Spatial Pattern of Water Quality Parameters in Ologe Lagoon Lagos State, Nigeria

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Abstract

This study examines the spatial pattern of water quality parameters in Ologe lagoon, Lagos State. Purposive sampling method was used to categorize the lagoon into upstream, middle stream and downstream and water samples were collected from the sections of the lagoon. Eighteen physiochemical and biological parameters were tested by conducting a standardized laboratory analysis on the water samples. Tables, graphs and ANOVA were employed to show inter-station comparisons and significant differences between parameters. The study revealed that there was no significant variations (p>0.05) in temperature, pH, TDO, phosphorus, zinc, nitrate and lead across all the stations. However, significant differences (p<0.05) exist in the values of EC, Turbidity, alkalinity, TDS, total hardness, Coliform and E. Coli across the stations. Many of the parameters examined were within the limits of the World Health Organization standard for human consumption except for the values of turbidity (224NTU), iron (8.65±0.21) recorded at the upstream and all the values of DO in the three stations. The study concluded that the values obtained from the different stations showed that their concentration varies across the lagoon, however, many of these values are within the WHO acceptable limit safe for human consumption. Therefore, apt attention must be given to continuous monitoring of the lagoon so as to protect, plan and device management strategies to the lagoon as regards the uses around it. Hence, future studies on the influence of natural processes on Ologe lagoon is important to make an effective water quality management plan.

Keywords: Surface Water; Water quality; Spatial Variation; lagoon

INTRODUCTION

Water is an unavoidable natural resource that is paramount to the development of nations and sustenance of living things. However, in recent times, human society and the natural ecosystem have been faced with a growing threat of water pollution. For instance, Sugirtharan *et al.*, (2017) observed that the coastal lagoons comprise of 13% of worldwide coastal areas which have been threatened by both natural and man-made changes. Furthermore, Yang *et al.* (2012) reported that surface waters (rivers, lagoons, streams, and lakes among others) have increasingly been contaminated by natural processes (such as rate of precipitation, soil erosion, weathering among others) and human activities (not limited to urbanisation, industrialisation, agricultural expansion and human exploitation of water resources). For example, about 90-95% and 70% of industrial waste and sewage respectively are dumped into surface water in developing countries (Galadima and Garba 2012; Ocheri and Okele, 2012).

In addition, runoff from impervious surfaces especially roads often cause water pollution as gasoline, motor oil, heavy metals, trash and other contaminants from roads are washed directly into water bodies (Alum-Udensi *et al.,* 2016). Moreover, surface water particularly in urban centres are often degraded principally by eutrophication due to industrial effluents, domestic sewage, and farming activities (Zhang *et al*. 2012; Mustapha and Aris, 2012). These activities together with the overexploitation of water resources are responsible for increasing the pollution level which endangers the quality of water in catchment areas (Singh et al. 2005). Consequently, this does not only affect the aquatic ecosystems, but also deteriorate the quality of water available for the populations living downstream (Adeosun *et al.,* 2016). Thus, many communities have been affected by poor health due to unsafe water use. For instance, Kithinji (2015) reported that 51% of the rural populace which experiences domestic water-related problems such as diseases may be attributed to their dependence on unprotected water sources such as surface water and hand dug-wells.

Water-borne pathogens affect about 250 million people yearly resulting in 10-20 million deaths around the globe (Zektser, 2005). In addition, WHO (2004) reported that about 1.8 million people die each year due to diarrhea diseases, and 90% of these deaths are of children under five years. This highlights the potential of infection due to water - borne pathogens. In another report by WHO and UNICEF (2014) it was reported that globally, 4% and 5.7% of all deaths and ill health respectively results from diseases relating to poor drinking water, unimproved sanitation facilities and poor hygiene practices.

Monitoring quality of inland water bodies such as lagoons is important in curtailing waterborne diseases. In view of the above, the reports by Food and Agricultural Organization (FAO) (2007) revealed that Nigeria and many African nations have been experiencing water related diseases which ultimately affect basic human development. This constitutes challenges to achievement of the 2015 MDGs, attaining the 2030 SDGs and the 2025 African Water Vision.

The Ologe lagoon is a large body of water that flows through many communities and is affected by deposition of both industrial and domestic wastes. It receives industrial effluent throughout the year from the neighboring Agbara industrial estate, where pharmaceutical, brewery, glass, paint and other industries operates. As a result, Ologe lagoon experiences eutrophication, acidification, and sediment inflow consisting of organics and trace metals arising from hydrocarbon activities (Yusuf and Osibanjo, 2006).

In view of the above, the need to assess water conditions by monitoring the quality of water along the sections of the water body have spur this study. As such, the need for proper planning, monitoring and management of water provides baseline information regarding water safety. It is against this background that this study seeks to provide additional information to existing data on water quality assessment of this water body (Ologe lagoon) as it examines the spatial variability and pattern of pollutants along the water body. It further augments existing data by providing information on biological characteristics of Ologe lagoon which have been neglected in most previous studies (Nkwoji, *et al.,* 2010; Ndimele, *et al.,* 2011 & Clarke, *et al.,* 2020).

This study examines the variability of pollutants within aquatic systems in order to provide information on water safety. This is by investigating the spatial pattern and variations of water quality parameters along Ologe lagoon, Lagos State, Nigeria.

METHODOLOGY

The Study Area

Ologe lagoon is a semi-enclosed natural fresh water resource which lies between latitudes 6°27' N and 6°30' North of the equator and longitudes 3°02’ E and 3°07’ East of the Greenwich meridian (Figure 1). The lagoon is located about 30 km west of Lagos city on the

Lagos-Badagry expressway along the border between Lagos State and Ogun State, in southwest Nigeria.

The sources of water of Ologe Lagoon are Rivers Owo, Ore and Opomu in Ogun State (Odewunmi, 1995). Ologe lagoon drains into the sea through the Badagry creek and the Lagos harbor. Like other coastal areas in Nigeria, Ologe lagoon belongs to the equatorial hot and humid climate. It has an annual temperature which ranges between 26 to 34^0C, with the highest temperatures occurring, during the dry season (November to March). The annual rainfall occurs between the months of April and October. The rainfall which is usually heavy, sometimes last over 24 hours. Rainfall of about 50mm / hour are common and result in flash floods between the months July of and August. The study area exhibits a double maxima rainfall pattern.

Ologe lagoon is almost flat in nature and the vegetation type around the study area is characterized by still rooted trees with a dense undergrowth of shrubs, palm trees and swards of floating grass. The water hyacinth, Eichhomia crassipes usually covers the edges of the lagoon. The soil comprises of hydromorphic soil which are usually water logged. The lagoon is threatened by human activities such as farming, sand dredging, fishing and industrial activities from the neighboring Agbara industrial estate, where pharmaceutical, brewery, glass, paint and other industries takes place (Yusuf and Osibanjo, 2006).

Purposive sampling method was used to purposely categorize the study area (Ologe lagoon) into three stations such as: upstream, middle stream and downstream. Thereafter, the stations were labeled A, B and C (Table 1) and water samples were collected from different sections of the study area. In other words, one sample was taken from each station that is; upstream (Agbara), middlestream (Idoluwo) and downstream (Gbanko). This method was also adopted by (Ndimele, et al., 2011; Agaja, et al., 2013) and samples were tested for physiochemical and biological parameters.

Table 1. Coordinates of the sampling stations (see figure 1)

Stations	Latitude	Longitude
A Upstream (Agbara)	6^o 30' 56.4"	03^o 06' 21.2"
B Middle stream (Idoluwo)	6^o 45' 75.82"	03^o10'30.67"
C Downstream (Gbanko)	6^o 29' 57.0"	03^o 06' 21.4'`

The following physicochemical parameters were tested which are Odour, turbidity, true colour, temperature, electrical conductivity, pH, Total Alkalinity, Total hardness, Total Dissolved Oxygen, Total dissolved solid (TDS), Phosphate, Iron, Zinc, Nitrate and Lead. In other to fill the gap in knowledge, two biological parameters such as Coliforms and Escherichia coli (*E. coli*) were tested in the study area as previous studies (Nkwoji, *et al.*, 2010; Ndimele, *et al.*, 2011 & Adeyemi, *et al.,* 2019 among others) had only tested for physiochemical parameters.

Sample bottles were washed first with distilled water before collecting the water samples at every marked station. The collected samples were kept in a cooler containing ice after which it was delivered on the same day to the laboratory. At the laboratory, it was ensured that the samples had attained room temperature before carrying out the analysis. Parameters such as temperature, odour, colour, electrical conductivity, dissolved oxygen and pH were tested *in situ*. Other parameters that were tested include Phosphate (P), Nitrate (N), Zinc (Zn), Iron (Fe) and Lead (Pb) coliform and Escherichia coli.

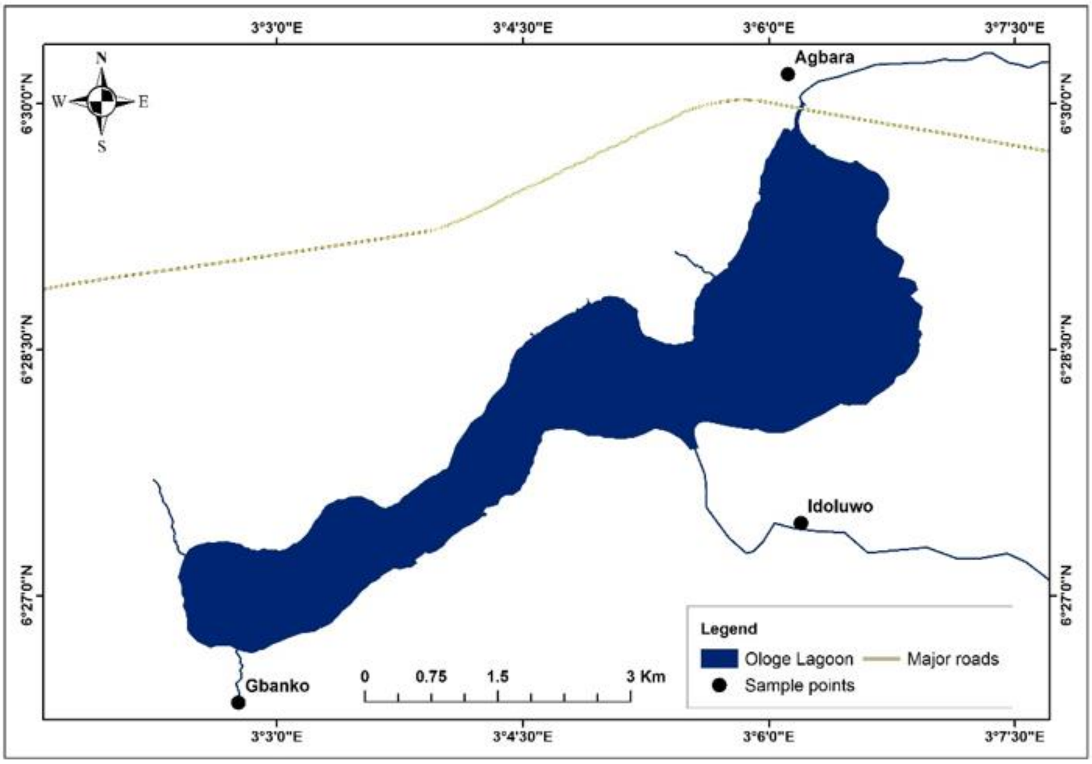

Figure 1: Sample points along Ologe Lagoon (see Table 1)
Source: Adapted from Google Earth Pro (2021) and digitised by the Authors (2022)

Temperature was determined using a mercury-in-glass thermometer, pH was measured using a Metrohm Herisau E520pH meter and turbidity was measured using nephelometer Model 156. Dissolved Oxygen was determined using the Dissolved oxygen meter ASTM D88803, Alkalinity through the use of pH meter using the American Standard for Testing and Materials. Phophate, Nitrate, Zinc, iron and lead were determined by spectrophotometre using both the method designed by the American Public Health Association method (APHA) and the American Standard for Testing and Materials (ASTM) respectively. The biological parameters such as coliform and the Escherichia coli were determined using the America Public Health Association method APHA 9221E.

Both descriptive statistics and One-Way Analysis of Variance (ANOVA) were employed in the study. Tables were used to present the result of each composition of the tested parameters at different stations of the study area. Graphs were also used to show the variations and pattern of water quality across the sampled locations. ANOVA test was employed to further determine the spatial variations of the parameters among the sampling stations. The result of the sample analysis was compared with the World Health Organization standard for water quality (WHO, 2011).

RESULTS AND DISCUSSION

Physical properties of Surface Water in Ologe Lagoon

The result of the Physical parameters in Ologe Lagoon are presented in Table 2 and Figure 2. The general surface appears brownish and the samples collected appeared slightly brown with turbid particles. According to Meride and Ayenew (2016), materials decayed from organic matter such as vegetation and inorganic matter influence the colour and appearance of water.

The odour of the water from the upstream, middle stream and downstream were generally objectionable as indicated in Table 2. Objectionable odour means any odour present in the ambient air that by itself, or in combination with other odour, is or maybe harmful or injurious to human health or welfare. Odour in water can be caused by external materials such as organic materials, inorganic compounds, or dissolved gasses. These materials may come from natural, domestic, or agricultural sources. This could be as a result of domestic and industrial waste that is been disposed in Ologe lagoon.

The study revealed that there is no significant variation in temperature across the stations. The upstream recorded the lowest 28.40±0.14, the middle stream had the temperature of 28.80±0.14 which is slightly different from the upstream while the downstream had the highest temperature reading of 29.20±0.14. The major environmental factor that is responsible for surface water temperature increase is the solar radiation. Nevertheless, temperature in this study falls within permissible limit of 30^0C by W.H.O. The result of this study agrees with the findings of Ezeribe *et al* (2012). This implied that the study area has a uniform weather pattern. High temperature increases the rate of reactions and increases the level of dissolved oxygen in the water.

The observed level of electrical conductivity in Ologe lagoon ranged between 92.5 and 143µs/cm. Although, it was significantly high at the middle stream with 143µs/cm compared to other stations, but it is still within the World Health Organization standard of 400µs/cm. This result is in line with the report of previous studies (Soylak *et al*., 2001 and Meride and Ayenew, 2016). Significant changes in conductivity may indicate that a discharge or some other source of disturbance such as the sand dredging activity as evident in the study area has decreased the relative condition of the water body and its associated biota. Since the electrical current is carried by ions in solution, the conductivity increases as the concentration of ions increases. Conductivity is also affected by temperature, the warmer the water, the higher the conductivity. Hence, it is among the major parameters used in ensuring the quality of water is appropriate for irrigation and firefighting (Omer, 2019).

The measured turbidity value was reported in Nephelometric Turbidity Units (NTU) and this ranged between 10.15 and 224.15NTU. The study showed that the highest turbidity of 224NTU which is very much above the W.H.O limit of <5NTU occurred at the upstream. The continuous release of sediment and industrial waste into the lagoon is responsible for the high value at the upstream which is around the Agbara industrial layout. In addition, during a rainstorm, particles from the surrounding land are washed into the lagoon making the water a muddy brown colour, indicating water that has higher turbidity value. Excessive turbidity may present health issues. Turbidity in drinking water is aesthetically unacceptable, which makes the water look unappealing. Though turbidity can provide food and shelter for pathogens. If not removed, the causes of high turbidity can promote re-growth of pathogens in the water, leading to water borne disease outbreaks such as gastroenteritis (Okpokwasili, *et al*., 2013).

Table 2: Physical parameters of water quality in Ologe Lagoon.

Location	General Appearance	Odour	Turbidity (NTU)	True Colour (Hz)	Temperature (°C)	EC (umhos/cm)
Upstream	Brownish, turbid with particles	Objectionable	224.45±0.35	10.00	28.40±0.14	92.50±0.71
Middle stream	Brownish, turbid with particles	Objectionable	35.85±0.21	10.00	28.80±0.14	143.00±0.00
Down Stream	Brownish, turbid with particles	Objectionable	10.15±0.07	10.00	29.20±0.14	127.87±0.03

Note: Values are means of duplicates of data ± standard deviation. Means with the same superscript along the same column are not significantly different. ($p>0.05$).

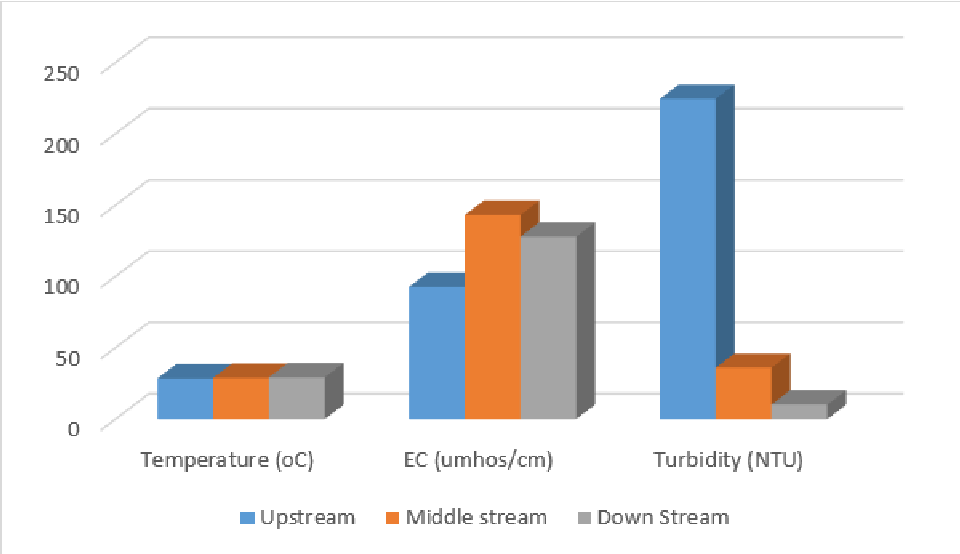

Figure 2: Spatial Pattern of Physical parameters in Ologe Lagoon

Chemical properties of Surface Water in Ologe Lagoon.

The result of the spatial variation of chemical parameters of the water quality in Ologe lagoon is presented in Table 3 and Figure 3. The result was computed with the standard deviation of each parameters at ($p>0.05$) level of significant difference. The pH value observed in all sampled stations were slightly alkaline as it ranged from 6.5 and 7.35 across the stations (Table 3). The pH values observed were: 7.35 at the downstream (Agbara), 7.10 at the middle stream (Idoluwo) and 6.50 at the upstream (Gbanko). Thus, there was no significant difference in the pH value of the study area (Figure 3). Looking at the result, the limit falls within the W.H.O (2011) acceptable standards of 6.5-8.5 for drinking water, which implies that the water according to pH test is fit for consumption. Hence, there is no direct effect on human health.

However, most aquatic organisms have adapted to life in water with a specific pH as their metabolic activities depends on pH level (Wang, *et al.*, 2002). Low pH value produces sour taste and corrodes metals and other substances, while high pH value are alkaline and decreases the effectiveness of the chlorine in water (Shikhar Firmal, 2009). Furthermore, a pH value below 4 or above 10 affects most aquatic lives and very few aquatic animals can endure water with a pH below 3 or above 11 (Wang, *et al.*, 2002).

The mean value for alkalinity and total hardness recorded in the study as presented in Table 3 ranged between 28.7mg/l-54.5mg/l and 56.50mg/l-34.50mg/l respectively. Moreover, there was significant difference in both the level of alkalinity and total hardness across the sampled locations in the study area with the highest value (54.35±0.21) for alkalinity observed at the downstream (Gbanko), compared to 29.65±0.07 for upstream and 28.70±0.14 for middle stream.

Conversely, the middle stream accounted for the highest value for total hardness (56.50±0.71), after which was the downstream with value of 42.15±0.21, and the lowest value at the upstream (34.50±0.14). The result of the study showed that high level of total hardness was recorded in the study area than alkalinity. However, this result is within the WHO acceptable standard. This can be due to high proportion of calcium and magnesium in the body of water, thus limiting its use for domestic activities such as washing. In addition, its use can also be curtailed due to clog forming especially as it relates to irrigation and industrial activities unless well treated (Ndefo, *et al*., 2011).

Thus, alkalinity is often related to hardness because the main source of alkalinity is usually from carbonate rocks (limestone) which are mostly CaCO3, (Pradeep et al, 2014). This high value of total hardness in water might be an indication of disposal of domestic wastes into the water body. This study support the findings of Umunnakwe *et al*., (2013) that water bodies that receive discharge from homes and industries have higher values of total hardness and alkaline.

The total dissolved Oxygen value recorded range between 6.5-10.25mg/l across the stations. However, dissolved oxygen (DO) showed slight variations across the sample locations as indicated in Table 3. Although, all the values were above the limit of 5 mg/l recommended by the WHO. The downstream recorded the highest quantity of DO (10.25±0.07), and this implied that there is high presence of organic pollutants which suggests that the Lagoon has been polluted as a result of anthropogenic activities evident in the dumping of refuse by residences and excessive plant growth around the shore. This reduces the oxygen content in the lagoon and can eventually cause the death of aquatic organisms in the lagoon. Thus, this study supports the findings of Ayobahan *et al*., (2014) that the level of DO in water bodies changes due to the presence of organic pollutants through human activities.

Total dissolved solid ranged between 82.5mg/l-101.13mg/l. The highest value of 101.13±0.11 was recorded at the downstream as indicated in Figure 3. The study revealed that there is significant difference in the proportion of TDS present in the study area as indicated in Table 3. The values recorded are negligible as they are within the WHO limits of 500. Phyllis (2007) opined that, total dissolved solid are naturally present in water or are the result of human activities such as sand mining, effluent discharge from industries and refuse disposal. Thus, the study agrees with the results of Klein (1962) that human activities such as sand mining and effluents from industrial activities contribute to the total dissolved solid concentration in the lagoon. The result of this study further concurred with results of past studies (Soylak *et al*., 2001; Sasikaran *et al*., 2012 and Meride and Ayenew, 2016) that the presence of TDS in water does not really pose health threat on humans except that it produces undesirable taste; changes the appearance of water and may result in constipation.

The recorded values for Phosphate ranged from 3.7 - 6.2mg/l. The highest recorded value of 6.2mg/l was recorded at the downstream. Although there is a slight variation in the quantity of phosphorus present across the study area, however, these values are not significant as they are within the limit of WHO standard of 100.

In addition, the result gotten for Nitrate was not significant so it was recorded as <0.05 through the stations. The recorded values are insignificant but does not mean there was no presence of Nitrate detected. The industrial waste discharged into the lagoon by the surrounding industries and the water hyacinth found in the lagoon could have caused the presence of nitrate in the water body. This suggests the possibility of algae bloom and eutrophication which curtails the use of the lagoon for recreation activities as the growth of algae brings about odour and reduces clarity (Klein, 1962; Radajevic and Bashkin 1999).

Furthermore, the excessive combination of nitrate and phosphorus in surface water can cause loss of aquatic lives, increase cost of water treatment due to clogging of water filter; and an immediate and severe health threat to infants as the nitrate ions react with blood hemoglobin, thereby reducing the blood's ability to hold oxygen which leads to a disease called blue baby or Methemoglobinemia (Oketola, *et al.*, 2013).

Iron value ranged between 1.5-8.65. The highest value was recorded at the upstream (8.65±0.21) while it keeps decreasing till it got to the downstream. The high mean value for iron at the upstream may be attributed to the presence of corrosive materials (metals) dumped by the surrounding industries to the lagoon. The implications to the study area is that the presence of corrosive materials lead to high concentration of iron in the water and this causes stains when washing the fabrics and plumbing fixture in the study area. Although, the values recorded were higher compared to the W.H.O limit of 3.0, iron (Fe) do not cause health problems, in fact, they are vital element needed for human nutrition. However, the minimum daily requirement for iron should be adhered to; as this depends on certain factors such as age, gender among others (WHO, 2003).

Table 3: Spatial Variation of Chemical Parameters in Ologe Lagoon.

Location	pH	TA (mg/ $CaCO_3$)	TH (mg/ $CaCO_3$)	TDO (mg/1)	TDS (mg/1)	Phosphate (mg/1)	Iron (mg/1)	Zinc (mg/1)	Nitrate (mg/1)	Lead (mg/1)
Up stream	6.50 ±0.14	29.65 ±0.07	34.50 ±0.14	8.64 ±0.01	82.55 ±0.21	5.60 ±0.14	8.65 ±0.21	0.245 ±0.003	<0.05	<0.01
Mid Stream	7.10 ±0.14	28.70 ±0.14	56.50 ±0.71	6.50 ±0.28	93.85 ±0.71	3.70 ±0.14	4.85 ±0.70	0.003 ±0.000	<0.05	<0.01
Down Stream	7.35 ±0.07	54.35 ±0.21	42.15 ±0.21	10.25 ±0.07	101.13 ±0.11	6.20 ±0.14	1.55 ±0.07	0.225 ±0.007	<0.05	<0.01

Note: Values are means of duplicates of data ± standard deviation. Means with the same superscript along the same column are not significantly different (p>0.05).

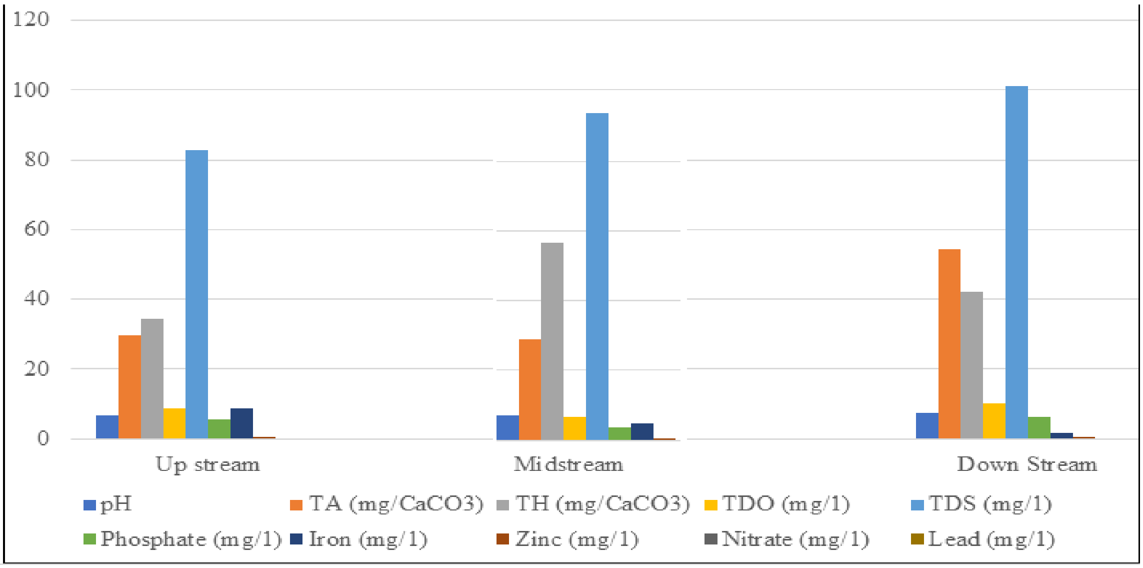

Figure 3: Spatial Pattern of Chemical parameters in Ologe Lagoon

Microbiological parameters of water quality in Ologe Lagoon

The microbial quality of water in Ologe lagoon, is presented in Table 4. Only two microbiological parameters which include Coliforms and *E.Coli* were considered. Both were found present in the water sample that were collected and analyzed at the three stations. A very important biological indicator of water pollution is the group of bacteria called coliforms. Coliforms is the use of bacteria as indicator of the sanitary quality of water. Value recorded ranged between 40-180cfu/ml. The recorded value at the downstream is significantly higher than the middle stream and the upstream with $p>0.05$. The Coliform count of the upstream is 140cfu/ml. The middle stream recorded a Coliform count of 40cfu/ml while the downstream recorded 180cfu/ml which was the highest of all. The study revealed high bacteria load and coliform count which far exceed the WHO standard of $1x10^2$cfu/ml.

Coliforms are bacteria and they can cause water related diseases when consumed in a polluted water. The result implied that Ologe lagoon has continuously been contaminated with excretal which implied that the discharge of domestic sewage and open defecation occurs within the study area as can be observed during the fieldwork. The result of the study is similar with the findings of Anyanwu and Okoli (2012) which shows the presence of coliforms in water supplies in Nsukka.

Furthermore, the detection of *Escherichia coli* in the study area provides definite evidence of faecal pollution. A particular species of coliforms found in domestic sewage is Escherichia coli or E. coli. According to UNICEF (1999), one gram of feces may contain as many as 10,000,000 viruses, 1,000,000 bacteria, 1,000 parasite cysts and100 worm eggs. The concentration of *E. coli* that was recorded ranged from 35 to 55cfu/ml and the highest value was found in the middle stream station of Ologe Lagoon. Even if the water is only slightly polluted, they are very likely to be found.

The result implied that open defecation is practiced around the water course. This is because, there are houses around the study area without good toilet facilities and therefore they are involve in open defecation along the course of the lagoon as some of the residents are also fishermen, who easily defecate directly on the lagoon during the course of their fishing activity. More so, there are people that are involved in sand dredging, they also defecate in the lagoon because of lack of toilet. The implication of this is that, the aquatic animals will have more sources of nutrient and food while the water becomes dangerous for consumption and domestic uses as this can cause water related diseases such as cholera, dysentery and diarrhea.

Table 4: Microbiological Parameters of Ologe Lagoon.

Location	Coliform (cfu/ml)	E. Coli. (cfu/ml)
Upstream	$150.00^{a}\pm14.14$	$25.00^{b}\pm7.07$
Middle stream	$40.00^{b}\pm0.00$	$55.00^{a}\pm7.07$
Down Stream	$180^{a}\pm14.14$	$35.00^{a}\pm7.07$

Note: values are means of duplicates of data ± standard deviation. Means with the same superscript along the same column are not significantly different ($p>0.05$).

CONCLUSION

Monitoring of water in water bodies is very fundamental to productivity and health of humans and aquatic lives. Majority of the physiochemical and biological parameters considered in this study were present in Ologe lagoon. Although, the values obtained from different stations showed that their concentration varies across the lagoon, however, many of these values are within the WHO standard. Therefore, the lagoon is safe for human consumption. However, apt attention must be given to continuous monitoring of the lagoon so as to protect, plan and device management strategies to the lagoon as regards the uses around it. Hence, future studies on the influence of natural processes on Ologe lagoon is important in other to make an effective water quality management plan.

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