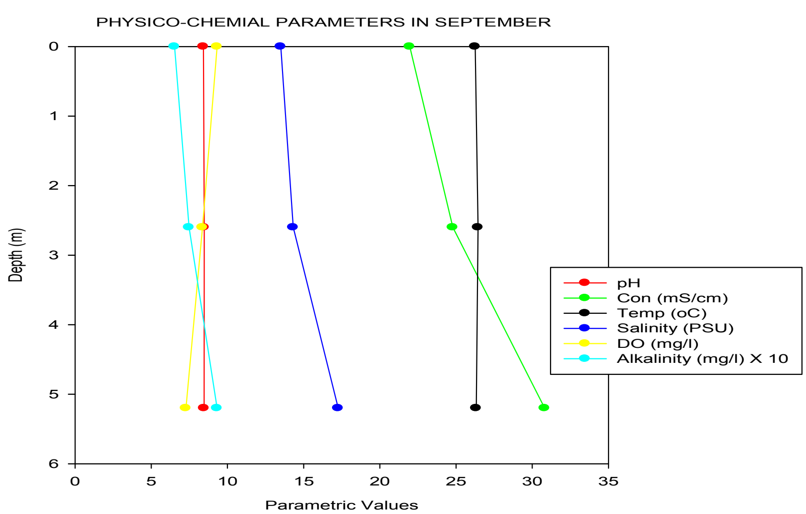

Fig. 3. Mean values of physico-chemical parameters in September

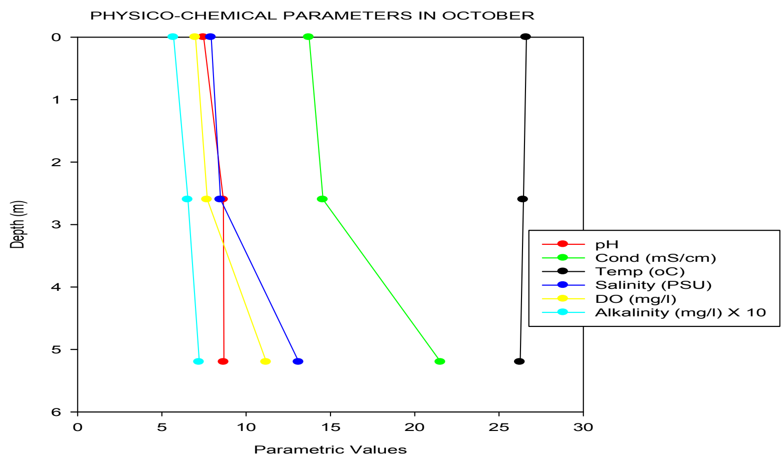

Fig. 4. Mean values of physico-chemical parameters in October

The mean values of nutrient concentrations in Lagos harbour during the period August to October (rainy season) are represented in Figs. 5, 6 and 7. Based on the results obtained, the lagoon reflects oligotrophic features with relatively low nutrients (nitrite, nitrate and Soluble Reactive Phosphorus-SRP). Calcium concentrations were related to the intensity of rainfall i.e. concentrations increased with rainfall. The highest mean concentration of 460.7 mg/l was recorded towards the end of the wet-season in October at a depth of 5.2 m while the lowest mean concentration of 55 mg/l was in August at depth 5.2 m. Unlike Calcium, magnesium mean concentrations did not follow this trend, indicating other factors responsible for the varying concentrations of magnesium at different depth during this study. Lowest observed mean concentrations of magnesium for the months of August, September and October at 2.6 m are 458.33 mg/l, 2503.33 mg/l and 2285.2 mg/l respectively. Chloride concentrations showed chemical precipitation/dilution effect as mean concentrations in August which ranged from 78.39- 92.65 mg/l reduced in September (67.05-77.6 mg/l). Though October gave the lowest mean concentration of 53.25 mg/l (at 5.2 m), a concentration of 89.64 mg/l (at surface) was higher than concentrations recorded in September at different depths. Concentrations recorded for sulphate showed the influence of high tidal energy experienced during the month of September which resulted to highest values obtained (223.74-235.67 mg/l) during the course of the study. Lowest mean values were seen in the month of August (103.21- 178.11 mg/l) while values in October were higher (157.61-196.59 mg/l) but lower compared to September values. The mean Soluble Reactive Silica (SRSi) concentration was highest in September (2.11-23.74 mg/l) and lowest in the month of October (0.99-9.61 mg/l). However a similar pattern was observed at different depths of the months studied with the lowest values observed at depth 5.2 m (1.69, 2.11 and 0.99 mg/l) for August, September and October respectively. Mean values of SRP for August (0.07-1.2 mg/l) and October (0.25-0.89 mg/l) followed the same trend as concentrations decreased as depth increased. The values obtained in September showed a slight deviation from this trend with a reduction in concentration from surface (0.74 mg/l) to 2.6m (0.57 mg/l) but increased at depth 5.2m to 1.16mg/l. The mean values of nitrites (0.1-40.45 mg/l) and nitrates (0.05-0.73 mg/l) were shown to be low during the study with the exception of nitrite concentration at 2.6m (40.45 mg/l). Compared to the month of August and October, nitrate values for September had higher values with the highest reported at 2.6m (0.73 mg/l). The analysis of variance showed that there was no significant difference in physico-chemical parameters and nutrient concentrations at the different depths during the months studied with $p>0.05$.

4. DISCUSSION

The gradients observed in water quality at different months with depths suggest that chemical characteristics and physical processes are factors that play an important role in promoting changes in the water body. Due to high tidal energy and relatively shallow water, the water mass is generally well mixed.

pH is an index of the hydrogen ion concentration and a very important environmental variable. Surface water generally tends to be alkaline while ground waters are more acidic. The pH of water may influence the species composition of an aquatic environment and the availability of nutrients as well as the relative toxicity of many trace metals [10]. Mean pH values were well within the susceptible range for drinking water (6.5-8.5), optimal aquatic productivity (6.5-9.0) and liveable range of 5.5-10 [11]. The pH values obtained are characteristic of tidal brackish water environment [12,13]. The slight to moderate alkaline difference at the surface, 2.6 m and 5.2 m may be due to high photosynthetic activities which occurred at the surface and 2.6 m relative to that at 5.2m. According to Lawson [14], high pH may result from high rate of photosynthesis by dense phytoplankton blooms. Apparently, pH in September had a constant alkaline distribution downwards. This period coincided with the occurrence of surge with even mixing of the water and suggests the consistent pH values recorded. Conductivity and salinity which naturally increases towards the sea, exhibited similar trends by increasing vertically downwards for the recorded period.

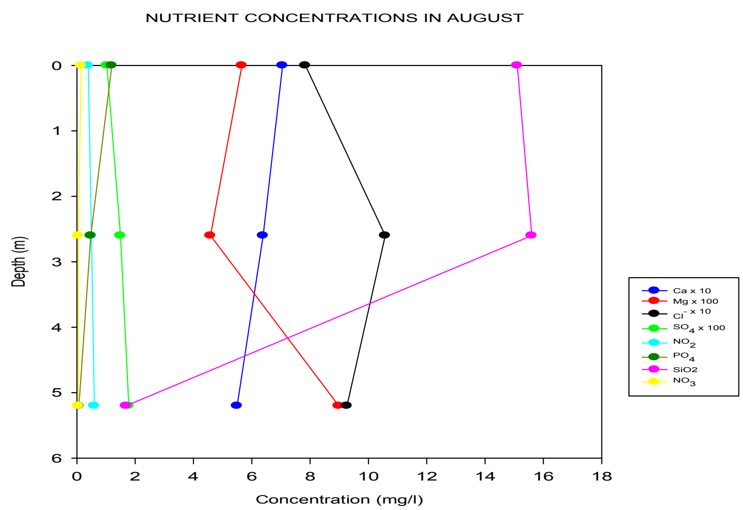

Fig. 5. Mean concentrations of nutrients in August

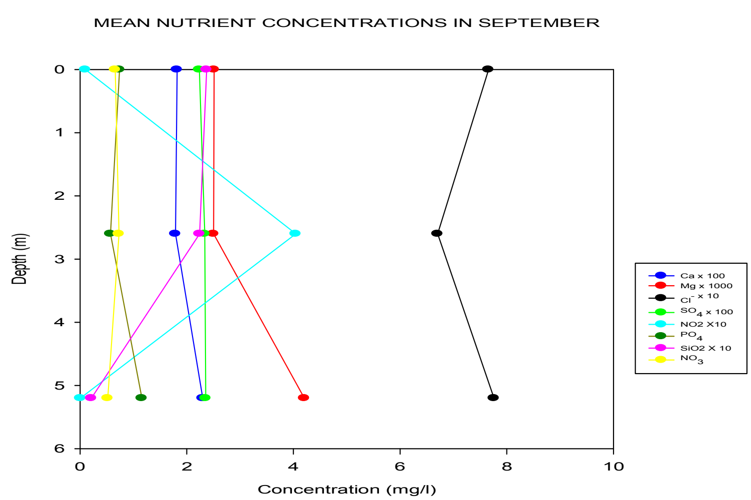

Fig. 6. Mean concentrations of nutrients in September

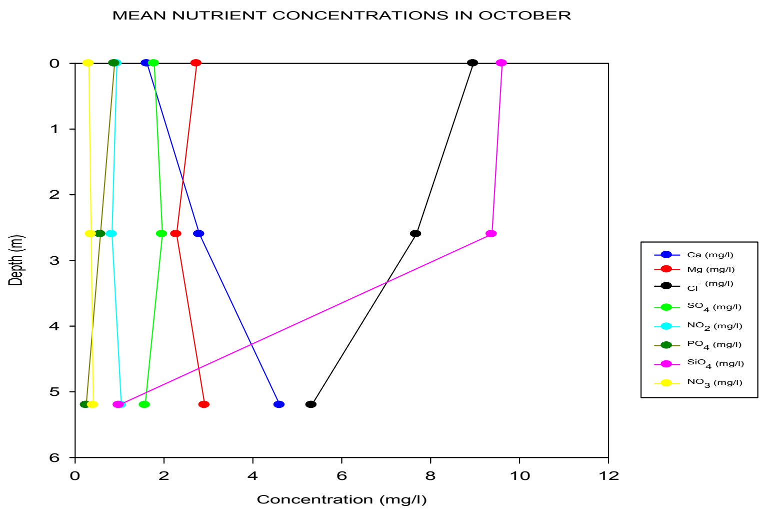

Fig. 7. Mean concentrations of nutrients in October

Air-ocean interactions results in cooler surface water temperature and is responsible for the relatively low surface temperature reported in August and September. Water temperature in October decreased with depth due to high insolation. Narrow amplitude of temperature variations was maintained with depth in September and October at constant values (Figs. 3 and 4). However, temperature showed characteristics of tropical water environment and falls within acceptable ranges [10,15].

Coastal waters typically require a minimum of 4.0 mg/L and also do better with 5.0 mg/L of oxygen to provide for optimum ecosystem function and highest carrying capacity [16]. As observed by Babalola and Agbebi [17], in the Kuramo lagoon, oxygen concentration was inversely proportional to depth. Dissolved oxygen recorded in September in this study corroborates this relationship as it decreased from 9.32 mg/L at the surface to 8.3 mg/L at 2.6 m and 7.28 mg/L at the bottom. Conversely a direct relationship was evident in dissolved oxygen distribution with depth in August and October as it increased from the surface to 5.2 m.

Alkalinity of a water body is a measure of its capacity to neutralize acids to a designated pH, it is an indirect measure of the concentration of anions in water [7,18]. According to McNeely et al. [19], the dissolved anions may be sourced from bicarbonates, carbonates, hydroxides, phosphates, borates or silicates which may be derived from industrial waters, dissolved rocks, salts or bottom sediments. Reported alkalinity in this study is within the acceptable range for natural surface waters, Department of National Health and Welfare [20] recommended an acceptable range of 30 mg/L to 500 mg/L for natural waters. Observed alkalinity in this study was in accordance with studies on estuarine environment [21]. Alkalinity generally increased with depth from surface to 5.2m across the period of study. This was shown to be high indicating presence of carbonates and bicarbonates [22]. The pattern could be traced to bottom sediments as source of the anions that accounts for alkalinity in the water.

This is in agreement with the mean concentrations of calcium and magnesium ions found in the water body. Calcium was found to be higher at lower temperatures for the months of August and October. This is because calcium dissolves rapidly in cold water where carbon-dioxide which makes water acidic dissolves calcium carbonate [23]. In September, temperature was shown to have little effect on the mean concentration of calcium. Concentrations observed could be attributed to the effect of surge leading to mixing of the water body which occurred in September. Also, highest concentration of calcium for the period of study was observed in October at 5.2 m depth, resulting from down-welling of accumulated calcium as a result of input from the sea, lower temperature and higher salinity [24]. Mean concentrations of magnesium were found to be higher than other water parameters as magnesium is said to be the third most abundant ion in water [25]. The mean concentration of magnesium in the months studied, followed the same trend with the lowest values occurring at 2.6 m depth. This is probably an indication of the effect of magnesium on calcium carbonate present in the water body. Magnesium is said to be attracted to calcium carbonate surface and precipitates to the bottom as magnesium/calcium carbonate (magnesian-calcite) [25]. Higher values at the surface compared to 2.6 m depth could be due to influx from the sea. Highest concentrations were shown for magnesium at depth 5.2 m for the three months. Magnesium which is more abundant than calcium binds to carbonates in the water body remains as ions since magnesium carbonates do not precipitate out [25]. Sulphate was found to have higher concentrations when compared to other anions in this study. Sulphate is second to bicarbonates as a major anion in water bodies [26]. Concentrations were highest in the month of September with values increasing with depth. Changes in water quality during the month of September which is related to nutrient input, decomposition and sediment resuspension could be attributed to tidal influence [27]. Decomposition of introduced aquatic macrophytes could have contributed to the increased mean concentration of sulphate at depth 2.6 and 5.2 m. Reduced values were reported in October due to water circulation dominated by tides [28,29]. Silica which is the second most abundant element in the earth crust reaches the marine system through erosion [30]. Values were reported to be at peak in the month of September due to tidal influence which reduced during the month of October resulting to lower concentrations. Higher mean concentrations were reported at the surface and 2.6 m depth for the three months studied, this is because silica remains in solution in warm water [23]. Contrary to this, lowest mean values were seen at depth 5.2 m for the months studied. This could be explained by the ability of silica to form colloids which are stable at pH 7-8.5, increasing in size and precipitating out of solution [31].

Also the presence of magnesium and calcium carbonate at pH >8.5 have been shown to cause massive precipitation of magnesium silicate [32]. Following the trend of increase in salinity from August to September and decrease in October, it is expected to have chloride concentrations in a similar trend. Conversely, a decrease in chloride concentration was observed in September and October. Though salinity increased in the month of September due to high tidal influences, reduction in chloride ions could be as a result of precipitation of less soluble chloride salts in water [33]. Chloride mean concentrations varied with depth and these variations were not consistent in the months studied as a result of the degree of factors such as dilution by rainfall, tide and precipitation leading to changes in chloride composition. Nitrite, nitrate and phosphate were observed to be low with the exception of nitrite at depth 2.6 m in the month of September. Nitrite is formed naturally from decomposition of organic matter by bacteria, high nitrite observed at depth 2.6 m in September could be related to decomposition of marine macrophytes introduced into the harbour due to high rainfall.

5. CONCLUSION

The study has shown variation in the vertical distribution of physico- chemical parameters and dissolved nutrient concentration in the Lagos harbour during the wet season in August, September and October. Under the combined effects of both physical and chemical processes, nutrients are been transported from the surface to the bottom and vice versa. Temperature and pH had little effect on the distribution of nutrients as the water sampled was relatively shallow and well mixed. Anthropogenic activity was seen to be minimal as the water body was oligotrophic in nature with relatively low nutrients (nitrite, nitrate and phosphate) and adequate dissolved oxygen. Influence of tide variation was evident in conductivity and salinity levels; and in concentrations of calcium, magnesium, sulphate. Factors contributing to this marginal variation were rainfall, surge, chemical precipitation and the presence of marine macrophytes that appeared in September during the study. Though variations in physico- chemical parameters and nutrient concentrations were shown to have no significant difference, it is important to note that vertical profiling of nutrient and water parameters is crucial when investigating deeper waters to understand and provide information on biological productivity of water bodies.

COMPETING INTERESTS

Authors have declared that no competing interests exist

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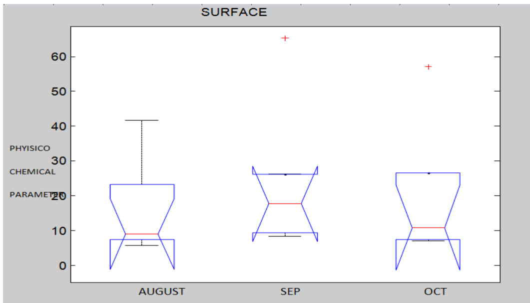
APPENDIX



ANOVA Table

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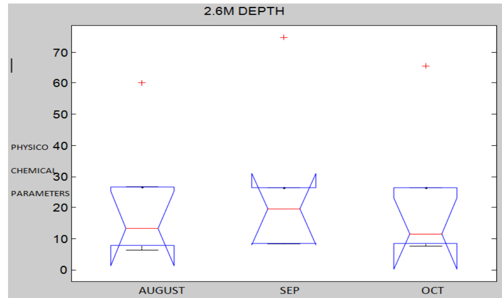

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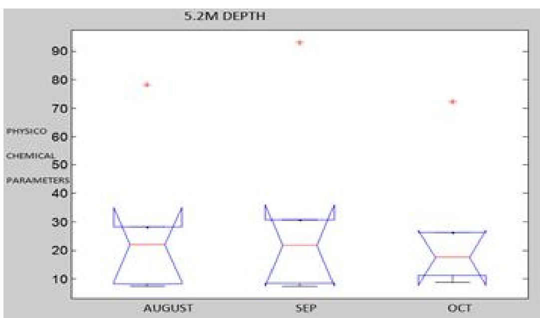

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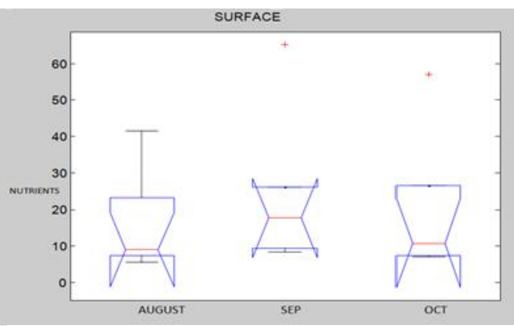
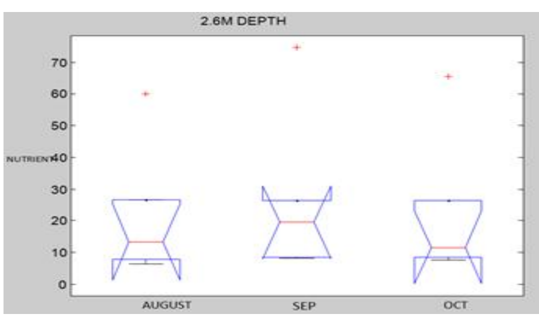


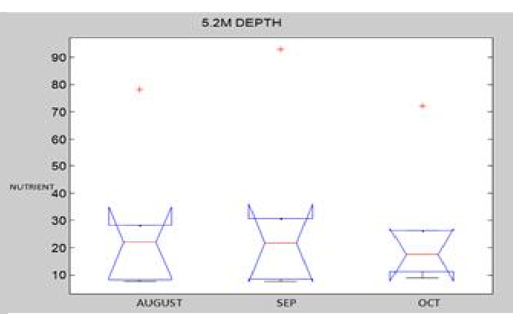
ANOVA Table

Source	SS	df	MS	F	Prob>F
Columns	199.62	2	99.812	0.29	0.754
Error	5203.55	15	346.904		
Total	5403.18	17			



ANOVA Table

Source	SS	df	MS	F	Prob>F
Columns	86.54	2	43.272	0.08	0.9201
Error	7749.54	15	516.636		
Total	7836.08	17			



ANOVA Table

Source	SS	df	MS	F	Prob>F
Columns	77.1	2	38.559	0.05	0.9509
Error	11455.2	15	763.678		
Total	11532.3	17			

ANOVA on physico-chemical parameters

		Sum of squares	df	Mean square	F	Sig.
pH	Between groups	.380	2	.190	1.197	.365
	Within groups	.954	6	.159		
	Total	1.334	8			
Conductivity	Between groups	215.048	2	107.524	3.594	.094
	Within groups	179.498	6	29.916		
	Total	394.546	8			
Temperature	Between groups	2.162	2	1.081	.950	.438
	Within groups	6.825	6	1.138		
	Total	8.988	8			
Salinity	Between groups	77.911	2	38.956	3.686	.090
	Within groups	63.420	6	10.570		
	Total	141.331	8			
Dissolved Oxygen	Between groups	2.118	2	1.059	.426	.672
	Within groups	14.923	6	2.487		
	Total	17.042	8			
Alkalinity	Between groups	1063.930	2	531.965	5.049	.052
	Within groups	632.107	6	105.351		
	Total	1696.037	8			
Month	Between groups	.000	2	.000	.000	1.000
	Within groups	6.000	6	1.000		
	Total	6.000	8			

ANOVA on nutrients

		Sum of squares	df	Mean square	F	Sig.
Calcium	Between groups	.658	2	.329	.055	.947
	Within groups	36.140	6	6.023		
	Total	36.799	8			
Magnesium	Between groups	8.298	2	4.149	.835	.479
	Within groups	29.807	6	4.968		
	Total	38.104	8			
Chloride	Between groups	1.280	2	.640	.226	.804
	Within groups	17.020	6	2.837		
	Total	18.300	8			
Sulphate	Between groups	.113	2	.056	.238	.795
	Within groups	1.423	6	.237		
	Total	1.535	8			
Nitrite	Between groups	3.279	2	1.640	1.148	.378
	Within groups	8.573	6	1.429		
	Total	11.853	8			
Phosphate	Between groups	.367	2	.184	1.380	.321
	Within groups	.798	6	.133		
	Total	1.166	8			
Silicate	Between groups	130.867	2	65.433	2.282	.183
	Within groups	172.058	6	28.676		
	Total	302.925	8			

Nitrate	Between groups	.005	2	.003	.031	.970
	Within groups	.489	6	.081		
	Total	.494	8			
Month	Between groups	.000	2	.000	.000	1.000
	Within groups	6.000	6	1.000		
	Total	6.000	8			

Peer-review history:
The peer review history for this paper can be accessed here:
http://sciencedomain.org/review-history/10326