Assesment of Sawmill and other Associated Wastes on the Water Quality of Ilo-abuchi Creek, Rivers State, Niger Delta

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

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ABSTRACT

A study was conducted on physicochemical parameters water from Ilo-abuchi, creek Niger Delta, Nigeria. The study aimed at evaluating the impact of sawmills and other associated wastes on water quality of the creek. The physicochemical parameters investigated were from February to July 2020 and the samples were analysed for pH, Temperature, Salinity, Conductivity, Total Suspended Solid (TSS), Total Dissolved Solids (TDS), and Total alkalinity using an in-situ Handheld Multimeter (Milwaukee Model pH600 and Laboratory Benchtop meter 860033-model. The Dissolved Oxygen (DO) was measured using Winkler's method. Biochemical Oxygen Demand (BOD) was determined by the 5-day BOD test (APHA, 2005). Turbidity was measured using a 20cm diameter Secchi disc. Total alkalinity was determined by the American Society for Testing and Materials (ASTM D 1067B) Nitrate, Chloride, Phosphate, and Sulphate were determined using the method recommended by APHA 2340C (1995) standard. Water Temperature ranges between 27.7 -27.8 ^{O}C, pH 6.65 - 6.73, Conductivity 438.2 - 494.2 µS/cm, Salinity 2.8 -3.23ppt, TDS 77 – 87.27 mg/l, TSS 30.7 - 37.66 mg/l, DO 3.19 – 3.46 mg/l, BOD 2.05 - 3.38 mg/l, Turbidity 5.41- 5.98 NTU, Nitrate 8.78 - 10.02 mg/l, Hardness 31.77 - 33.98 mg/l, Chloride 23.03 -25.7 mg/l, Phosphorus 0.31 - 0.51 mg/l, Sulphate 13.27 - 16.60 mg/l. Alterations in water quality were more pronounced in the wet season (May, June, and July) compared to the dry season (February and March, and April). The nature of the effluents discharged into the creek were found to be

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essentially within the acceptable limits prescribed by law except for TSD and turbidity. These two parameters were slightly above the WHO standards. It is therefore recommended that environmental regulatory agencies such as NESREA and the Ministry of Environment should devise mechanisms to enforce existing environmental regulations concerning the discharge of effluents from different sources into the Ilo-abuchi Creek, which will aid in reducing the dumping of untreated wastes from the sawmills/other associated wastes and by extension conserve the aquatic life therein.

Keywords: Abattoir; saw-mill waste; water quality; Ilo-abuchi and Creek.

1. INTRODUCTION

Manufacturing operations that produce raw wood, such as a sawmill, paper mills, furniture manufacturers, discharge from abattoirs, sewage, and domestic wastes are the major source of pollution in the Nigeria waterways [1]. Water can become polluted either through point sources or non-point sources. The physical and chemical properties of water immensely influence its uses, distribution, and richness of the biota [2]. Sawmill wood waste in developing countries especially in Nigeria is known to pollute the environment directly or indirectly through various processes [3]. There is a lack of treatment facilities for abattoir and sawmill wood effluents in the majority of developing countries [4]. The pollution of water bodies from sawmill wood wastes may result in substantial environmental and public health hazards [5,6] and [7]. In Nigeria, local abattoirs which are the major meat processing industries are typically located close to water bodies to ease waste disposal [6]. Municipal solid wastes and sawmill wood effluents also reduce oxygen in the water and endanger aquatic life which leads to life-threatening effects. The organic nutrients added to groundwater through wastes from some municipal solids such as sawmill woods, abattoir leachates, and many other associated products produce excessive microbial growth causing unpleasant tastes and odour of water from this source [3].

Among other forms of waste, solid waste constitutes a major source of environmental pollution that introduces chemical substances above their threshold limit into the environment [8]. The wastes from most anthropogenic waste disposals are often not separated into solid, liquid, and fats that could be highly organic. Negative effects and impairment by effluents discharged from the abattoir and saw-mill industries cause alteration in water quality are more pronounced in the dry season compared to the wet season [8,7].

Wood residue leachates are produced when water percolates or flows through wood residue; storing wood waste in pits where it has contact with groundwater creates another source of leachate [2]. Typically, pure wood residue leachate is a black liquid with a petroleum-like odour that causes foaming water. Wood residue decomposition is a slow process. These wastes are washed down into the river [9]. Saw wood waste could significantly intensify the amounts of nitrogen, phosphorus, and total solids in the receiving water body [10]. An abattoir pollutes the environment either directly or indirectly from its various processes [11]. In buttress of the previous observation, that effluent discharged from sawmill industries, sewage and domestic wastes and slaughterhouses have caused the deoxygenating of rivers because there are usually no modern landfills for disposing of solid waste in most of the dumpsites in Nigeria [12]. Hence, waste sorting for segregating degradable, non-degradable, and recyclable materials is rarely practiced [13].

Wood shavings and leachates are sources of inert solids as well as toxic pollutants that directly clog fish sill and indirectly reduce light penetration [2] which limits productivity contamination of the aquatic environment, makes aquatic organisms vulnerable [5], fish immune systems, in particular, are weakened leading to increased incidence of parasites.

Water serves many purposes such as drinking water source, bathing and cleaning, agricultural irrigation, fishery, sustainable use for industry, boosting of natural groundwater level, aesthetic value, and many other livelihoods [13]. It is therefore very important that all sources of water (including the Ilo-abuchi Creek water) harnessed for human uses should be consciously monitored for and protected from pollutants. Consequently, this study is focused on analyzing some important physicochemical parameters of the Ilo-abuchi Creek water. This would help researchers, policymakers, and regulators to

understand the pollution impact of the Abattoir and sawmill wastes on the creek water/organisms inhabiting it and this will be used to plan pollution abatement programs for the water of the creek. Ultimately, this results in scientifically guided ecological protection actions for aquatic organisms inhabiting the creek waters and the prevention of possible adverse health that the use of its water could ordinarily impact on humans either directly or indirectly.

2. MATERIALS AND METHODS

2.1 Study Area

The study area is a tidal creek with exposed mudflats at low tide, located at latitude $4^o47'16.8443''$ and long E6o59'5.2926''. The major vegetation along this creek is mangrove vegetation mainly *Rhizophora sp*, *Nypa fruticans,* and *Avicennia sp.* This river water is important as it serves as a means of transportation for humans, domestic use, and a source of livelihood for fishermen. Also, the surrounding environment is characterized by various human activities such as waste disposal, fishing activities, and frequent defecation on the banks of the creek. This research cuts across three stations along the creek with {Station 1: Lat $N4^o47'16.8443''$ and Long $E6^o59'5.2926''$, Station 2: Lat $N4^o47'13.158''$ and Long $E6^o59'10.512''$, Station 3: Lat $N4^o47'10.30308''$ and Long $E6^o59'19.4784''$).

The main major source of water that feeds Ilo-abuchi Creek with water is from Bonny River which flows into Ilo-Abuchi Creek and to Diobu area of Port Harcourt metropolis. Ilo-abuchi Creek is bounded by Eagle Island on the South-West of Port Harcourt and bounded on the North by the Rivers State University of Science and Technology in Nkpolu-Oroworukwo area of Diobu. This creek is influenced by tidal flux as it flows back and forth at different times and seasons. The major saw sawmill serving the various construction industry wood needs of the Port Harcourt city and River's state at large is located in the Diobu axis of the Ilo-abuchi creek. As shown in plate 2, the logs of wood cut from remote areas are often transported in bound batches floated across long distances to the Diobu area of the Ilo-abuci where the creek is located. The logs remain in the water until they are taken into the various small, medium, and relatively large privately owned Sawmill enterprises that are also located across a vast stretch of the creek. These Sawmills are operated with non or minimal consideration for

the environmental regulations that should guide the operations of such Sawmills. Consequently, virtually all the wood dusts and shavings generated from the sawmilling operations are directly discharged into the creek untreated. This has made the water of the creek in this area of the creek always appear very dark in colour all year round. The water also has a putrefactive smell characteristic of the continuous decay of woody materials in water. Due to the relatively large areas covered by this sawmill and the high intensity of commercial activities associated with its operational linkages, it has induced several other activities that amplify pollution from several anthropogenic activities. Some of these activities include an indiscriminate proliferation of slaughter platforms or micro abattoirs utilizing wood fuels arising from the Sawmill operations for roasting their slaughtered animals, before dressing them. Both the soot/ash deposits and other effluents generated in the process of dressing the animals are all discharged directly into the waters of the creek. The area is also a major transportation hub for sawn wood and other human and mechanical materials/tools required for the sawmill industry and its associated commercial activities to thrive. All these activities lead to the area being densely populated, resulting in all forms of heightened anthropogenic activities polluting the waters of the creek. Examples include indiscriminate defecation directly into the creek and dumping of household wastes, waste hydrocarbon oil dispensed from serviced machinery, plastics, and other biodegradable and non-biodegradable materials. Plates 1 to 3 show the obvious typical pollution scenarios from various types of waste generating activities (sawmills, Animal slaughters houses, public toilets, artisans' workshops, etc.) that impacts the creek water from a collection of sources that can be considered a complex pollution stream impacting the creek water.

2.2 Sampling Procedure

The sampling stations from which water samples were collected for these study areas are indicated in Fig. 1. A total of three stations were chosen and were at least 500 meters apart along the Creek. Based on the peculiarities and features observed around the study area of this creek, three sampling stations were selected within the Creek to reflect different activities in the areas: Station I, Station II, and Station III. Water samples were collected for analysis. All sites were geo-referenced using a handheld global positioning system (GPS) receiver unit

(Magellan GPS 315) to generate geographic coordinates (longitudes and latitudes) of the sampling area. Sampling was carried out once a month between February to July 2020. This was carried out during the first week of each sampling month.

2.3 Water Samples Collection

Surface water samples were collected in pre-cleaned high-density Schott glass bottles. The sampling bottles were cleaned using detergent then rinsed with tap water and soaked in 50% hydrochloric acid (HCl) for 24 hours before sampling. The bottles were then washed with tap water and rinsed with triple distilled water before sampling. The bottles were cleaned to ensure that they are not contaminated with metal residue before sampling and to prevent adhering of metals to glass surfaces since acidification of the glass enhances metals dissolution. Samples after collection were properly sealed and transported to the laboratory for analysis.
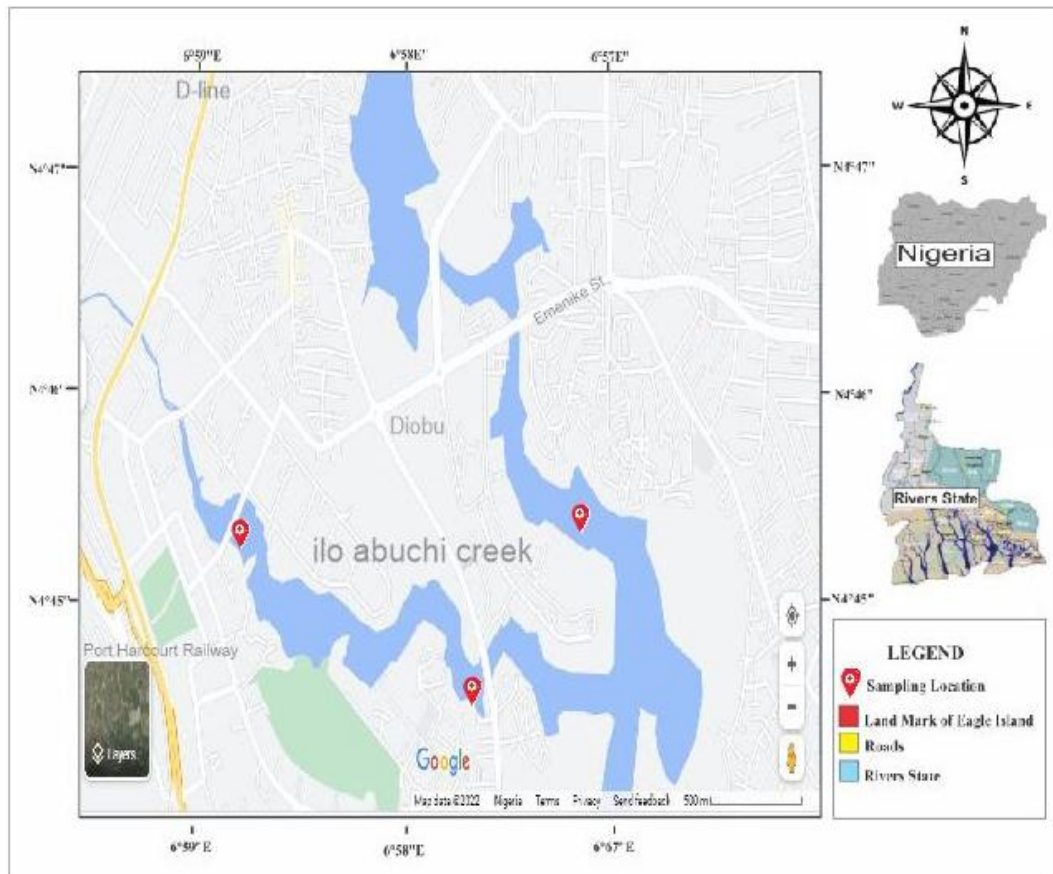

Fig. 1. Map showing the sampling stations

Plate 1. Station 1

Plate 2. Station 2

Plate 3. Station 3

2.4 Physicochemical Parameters Analysis

Surface water samples were collected using Schott glass bottles. The pH, Temperature, Salinity, Conductivity, Total Suspended Solid (TSS), Total Dissolved Solids (TDS) Total alkalinity of the water were measured using an in-situ Handheld Multimeter (Milwaukee Model pH600 and Laboratory Benchtop meter 860033-model). The Dissolved Oxygen (DO) was measured using Winkler's method. Biochemical Oxygen Demand (BOD) was determined by the 5-day BOD test [14]. Turbidity was measured using a 20cm diameter Secchi disc. Total alkalinity was determined by the American Society for Testing and Materials (ASTM D 1067B). Nitrate, Chloride, Phosphate, and Sulphate were determined using the method recommended by APHA 2340C [14] standards.

2.5 Statistical Analysis

Multiple Range Test [15] was used to determine the difference in analyzed physicochemical parameters between the seasons and across stations sampled. The test of significance was based on a 5% (P<0.05) level of probability.

3. RESULTS

3.1 Physicochemical Parameters Across the Stations

The results of the physicochemical characteristics of the three sampled points along Ilo-abuchi are shown in Table 1. The results showed no significant (P>0.05) variation in most of the physicochemical parameters across the station. However, the water temperature was highest in station 2 (27.83±0.38) and the lowest was recorded in station 1 (27.68±0.37). The pH value was highest (6.73±0.16) in station 1 and lowest in station 2 (6.49±0.12). No significant (P>0.05) differences were observed in the Temperature and the pH values. The highest value for conductivity was recorded in station 2 (494.16±61.44) and the least was recorded in station 3. There was a significant difference (P<0.05) between the stations. Salinity was highest in station 1 (3.23±2.60) and the least was recorded in station 3 (2.79±7.99). Total dissolved solids (TDS) were highest in station 3 (87.27±6.86) and the least was in station 1 (77±4.72). Total suspended solids (TSS) were highest in station 3 (37.66±12.81) and the lowest was recorded in station 2 (30.66±7.39) and there was a significant difference (P<0.05) between the stations. The Dissolved Oxygen (DO) was highest in station 1 (3.46±0.77) and lowest in station 3 (3.19±0.63). The water was more turbid in station 2 (5.98±0.36) and least in station 1 (5.41±0.52). No significant (P>0.05) differences were observed between the stations for DO and Turbidity. The biological oxygen demand (BOD) value (3.68±4.90) was highest in station 2 and the least (2.05±4.84) was recorded in station 1. No significant (P>0.05) differences were observed between the stations. Nitrate recorded the highest value in station 3 10.71±2.51) and the least at station 1 (8.78±2.06). The water hardness was highest in station 2 (33.98±2.62) while the least was observed in station 1 (31.77±1.73). No significant (P>0.05) differences were observed between stations 2 and 3 but there was a significant difference (P<0.05) between 1 and the others for Nitrate and Hardness. Chloride was highest in station 3 (25.68±4974) and least in station 1 (23.03±43.87). Phosphorus was reported highest in station 3 (0.51±40.76) and least in station 2 (0.31±35.79). the highest value of Sulphate was observed in station 3 (16.60±2.87) and the least was recorded in station 1 (13.27±1.91). There was a significant difference (P<0.05) between the values of Phosphorus, Chloride, and Sulphate across the stations.

Table 1. Mean values of physiochemical parameters for the three sampled stations

Parameters	Station 1	Station 2	Station 3	Range	WHO 2006
Temperature	27.7±0.4[a]	27.8±0.4[a]	27.8±0.5[a]	27.7 -27.8	24 - 28 °C
pH	6.7±0.2[a]	6.5±0.1[a]	6.7±0.1[a]	6.65 - 6.7	6.8 - 8.5
Conductivity	456.5±3.9[ab]	494.2±1.4[a]	438.3±1.4[b]	438.2 - 494.2	1000 µS/cm
Salinity	3.2±2.6[a]	2.95±3.5[a]	2.8±7.9[a]	2.8 -3.23	1000-3000‰
TDS	77±4.7[b]	79±5.4[ab]	87.3±6.9[a]	77 – 87.27	200 mg/l
TSS	30.8±9.2[b]	30.7±7.4[b]	37.7±12.8[a]	30.7 - 37.7	20 mg/l
DO	3.5±0.7[a]	3.4±0.7[a]	3.2±0.6[a]	3.19 – 3.5	4 mg/l
BOD	2.5±4.8[a]	3.7±4.9[a]	3.4±4.3[a]	2.05 - 3.4	10 mg/l
Turbidity	5.4±0.5[a]	5.9±0.4[a]	5.8±0.2[a]	5.41- 5.9	5 NTU
Nitrate	8.8±2.1[b]	10.0±2.2[a]	8.8±2.5[a]	8.78 - 10.0	10 mg/l

Parameters	Station 1	Station 2	Station 3	Range	WHO 2006
Hardness	31.8±1.7 [b]	33.9±2.6 [a]	33.3±2.1 [a]	31.77 - 33.9	500 mg/l
Chloride	23.0±4.9 [b]	25.0±4.5 [a]	25.7±4.4 [a]	23.03 -25.7	250 mg/l
Phosphorus	0.5±36.8 [ab]	0.31±35.8 [b]	0.5±40.8 [a]	0.31 - 0.51	5 mg/l
Sulphate	13.3±1.9 [b]	14.2±1.2 [ab]	16.6±2.9 [a]	13.27 - 16.6	250 mg/l

Means of values with different superscripts on the same row are significantly different from each other

3.2 Physicochemical Parameters Across the Months

The results of the physicochemical characteristics of the Iluo-Abuchi axis of the Iwofe River across the six months (February to July) are presented in Table 2. There were significant variations in most of the physicochemical parameters across the months. February recorded the highest temperature value (29.2±0.1) and the least value (26.93±0.2) was recorded in July and there was a significant difference ($P<0.05$) between the different months. The pH value was highest (6.86±0.27) in February and lowest in May (6.42±0.12). There were significant ($P>0.05$) differences observed across the months. The highest value for conductivity was observed in February (601.66±0.7) and the least was recorded in July (350.33±0.14). There was a significant difference ($P<0.05$) between the conductivity across the different months. May recorded the highest Salinity value (4.73±31.86) while the least value was observed in February (2.68±0.82). There were significant ($P>0.05$) differences observed across the months. Total dissolved solids (TDS) were reported highest in July (32.66±41.83) while the least value was observed in June (23.66±9.59). Total suspended solids (TSS) were highest in February (6.3±9.86) and the lowest was recorded in May (2.5±1.52). July recorded the highest Dissolved oxygen (DO) value (4.63±0.14) and the lowest in February (2.23±0.03). There was a significant difference ($P<0.05$) for DO and TSS across the stations. Biological Oxygen Demand (BOD) was highest (2.66±1.45) in June while the least value (2.10±0.0) was observed in February. No significant ($P>0.05$) differences were observed between the BOD values across the months. The turbidity was highest (6.76±0.26) in July and the least value (4.63±0.43) was recorded in April. Nitrate recorded the highest value (7.83±1.71) in February and the least value (4.06±0.75) was recorded in April. The highest water hardness (39.53±2.34) was observed in May while the least (27.0±2.08) was recorded in March. Chloride was highest (33.66±20.93) in May and

least (20.16±0.61) was recorded in March. Phosphorus was highest (0.57±8.98) in February and least (0.04±0.0) was recorded in April. The highest value (21.53±2.11) of Sulphate was recorded in February and the least was (8.66±0.88) was observed in April. There was a significant difference ($P<0.05$) between the values of Nitrate, Hardness, Chloride, Phosphorus, and Sulphate across the different months.

4. DISCUSSION

The results of the water physicochemical parameters are shown in Tables 1 and 2 and Fig. 2 respectively. Abattoir wastes are generally defined as a difficult substrate for anaerobic treatment due to their typically high rates of proteins and lipids. The wastewaters of the entire slaughtering line of both types of abattoirs have high polluting factors when Total Kjeldahl Nitrogen, nitrate, and nitrite concentrations are taken into account.

4.1 Temperature

Temperature is known to be a critical factor that regulates the biogeochemical activities in the aquatic environment. There were slight variations in the temperature across the three stations during the period of study. The temperature values ranged between 26.93°C and 27.8°C with a high temperature of 29.2°C in February and a lower temperature of 26.93°C in July across the three stations during the sampling period. A similar assertion was made by [16] who stated that water temperatures were generally higher in February at all points of effluent discharge. During the sampling in July, the temperature remains low due to cold low ambient temperature, and shorter photoperiod. The values were within the standard range of 24 to 28°C [17] This variation might be connected with the direct discharge of effluents, which usually have a higher temperature than recipient water. This could also be attributed to high ambient temperature in the dry season which is typical of West African rivers [18].

Table 2. The monthly variation of the mean values of the physicochemical parameters

Parameters	February	March	April	May	June	July	WHO 2006
Temperature	29.2±0.1[a]	28.4±0.36[a]	27.5±0.42[ab]	27.6±0.46 [ab]	26.93±0.14[b]	26.93±0.2[b]	24 - 28 $^\circ$C
pH	6.86±0.27[a]	6.66±0.09[a]	6.46±0.2[a]	6.42±0.12[a]	6.54±0.16[a]	6.80±0.06[a]	6.8 - 8.5
Conductivity	601.66±0.70[a]	587.66±0.93[a]	438.33±0.84 [ab]	378.66±0.11[bc]	362.00±0.58[c]	350.33±0.14[c]	1000 µS/cm
Salinity	2.68±0.82[b]	3.60±0.29[ab]	4.48±9.07[a]	4.73±31.86[a]	4.58±30.73[a]	4.19±14.89[a]	-
TDS	24±0.66[b]	35±0.53[a]	29.0±5.86[a]	27.0±13.57[ab]	23.66±9.59[b]	32.66±41.83[a]	200 mg/l
TSS	6.3±9.86[a]	6.1±6.02[a]	4.3±0.88[b]	2.5±1.52[c]	2.4±2.08[c]	2.9±1.73[c]	20 mg/l
DO	2.23±0.03[b]	2.76±0.28[b]	3.60±0.11[ab]	4.14±0.27[a]	4.80±0.34[a]	4.63±0.14[a]	4 mg/l
BOD	2.10±0.0[a]	2.46±2.66[a]	2.33±0.88[a]	2.33±2.02[a]	2.66±1.45[a]	2.53±1.45[a]	20 mg/l
Turbidity	5.0±0.41[ab]	5.53±0.38[ab]	4.63±0.43[b]	6.20±0.32[a]	6.26±0.09[a]	6.76±0.26[a]	5 NTU
Nitrate	7.83±1.71[a]	5.46±0.52[ab]	4.06±0.75[b]	7.41±0.61[a]	6.83±0.29[ab]	7.43±0.18[a]	10 mg/l
Hardness	33.06±0.89[a]	27.0±2.08[b]	28.10±2.30[ab]	39.53±2.34[a]	34.76±0.88[a]	35.60±0.85[a]	500 mg/l
Chloride	26.66±21.31[b]	20.16±0.61[c]	28.0±7.81[a]	33.66±20.93[a]	25.66±8.25[b]	32.33±8.81[a]	250 mg/l
Phosphate	0.57±8.98[a]	0.46±1.31[a]	0.04±0.0[c]	0.17±0.06[b]	0.05±0.0[c]	0.05±0.0[c]	5 mg/l
Sulphate	21.53±2.11[a]	17.26±3.54[b]	8.66±0.88[c]	12.33±0.88[bc]	12.66±1.20[bc]	15.66±1.45[b]	250 mg/l

Means of values with different superscripts on the same row are significantly different from each othe

4.2 pH

The pH is among the most important parameters in operational water quality study and is the measurement of acid-base equilibrium in water [19]. The pH of any water is a measure of the free hydrogen ion and hydroxyl ions which maintain acidic and basic properties in the water system. pH is an important indicator of water quality which keeps altering chemically because it can be affected by chemicals in the water [20]. In the water quality standards prescribed by WHO, desirable dual limits of the pH of potable water are between 6.5- 8.5 and 6.8 - 8.5. However, this study's pH results ranged between 6.65 - and 6.73. pH values govern the behavior of several other important parameters of water quality like chlorine disinfection efficiency and metal solubility [21].

From the results, the highest values of 6.86 were recorded at station 1 in February and the lowest value of 6.42 was recorded at station 2 in May were within the recommended levels of 6.5-8.5 [22] and [23]. The Lower pH values recorded during the sampling period could be attributed to the buffering capacity of seawater or due to freshwater influx, low temperature, organic matter decomposition and anthropogenic factors, human or industrial, or agricultural activities [18]. The influx of abattoir waste into the creek could be made available by the proliferation of markets and other anthropogenic activities around the creek could also be a factor that affected the variation across the stations and the months [24]. [16] explained that the pH of water is an important environmental factor and the fluctuation in water is linked with the chemical changes, species composition, and life processes. This also agreed with [25] who reported that the dumping of anthropogenic and industrial effluents affects the acidity and alkalinity of the water and hence the pH of water bodies.

4.3 Conductivity

Electronic Conductivity is a measure of water capability to transmit electric current and also it is a tool to assess the purity of water. The conductivity of water is mainly attributed to the presence of dissolved solids. In the present study, the electrical conductance of water ranged from 350.33 µS/cm July to 601.66 µS/cm. Higher values of conductivity were reported in February as the salinity intrusion was severely affected and hence imparting a considerable number of ions into the water that may have led to the

reduction in July. The values were within the acceptable standard of [23] which is 1000 µS/cm. Relative, the high conductivity recorded during the study may be attributed to the predominance of non-leached substratum and the large size of the catchments area [26]. A high level of conductivity reflects the pollution status as well as trophic levels of the aquatic body [27]. Seasonal variation in the conductivity is mostly due to increased concentration of salt because of evaporation. [18] reported similar result was observed in Tin Can Island creek in Lagos. The report stated that dilution of water during the wet season causes a decrease in electrical conductance due to the addition of rainwater.

4.4 Salinity

The salinity in the study area measured from February to July ranges from 2.68 to 4.73 where the lowest salinity was at station 3 in February. The values of salinity from the study showed no significant differences (P>0.05) across the three stations. No similar patterns of distribution in salinity were observed in all the months because there was a gradual increase between February to May and then a slight decrease from June to July. This may be due to the excessive lowering of the water table along the creek leading to a reversal of hydraulic gradient and saltwater intrusion [8]. For saltwater intrusion to occur, the permeable formation must have hydraulic connectivity with seawater either directly or indirectly [1].

4.5 Total Dissolved Solids (TDS)

The TDS varies between 77 to 87.27 mg/l. TDS values were within the [23] acceptable limit (1000 mg/l) recorded across the months during the study. Total dissolved solids (TDS) values obtained from this study followed the same trend as TSS values obtained from the samples reported by [28]. The variation of the total dissolved solids could be attributed to the refractive capacity of the water body and the light dispersion pattern which have a significant effect on the heat capacity of the system. Organic effluents from such activities also frequently contain large quantities of suspended solids which reduce the light available to photosynthetic organisms and on settling down, alter the characteristics of the river bed, rendering it an unsuitable habitat for many organisms [29].

4.6 Biochemical oxygen demand (BOD$_5$)

Biochemical oxygen demand is a measure of the oxygen requirement for the biochemical of

organic materials and the oxygen used to oxidize inorganic materials such as sulfides, ferrous ions, and reduced forms of nitrogen. The BOD values varied between 2.05 to 3.38 across the stations and the months which could be attributed to the organic and inorganic wastes generated in the saw wood and especially from surface run-offs and soil erosion during the rainy season months. Moreover, these levels of BOD values at the discharge point could be attributed to the low DO level, since low DO will result in high BOD and this is a strong indication of pollution [30]. Excessive production of organic matter leads to the buildup of sludge and the mineralization process consumes all dissolved oxygen from the water column [31]. This also depicts the amount of putrescible organic matter degradable by microbial metabolism on the assumption that the water has no bactericidal or bacteriostatic effects [32].

4.7 Dissolved Oxygen

DO have a range of 3.19 to 4.80mg/L. This value for some stations and months such as February to April was within the [23] permissible limit of 4 mg/L. May to July exhibited a DO value higher than 4 mg/l. It has been recommended that a minimum of 4 mg/l of dissolved oxygen should be maintained in water for the healthy growth of fish and other planktonic populations. The values of Dissolved Oxygen (DO) recorded during the study could be due to the high transparency allowing for sufficient sunlight penetration causing an increase in photosynthetic activity within the aquatic system. Similar findings were reported by [33] in the upper Ogun River. And the water quality is deteriorating towards downstream stretches of the months, especially in the rainy season where the population density is very high for parameters like turbidity, chlorides, iron, and cadmium are high when compared to the [23] Standards.

4.8 Turbidity

Turbidity measurements in water are a key test of water quality as high turbidity in water may indicate ineffectiveness infiltration [19]. Values varied from 5.41 to 5.98 NTU and the month of July exhibited the highest value of 6.76 while April recorded the least 4.63. These values were found to be higher than the acceptable value of [17] (5NTU). The turbidity is a key test of water quality as high turbidity in water may indicate ineffectiveness in the filtration therefore increasing the turbidity reduces the clarity of water thereby limiting the penetration of light by

reducing the dissolved oxygen [3]. Although most particles that contribute to turbidity have no health significance, they may indicate the presence of hazardous chemical and microbial contaminants [2]. The higher values of turbidity in April agree with the findings of [34] who reported that during this season, the higher level of turbidity could be caused by sewage matter in water which could lead to the rise in pathogenic organisms which could be shielded by the turbidity particles and hence flee the action of the disinfectant [7] and [1].

4.9 Nitrate

The Nitrate concentration ranges from 8.78 - 10.02 mg/L, although the mean values were lowest in April (4.06) and highest in February at 7.83. The level of nitrate in water could be due to anthropogenic activities taking place at the abattoir. This agrees with [35] who reported that Nitrates have a high potential to migrate to groundwater since they are very soluble and do not bind to soil. [36] reported values ranging between 9.30 - 68.0 which are higher than surface water pollution around Gboko abattoir. It is reported that nitrate concentration above the permissible value of 45 mg/L is dangerous and poses a serious health threat to infants less than three to six months of age because of its ability to cause methemoglobinemia [37].

4.10 Hardness

The total hardness is indicative of the calcium and magnesium concentrations and is expressed as mg/l CaCO [38]. The highest total hardness value of 31.77mg/l was at station 1 recorded in May and the lowest value of 33.98 mg/l was at station 2 recorded in March. In the present investigation, hardness is found to vary from 31.77 mg/l to 33.98 mg/l. The higher hardness values were within the potable limit of 500 mg/l prescribed by [23]. This agrees with [39] who reported that a similar value of total hardness at different sample stations may be attributed to discharges from the domestic wastes through drains and wash off from the neighboring abattoir effluents. The level of hardness reported in the study may also be attributed to the presence of dissolved calcium and magnesium at different levels [40].

4.11 Chloride

The value of chloride in this study varies between 20.16 to 33.66 with the highest values in the month of May at station 3 and the least in March

at station 1. This aggresses with [41]. Who reported that the natural levels of chlorides in rivers and other freshwater sources are usually in the range of 15 to 35 mg/l, which is much below drinking water standards [21] (EPA, 2001 and [23]. The chloride value across the three stations increased across the months which may be due to saltwater ingression and sewage discharges. These findings suggested contamination of the water bodies which could be due to the unscientific disposal of heavily contaminated waste products originating from the abattoir through sewage channels [42]. Since abattoirs and sewages are rich sources of chloride, the level of high chloride values may indicate a progressive increase in the pollution of water. As reported earlier, in coastal areas, elevated chloride values may be due to sea spray or seawater infiltration and not necessarily due to discharges alone [21].

4.12 Phosphate

The mean concentration of phosphate in the study area ranges between 0.31-0.51 which is below the WHO/USEPA limits of 5mg/L for the discharge of wastewater into the river. The levels of phosphate observed in this study can cause eutrophication and may pose a problem if discharged into a river or stream [43]. The slightly high concentration of Phosphate may be from other sources such as detergents used by the abattoir workers to wash roasted slaughtered animals [6], laundry activities of surrounding residents, and run-off of household effluents into the river [44].

4.13 Sulphate

Sulphates exist in all-natural waters and their concentrations vary according to the nature of the terrain through which they flow. They are often derived from the sulphides of heavy metals (iron, nickel, copper, and lead). The concentration of sulphate in the present study varied from 13.27 to 16.60mg/l which is lower than the maximum permissible limit of 250 mg/L set by [23]. Sulphates have been categorized under secondary drinking water standards of [45] as it affects the taste and have laxative effects. Sulphides are present in sedimentary rocks from which they can be oxidized to sulphate in humid climates; the latter may then leach into watercourses so that ground waters are often excessively high in sulphates [21].

5. CONCLUSION

From this study, it is evident that the quality of the water along the course of Ilo-abuchi creek sampled was not adversely impacted significantly, as most of the physicochemical parameters were within the acceptable limits prescribed by EPA and WHO. Examples of some of the observed alterations of some parameters from the ideal standards set by the relevant regulatory bodies due to effluents discharged from the sawmills cum other associated waste generating activities mainly include TDS and turbidity, which were slightly above the WHO standards. The alteration in water quality was more pronounced in the wet season (May, June, and July) compared to the dry season (February March and April). The levels of parameters downstream were significantly more elevated than the corresponding levels upstream. This trend of progressively elevated levels of studied parameters downstream can be attributed to accumulated concentrations of the polluting wastes from the sawmills and other associated anthropogenic waste generating activities in the downstream area where the water flow velocity is very low. Generally, the study results are indicative that the Ilo-abuchi creek is constantly inundated with pollutants mainly from the sawmill industry effluents. The effluents discharged into the creek are not in any way treated to prescribed standards by the regulatory bodies, as they are directly dumped in the water.

6. RECOMMENDATIONS

The values of the physicochemical parameters of the Ilo-abuchi creek waters within and around the study area reflects the activities of the sawmills and other associated waste generating ventures might have contributed significantly to the reported values which may lead to increased pollution on the surface water in the area. This trend if left unchecked constitutes a potential source of full-blown environmental problems shortly. Regular monitoring of the physicochemical properties of the Creek is therefore the application of recommended actions to reverse the adverse effects of human activities on the water quality and subsequent conservation and protection of the organisms habiting it. It is pertinent, therefore, that the relevant concerned environmental regulatory Agencies like NOSDRA, NESREA, and the States/Federal Ministries of Environments devise mechanisms to enforce existing environmental

laws concerning the discharge of effluents from different sources. Such efforts will go a long way in ensuring an appreciable reduction in contamination of surface waters and ensure their suitability for domestic and industrial utilization within Nigeria.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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