# Assessment of Impact of Effluent Discharge on the Quality of Emene River, Enugu, Nigeria

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**Abstract:** This study assessed the impacts of industrial effluent discharge on the quality of Emene River. Samples were collected from river at three sample points in order to evaluate the spatial concentration of industrial effluent in Emene River. Samples were analyzed following the procedure described by America Public Health Association (APHA). Statistical analysis shows that significant variation ($p<0.05$) was observed in the sample points. The results showed that TDS, TSS, ion, calcium, nitrate, chloride, magnesium, electrical conductivity, BOD, turbidity, color, temperature, zinc, odour and total hardness are significantly difference ($p<0.05$) at point source when compared with values obtained at upstream. TCG and *E.coli* are the only variables that recorded higher values at upstream and downstream of Emene River. This shows that non point sources are contributory to microbial pollution of Emene River. Nine variables exceeded maximum permissible limit (MPL) in all the sample points, while seven variables exceeded MPL at control point of Emene River. All the variables except chloride exceeded MPL of industrial effluent discharge as recommended by World Health Organization (WHO) and Nigeria Industrial Standard (NIS). Three factors identified by PCA that influence the pattern of surface water quality are chemical (39.73%), physical (32.47%) and microbial (25.31%) characteristics of Emene River, and they altogether explained about 97% of the total variance.

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**Keyword:** River, Effluent, Pollution, Water quality, Permissible limit

## 1. Introduction

Surface water is one of the main sources of water supply (NEST 1991), and it comprises of rivers, lakes, reservoirs, ponds, wetland and oceans (Nigeria Industrial Standard (NIS), 2007). However, surface water has been adversely affected because of pollution from point and non-point sources. Surface water pollution occurs when harmful substances are released into water bodies and this could be through natural and artificial sources (Uchegbu, 2002). Akaninwor *et al.,* (2007) and Singh and Singh, (2012) pointed that surface waters pollution is mostly experienced as a result of domestic waste water, surface run-off and industrial effluent discharge (Taghinia *et al.,* 2010); and their sources (NPDES, 2008) are manufacturing, commercial businesses, mining, agricultural production processing and effluent from clean-up of petroleum and chemical contaminated sites. Fellman *et al.,* (1995) reported that manufacturing companies in United States of America dumped polychlorinated biphenyls (PCBs) into rivers. Industrial effluent contain heavy metals (Badmus *et al.,* 2007) which may damage aquatic ecosystem, health of aquatic animals and those who eat them (The Guides Network, 2008). Although not all of the effects of PCBs on surface waters and human health are known, they have been linked to birth defects, damage to immune system, liver disease and cancer (Fellman *et al.,* 1995).

Surface water is used in various ways such as drinking, commercial, agricultural and industrial activities (Akan, *et al.,* 2009). Despite the importance of surface water in human life; it is the most poorly managed resources in the world (Fakayode, 2005). The increase in demand of water for various uses arising from increase in global population and fast growth of industries around the world has put pressure on limited water resources (Norman and Michel, 2000, Phiri *et al.,* and kadewa, 2005 and NPDES, 2008). The principal cause of water scarcity is water quality degradation, which critically reduce the quantity and quality of water available for potable, agricultural and industrial uses (Norman and Michel, 2000). Thus, the quantity of available water is closely linked to the quality of water, which may limit its uses. However, industrial survey carried out in Nigeria by Dada, (1997) showed that more than 60% of the industries discharged untreated effluent into surface water and it is attributed to increase in concentration of industries around rivers in Nigeria. The concentrations of industrial activities according to Bichi, (2000) around rivers and the release of effluent from industries into surface waters (Ajibola and Ladipo, 2011) have led to deterioration of surface water quality.

The supply of potable water in Enugu has become a major problem because of discharge of acid water from coal mining into surface waters (Ezeigbo and Ezeanyim, 1993). Emene River, the main sources of water supply (Ezenwaji, 2008) for population of over 1.2million, using NPC 2.8% annual rate of increase (NPC, 2007), is one of the rivers polluted. Enugu urban area is witnessing an unprecedented growth of industries such as brewery, paint, plastic; soap, chemicals, building material, food and agro-allied industries and most of them are located alongside rivers. The location for the study was chosen because of concentrations of industries that discharge effluent in the area. The major industries include Emenite Building Industry, Innoson Plastics Nigeria Limited, Fertcho Industry Nigeria Limited, General Tyres and Tubes Limited, and Triple Star Limited. Emene River and its tributaries serve as receptacle of effluent discharge from industry. Effluent is discharged into them through channels. This phenomenon is attributed because of increase in number of industries that discharge effluent in the study area.

There are several studies that confirmed the existence of surface water pollution at various levels in Nigeria (,Federal Environmental Protection Agency (FEPA), 1991, NEST, 1991, Ezeigbo and Ezeanyim, 1993, Nnodu and Ilo, 2000, Adekunle, and Eniola, 2008 and Chima *et al.,* 2009), none of the studies made reference to discharge of effluent into Emene River in Enugu, and its quality. It is the need to address this problem that this study is considered pertinent. This study therefore assessed the impact of industrial effluent discharge on surface water quality of Emene River within the industrial area. The finding shows the present level of effluent concentration and the quality of Emene River.

## 2. Materials and Methods

### Study Area

Enugu is located between latitude $6^0$ 30'N and $6^0$40'N and longitude $7^0$20'E and $7^0$35'E. The study area is commonly referred as "Newcastle of Nigeria" the Coal City (Ilesanmi 1997), and it is situated at the foothill of Udi cuesta. The study area is drained by rivers. The major rivers include Emene, Ekulu, Akwata, Nyaba, Asata, Idaw and Iyiukwu (Figure 1.). Iyiukwu, Eyo and Iyioku Rivers are tributaries of Emene River which originate from eastern part of the study area. Emene River captures Ekulu river system which comprises of Asata, Akwata, Aria, and Ogbete Rivers; and they empty into Nyaba River which drains into Cross River Basin. The study area has rainy and dry seasons due to its latitudinal location. The pattern of the two seasons in the study area show that it is under the influenced of Intertropical Discontinuity. The vegetation of the area is made up of trees and grasses such as *verbanaceae*, *anacardium occidentalis*, *elaeis guineensis*, *magnifera indica, pennisetum purpureum;* and it is believed to have derived from forest, through prolonged cultivation, annual burning and coal exploration (NEST, 1991).

### Sample Collection

Samples were collected according to procedure recommended by Industrial Waste Resources Guidelines (IWRG) (2009). Samples were taken at three sample points (Figure 1.) with screw caped containers rinsed in distilled water. Each container was rinsed with appropriate sample before sample collection. The three sample points are upstream (control point), point of discharge and downstream. A composite sample was formed by mixing samples in equal proportion. Samples for biological analysis were collected in air tight bottles. The samples were used to compare the quality of Emene River at upstream (control point) and at downstream. All samples were labeled, and they bear information on (i) sample site, (ii) date and time of collection, and (iii) purpose of collection.

### Sample Analysis

Samples were subjected to physicochemical analysis at PRODA lab, Enugu. pH and temperature were determined in situ using a portable pH digital meter, HANNA 211 model. TSS, turbidity and color were determined using spectrophotometer. Electrical conductivity meter was used to determine electrical conductivity and TDS, while DO and BOD were analyzed using digital meter. Also, odor was determined by diluting sample with odor free water and the mixture at which odor becomes undetected was determined. Chloride was determined by adding water sample in a porcelain dish and three drops of potassium chromate solution to it. Titration was carried out with standard solution silver nitrate (Gurcharan and Jagdish, 2007). Ion, calcium, TCG, *E.Coli*, nitrate, magnesium, zinc and total hardness were analyzed as described by FEPA, (1991) and APHA, (1995) in the standard methods for examination of industrial waste water.

Chemicals and reagents used in the analysis were of analytical grade and they were obtained from PRODA Lab, Enugu. During analysis, nineteen (19) water quality indicators identified are classified as conventional water pollutants (NPDES, 2008). These are total dissolve solid (TDS), total suspended solid (TSS), ion, calcium, pH, nitrate, chloride magnesium, electrical conductivity and total coliform group (TCG). Others are biological oxygen demand (BOD), dissolve oxygen (DO), *escherichia coli (E coli),* turbidity, color, temperature, zinc, odour and total hardness. They were compared with recommended standard set by World Health Organization (WHO) and Nigeria Industrial Standard (NIS), so as to find variables that exceed maximum permissible limit (MPL).

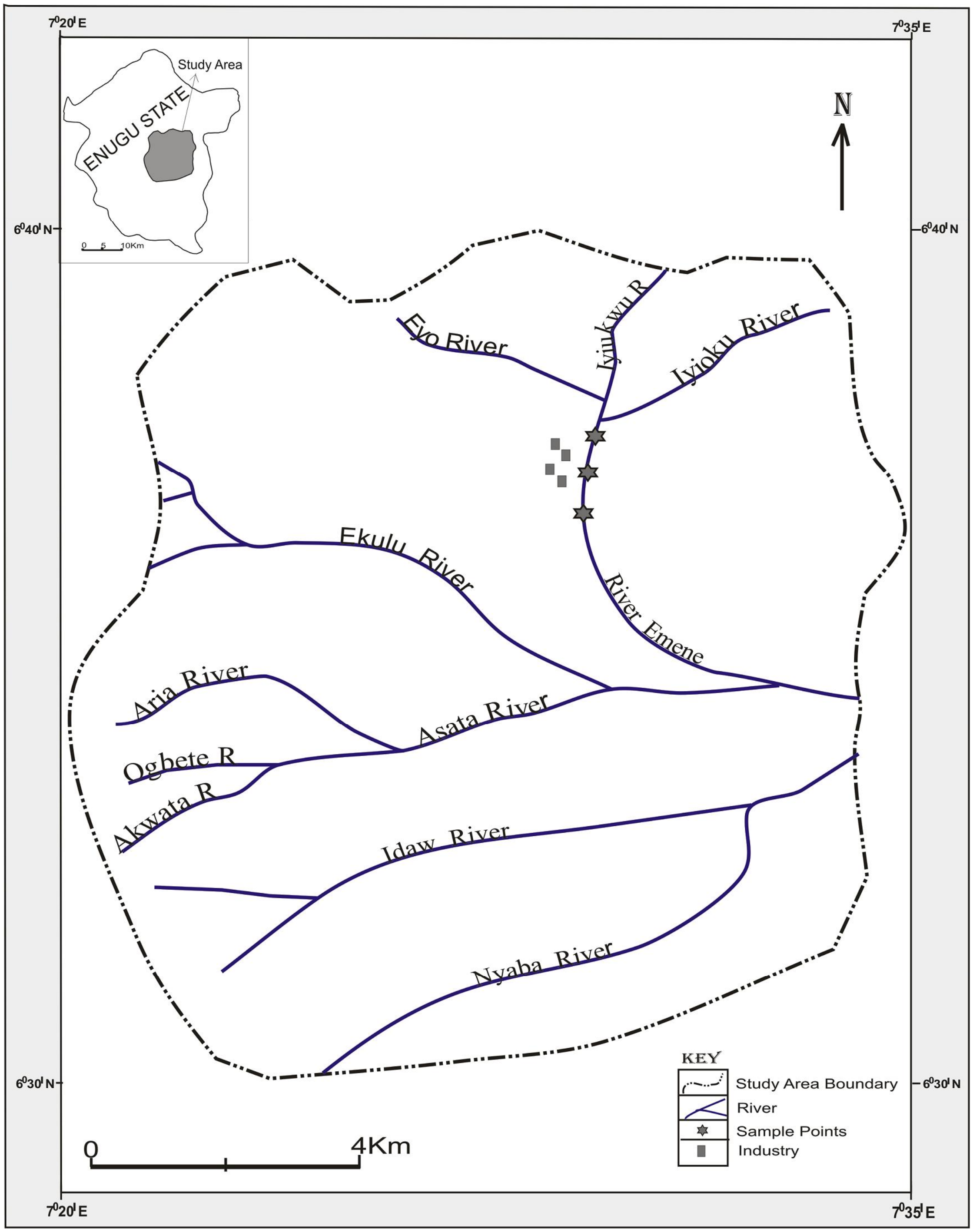


**Figure 1: Map of Enugu Showing Emene River and Sample Points**

**Statistical Analysis**

Data were analyzed for mean and standard deviation. Difference in parameters were tested for statistical significance at $p<0.05$ using student's t-test. This was used to find whether there was spatial variation between sample points. Also, Principal Component Analysis (PCA) was used to extract underlying factors influencing the pattern of surface water quality of Emene River. Principal component analysis using varimax rotation with Kaiser Normalization was used because it maximizes the covariance of the loadings on each component so as to achieve high and low loadings as possible while maintaining the orthogonality of the original components. All the data were analyzed using SPSS 15.0 version.

## 3. Result and Discussion

The results of water quality indicators in table 1 show that many variables such as TDS, TSS, ion, electrical conductivity, TCG, BOD, *E.Coli*, temperature, zinc, chloride, color, odor, nitrate, calcium, magnesium, TCG, turbidity and total hardness at downstream were found to be greater than the values obtained at upstream (control point). This has indicated that effluent from industries is contributory to pollution of Emene River. This finding is similar to earlier study carried by Adekunle and Eniola (2008) and also in accordance with another work done by Sushil, Rohit and Joshi (2012). This has shown that variables are significantly different ($p<0.05$) at sample sites.

**Table 1: Mean (±SD) Spatial Variation of Water Quality Indicators obtained at Upstream, Point Source and Downstream of Emene River**

| S/no | Variables | Upstream | Point source | Down stream | WHO (MPL) | NIS (MPL) |
|---|---|---|---|---|---|---|
| 1. | TDS (mg/l) | 470±1.08 | 2100±1.75 | 1580±1.56 | 300 | NS |
| 2. | TSS (mg/l) | 810±0.45 | 3960±00.33 | 2800±0.71 | 200 | 500 |
| 3. | Ion (mg/l) | 0.20±0.01 | 4.5±0.99 | 2.5±0.10 | 1 | 0.3 |
| 4. | Calcium (mg/l) | 115±1.10 | 410±2.00 | 276±1.02 | 200 | NS |
| 5. | pH (pH scale 1-14) | 6.8±0.87 | 4.6±0.06 | 9.6±0.29 | 6.5-9.2 | 6.5-8.5 |
| 6. | Nitrate (mg/l) | 67±0.29 | 105±0.87 | 84±0.43 | 30 | 50 |
| 7. | Chloride (mg/l) | 160±2.54 | 205±1.03 | 200±2.30 | 250 | 250 |
| 8. | Magnesium (mg/l) | 150±1.90 | 501±1.71 | 180±2.07 | 150 | 100 |
| 9. | E.Conductivity (µmho/cm) | 800±0.43 | 2580±0.24 | 2050±0.49 | 1250 | 1000 |
| 10 | TCG (No/100ml) | 96±4.56 | 26±2.65 | 115±3.21 | <3 | <10 |
| 11 | BOD (mg/l) | 48±2.71 | 960±1.79 | 752±1.83 | 10 | 10 |
| 12 | DO (mg/l) | 7.8±1.32 | 3.6±1.11 | 4.5±2.60 | >10 | >8 |
| 13 | *E.Coli* (No/100ml) | 65±0.12 | 8±0.34 | 80±0.65 | 0 | 0 |
| 14 | Turbidity (NTU) | 10±2.20 | 152±2.10 | 110±1.07 | 5 | 5 |
| 15 | Color (Pt-Co) | 35±0.01 | 80±0.21 | 45±0.55 | 15 | 15 |
| 16 | Temperature ($^{o}$C) | 27±0.11 | 32±0.33 | 30±0.27 | 30 | 30 |
| 17 | Zinc (mg/l) | 170±3.01 | 345±2.10 | 320±1.87 | 5 | 3 |
| 18 | Odour (TON) | 3±0.82 | 7±0.046 | 7±0.01 | NS | NS |
| 19 | Total Hardness (mg/l) | 200±1.11 | 750±1.32 | 720±1.71 | 500 | 150 |

***NS -Not Specified *MPL -Maximum Permissible Limit**

The values of total dissolved solid and total suspended solid in Emene river at upstream (control point) are 470±1.08 and 810±0.45 respectively. These values are lower than values obtained at downstream and point sources which range from minimum and maximum of 1580±1.56 to 3960±00.33 (TDS). Statistical analysis indicate that both variables were significantly different ($p<0.05$) at sample points. All the values of TDS and TSS at three sample points exceeded MPL as recommended by WHO and NIS. High concentration of TDS and TSS led to increase in other variables such as total hardness, nitrate, calcium, electrical conductivity and temperature.

The value of ion (0.2±0.01) at control point is within the recommended allowable limit, but at downstream and point source, the values increased from 2.5±0.10 to 4.5±0.99. These values are above 1mg/l and 0.3mg/l MPL as recommended by WHO and NIS respectively. The hydrogen ion concentration index (pH) measures the alkalinity and acidity concentration. The values of pH recorded in table 1 shows that 9.6±0.29 recorded at downstream are greater than 6.8±0.87 recorded at upstream in Emene River. It shows that there is significant variation ($p<0.05$) between the values of pH obtained at point source and downstream, and this indicated that Emene River is acidic and alkaline at the two sample points respectively. The increase values of pH from acid at upstream to alkaline in the downstream was due to dilution of Emene River from other sources. The maximum pH values recorded in this study are higher than values reported in similar water bodies in Nigeria (Fakoyade, 2005 and Adekunle and Eniola, 2008). It is only values at upstream (6.8±0.87) that are within the allowable limit. The value of industrial waste water exceeding 6.5-9.2 according to WHO (2008), should not be discharged into surface water used for domestic water supply, irrigation, bathing and aquatic breeding. The study observed that Emene River is used to irrigate farmlands for cultivation of vegetable crops.

There is also remarkable increase in values of electrical conductivity at point source and downstream of Emene river (2580±0.24 and 2050±0.49) respectively. The two values exceeded both WHO and NIS maximum permissible limit. It is only values of 800 ±0.43 obtained at control point of Emene River that met the required standard set by WHO and NIS. This shows that electrical conductivity is significantly difference ($p<0.05$) in all the sample points. The values of BOD and DO recorded in all the three sampling points of Emene River did not meet the "red" least test for MPL set by WHO and NIS. The values range from minimum and maximum of 48±2.71 to 960±1.79 (BOD) and 3.6±1.11 to 7.8±1.32 (DO). A significant spatial variation ($p<0.05$) was observed for both BOD and DO in all the sample points. The increase in BOD and subsequent decrease in values of DO led to eutrophication of Emene River. Extensive death of vegetation, white salt crust on the soil surface, increase in algal growth and pale blue cloudy appearance of river were also observed during field investigation made at the river. This finding is similar and in line with research made by The Guides Network, (2008) and NEST, (1991).

The values of temperature at control point and downstream of Emene River are within allowable limit. It is only values at point source (32±0.33) with significant difference ($p<0.05$) that exceeded WHO and NIS MPL. Increase in water temperature altered the general biochemical activities of river. Emene River at point source recorded the highest values of zinc; this is closely followed by values of 320±1.87 at downstream and 345±2.10 at point source. The values in all the sample points exceeded MPL.

Interestingly, the values of chloride at upstream, point source and downstream of Emene river are within the MPL of industrial effluent discharge as recommended by WHO and NIS. The values (160±2.54, 205±1.03 and 200±2.30) show that there are significant variation ($p<0.05$) of samples in the three sample points. The results have shown that chloride from both point and non-point sources are not contributory to pollution of Emene River. The values of color and odor range from 35±0.01 to 80±0.21 and 3±0.82 to 7±0.046 respectively. It is only values of color that exceeded MPL of effluent discharge as recommended by WHO and NIS in all the sample points. Both variables show significant variation ($p<0.05$). The highest values of color are from samples obtained at point source of Emene River. Increase in color as was observed in the river affected aesthetic quality of river and this is primarily caused by the presence of decomposing organic matters.

The values of nitrate concentration obtained from the three sample points show that Emene River is adversely polluted. The maximum values of 105±0.87 were obtained at point source. Significant spatial variation was observed ($p<0.05$). Values of nitrate obtained at point source and downstream are higher than values obtained at upstream (control). Study observed that irrigated farmlands used for cultivation of vegetables around Emene introduced organic and inorganic fertilizers into Emene River. This finding is similar with investigation made by Steve (2009) which linked heavily fertilized cropland as one of the non-point sources of nitrate pollution in surface rivers. However, all the values exceeded MPL of 30mg/l and 50mg/l as recommended by WHO and NIS respectively.

The values of magnesium obtained at point source and downstream are above MPL as recommended by WHO and NIS. The values of calcium exceeded only WHO allowable standard. Values of magnesium and calcium at point sources (501±1.71 and 410±2.00) and at downstream (180±2.07 and 276±1.02) are above the required standard. However, the values of calcium at upstream (control) are within the permissible limit, while the values of magnesium are within WHO standard.

Contrastingly, total coliform group and *escherichia coli* are the only variables that recorded the lowest values at point source in all the sample points (fig 2). The variables show that non-point sources are also contributing to microbial pollution. The decrease in values of the two variables at point source was due to trapping and degradation of the microorganisms by effluent from industrial sources. The highest values recorded in the river (96/100±4.56 and 65/100 ±0.12) are obtained at upstream and downstream (115/100±3.21 and 80/100±0.65). Statistical analysis shows that the concentration and distribution of the variables were significantly difference ($p<0.05$) between sample points. All the values are above MPL as recommended by WHO and NIS. The present of total coliform group and *E.Coli* show that disease-causing microorganisms such as bacteria, protozoa are present in Emene River. The high increase in values of total coliform group and *E.Coli* at upstream and downstream of Emene River are indication of fecal discharge (Manju, *et al.,* 2012) to Emene River through domestic waste waters discharged from residents of the area.

The values of turbidity range from minimum of 10±2.20 at control point to maximum of 152±2.10 at point source. There was significant difference ($p<0.05$) of turbidity among the sample points All the values recorded at the three sample points exceeded MPL. Emene River has high concentration of total hardness. Values of 750±1.32 and 720±1.71 obtained at point source and downstream respectively are above WHO and NIS MPL of effluent discharge guidelines. It is only values at control point of Emene River (200±1.11) that fall within NIS standard.

Figure 2 shows spatial variation in concentration and distribution of effluent at upstream, point source and downstream of Emene River. It shows that 15 variables (TDS, TSS, ion, calcium, nitrate, chloride, Mg, BOD, electrical conductivity, turbidity, color, temperature, zinc, odor and total hardness) recorded higher values at point source indicative of industrial sources. The decrease in values of DO and pH at the same sample point is also an indication of effluent discharge from industry. It is only TCG and *E.Coli* that recorded higher values at upstream and downstream indicating that non-point sources are contributory to pollution of Emene River. All the values of variables analyzed statistically show that values are significantly difference ($p<0.05$) in the sample points

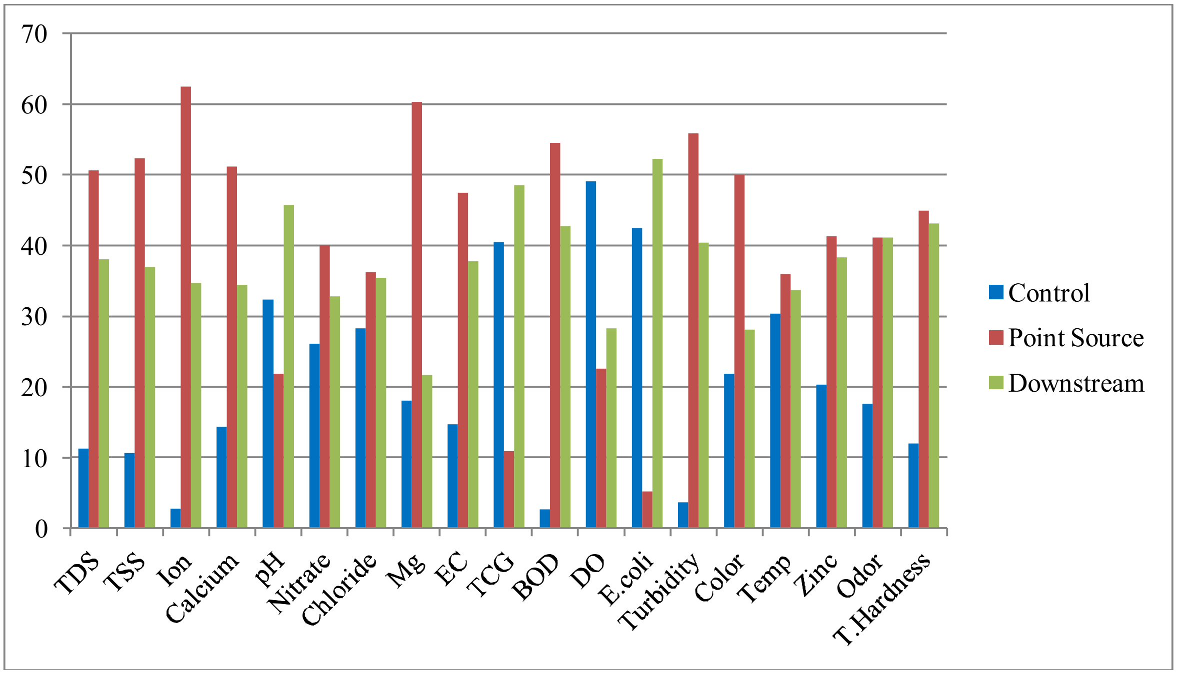


**Figure 2: Percentage (%) Concentration of Industrial Effluent at Control, Point Source and Downstream**

Results show that eighteen (18) out of nineteen (19) water quality indicators identified have higher values in the downstream when compared with values obtained at control (Fig.2). The high values at downstream is as a result of industrial effluent disposal from industrial sources. This shows that industrial sources are contributory to pollution of Emene River. This finding is in consonance with research done by Taghinia *et al.,* (2010) which linked heavy metal to pollution of Kabiri Rivers. Total coliform group, dissolved oxygen, pH and *escherichia coli* are the only variables that have lower values at point sources (Fig. 2). The low values of TCG (26/100±2.65) and *E.Coli* (8/100±0.34) at point source indicate that the sources of microbial pollution of Emene River are from non-point sources, while pH and DO show increase in concentration of acid and reduction of oxygen at point sources in Emene River respectively.

Nine (9) variables exceeded MPL of industrial effluent discharge as recommended by WHO and NIS in all the sample points. The variables include; TDS, TSS, nitrate, TCG, BOD, DO, *E.Coli*, color and zinc. Seven (7) variables have values within WHO and NIS recommended limit only at control point of Emene River. The variables include ion, calcium, pH, electrical conductivity, turbidity, temperature and total hardness. The values of magnesium exceeded only NIS permissible limit at the same sample point, while the values of temperature at downstream are within the allowable limit. Chloride is the only variable that has values within WHO and NIS MPL in all the sample points.

Also, results in table 1 show that the values of DO decreased sharply at point source and downstream of Emene River with appreciable high values at upstream. The decrease in values of DO at point source and downstream is as a result of increase amount of oxygen consumed by microorganisms at both sources during degradation of organic matters disposed into Emene river. This shows why the values of BOD at upstream (control point) and point source are at variance with values of DO at the same source (table 1). Both BOD and DO are among eighteen (18) variables that exceeded substantially the required MPL as recommended by World Health Organization and Nigeria Industrial Standard.

To carry out factor analysis using PCA, 19 predictor variables were coded X1-X19. The values of data were also standardized and normalized by transforming values using anti-log so as to measure them using the same scale. Correlation matrix analysis shows that 30 variables have significant correlation coefficient at 0.05 levels, while 12 variables have significant correlations coefficient at 0.01 levels analysis. A total of 14 variables have positive correlations with each other, while the remaining 5 variables have no significant correlations coefficient. In order to minimize the effects of inter-correlations, attributes of the variables were transformed into orthogonal values using principal component analysis. Principal component analysis using varimax rotation was used in order to extract underlying dimensions influencing the pattern of impact of effluent discharge in the river.

**Table 4: Result of Factor Loadings for the Analyzed Variables**

| | Component | | |
|---|---|---|---|
| | 1 | 2 | 3 |
| X1 | .391 | .901* | -.259 |
| X2 | -.041 | .782* | -322 |
| X3 | .970* | .201 | .275 |
| X4 | .785* | .914 | .267 |
| X5 | .854* | .459 | -.120 |
| X6 | .780* | -.195 | .182 |
| X7 | .841* | .447 | .154 |
| X8 | .710* | .409 | .203 |
| X9 | .145 | .905* | .322 |
| X10 | .533 | -.279 | .876* |
| X11 | .490 | .318 | 971* |
| X12 | .212 | .273 | .196 |
| X13 | - .101 | - .280 | .911* |
| X14 | .109 | . 765* | .185 |
| X15 | .350 | 871* | .367 |
| X16 | -.452 | .728* | .402 |
| X17 | .755* | .089 | -.131 |
| X18 | .153 | .885* | .137 |
| X19 | .872* | .121 | .092 |
| Eigenvalue | 7.55 | 6.17 | 4.81 |
| % of Explain variance | 39.73 | 32.47 | 25.31 |
| Cumulative % of variance | 39.73 | 72.2 | 97.51 |

* Significant loadings exceeding ±0.7 at 95% confidence level.
Rotation Method: Varimax with Kaiser Normalization.

The analysis in table 4 shows that PCA using varimax rotation succeeded in reducing the 19 predictor variables into three underlying components which accounted for about 97% of the total variance thus leaving only 3% of the total variance unexplained. The unexplained variance can be attributed to other factors not factored in the analysis.

Component one has an eigenvalue of 7.55 and explained 39.73% of the total variance. It loads significantly on 8 variables (ion, calcium, pH, nitrate, chloride, magnesium, zinc and total hardness). The loading pattern shows that there is strong positive relationship between the variables and the component. This implies that inorganic chemicals from industrial wastes are the major parameters influencing the distribution and concentration of effluent disposal in river Emene. The underlying factor identified by this component is chemical characteristics of river.

Component two has eigenvalue of 6.17 and explained 32.47% of the total variance. It loads significantly on seven variables which include TDS, TSS, electrical conductivity, color, temperature, turbidity and odor. This component exhibited high positive loadings on TDS, electrical conductivity, color and odor, with moderate loadings on TSS, temperature and turbidity. This is an indication of physical pollution of river as was observed in physical discoloration of the river during field study in the river. This reflects the type of waste coming from industries located in the areas. The underlying factor indentified is physical properties of river.

Component three has significantly loading on three variables. The variables are TCG, BOD and *E.Coli.* It explained additional 25.31% of the total variance with eigenvalue of 4.81. It has strong positive loadings on all the major variables and this has shown that there is positive relationship between third component and the three variables. This suggests that fecal discharge, microbiological and organic wastes from other sources are discharge into Emene River. The present of these variables especially TCG and *E.Coli* may lead to an outbreak of cholera, dysentery, typhoid and yellow fever, and other water borne diseases in the area if discharge is not discontinued. Microbial pollutants are the underlying dimension identified by this component. The summary of the relative contribution of the underlying components identified is shown in table 5.

**Table 5: The Relative Contribution of the Underlying Component**

| Component | Underlying Component | Eigenvalue | Relative contribution (%) | Cumulative (%) |
|---|---|---|---|---|
| 1 | Chemical characteristics of river | 7.55 | 39.73 | 39.73 |
| 2 | Physical properties of river | 6.17 | 32.47 | 72.2 |
| 3 | Microbial pollutants | 4.81 | 25.31 | 97.51 |

In conclusion, this research work has shown that the discharge of effluent into the river has impacted negative in water quality degradation of Emene River. The water quality indicators analyzed did not only show that all the variables except one (chloride) exceeded the MPL of effluent discharge as recommended by WHO and NIS, but also show that is no longer safe for aquatic resources such as phytoplankton, tadpoles and edible frogs; and for socio-economic activities. This is attributed to improper management and disposal of industrial effluent in the river. This finding is in accordance and similar with work done by Sushil, Rohit and Joshi (2012) and Ogunjobi, Oyinloye and Sanuth (2012). Statistical analysis shows that there are significant difference ($p<0.05$) among all the variables in the sample points. The PCA identified three factors which altogether explained about 97% of total variance. The three factors identified are chemical characteristics of river (39.73%), physical properties of river (32.47%) and microbial pollutants (25.31%) table 5. The factors influence the pattern of surface water quality of Emene River. This research work recommends treatment of effluent before discharge as pointed by (Ahmed and Al-Hajiri, 2009) and enforcement of recommended standard of MPL set by WHO and NIS. This will help to restore natural purification potentials of river polluted and boost aquatic resources and socio-economic status of the residents of the study area.

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