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Seasonal Impact of Ikeja Industrial Wastewaters on Water Quality of Proximate Iya Alaro River in Lagos, Nigeria

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Abstract: This study determined the seasonal impacts of wastewaters from Ikeja industrial estates on the water quality of proximate Iya Alaro River being one of the longest rivers employed for irrigational and washing purposes in the estate. Wastewater samples from industrial estate were collected at the point of discharge of effluents into the streams and at spatial interval of 50 to 200 meters upstream and downstream of the discharge point over a two- year period (2005-2007) .The effluents were analysed for physico-chemical parameters using standard methods. At discharge point during dry and rainy seasons, the pH were acidic (5.51 ± 0.16 to 6.46 ± 1.27 and 6.13 ± 0.96 to 6.80 ± 1.04).Total Dissolved Solid and Electrical Conductivity levels showed significant difference ($p < 0.05$) between seasons at discharge points and higher than permissible levels at upstream and downstream. Mean levels of Dissolved Oxygen (DO) were low at discharge points during the dry and rainy seasons (2.20 ± 0.66 to 3.93 ± 0.71 and 2.41 ± 0.30 to 2.83 ± 0.72). Biochemical Oxygen Demand and Chemical Oxygen Demand increased in the range of 579-1186 mg/L and 1247-2610mg/L respectively from March to July with low levels of DO ranging from 1.70 to 3.70 mg O_2/L. Mean levels of Nitrate were within permissible limits downstream and upstream and higher in rainy than dry seasons at the discharge points. Sulphate levels detected were below WHO levels of 400mg/L while Chromium levels were above the limits of 0.05 mg/L. Mean levels of Phosphate at discharge points was higher (31.97 ±1.12mg/L) during dry season of the second year, and were also higher upstream and downstream than permissible limits. Manganese showed significant difference ($p < 0.05$) at the discharge points. Downstream accumulations were relatively higher for Copper (4.04mg/L) and Manganese (4.10mg/L) in the dry season and Cadmium(5.93mg/L) in the rainy season. It showed that industrial wastewater majorly caused the stream to be polluted and unsuitable for drinking. The degradation of the water quality of proximate streams in the estate therefore needs preventive and remedial measures of combined central effluent and treatment plants in order to bring back the waters to a level before the pollution discharges.
Key words: industrial wastewaters, water quality, discharge point, upstream, downstream.

INTRODUCTION

Industrial developments and processes can enhance societal living standards to unimaginable levels as they serve as indispensable tools for national growth. Wealth creation through employment, dynamic socio-economic stability through energy development is sustainably achievable through industrialization [1]. However, the associated threats which industrial wastes impose on the environment, natural resources human health are grave especially if they are not properly disposed of in an environmentally safe manner [2]. Unlike in industrialized countries, where keen attention and prior consideration are given to generation, collection and disposal of industrial effluents because of its large volumes and high inherent toxic chemicals [3],pollution through indiscriminate release of untreated and/or partially treated effluents is common practice in developing countries. This often renders the receiving water bodies unsuitable for both primary and/or secondary usage. The situation, in most of these countries, is exacerbated by inaccessibility to portable water, and in many instances, raw river water is used as source of drinking water. Because of lack of effective monitoring, so any abnormal change in water quality is not promptly identified and dealt with until epidemic breaks out.

Pollution of rivers from nonpoint sources is often larger and harder to mitigate than point source. Though non fixed, are characterized by emission from mobile sources and sources that coves wide number of sources with low level of pollution. The effluents entering directly from industries can be

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easily monitored and regulated. Usually there is a spatial variation in quality and quantity depending on the activities concerned. Quality of surface waters may vary due to natural environmental factors which may or may not be periodic, biotic or abiotic and external or internal to the water body [4]. These variations often depend on the origin, pathway and behaviour of the components pollutants as well as on the hydrology characteristics of the water body. In rivers, water discharge has been considered the most common variable [5][4]. However internal processes related to climatic and biological processes have been considered particularly in water bodies whose water residence time spanned more than one year. Although the quality of rivers depend upon the water flow regime of river borne substances, the levels and variations in patterns of pollutants, concentration introduced through anthropogenic activities are also closely linked to its water quality and chemistry at upstream and downstream [6-7].

Studies had shown that an improvement in water quality had a direct effect on people's health and reduce exposure to water associated diseases. [8] reported that cases of patronage to hospitals and other health care facilities were on the increase due to increasing populations coupled with polluted water resources. According to him, there was high incidence of typhoid, cholera, dysentery, infectious hepatitis and guinea worm in urban settlements of Nigeria. In a study about top ten diseases from hospital records, it was observed that diarrhea had 25 percent which was the highest recorded cases of 1530 out of 6120 cases considered [9]. To stem the tide of water pollution occasioned by industrial activities, it becomes necessary to assess the impact of zonal industrial wastewaters on receiving water bodies so as to sensitize environmental regulatory agencies to intensify efforts in monitoring industrial wastewater discharges Also, problems of discharging of toxic effluents can be tackled at zonal level with combined efforts of industries and regulatory bodies since it may be difficult to move from one industry to the other.

The indiscriminate release of partially treated or untreated industrial wastewaters in to water bodies either by direct or indirect means often create degradation of water quality with gross attendant effects primarily on aquatic organisms and largely on human beings who are end consumers. Such pronounced effects on water chemistry are often governed by seasonal changes occasioned by climatic factors or sundry activities especially when the water is engaged to harness its uses to man's advantage.

MATERIAL AND METHOD

Study Area

The study was conducted in Ikeja industrial zone in Lagos city,Ngeria.It is located 30km North of Lagos Island and spans a total area of 325sqkm. It is bounded on the North by Agege / Ifako Ijaiye; on the South by Oshodi/Isolo; on the West by Alimosho and on the east by Kosofe Local Government area NBI, 2002 [10]. The major industrial sectors ranges from pharmaceutical, food and beverages, pulp and paper, textiles, dyeing, chemical to electrical appliances. Wastewaters discharged from different industries in the estate are connected by a network of canals and sewers and channeled directly into Iya Alaro River which is a long river that transverses across Ikeja and receives effluents from industries at different points . The river meets Shasha River at the Northern part of Lagos and flows to join Aromire River in the vicinity of Nigerian Bottling Company along WEMABOD site (Figure 1). The downward flow creeps through Oregun and Ojota and finally empties into Lagoon (Figure 1). In- between Oregun and Ojota, along Access Road, the water is being used by dwellers for washing and fishing purposes.

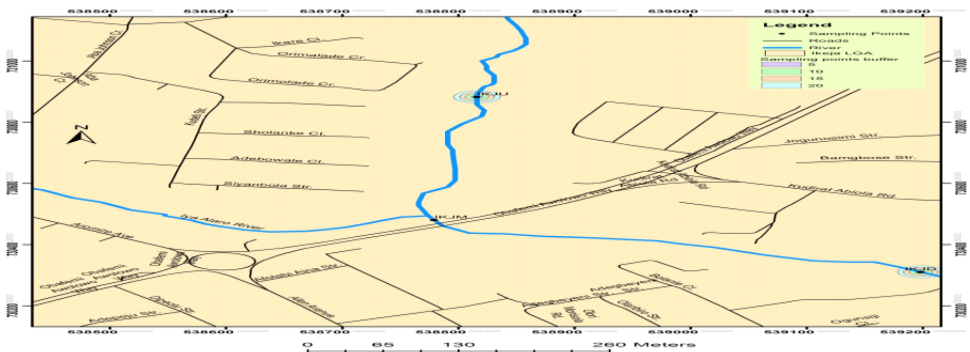

Figure 1. Sampling points in Ikeja Industrial Area

METHODOLOGY

Glassware Cleaning Procedures

Sampling materials and collection bottles were thoroughly washed with dilute (0.1 percent) low phosphate soap and tap water,rinsed with dilute (5 percent) nitric acid solution followed by deioned water. At the points of sample collection, they were rinsed two to three times with some quantity of the water being sampled.

Sampling points and duration

Three points were carefully chosen along the river that best represent the sample as well as ready accessibility for sampling. The samples were collected at point of industrial wastewaters discharge into the river, upstream point of about 50- 200 meters from discharge point and downstream point at about 50-200 meters away from discharge point. Upstream and downstream points were100- 400 metres apart. The sampling was carried out bi-monthly for two years spanning two dry and two rainy seasons. A dry season covers November to March and rainy season covers May to September.

Sample collection and preservation

At any sampling site, five separate sets of samples were collected. One for determination of dissolved oxygen contents of the water (DOu, DOm, DOd) which were fixed on the field by addition of manganous sulphate solution and alkali-iodide-azide and determined immediately on arrival at the laboratory.

The second set was used for determination of anions such as nitrate, sulphate and phosphates which were preserved by adding 2 ml concentrated H_2S0_4 per litre at 4°C, refrigeration at 4°C and addition of 40mg Hg^+ per litre at 4°C respectively. The third set of samples which was used for determination of BOD and COD were preserved by refrigeration at 4°C and acidifying with 2 ml concentrated H_2S0_4 per litre respectively. The fourth set of samples used to determine heavy-metal were filtered and the filtrate treated with 3 ml 1: 1 $HN0_3$ per litre in order to keep the metal ions in solution before analysis. The fifth set of samples was used to determine other physico-chemical parameters.

Samples were collected in clean standard plastic bottles ($1000cm^3$) in such a way that no bubbles were formed in the bottles as they were tightly closed. To enhance homogeneity and uniformity, the water samples were collected at the 20cm sub-surface and middle depth of the river. After collection, the samples were taken to the laboratory, Department of Chemistry, University of Lagos, Akoka where all analytical work was carried out within 5 days.

Sample analytical procedure

Non conservable parameters such as pH, TDS and electrical conductivity were determined at the sampling site. The pH of water sample was measured with a pH meter previously calibrated with buffer solutions [11]. Conductivity was measured with a conductivity meter calibrated with potassium chloride solution. Dissolved oxygen (DO) was determined by Winkler's titration. Total dissolved solid (TDS) was determined gravimetrically by evaporating a known volume of water to dryness in a pre-weighed crucible on a steam bath [12]. Biological Oxygen Demand (BOD) was determined using the relationship BOD = DO-DO5 [13].COD was measured by titration of excess dichromate with N/10 Ferrous Ammonium Sulphate (FAS) using Ferroin as the indicator .Phosphates was determined by addition of 8ml prepacked combined reagents to 50ml sample in a 250 ml flask, and the absorbance measured on spectrophotometer (Spectronic 20^{D+}) against the blank at 690mm [14].

Nitrate was determined by a colorimetric method where 10ml of sample in a sample tube was added to 10ml of 13 M sulphuric followed by addition 0.5ml brucine reagent and the absorbance of the sample was read at 410mm using colorimeter. A turbidimetric method as described by APHA-AWWA-WPCF [14-15] and was adapted to determine the concentration of sulphate in sample. The sulphate turbidity was measured on a spectrophotometer at 420mm.

Heavy metal was determined by digesting a known volume of water sample with analytical grade HNO3. This was filtered into a 20ml standard flask, made up to mark with distilled-deionised water and stored in a nitric acid pre-washed polyethylene bottle in the refrigerator prior to analysis. Metal analysis was carried out using Atomic Absorption Spectrophotometer (Perkins Elmer Model 2380)

.Each sample was analysed in duplicate and the mean result reported. General laboratory quality assurance measures were always maintained.

Statistical Package for Social Science (SPSS) version 11.0) was used to analyze data as follows: The paired t-test was used to compare the mean of seasonal variations.

RESULTS AND DISCUSSION

At the point of industrial wastewater entering the river

The values of pH obtained at the point of industrial wastewater entering the river were low varying from 5.51 ± 0.16 to 6.46 ± 1.27 in dry season and 6.13 ± 0.96 to 6.80 ± 1.04 in rainy season. (Table 1.) The low pH levels of water at point of wastewater discharge and downstream could be attributed to mineral acids such as hydrochloric, nitric, phosphoric and sulphuric acids employed as essential reagents and raw materials in many industries. Similar pattern in variation of pH levels at wastewater discharged points had been reported which corroborated findings from this study [16-17]. [18] determined water quality at exactly 200 meters downstream the point of industrial effluent discharge reported similar results of pH range from 5. 50 to 6.00 as that obtained in this study. The discharge of industrial wastewaters into the rivers which resulted to a decrease in pH levels of the water downstream could affect metal solubility. In line with this finding, it has been reported that zinc had an increased detrimental environmental effect as a result of lowered pH [19]

At this point, total dissolved solid (TDS) values were within the range of 246.67 ± 4.24 mg/L to 1402.50 ± 3.21 mg/L in the dry seasons. The lower values in range of 275.00 ± 2.50 mg/L to 294.33 ± 4.74 mg/L were observed in the rainy seasons. The significant difference observed between seasons, at $p \leq 0.05$ confidence limit, implies seasonal pattern in variation. This might be caused primarily from influx of dissolved solids. High values of TDS in the dry season and low values in the rainy season have been reported in similar studies [20]. Their findings also reflected a seasonal pattern of variation. In dry seasons of first year, the EC values (2803.33 ± 45.22 Scm^{-I}) was very high. The could be attributed to high levels of conducting species such as sulphate, chloride, phosphate and heavy metals present in industrial wastewater. An average level of 22000/Ωm has been reported from a similar study in support of this study [17]. However, a relative lower levels of EC obtained in the rainy seasons (536.33 ± 4.38 Scm^{-I} and 530.67 ± 7.47 Scm^{-I}) was in line with similar study in the literature [21]. Evidence of significance difference ($P \leq 0.05$) observed in the first year of sampling showed seasonal variation. This might be accounted for by the mobility and effect of dilution during rainy season. This implied a regular pattern of seasonal variation. Although, higher values was expected in rainy than dry seasons due to more mobility of ions as reported in some literatures [16, 22]. The results obtained in this study were contrary to the expected.

Significant difference of EC at $p \leq 0.05$ confidence limit observed in the first year of sampling in Ikeja industrial zone was an indication of systematic change in discharge of EC in the wastewater and hence seasonal effect in variation.

In the first year, the effluents discharged, at this point in the rainy season had DO level of 2.41 ± 0.30 mgO_2/L. This suggests that industries were releasing some organic substances that were high oxygen- demanding most especially food, textiles and pulp industrial wastes .In a similar study on pollution of water resources from industrial effluents, [23] identified that discharge of industrial effluents rich in organic substances lowered oxygen of the river. Contrary findings to the results obtained from this study were also reported. They reported total absence of dissolved oxygen at the confluence point of wastewater with rivers [17, 24].

The levels of biochemical and chemical oxygen demands at the confluence point were higher in the rainy than dry seasons except for the second year of sampling. This exception might be due to human influence. Higher values of biochemical and chemical oxygen demand in the rainy seasons were indicative of excessive organic matter contained in the industrial wastewater discharged into the rivers. In an assessment of water physico chemistry, it was reported that 70- 90 % of the pollutants reaching the water were organic in nature which were primarily generated from food, paper, battery, glass, plastic and textile industries [25].

Relative higher levels of sulphate were recorded in dry season than rainy one. This was shown by significant seasonal differences. This might be due to discharges from industries employing sulphuric acid or sulphate salts as common reagents and raw materials.. A 'high level of sulphate (52 mg/L) from similar study at point of effluent discharge had been reported in line with the result obtained from this study [17]. He ascribed the high levels to the use of sulphuric and sulphate salts which are commonly used in some industries.

The high mean concentration of phosphate was observed in the dry season (31.97 ± 1.12 mg/L). This could emanate from phosphoric acid, phosphate salts and detergents used for washing in the canteens of most of the industries. An average phosphate level of 88.1 mg/L being reported from a similar work in the literature supported findings from this study [17].

Chromium levels were still high ranging from 0.25 ± 0.01 mg/L to 0.77 ± 0.03 mg/L (Table 2.) This might be attributed to chromium in wastewater from tannery and textiles industries used as tanning and oxidizing agents respectively [21, 26].

Higher level of Iron (Fe) was observed in the rainy than dry season at the point of industrial wastewater discharge into the waterways. In the rainy season, the level of iron fluctuated from 6.23 ± 0.31 mg/L to 10.23 ± 1.00 mg/L .The higher levels in the· rainy season might be attributed to iron salts in wastewater from iron and steel industries aided by water flow.

Lead levels range between 0.09 ± 0.01 mg/L and 0.16 ± 0.02 mg/L. This could be attributed to some domestic and commercial activities.

Table 1. Seasonal Mean composition of physicochemical parameters at the point of effluents discharge into waterways (mean ± SD) n=3

Parameters	[1]Dry Season	[1]Rainy Season	P≤0.05 Ind. T – test	[2]Dry Season	[2]Rainy Season	P≤0.05 Ind. T-test
Ph	5.51±0.16	6.80±1.04	0.1	6.46±1.27	6.13±0.96	1.74
TDS (mg/L)	1402.50±3.21	275.00±2.50	0.01*	246.67±4.24	294.33±4.74	0.54
EC (Scm^{-1})	2803.33±5.22	536.33±4.38	0.01*	693.33±2.20	530.67±7.47	0.27
DO (mg/L)	3.93±0.71	2.41±0.30	0.28	2.20±0.66	2.83±0.72	0.32
BOD (mg/L)	759.00±3.94	817.50±4.59	0.87	549.00±3.44	519.70±1.21	0.84
COD (mg/L)	1670.67±3.72	1798.77±2.00	0.86	1208.00±3.30	1142.93±3.16	0.83
NO_3^- (mg/L)	0.94±0.32	0.51±0.17	0.60	1.60±0.31	2.37±0.45	0.23
SO_4^{2-} (mg/L)	1.58±0.44	0.46±0.24	0.02*	0.48±0.27	0.30±0.15	0.37
PO_4^{3-} (mg/L)	0.51±0.31	0.61±0.41	0.76	31.97±1.12	2.87±0.31	0.38

Note: * Independent T-test is significant at the 0.05 level (2-tailed) [1,2] First and second year mean concentration.

Table 2. Seasonal Mean composition of heavy metals at the point of effluents discharge into waterways (mean ± SD) n=3

Parameters	[1]Dry Season	[1]Rainy Season	p≤0.05 Ind. T – test	[2]Dry Season	[2]Rainy Season	P≤0.05 Ind. T-test
Cr (mg/L)	0.71±0.01	0.77±0.03	0.94	0.25±0.02	0.25±0.01	0.99
Mn (mg/L)	0.15±0.04	0.40±0.06	0.01*	2.62±0.03	0.91±0.04	0.43
Fe (mg/L)	0.92±0.06	0.64±0.03	0.31	6.23±0.31	10.23±0.10	0.34
Cu (mg/L)	0.78±0.03	0.69±0.09	0.75	0.08±0.01	0.06±0.02	0.31
Zn (mg/L)	0.75±0.03	0.28±0.08	0.26	2.54±0.05	1.76±0.06	0.70
Cd (mg/L)	0.02±0.01	0.50±0.05	0.50	0.01±0.01	0.14±0.01	0.47
Pb (mg/L)	ND	0.09±0.01	ND	0.16±0.02	ND	ND

Note: * Independent T-test is significant at the 0.05 level (2-tailed) [1, 2] First and second year mean concentration ND :Not Detected

Upstream and downstream

The results obtained for water quality upstream and downstream were also acidic especially in dry season because the pH levels were slightly lower (Table 3) than acceptable limits of 6.5 - 9.2 set for drinking water by World Health Organization [27] . The pH levels of water upstream from this study was also at variance with average pH level of 7.8 obtained from similar study carried out on Alaro River in Ibadan [17]. The high level of TDS in water at upstream (7175.00 ± 76.16 mg/L and downstream (4208.33 ± 39.57 mg/L) points was observed in the dry season of the first year. These high values were beyond 500.00 mg/L permissible values set for drinking water.

[20,28] reported that high dissolved solids as the ones obtained in dry seasons might be harmful to aquatic organisms and could caused gizzard stone when accumulated in human body. The TDS values obtained in the rainy seasons were within acceptable limits.

The results obtained in dry season showed lower levels of dissolved oxygen in the water downstream than upstream .The depletion of dissolved oxygen downstream might be due to the enormous quantity of organic loads which required high levels of oxygen for chemical oxidation and/or decomposition. Analysis of water upstream and downstream of a river in Pakistan showed similar lower level of dissolved oxygen downstream (4.8 - 5.8 mg 0_2/L) than upstream level (5.8 - 6.9 mg 0_2/L) as the ones observed from this study [29].

The levels of biochemical and chemical and chemical oxygen demand of water upstream and downstream were higher in multiples of hundreds than the acceptable level which implies that the water was grossly polluted and could mean that little or no biological and/or chemical pretreatment of water was carried out before releasing to the environment.

The nitrate levels were generally low. Nitrate concentrations above 5.0mg/L in surface waters usually indicate pollution by anthropogenic activities. Concentration of nitrate above 5mg/L was not detected in water downstream and upstream. Also maximum allowable limits set by WHO was not exceeded [30].

The levels of sulphate upstream which ranged from 0.20 ± 0.05 mg/L to 4.97 ± 5.14 mg/L were similar to the natural background sulphate levels of 1.0 - 5.0 mg/L reported for other unpolluted rivers elsewhere [17, 31].

However, highest level of sulphate downstream (1.13 ± 0.39 mg/L) was comparatively lower than the sulphate levels of 662 mg/L, 168mg/L and 52 mg/L reported from similar studies conducted elsewhere [32-34].

The phosphate contents for upstream and downstream water exceeded 0.03mg/L for unpolluted fresh water. By implication, the water was not good for drinking and with such enormous quantity of nutrients the water could become eutrophic. Higher levels of phosphate noted downstream were as a result of direct contribution of effluents discharge which aggravated phosphate level downstream. Elevated concentrations of phosphate and other nutrients downstream have been reported whose origin were associated with proliferation of algal growth [35-36. This could be responsible for further depletion of dissolved oxygen levels of the river [37].

More downstream levels of chromium was observed in the dry than rainy seasons. This could be explained on the basis of low solubility of heavy metals as a result of less dilution of water and warm temperature. An average concentration of 3.25 mg/L chromium in warm dry and 1.44 mg/L in cold wet seasons reported was in harmony with this study [38].

The upstream and downstream levels of manganese were higher beyond permissible level. Higher levels of manganese at downstream point caused by effluents discharged into water ways reported in the literature corroborated findings from this study [17, 39]. Considerable levels of manganese in form of permanganate are harmful and could kill fish at concentration between 2.0 - 40mg/L [40].

The upstream low levels of copper in the range of 0.05± 0.02-1.21± 0.34 were in some cases greater than upstream levels of 0.01 - 0.09mg/L reported from similar studies in the literature [41-42]. This showed impact from non-point sources.

Similarly, the downstream concentrations of iron were higher than upstream especially in rainy season. The concentration of iron was 8.696 ± 4.88 mg/L. In consonant with this study, higher concentration of iron has been reported in a similar study in the literature [43] .Although, iron could serve as an essential nutrient of the blood and skeleton, accumulations of large amount in the body could lead to tissue damage and hyperhaemoglobularia [44].

The higher zinc concentration in the dry seasons than rainy season might be due to low dissolution of zinc as a result of water temperature. [38] reported the concentration of some heavy metals in dry and wet seasons. They observed that zinc levels were significantly higher in warm period than cold period due to change in river flow and water temperature. In effect, concentration of zinc tended to accumulate downstream during dry season especially in the secondyear sampling. The considerable levels of zinc observed in water upstream might be attributed to impact of nearby Olusosun land fill. According to the findings, zinc was reported as the most predominant metal in the Olusosun landfill which have tendency of leaching to nearby stream and enhancing its concentration downstream [45].

Downstream accumulation of cadmium generally increased in rainy season of the first year in Ikeja industrial zone. Reports on variations of dissolved trace metals as well as on quality of water downstream were in support of this finding. Accumulated cadmium level has been linked with a number of health and significant kidney damage in people that drink cadmium contaminated water [46-48].

Upstream and downstream levels of Lead showed similar trend in seasonal variation. The levels were above the permissible level in water. Concentration of Lead in water above permissible limit has been reported in the literature [49]. However, in support of this finding, high concentration of Lead upstream in the range of 0.32 ± 0.04 mg/L due to domestic activities has also been reported elsewhere [38].

Table 3. Seasonal mean levels of upstream and downstream water quality (Mean ± SD) n=3

Water Quality Parameters	Dry Season		Rainy Season		WHO recommended limit
	IKJu	`IKJd	IKJu	IKJd	
PH	5.10±0.30	5.49±0.25	7.07±0.19	6.83±0.12	6.5-9.2
TDS (mg/L)	7175.00±6.16	4208.33±5.57	415.33±3.62	258.00±2.39	500
EC (Scm^{-1})	3416.67±3.19	2343.33±4.76	497.33±1.00	518.00±4.16	400
DO (mg/L)	3.97±0.19	3.50±0.96	2.17±0.15	2.43±0.46	4-6
BOD (mg/L)	431.67±2.41	687.50±1.45	966.35±2.25	844.62±4.72	<2.0
COD (mg/L)	1683.03±3.82	916.13±2.60	2129.37±2.01	1925.03±1.27	10
NO_3^- (mg/L)	0.34±0.05	0.67±0.02	1.03±0.01	0.74±0.02	45
SO_4^{2-} (mg/L)	4.97±0.03	1.13±0.09	0.59±0.04	0.78±0.03	200-400
PO_4^{3-} (mg/L)	0.67±0.05	0.53±0.08	0.71±0.02	0.82±0.05	0.03
Cr (mg/L)	1.21±0.21	0.89±0.13	1.41±0.35	0.76±0.16	0.05
Mn (mg/L)	0.07±0.02	0.06±0.01	0.67±0.01	0.69±0.06	0.1
Fe (mg/L)	0.77±0.07	0.93±0.05	0.76±0.01	0.92±0.04	0.3
Cu (mg/L)	1.21±0.04	0.85±0.06	0.54±0.01	0.80±0.09	1.0
Zn (mg/L)	1.15±0.05	0.79±0.09	0.70±0.06	0.36±0.03	5.0
Cd (mg/L)	ND	ND	0.34±0.06	2.04±0.01	0.05
Pb (mg/L)	ND	ND	ND	0.14±0.01	0.06

IKJu = upstream mean concentration of water parameter of the water body IKJd = downstream mean concentration of water parameter of the water body ND = Not Detected

Bimonthly spatial and seasonal variation

Figures 2-10 showed that pH levels were acidic in dry season due to release of wastewaters but tending towards neutrality during raining season because of dilution effect.TDS and EC levels were generally high in dry season and lower in rainy season. Higher level of EC observed in month of May might be due to high mobility of ions at the onset of rain.

A sharp decrease and increase in level of dissolved oxygen was observed in month of January and May respectively which might be attributed to a copious discharge of wastewaters due to an increased level of production. It was observed that major manufacturing and processing industries close down their operations for vacation from middle of December to middle of January. On resumption, there is likelihood of increased operations to compensate for holiday period which invariably might generate more wastewaters and reduce dissolved oxygen levels. Similar studies carried out between November and January reported low levels of DO in range of 2.32 mgO_2/L to 2.70 mgO_2/L agreed favourably with the findings from this study [50-51]. A sharp increase of DO level in May might be caused by rain. Low levels from July to September might be caused by August break

The high levels of BOD and COD in January might be due to increased release of organic waste waters, from March to July due to high volume of rain. August break might account for sharp decrease in levels in September. Nitrate, Suphate and Phosphate levels were high in dry season and increased from March to July and July to September respectively.

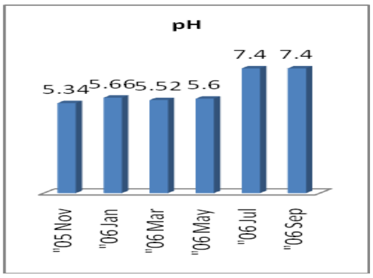

Figure 2.

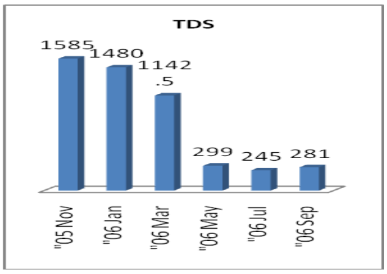

Figure 3.

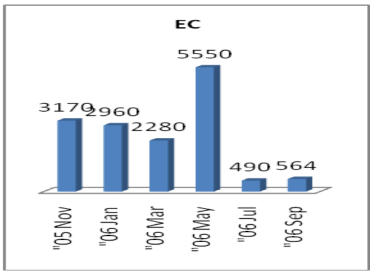

Figure 4.

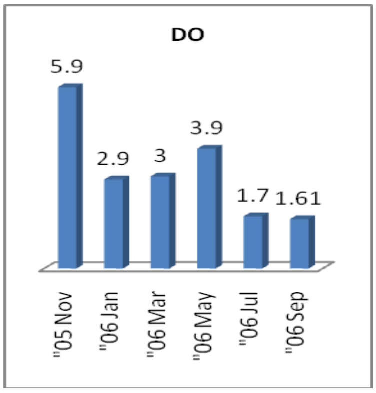

Figure 5.

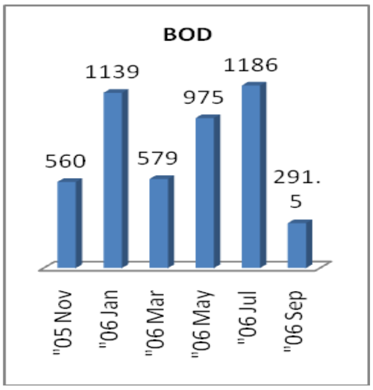

Figure 6.

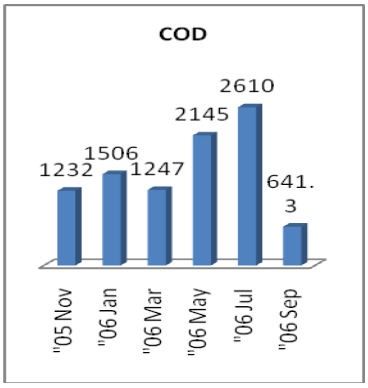

Figure 7.

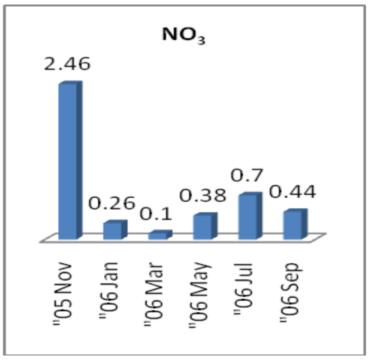

Figure 8.

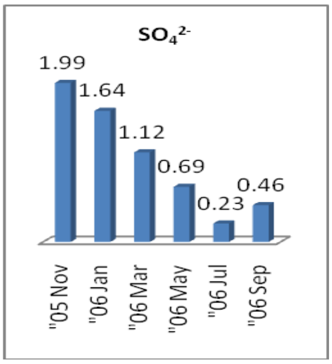

Figure 9.

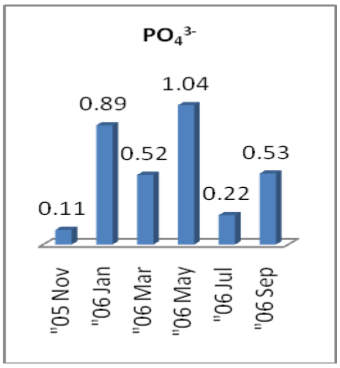

Figure 10.

Table 4. Bimonthly and seasonal variation of some heavy metals at the point of industrial wastewater discharge

Month	Cr mg/L	Mn mg/L	Fe mg/L	Cu mg/L	Zn mg/L	Cd mg/L	Pb mg/L
Nov. 05	1.12	0.12	0.83	0.31	0.30	0.03	ND
Jan. 06	1.00	0.22	0.62	1.14	1.29	0.01	ND
Mar. 06	0.01	0.10	1.32	0.90	0.65	ND	ND
May. 06	1.50	0.44	0.55	0.55	0.71	0.01	ND
Jul. 06	0.04	0.44	0.90	0.91	0.06	1.48	ND
Sept. 06	ND	0.33	0.46	0.61	0.06	0.20	0.90

ND: Not Detected

As noted in this study for some physiochemical parameters, increase in level of copper concentration in January was also observed in the water. This compared favourably with variation observed for copper in Ikpoba River and Olamoro River in Edo State of Nigeria [52].

The levels of iron were high in January which might be as a result of resumption for operation in New Year by many industries. Higher levels observed from May to September might be attributed to effect of rain and high water flow. The impact was pronounced in Ikeja industrial zone with highest concentrations of 9.86mg/L in January, 12.00 mg/L in May, 6.77 mg/L in July and 11.90 mg/L in September. Increased industrial operations and effect of rain might account for this.

CONCLUSION

The water bodies considered in Ikeja, industrial zones were grossly polluted. The pH values of water were low (acidic) due to impact of pickling industries. The levels of the pollutants assessed to determine the pollution load of the rivers showed that in all the points of sampling they were generally higher than the acceptable limit. The only exceptions were nitrate and sulphate whose levels were well below the recommended limit. This implies that the water bodies receiving industrial waste water were grossly polluted and might not be suitable for domestic as well as for drinking purposes.

High content of organic matter observed at confluence point, downstream than upstream as shown by the high values of BOD and COD imply that there was no prior biological treatment before discharge of waste waters. Release of wastewater from industries through the confluence points had great impact on the receiving rivers. Although the nitrates levels were low at the points of effluent discharge, other domestic and commercial activities have contributed to the influx of nitrate and sulphate to the river.

At the point of effluent discharge into the river, phosphate level increased showing more of phosphate – producing industries and implying that no pretreatment was undertaken before releasing the wastewater to the environment.

Dissolved oxygen levels were very low due high organic content. The levels were much lower at confluence and downstream points due to high oxygen demand in wastewater from industries. This shows that the receiving water bodies were poorly aerated and grossly polluted. It may however not be suitable for maintenance of aquatic life.

The levels of total dissolved solids and electrical conductivity in the water bodies exceeded the recommended value by World Health Organization with significance difference at $p = 0.05$ confidence level implied seasonal variation. All heavy metals considered were higher in levels than recommended level for water with the exception of zinc. Some heavy metals were not detected in the water bodies possibly because of their complexation tendency and high rate of sediment absorption. For all the heavy metals examined in this study, their levels increased in the months of January and May which due to increase of industrial activities and effect of rain respectively.

RECOMMENDATIONS

The environmental Agency should be properly funded so as to carry out its supervisory roles to ensure standard are maintained before industrial wastewater are released to the environment. Also it should be more aggressive in assessment and enforcement of laws and regulations.

All commercial and domestic activities at the upstream which contribute to the pollution of the industrial water bodies should be regulated by laws.

Individual industries should be mandated to install simple effluent treatment plant to treat the wastewater before discharge into the surrounding and to reduce the quantity of wastewater released to the surrounding. This can be accomplished by limiting quantity of wastewater each industry should generate within a set of period. An industry that exceeds such limit could be fined heavily. This will ultimately compel industries to use Best Available Technology (BAT) or Best Practiced Technology (BPT) to reduce the type and quantity of wastes so generated. In this regard, the industries could be encouraged in terms of loans or subsidy from the governmental and non-governmental organizations**.**

A combined effluent treatment plant should be installed in each industrial zone at or near the confluence point with the waterbodies .The plant should be capable of treating biological, organic, inorganic and chemical wastes.

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