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Impact of Industrial Effluent Discharge on the Physico-chemical Properties of Aleto Stream, Eleme, Rivers State, Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. Author SLG designed the study, wrote the protocol and the first draft of the manuscript. Author TNG performed and managed the statistical analyses while author WLE managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Aim: This research work aimed to determine the impact of industrial effluent discharge on the physicochemical properties of Aleto Stream, Eleme and Rivers State.
Study Design: Random sampling technique was applied in this study. The study area was divided into three sites; upstream, downstream all of Aleto Stream and Agbonchia Stream which serves for the control experiment. Water samples for eleven physical and six chemical parameters were collected in a Completely Randomized Design.
Place and Duration of Study: This study was carried out on Aleto and Agbonchia streams at Eleme, Rivers State, Nigeria from 2017 to 2018.
Methodology: Two samples were collected; one sample at the Aleto stream where the industrial effluent is being channelled into the stream and the other sample was collected from Agbonchia stream, which was used as a control. In the Aleto Stream, sampling was made at two points; point A (upstream) point B (downstream) and each of these points had their Physico-chemical properties

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tested while only one sample was collected from the Agbonchia Stream. Physico-chemical properties were analyzed in the samples using pH meter for pH, Turbidity meter for turbidity, Conductivity meter for electrical conductivity, phosphate by colourimetric method, total dissolved solids (TDS) and total suspended solids (TSS) by gravimetric method, biochemical oxygen demand (BOD) and chemical oxygen demand (COD) by standard method, chloride, alkalinity, dissolved oxygen (DO), calcium hardness, total hardness by titrimetric method, colour, odour and taste by sensory method.

Results: Results obtained on the Physico-chemical properties had varying concentrations of Temperature, Total hardness, Chloride, Alkalinity, DO and Phosphate that were within world health organization (24) and Federal Ministry of Environment (1991) permissible limits on both upstream and downstream with values ranging from 29.0-23.7°C, 360-125 mg/l, 120-100 mg/l, 36-30 mg/l, 4.9-4.4 mg/l, 1.92-1.2 mg/l respectively while Electrical conductivity, Turbidity, TSS, TDS, Calcium hardness, COD, BOD, Colour, Taste and Odour were above permissible limits on both upstream and downstream with values ranging from 1660-1700 mg/l, 83-112NTU, 82-80 mg/l, 910-914 mg/l, 1590-1900 mg/l, 100-165 mg/l, 4.36-3.88 mg/l respectively. The pH values ranged from 9.0-6.3 mg/l showing a result on the upstream to be alkaline while the downstream was slightly acidic. The increase in the above parameters above their permissible limits is as a result of the impact of industrial effluent discharges drained into the stream. This indicates that the stream is unfit for both human and aquatic inmates.

Conclusion: Therefore, proper management of this effluent should be ensured and an acute test with lethal concentration ($LC_{50)}$ as the endpoint is recommended to determine the degree of toxicity of the effluent waste.

Keywords: Physico-chemical properties; Aleto stream; industrial effluent; water bodies; water pollution.

1. INTRODUCTION

Water bodies are a vital resource for agriculture, manufacturing, transportation and many other human activities. Despite its importance, water is the most poorly managed resource in the world [1]. The availability and quality of water have always played an important role in determining the quality of life. Water quality is closely linked to water use and to the state of economic development [2]. Water pollution due to discharge of untreated industrial effluents into water bodies are a major problem in the global context [3] and is being experienced by both developing and developed countries of the world. Most of the water bodies in the world especially developing countries like Nigeria are the endpoints of effluents discharged from industries [4]. In recent years, an increase in industrialization and urbanization in developing countries including Nigeria has gradually led to the generation of large amount of wastewater from domestic, commercial, industrial and other sources [5]. These industrial wastewaters directly channelled into rivers, lakes and creeks have led to pollution stress on surface waters, resulting to stench, discolouration and a greasy oily nature of such water bodies [6,5].

The major industries in Nigeria are metals and mining, food, beverages and tobacco; breweries, distilleries, textile, leather products, wood processing and manufacture, furniture, pulp and paper industries and chemical and allied industries. Industrial effluents contain toxic and hazardous materials from the wastes that settle in river water as bottom sediments and constitute health hazards to the urban as well as a rural population that depend on the water as a source of supply for domestic uses [6].

Increase in crude oil exploration, refining and activities of other industrial establishments in the Niger Delta of Nigeria have resulted in the wide-scale contamination of most of its creeks, swamps and rivers with hydrocarbon and dispersant products [7]. Wastewaters released by petrochemical industries are characterized by the presence of large quantities of petroleum products, polycyclic and aromatic hydrocarbons, phenols, metal derivatives, surface-active substances, sulphides, naphthylenic acid and other chemicals [8,4]. Considering the water bodies in industrial areas that receive untreated effluents from industries in semi-urban areas, the water quality of these rivers or streams has been tremendously affected as a result of the industrial activities. Due to the ineffectiveness of the purification system, wastewater may become seriously dangerous, leading to the accumulation of toxic products in the receiving water bodies with potentially serious consequences on the ecological communities [4]. It will also cause changes in the nutrient concentrations of water which may lead to harmful effects on humans and aquatic life. The physicochemical parameters of an aquatic body not only reflect the type and diversity of aquatic biota but also the water quality and pollution [1].

Apart from industrial and abattoir effluents, domestic waste runoff particularly untreated sewage from raw public sewage systems and sewage works, and garbage collection has been identified as another main source of stream and river channel of pollution [2].

Pollution cause changes in the physicochemical parameters of water bodies. Accordingly, an increase in water temperatures at stations close to the point of effluent discharge of Warri River in the Niger Delta has been reported [9]. The high temperature in Eruvbi stream caused by effluent discharge from a soft drink factory [10] and in Ogbere River caused by a large number of suspended solids from cassava peels and domestic wastes [11] has been reported.

It has also been pointed out that the pH of freshwater decreased following a decrease in pH of rainwater which was a runoff containing a high concentration of carbon (IV) oxide caused by gas flaring [12,13]. Wastewater, particularly those that contain detergents and soap based products also change water pH to alkaline [14].

Sewage leakages according to EPA (2016) caused an increase in water conductivity to increase in chloride, phosphate and nitrate ions. Total Dissolved Solids (TDS) in freshwater bodies' changes due to industrial effluents discharge [15], to exceed its normal range of 0 mg/l to 1000 mg/l [16].

Effluents and domestic or organic wastes from abattoir, refuse dumping and human defecation discharge into rivers and streams do not only affect nutrient composition of rivers but also the concentration of dissolved oxygen and its saturation. Arimoto and Ikomi [17] recorded an increase in nitrates and phosphates in River Orogodo in the Niger Delta caused by such anthropogenic discharge. They further stated that the increment reduce the level of oxygen but increase the level of Biological Oxygen Demand (BOD). On Dissolved Oxygen saturation in River Alaro, Ibadan, Nigeria, recorded 5.47 mg/l at the point of that receive organic effluents discharge from Oluyole Industrial Estate, 5.11 mg/l and 6.87 mg/l at downstream and upstream, respectively [18]. Saturation concentration of Dissolved oxygen was 12.79 g/m^3 at 5°C, 10.01 g/m^3at 15°C indicating that an increase in temperature caused a decrease in oxygen saturation [19,20].

Eleme, Rivers State is a host to a lot of industrial activities, including the four Nigerian Petroleum Oil Refineries and Indorama Petrochemical Company. Consequently, a large volume of effluents is generated and if untreated have a lot impacts on the surrounding freshwater bodies, including impacts on Physico-chemical parameters of the rivers. There are legislations on effluent discharge issued by regulatory agencies in Nigeria, but the issue of strict compliance to those legislations is not quite clear, particularly as there is the high colouration of the surrounding water at downstream.

It is in this direction that the objective of this present study is to evaluate the impact of industrial petroleum effluents on the physicochemical parameters of the Aleto Stream at Eleme.

2. MATERIALS AND METHODS

2.1 Description of Study Area

Eleme is a local government in Rivers State, one of the oil-producing and agro-ecological areas in the Niger Delta region of Nigeria. On the South Eastern Nigeria map, Eleme can be found between the coordinates 7E and 8E, 4N and 5N. Aleto Stream, a tributary of the Imo River lies between latitude 5°04'60.00'' North of the equator and longitude 6°38'55.99'' East of the Greenwich meridian in the Eleme Local Government Area of Rivers State, Nigeria (Fig. 1). Its climate is characterized by alternate wet and dry seasons. The wet season period occurs from April to October, although, occasional precipitations occur in the dry season months of November to March [21]. The total annual rainfall is between 160mm and 298mm; relative humidity is over 90% and means the temperature is 27°C [22]. The upper part of the stream extends from Imo River and meanders through Oyigbo and Agbonchia. The upstream reaches particularly Agbonchia is freshwater with forest vegetation comprising of various palms and aquatic macrophytes such as *Raffia, Lemna* and *Pistia* sp. The downstream reaches extend to Akpajo and are linked to Okrika arm of the Bonny River estuary. It consists of normal mangrove vegetation comprising of trees such as *Avecenia africana, Rhizophora racemosa, Achrostichum,* etc.

The river experiences two types of tides; the high tide and the low tide, since the upper reaches is freshwater and down reaches is saltwater.

2.2 Study Design

The study area was divided into three sites; upstream and downstream of Aleto Stream and Agbonchia Stream which serve for the control experiment. Water samples for eleven physical and six chemical parameters were collected in a Completely Randomized Design.

2.3 Sample Collection and Preparation

Sample collection was limited to surface water. The water samples were collected from Aleto Stream and Agbonchia Stream both in Eleme local government area, Rivers State, Nigeria. The samples were collected randomly and manually from the three study sites, into pre-cleaned 1-litre plastic containers while the sample for dissolved oxygen (DO) and biochemical oxygen demand (BOD) were collected using a DO and BOD bottles of 100-150 ml. The sensitive water parameters like temperature, pH, taste and odour were analyzed *in situ*, whereas samples for the estimation of total hardness, BOD, COD, DO, TDS, TSS, total alkalinity, calcium hardness, phosphate and chloride were brought to the Laboratory for analysis.

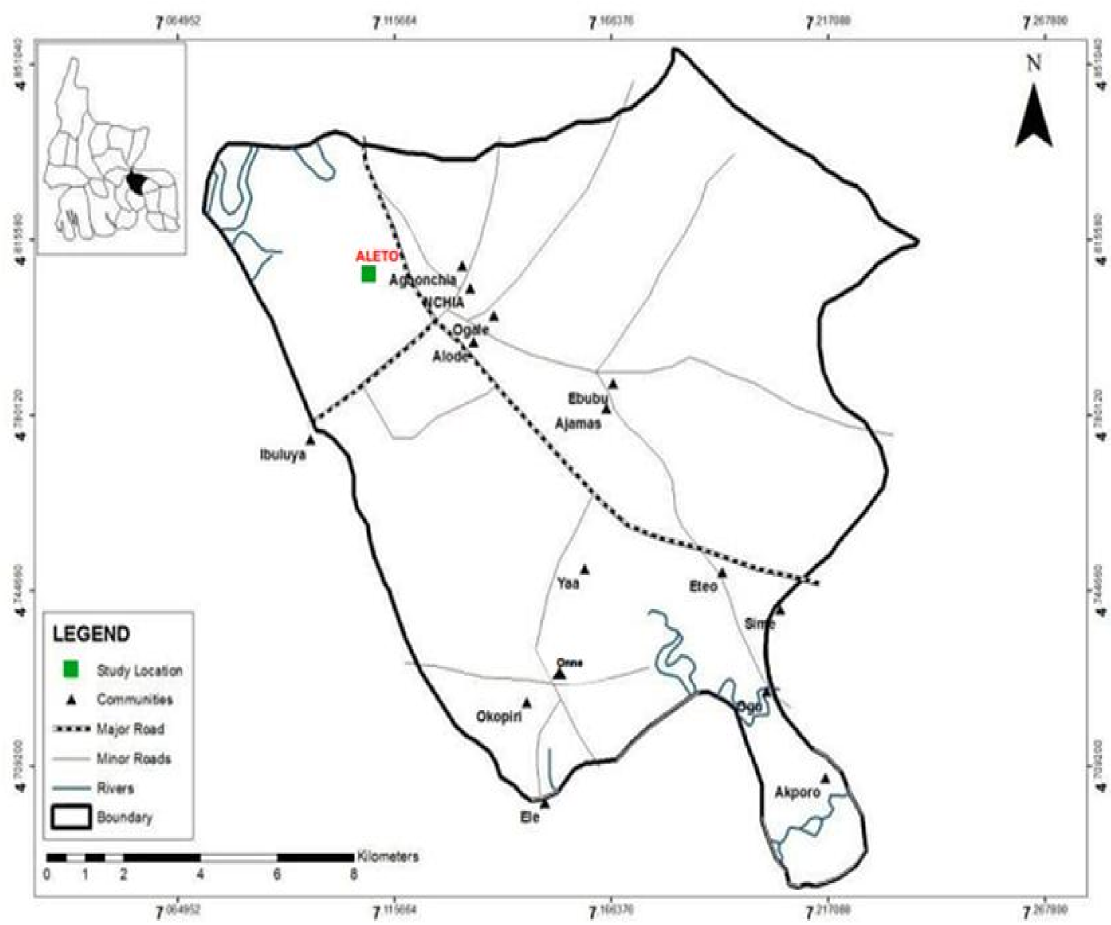

Fig. 1. Map of Eleme showing study areas

2.4 Physico-chemical Analysis

The standard analytical methods were followed for the analysis of each parameter [23]. The parameters analyzed included temperature which was taken at the site of collection using a calibrated thermometer, turbidity using turbidity meter, pH using a pH meter, electrical conductivity using conductivity meter; phosphate by colorimetric method, total dissolved solids and total suspended solids by gravimetric method, alkalinity, total hardness, calcium hardness, chloride and dissolved oxygen by titrimetric method; biochemical oxygen demand and chemical oxygen demand by standard methods. Color, odour and taste were by sensory test.

2.5 Statistical Analysis

Data collected from the study were collated and analyzed using One-way Analysis of Variance (ANOVA) and Turkey HSD (Honestly Significant Difference) test to determine the significant difference between physico-chemical parameters collected from the control and experimental sites, with the level of significance set at $P< 0.05$.

3. RESULTS AND DISCUSSION

pH is an important parameter for water quality measurement. It is a measure of the acidity or alkalinity of the water. The pH fluctuated in the range of 6.3–9.0 with 9.0 for sample A (upstream) indicating that the sample at the upstream is alkaline and 6.3 for sample B (downstream) indicating that the sample at the downstream is slightly acidic. This result is synonymous with the result obtained by Abeysinghe and Samarakoon [25]. This pH values also fall within the pH results recorded by Rout et al. [26,5]. The slight variation in water pH may be a function of effluent and intertidal effect. The normal range of pH for surface water is 6.5 to 8.5. Water pH less than 6.5 or above 9.5 for a prolonged period would diminish the reproduction and growth of fishes [26]. The pH value of Aleto Stream is gradually changing from alkaline to acidic, thus exceeding its allowable range.

Turbidity is the amount of cloudiness in the water. Water with high turbidity is cloudy, while water with low turbidity is clear. Turbidity ranged from 83NTU (upstream) to 112NTU (downstream) which was comparable to the control (22.7 NTU) and WHO limit (5-25 mg/l). It was high in both upstream and downstream probably because of high dissolved solids and suspended solid particles like colloidal organic matter and silt. The increase in turbidity at the downstream where abattoir activities are in operation and wastes are discharged into the nearby river is shown in Fig. 2.

The temperature of surface water is usually between 0ºC and 30ºC and all the values obtained from sample A (upstream) and sample B (downstream) are in this range when compared to World Health Organisation (WHO) and Federal Ministry of Environment (FME) allowable limits of which the sample A (upstream) has a value of 29°C and sample B (downstream) has a value of 23.7°C. These values agree with the temperature values reported by several authors [26,27,28,29].

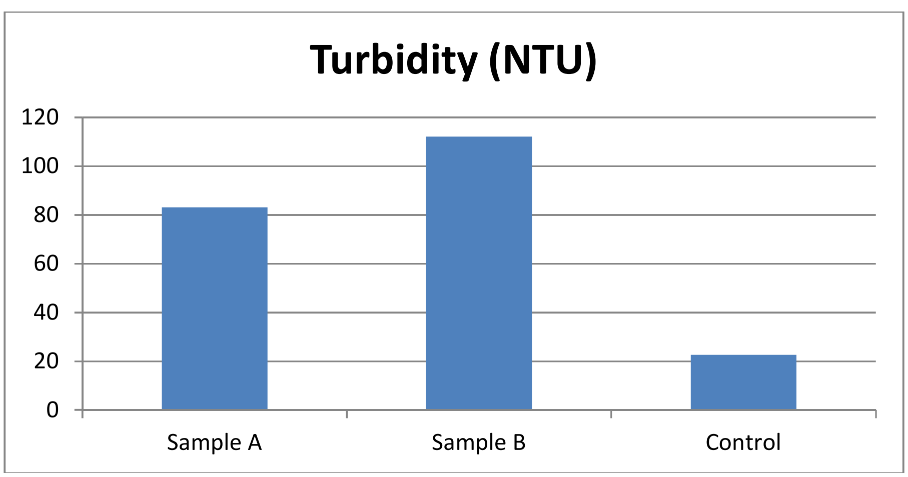

Fig. 2. Turbidity values due to effluent at different points

Electrical Conductivity (EC) levels in rivers are influenced by total dissolved solids deposited in water. A load of total dissolved solids is determined by the type of soils at the catchments area and human activities. In tropical waters, marked seasonal variation in temperature, rainfall and tidal flux also influence the conductivity of rivers as well as the time of residence, evapotranspiration and the flow rate of the river. High electrical conductivity was recorded at both the upstream and downstream which ranges from 1660-1700 mg/l respectively. The observed value may be due to the high volume of a combination of partially treated and untreated industrial effluents which contained dissolved solids and are regularly discharged into the stream. There is also some form of human settlement along the Aleto Stream and commercial activities such as car wash and sand mining activities that take place at the downstream of the stream. All these may have contributed to the rise in electrical conductivity (EC). All values from both upstream and downstream and even the control are above the permissible limit. These values are higher than the values recorded by [28,29].

Total dissolved solid (TDS) denote the various kinds of minerals present in water; however, some organic substances present in water also contribute to TDS. TDS in drinking water should not exceed 500 mg/l. Water containing more than 500mg/l of TDS causes gastrointestinal irritation [5]. High values of TDS may be associated with organic matter, salts silts, cations and debris [26] and excessive use of pipes that had corroded. TDS for sample A (upstream) and sample B (downstream) are in the range of 910-914 mg/l respectively (Table 1). The increased level was due to effluent mixing, industrial and domestic discharge. The values for both samples A and B are above the WHO permissible limit, and the values reported by several authors [4,5, 26,30].

Total suspended solids (TSS) are solids in water that can be trapped by a filter. TSS can include a wide variety of minerals such as silt, decaying plant and animal matter, industrial wastes, and sewage [4]. High concentration can cause many problems to stream health and aquatic life. TSS in sample A (upstream) and sample B (downstream) ranges from 82-80 mg/l respectively. Both samples are relatively higher than the range of 11.4 mg/l in the sample for the control but both samples are lower than the BIS Tolerance Limit of 100 mg/l. The TSS of Aleto Stream is also lower than values observed by Chandan, et al. [5,29] but higher than the TSS obtained by Ogbonna [30].

Total hardness (TH); hardness in water is mainly due to calcium ion Ca^{++} and magnesium ion Mg^{++}. Other divalent cations like Zn^{++}, Fe^{++}, Mn^{++}, Sr^{++}, may combine with anions like CO_3^{--}, HCO_3^-, SO_4^-, Cl^-, NO_3^-, SiO_3^-, etc. [5] and contribute to cause hardness in water. Though hardness has no direct impact on health it may cause sealing in the pipes. TH for sample A (upstream) and sample B (downstream) fluctuated in the range of 360-125 mg/l respectively. The values are within the desirable limits of 500mg/l according to W.H.O and the values obtained by Chandan, et al. [5].

Calcium hardness is naturally present in water and it comes from leaching of calcium-rich rocks such as limestone, marble, calcite, dolomite or mineralization of organic matter by bacteria. Calcium hardness for sample A (upstream) and sample B(downstream) ranges from 1590-1500 mg/l respectively. The values for both samples are above the permissible limits of W.H.O. (Table 1).

Alkalinity occurs in water due to the presence of carbonates, bicarbonates, hydroxides, occasionally borates, silicates and phosphate. It is a measure of the ability of water to neutralize acids. High alkalinity in water is harmful for irrigation as it damages soil and hence reduces crop [5]. The high value of alkalinity in water might be due to agricultural and domestic waste discharges that can cause accumulation of fatty acids, propionates, acetates, etc. Alkalinity for sample A(upstream) and sample B(downstream) ranges from 36-30mg/l respectively. The values for both samples are within the permissible limits of W.H.O. However, this result disagrees with those of Rout, et al. [26] and [5] who had high alkalinity values.

Chloride produces salty taste in water which varies with the number of sodium ions (Na^+) present in the water. Chlorides enter into the water through human excreta, sewage effluents, industrial activities, waters and chlorides in topsoil dissolved by rainwater [31]. The values for chloride Cl^- for Aleto River; sample A (120 mg/l) and sample B (100 mg/l) are within the WHO limit. These results are in concurrent with those of Raji, et al. [29].

Table 1. Physico-chemical parameters of Aleto stream during the period of study

S/N	Parameter	Sample A (Upstream)	Sample B (Downstream)	Agbonchia stream (Control)	Mean Value	FM Env limit (1991)	Who limit [24]
1.	Temperature (°C)	29.0	23.7	24.3	25.66	20-33	15-30
2.	Electrical Conductivity (µs/cm)	1660	1700	538.7	1299.56	-	400
3.	Turbidity (NTU)	83	112	22.7	217.7	-	5-25
4.	Total suspended solid TSS (mg/l)	82	80	11.4	58.13	NS	-
5.	Total dissolved solids, TDS (mg/l)	910	914	85.7	636.56	-	500
6.	Total hardness (mg/l)	360	125	4.7	163.23	NS	500
7.	Alkalinity (mg/l)	36	30	25	30.33	-	200
8.	Calcium hardness (mg/l)	1590	1500	500	1196.6	-	500
9.	Chloride, Cl^- (mg/l)	120	100	50	90	-	600
10.	Chemical oxygen demand, COD (mg/l)	165	100	20.7	89.12	40	5
11.	Phosphate, PO_4^{3-} mg/l	1.96	1.2	1.0	1.3	NS	2
12.	Dissolve oxygen DO mg/l	4.4	4.9	6.5	4.23	6.8	6.0
13.	Biochemical oxygen demand BOD mg/l	4.36	3.88	3.0	3.74	4.0	5
14.	pH	9.0	6.3	7.10	7.47	8.5	9.2
15.	Color	Turbid	Whitish	Clear	Ns	Clear	-
16.	Taste	Sour	Salty	Not Offensive	Ns	Not Offensive	-
17.	Odour	Choking	Foul	Not offensive	Ns	Not Offensive	-

Key: Non-specific description (-), NS = NOT SPECIFIED

Table 2. ANOVA

Values	Sum of squares	df	Mean square	F	Sig.
Between groups	613768.366	2	306884.183	1.279	.290
Within groups	9358469.264	39	239960.750		
Total	9972237.631	41			

Table 3. Post Hoc tests

Multiple comparisons

Dependent variable: Values

Tukey HSD

(I) Sample	(J)Sample	Mean difference (I-J)	Std. error	Sig.	95% confidence interval	
					Lower bound	Upper bound
Upstream	Downstream	25.26714	185.14888	.990	-425.8125	476.3468
	Control	268.13714	185.14888	.327	-182.9425	719.2168
Downstream	Upstream	-25.26714	185.14888	.990	-476.3468	425.8125
	Control	242.87000	185.14888	.397	-208.2096	693.9496
Control	Upstream	-268.13714	185.14888	.327	-719.2168	182.9425
	Downstream	-242.87000	185.14888	.397	-693.9496	208.2096

Dissolved oxygen (DO) is the amount of oxygen that is dissolved in water. It serves as a control parameter for the pollution of water. The DO values for this study varied between 4.4 and 4.9 mg/l respectively for sample A (upstream) and sample B(downstream) which is below the limits of W.H.O. and FME. However, the control had a DO of 6.5 mg/l. Moving water such as Aleto Stream is expected to have a large amount of dissolved oxygen. High values of DO provide river water with natural self-purification capacity. With the significant drop in the DO level of Aleto Stream, the quality of the water can be said to be impaired for the sustenance of life. This is because the standard for DO in good quality water is usually more than 5 mg/l to promote proper growth of fish and other aquatic organisms [5].

Biochemical oxygen demand (BOD) means the amount of oxygen required by the micro-organisms in stabilizing the biologically degradable organic matter under aerobic conditions. Increase in BOD concentration may cause the death of some aquatic organisms such as fish and increases eutrophication [5]. The values for BOD for sample A (upstream) and sample B (downstream) ranges from 4.36-3.88 mg/l respectively. The increase in BOD for sample A (upstream) is due to effluent mixing. The value for BOD in sample A (upstream) is above permissible limit for FME but within the limits for W.H.O. [26] noted that the most significant sources of BOD and COD were industrial effluents.

Chemical oxygen demand (COD) and BOD values are both a measure of the relative oxygen–depletion effects. The high concentration of COD indicates that organic and inorganic matter is present in the stream. The values of COD in this study range from 165-100 mg/l which is above the permissible limits of WHO and FME. The values recorded here are synonymous with those reported by Tekede, et al. [32]. They are how several authors 28].

Samples A (upstream) and B (downstream) were turbid and whitish. This could be as a result of the presence of either dissolved or suspended materials or organic matters associated with the humus fraction of soil in the stream. Colour is strongly influenced by the presence of iron and other metals, either as natural impurities or as corrosion products [13]. It can also result from contamination of the stream with industrial effluents. The sensory result obtained on both samples on colour does not agree with the FME limit.

The odour for sample A (upstream) was choking while sample B (downstream) had a foul smell.

This is due to the dissolving of certain compounds or substances from sewage effluents and industrial wastes discharged into the stream. The result obtained for the odour of Aleto Stream does not agree with the FME limit. Taste for sample A (upstream) was sour and sample B (downstream) was salty. This may be due to inorganic chemicals such as hydrogen sulphide, chloride, sulphate which may be present in the water.

The one-way between groups (samples) analysis of variance conducted to explore the difference between the physico-chemical properties collected from control and experimental sites shows that there is no statistically significant difference at the $P>0.05$ level for samples from the $F(2, 39) = 1.279$, with P-value > 0.05 (that is P-value = 0.290). The posthoc comparisons were carried out using Turkey HSD test (Honestly Significant Difference) to determine if the relationship between the two samples is statistically significant, that is whether there is a strong chance that an observed numerical change in one value in any sample is casually related to another. The Turkey HSD test statistics show that there was no statistically significant difference between upstream, downstream and control as all the P-values are greater than 0.05 at 0.05 levels.

4. CONCLUSION

The study has shown that there is a relatively low value of samples analyzed at downstream (point B) compared to that of upstream (point A). This implies that as the water flows from one point to the other the concentration of solute diffuses downstream. Physico-chemical parameters such as electrical conductivity, turbidity, COD, BOD, TSS, TDS, calcium hardness, pH, color, taste and odour were above the permissible limit. This implies that the impact of industrial effluent discharge from Indorama Eleme Petrochemicals Limited into Aleto Stream contributed to poor water quality for both human and aquatic inmates which are more noticeable at the point of discharge. The overall water quality parameters also indicated stress on the stream. Proper management of this effluent and other sources of effluent into the Aleto Strem are therefore imperative so as to save the water body from further degradation.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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