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# Impact of Anthropogenic Activities on Eutrophication of Anambra River in Anambra State, Nigeria

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## Abstract

*Eutrophication of Anambra River in Anambra East Local Government Area of Anambra State, Nigeria was carried out. Water samples were collected from five different sampling points in the river designated as A, B, C, D and E. Sample point A was upstream, Sample point B was downstream, while Sample points C, D and E were points of waste discharge. The water quality parameters assessed were colour, turbidity, conductivity, total dissolved solids, total suspended solids, total solids, potassium, dissolved oxygen, iron, phosphate and nitrate. The result of analysis revealed the degree of eutrophication of the river. There were variations in the level of the parameters measured across the sampling points. The parameters varied between 1.04 – 3.26 units, 1.21 – 4.64NTU, 12.31 – 32.48 mg/l, 1.27 – 8.10 mg/l ,1.43 – 3.86 mg/l, 2.70 -11.96 mg/l, 3.00 -16.84 mg/l, 1.00 – 3.01 mg/l, 1.21 – 3.74 mg/l, 0.02 – 0.30 mg/l, and 0.02– 0.08 mg/l. for colour, conductivity, total dissolved solids, total suspended solids, total solids, potassium, dissolved oxygen, iron, phosphate, nitrate, faecal coliform and total coliform respectively. All the parameters met the WHO standard for drinking water. However, nitrate and phosphate values exceeded the critical concentrations of 0.3 mg/l and 0.01 mg/l respectively, said to trigger eutrophication if exceeded. The result further revealed that sampling point E (Point of Waste discharge) recorded the highest concentrations of the parameters while sampling point A (Upstream) recorded the least. Statistical analysis revealed significant correlation between some of the parameters. Since detergents constitute a major source of phosphate in rivers, legislation against the use of phosphate in detergents was recommended.*

**Keywords:** *Anthropogenic activities, Waste discharge, Eutrophication, Anambra River*

## 1.1 Introduction

A river is a natural watercourse usually freshwater flowing towards an ocean, a lake, a sea or another river (Njoku *et al.*, 2016). The importance of rivers to man are multifarious. They are veritable sources of water which is essential in the maintenance of life. Rivers are used for transportation, for domestic and industrial purposes. They are used in the generation of energy, as in hydroelectricity. Rivers also serve as tourist attraction, thus a potential source of income for the government and the community where the rivers are located. Unfortunately this vital resource has in recent times been constantly subjected to all forms of pollution from various sources, ranging from sewage discharge, refuse dumps, agricultural inputs such as fertilizers and pesticides, industrial and domestic waste discharges. According to Akaninwor and Egwim

(2006), pollution of freshwater bodies such as rivers, streams, lakes, and ponds is most experienced as a result of industrial discharges, municipal wastes deposit and surface runoff. These have had adverse effects on the water bodies. One of such problems of pollution of the rivers is eutrophication.

According to (Ugochukwu *et al*., 2019), Eutrophication has been defined as the enrichment of water by nutrients, especially compounds of nitrogen and phosphorus, causing an accelerated growth of algae and higher forms of plant life to produce an undesirable disturbance to the balance of organisms present in the water and to the quality of the water concerned. It is a natural process that develops over geologic time span. It is characterized by excessive plant and algal growth due to the increased availability of one or more limiting growth factors needed for photosynthesis (Schindler 2006). Eutrophic waters have high nutrient concentrations and more abundant plant life. Conversely, Oligotrophic waters have very low nutrient concentrations and comparatively little plant life. Natural eutrophication that develops over a long period of time may not pose much threat to the ecosystem. Under normal conditions, changes in the ecosystem are barely noticeable. However, human activities can contribute to and accelerate the eutrophication process, which can in turn cause problems for humans and the aquatic flora and fauna using the water body. In the very past, eutrophication studies concentrated on lentic and transitional waters such as lakes and estuaries respectively, however, since about fifty years ago, research efforts are also directed to nutrient enrichment of lotic systems (Chislock *et al*., 2013). Anthropogenic eutrophication (which can be very rapid) became a problem in the middle to late 20th century (Harper, 1992). Anthropogenic sources of nutrients which include agricultural drainage, urban drainage, industrial waste waters and domestic waste waters; the mix of these land-uses in a catchment partly controls the extent of nutrient enrichment of affected water resources.

Human activities have accelerated the rate and extent of eutrophication through both point-source discharges and non-point loadings of limiting nutrients, such as nitrogen and phosphorus, into aquatic ecosystem (Chislock *et al*., 2013)

Most aquatic ecosystems in Nigeria like in most African countries are poorly characterized with respect to nutrient chemistry and the implication on eutrophication. Anambra River in Anambra State, Nigeria is an important lotic system that receives discharges from several anthropogenic point-source and non-point pollution sources. This study is therefore aimed at assessing the impacts of anthropogenic activities on eutrophication of Anambra River in Anambra Sytate Nigeria.

## 1.2 Materials and Methods

### 1.2.1 Study Area

The study area is Anambra where the river is located (Figure 1). Anambra lies between Longitudes $6^0 35^1$E and $7^0 21^1$E, and Latitudes $5^0 40^1$N and $6^0 45^1$N. The town is made up of Anambra North and Anambra South.The climate is tropical with an average yearly rainfall of 2000mm and temperature range of between $20^0$C and $36^0$C. It is characterized by the dust-laden North easterly wind which blows across the town during the dry season. Heavy rainfall occurs within the months of April to October during which the moisture laden south-westerly wind blows bringing with it rains. According to the 2006 National Population Commission, the population of Anambra is 531,340 in 2006, consisting of 281,328 males and 250,012 females, with an annual population growth rate of about 2.83%. Anambra is densely populated. Generally speaking, Anambra town houses a number of industries, hospitals, hotels and markets including the famous Onitsha Main market. The major occupation of the people is commerce and trade. Because of the rapid urbanization occasioned by population explosion, refuse generation and disposal has become a serious problem. Heaps of refuse dumps are a common site. Leachates from these dumps of refuse are carried as runoff into the Anambra River. The streets and markets were always littered with leaves, waste materials, fertilizers, and spilled oil, which are all sources of nutrients.

Guiness Nigeria plc, Nigerian breweries, Unilever plc, Anambra textile mills, Seven up bottling companies, NNPC depot, Pz plc, International glass industries, etc are some of the many industries located in Anambra.

Anambra River flows 210 kilometres into the Niger River. The river is the most important feeder of the River Niger below Lokoja. The flow of the Anambra River is released into the Atlantic through various outlets forming the 25,000-square-kilometre (9,700 sq mi) Niger Delta region.

A number of domestic activities go on in the area. They include the discharge of sewage and sorted town refuse. The inhabitants also took their baths and wash their clothing in and around the river. This involved the use of detergents. Detergent contains phosphate, which is one of the nutrients responsible for eutrophication. The river is also used for drinking, irrigation, washing, fishing and recreational purposes.

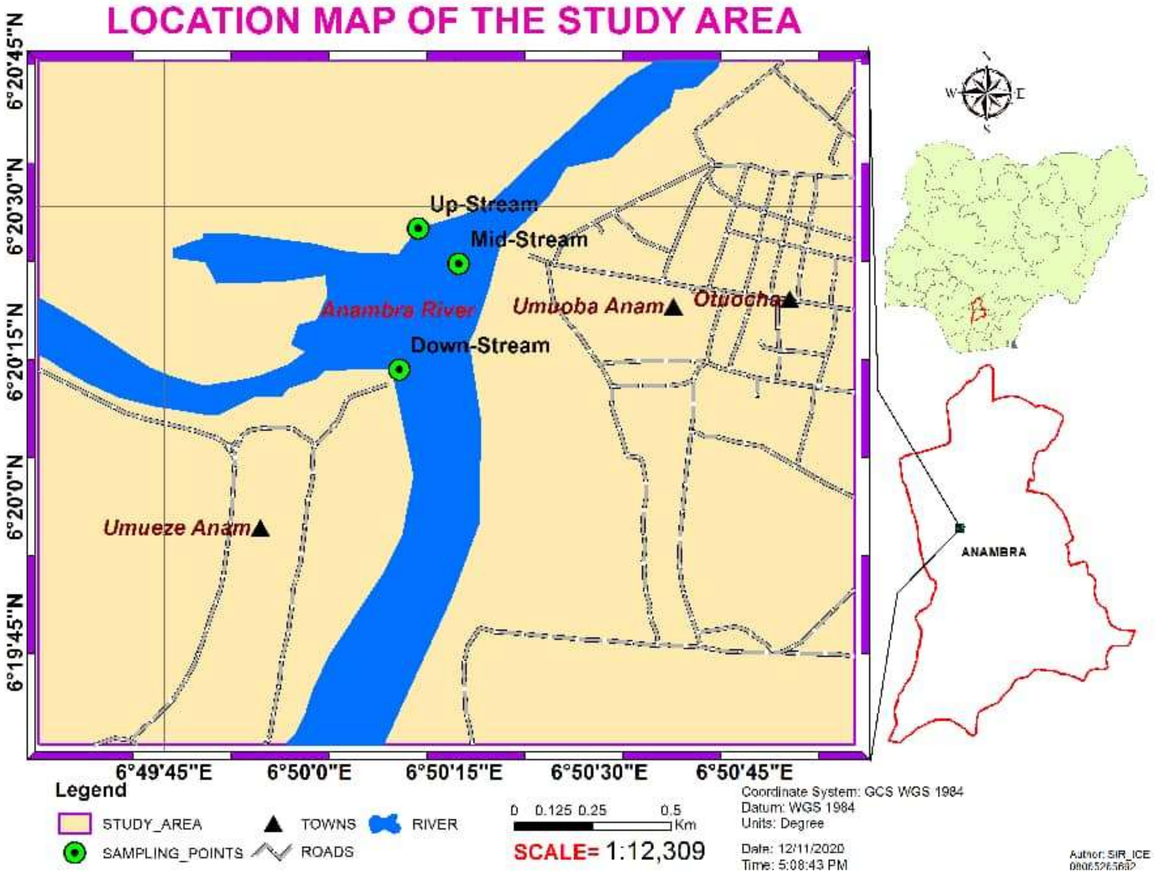

Figure 1: Anambra and Environs Showing Anambra River

### 1.2.2 Collection of Samples

Samples for physical and chemical analysis were collected using glass bottles known as Winchester quart, which were first thoroughly cleaned, rinsed and stoppered. Water samples were collected at monthly intervals for a total period of three months (July 2019 to September 2019). Five samples from five different points 120m apart on the river were collected. The sample points were designated as A, B, C, D, and E. Where "A" was the upstream and "B" the downstream. C, D, and E, were various points of waste discharge. All the collected samples were kept in the refrigerator before proceeding to the laboratory for analysis. All the water samples were tested within 72 hours of collection. A total of 11 parameters were tested using standard methods.

### 1.2.3 Methods of Determination of Parameters

#### 1.2.3.1 Determination of Colour

**Apparatus:** Neissler tubes, Nessleriser, Hazen comparator disc.

**Procedure:** The sample was thoroughly shaken and poured into one of the neissler tubes up to the 50ml mark, and was placed at the right compartment of the Nessleriser. The other neissler tube was filled to 50ml mark with distilled water and placed on the left compartment. The hazen comparator disc was inserted and rotated until the colour in the distilled water matched the colour of the sample. The apparent colour of each sample was then read up and recorded.

#### 1.2.3.2 Determination of Turbidity

**Apparatus:** Turbidimeter, electronic bulb.

**Procedure:** The water samples were poured into the turbidimeter up to the 50ml mark. The electronic bulb was plugged to the instrument and switched on. With the help of the light rays from the bulb, the number of visible light rays was counted. This was achieved with the help of a knob which was rotated until the slider inside the turbidimeter just touched but did not obscure the last visible light spot. The value of the turbidimeter was read directly for each sample.

#### 1.2.3.3 Determination of Conductivity

**Apparatus:** Conductivity meter, Temperature regulator.

**Procedure:** The temperature of the water sample was set using the temperature regulator (incorporated into the machine). The test electrode was immersed and rinsed thoroughly. With the aid of the button (switch), the testing range was taken by turning the testing range selector, gradually commencing at 10,000 until sufficient deflection of indicator was attained. The rotary knob then indicates the range selected.

#### 1.2.3.4 Determination of Total Solids

**Apparatus:** Pipette, evaporating dish, weighing balance, water bath, oven and desicator.

**Procedure:** 100ml of the sample was pipetted into a weighed evaporating dish and evaporated to dryness at 103$^{o}$C with the steam water bath. The dish was transferred to a temperature-controlled oven for thorough drying for about one hour; it was then cooled in a desicator for one hour. The dish was re-weighed and the new weight was noted.

#### 1.2.3.5 Determination of Total Dissolved Solids

**Apparatus:** Conductivity meter

**Procedure:** The conductivity method was used. The flask housing the electrode was filled to the mark with the water sample; the electrode was placed half-immersed, inside the flask. The conductivity meter was switched on and the first steady number of the counter in the meter was recorded as the conductivity of the sample. The total dissolved solid was then determined using known standards.

### 1.2.3.6 Determination of Total Suspended Solids

**Procedure:** This was determined by subtracting the total dissolved solid from the total solids.

### 1.2.3.7 Determination of Dissolved Oxygen

**Apparatus:** Conical flask, measuring cylinder, pipette, burette.

**Reagent:** 0.025 sodium thiosulphate, starch solution.

**Procedure:** 100cm$^3$ of water sample was transferred to the conical flask with a measuring cylinder. It was titrated with 0.025 sodium thiosulphate until the iodine colour in the sample was reduced to a pale straw colour. Six drops of starch solution was added. The titration was continued until the colour first disappeared. This was the end product of the titration. Subsequent return of the blue colour was ignored. The result of the titration was calculated as follows: The amount of dissolved oxygen (DO) in the water at the temperature recorded when the sample was taken is given by DO = 2n ppm or mg.dm$^{-3}$. Thus n was recorded as the value of the titration figure.

### 1.2.3.8 Determination of Iron ($Fe^{2+}$) Content

**Apparatus:** Spectrophotometer, volumetric flask, pipettes, beakers.

**Reagent:** 1, 10-Phenanthroline, Ferrous iron reagent (mix).

**Procedure:** This was determined spectrophotometrically. The stored programme number for iron was entered and the wavelength dialed to 510nm. The untreated sample was used as a blank. 25cm$^3$ of the sample was treated with 1, 10-phenanthroline in ferrous iron as reagent. This was placed in the cell holder and the light shield closed and the value read and recorded.

### 1.2.3.9 Determination of Phosphate Content

**Apparatus:** Spectrophotometer, volumetric flask, pipettes, beakers.

**Reagent:** Molybdate reagent, amino acid reagent powder pillow.

**Procedure:** The stored programme number for phosphate was entered and the wavelength dialed to 250cm$^3$ mixing graduated cylinder using a 1cm$^3$ calibrated dropper. 1cm$^3$ of molybdate reagent was added; the content of one amino acid reagent powder pillow was added and stoppered. It was swirled severally to mix. After this, it was allowed to stay for 10 minutes for possible reaction. During this period, another 25cm$^3$ sample was filled in a second cell (the blank). After the period of 10 minutes, the sample was placed into the cell holder and the read/enter key pressed and the result in mg/l was recorded.

### 1.2.3.10 Determination of Nitrate Content

**Apparatus:** Spectrophotometer, volumetric flasks, pipettes, beakers.

**Reagent:** 1 Nitraver 5 Nitrate reagent, Hydrochloric acid.

**Procedure:** The nitrate content was determined by the spectrophotometeric method using HACH equipment. The sample was treated by adding 1cm$^3$ of hydrochloric acid to 50cm$^3$ of sample in a beaker. The spectrophotometer was calibrated using standard nitrate solution. The absorbance was read against distilled water set at zero absorbance. Nitrates absorb at 500nm. The value for the treated sample was read directly and the concentration recorded in mg/L.

### 1.2.3.11 Determination of Potassium Content

**Apparatus:** Spectrophotometer, volumetric flasks, pipettes, beakers.

**Reagents:** Potassium 1 Reagent, Potassium 2 Reagent, and Potassium 3 Reagent.

**Procedure:** One Potassium 1 reagent was added to 25ml of water sample. One Potassium 2 reagent was then added and mixed. One Potassium 3 reagent was subsequently added. The entire mixture was shaken and then allowed for three minutes for the formation of precipitate (white turbidity developed). The value was then read at 450nm and expressed as mg/L.

## 1.3 Result and Discussion

### 1.3.1 Results

Table 1 shows the values of the parameters for the different Sampling Points in Anambra River. These results formed the bases of the discussion. The level of the various parameters varied greatly from sampling point to sampling point. It is easy to note that for most of the parameters, Sampling Points C, D and E had values which were much higher than other sampling points. This is because these Sample Points were the points of greatest discharge of wastes of all sorts. The data collected were subjected to descriptive statistical analysis. The correlation technique was used to determine the relationship between the water parameters.

**Table 1: Mean Result of Analysis of Water samples from Anambra River**

| PARAMETER | A | B | C | D | E | MEAN | WHO |
|---|---|---|---|---|---|---|---|
| COLOUR (AP-CO std) Units | 1.04 | 1.36 | 2.14 | 2.85 | 3.26 | 2.13 | 50 |
| TURBIDITY (NTU) | 1.21 | 1.79 | 2.62 | 3.58 | 4.64 | 2.77 | 25 |
| CONDUCTIVITY (µs/cm) | 12.31 | 17.56 | 22.08 | 25.15 | 32.48 | 21.92 | 500 |
| TOTAL DISSOLVED SOLIDS (Mg/l) | 1.27 | 3.26 | 5.70 | 4.22 | 8.10 | 4.51 | 500 |
| TOTAL SUSPENDED SOLIDS (Mg/l) | 1.43 | 1.72 | 2.47 | 2.44 | 3.86 | 2.38 | 500 |
| TOTAL SOLIDS (Mg/l) | 2.70 | 4.98 | 8.17 | 6.66 | 11.96 | 6.89 | 500 |
| DISSOLVED OXYGEN (Mg/l) | 16.84 | 10.88 | 10.16 | 6.21 | 3.00 | 9.42 | |
| POTASSIUM (Mg/l) | 1.00 | 1.87 | 2.45 | 2.34 | 3.01 | 2.13 | 10 |
| NITRATE (Mg/l) | 1.21 | 2.00 | 2.62 | 2.80 | 3.74 | 2.47 | 10 |
| IRON (Mg/l) | 0.30 | 0.08 | 0.05 | 0.02 | 0.13 | 0.116 | 0.3 |
| PHOSPHATE (Mg/l) | 0.02 | 0.06 | 0.04 | 0.04 | 0.08 | 0.048 | 10 |

*Significant at $p<0.05$.

A = Upstream

B = Downstream

C, D and E = Points of Waste Discharge

### 1.3.2 Discussions

The results show the values of the tested constituents of Anambra River (Table 1). The colour of Anambra River was somewhat turbid green. This was as a result of the growth of algae and other aquatic plants. The values of the water colour ranged from 1.36 units to 3.26units with a mean value of 2.13. The colours met the WHO (1991) standard for limit of drinking water, put at 50 (AP-CO std) units. This could be as a result of the self- purifying powers of the river.

The relatively high turbidity of the river was due to insoluble particles of soil, organic matter, microorganisms, and other materials. From the result, Sample Point A had the lowest average turbidity value of 1.21 NTU. The turbidity values ranged from 1.21 NTU to 4.64 NTU. Sample points C, D and E had high turbidity values because they were points of waste discharges. The average value is 2.77. The high turbidity of the river is an indication of feasibility of high pathogenic growth in the river. The dumping of refuse into Anambra River contributed to its high turbidity. Though the turbidity levels did not exceed the WHO (1991) standard (25 NTU), the levels recorded were indications of the process of eutrophication. This is because as aquatic plants increase and die, their remains increase the turbidity of the water (Anyanwu, 2009).

Determination of the electrical conductivity of water is appropriately done by the measurement of its conductivity. This capacity of a sample to conduct electrical current is related to the concentration of ions in the water. These ionized substances are the total solids. The presence of solids in water in excess is undesirable. In Anambra River, from the result of analysis, it is noted that the conductivity ranged from 12.31 µs/cm (lowest value) to 32.48 µs/cm (highest value). The average values for conductivity was 21.92 µs/cm. The values met the WHO (1991) maximum limit (500 µs/cm) for drinking water.

The suspended solids and dissolved solids constitute the total solids. In routine water analysis, the highest desirable limit of these solids is 500mg\l. From the results, the recorded values were less than this limit. The mean value was also less than this limit. This is true for both suspended and dissolved solids. Since the total solids, dissolved solids and suspended solids can give an insight into the degree of eutrophication of any water body, it follows that Anambra River is undergoing eutrophication.

The result of laboratory analysis showed that the dissolved oxygen content of Anambra River varied from an average of 3.00 mg/l (Sample Point E) to 16.84 mg/l (Sample Point A). The average value was 9.42 mg/l. Sample Points C, D and E had the lowest values because they were the points of greatest pollution (discharge of wastes) as a result of which there were high bacteria activities which required the use of oxygen (to break down the wastes), thus leading to the reduction of the oxygen contents. The reduction of oxygen at the hypolimnium (bottom) leads to fish kill. This is in agreement with the findings of Anyanwu *et al.*, (2006) in their work on Eutrophication of Nkisi and Anambra Rivers in Anambra State of Nigeria.

Potassium is one of the elements that promote aquatic plant growth. Although, it does not have much significance in public water supplies or water used for industrial purposes, it does contribute to increase in aquatic plant growth.

The results for potassium revealed that sample point A had the lowest value of 1.00mg\l while sample point E had an average value of 3.01 mg/l (highest value). The average value was 2.13 mg/l. They all met the WHO (1991) standard for limit of potassium in drinking water, which is 10Mg/l.

Iron is one of the very important elements limiting aquatic plant growth. It is the next most frequently mentioned cause of eutrophication after Nitrogen and Phosphorus. From the laboratory results, iron content in Anambra River varied from 0.02mg/l (Sample Point D) to 0.30 mg/l (Sample Point A). It had an average value of 0.116 mg/l. Though the values of iron recorded were not above the WHO (1991) standard of 0.3mg/l, for drinking water, their levels were however high enough to cause the proliferation of aquatic plant growth, especially when acting in synergy with other major nutrients.

Nitrate is one of the most significant aquatic plant nutrients that limit the growth of aquatic plants in surface waters. The values of Nitrate in Anambra River were 1.21, 2.00, 2.62, 2.80, and 3.74mg/l for Sample Points A, B, C, D, and E respectively, with an average value of 2.47 mg/l. These were below the WHO (1991) standard of 10mg/l for Nitrate in drinking water, but higher than the critical concentration of 0.3mg/l proposed by (Sawyer *et al*., 1945), which they said would cause eutrophication of water bodies if exceeded. The high nitrate contents of the river can be attributed to anthropogenic sources like refuse dumps, improper disposal of sewage, and runoff from the city and environs and numerous markets in the area including the popular Ariaria market. Discharge of industrial effluents was also a major cause of increased nitrate contents in the river. Fertilizer runoff from surrounding farmlands was a major source of nitrate concentration in Anambra River. The effect of the nitrates is noticeable in the growth of aquatic weeds. Babies using the river are in danger of contracting methamoglobinemia, a disease which affects newborn babies as a result of excess nitrate intake from water.

The phosphate values were much lower than other results. The result revealed that Sample Points A, B, C, D and E recorded 0.02, 0.06, 0.04, 0.04 and 0.08 mg/l respectively. The average value was 0.048 mg/l. The values were below the WHO (1991) standard for drinking water put at 10mg/l, but higher than the critical concentration above which eutrophication will occur which is put at 0.01mg/l (Vollenweider, 1961). The high phosphate levels in the sample points might be an indication of the presence of detergent, which is a major source of phosphate. This is more-so because industries and the numerous restaurants in the area discharged their wastewaters into drainage systems which invariably found their way as runoff into the river. The sale of detergents in the markets in the study area close to the river, as well as the use of detergents for washing and bathing around the river, contributed to the phosphate content.

| | Colour | Turbidity | Conductivity | TDS | K | DO | NO3 | Fe | TSS | TS | P |
|---|---|---|---|---|---|---|---|---|---|---|---|
| COLOUR | | 0.0012402 | 0.0054631 | 0.06223 | 0.12015 | 0.066082 | 0.013491 | 0.033743 | 0.010818 | 0.34513 | 0.28652 |
| Turbidity | 0.9897* | | 0.0012082 | 0.043621 | 0.17825 | 0.042771 | 0.0081552 | 0.029815 | 0.0052938 | 0.41072 | 0.198 |
| Conductivity | 0.97246 | 0.98995* | | 0.018003 | 0.24906 | 0.018899 | 0.0046514 | 0.010424 | 0.00037598 | 0.36036 | 0.13821 |
| TDS | 0.85895 | 0.88905 | 0.93881 | | 0.54252 | 0.0001887 | 0.05129 | 0.0080009 | 0.0093166 | 0.4077 | 0.11816 |
| K | 0.77943 | 0.71094 | 0.63566 | 0.36777 | | 0.56971 | 0.18991 | 0.34998 | 0.28942 | 0.30645 | 0.79781 |
| DO | 0.85309 | 0.89051 | 0.93678 | 0.99709* | 0.34491 | | 0.058097 | 0.015042 | 0.011713 | 0.48116 | 0.11254 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NO3 | -0.94957 | -0.964 | -0.97527* | -0.87623 | -0.69804 | -0.86535 | | 0.015776 | 0.0057988 | 0.24372 | 0.11293 |
| Fe | 0.90667 | 0.91413 | 0.95757 | 0.96446 | 0.53769 | 0.94575 | -0.944 | | 0.0033272 | 0.20333 | 0.13269 |
| TSS | 0.9565 | 0.97304* | 0.99539* | 0.96064 | 0.59543 | 0.95413 | -0.97134* | 0.98023* | | 0.313 | 0.1254 |
| TS | -0.54222 | -0.48222 | -0.52806 | -0.48493 | -0.57891 | -0.42022 | 0.6411 | -0.68346 | -0.57262 | | 0.52728 |
| P | 0.59827 | 0.68921 | 0.75727 | 0.78193 | 0.15948 | 0.78907 | -0.78857 | 0.76395 | 0.77289 | -0.38068 | |

**Table 2: Relationship between water parameters of Anambra River**
*Significant at $P< 0.05$
TDS = Total Dissolved Solid, K = potassium, DO = Dissolved Oxygen, $NO_3$ = Nitrate
Fe = Iron, TSS = Total Suspended Solid, TS = Total Solid, P = Phosphorus

Table 2 shows the linear relationship between water parameters from Anambra River. The analysis revealed correlations of different magnitude. The correlation analysis showed very high positive correlations between turbidity and colour (0.98977), conductivity and colour (0.97246), conductivity and turbidity (0.98977), total dissolved solids and conductivity (0.93881), total dissolved solids and colour (0.85895), total dissolved solids and turbidity (0.88905), dissolved oxygen and colour (0.85309), dissolved oxygen and turbidity (0.89051), dissolved oxygen and conductivity (0.93678), dissolved oxygen and TDS (0.99709), Fe and colour (0.90667), Fe and Turbidity (0.91413), Fe and conductivity (0.95757), Fe and total suspended solids (0.96446), Fe and DO (0.94575), total suspended solids and conductivity (0.99539), total suspended solids and dissolved solids (0.96064), total suspended solids and colour (0.9565), total suspended solids and turbidity (0.97304), total suspended solids and dissolved oxygen (0.95413), total suspended solids and Fe (0.98023). The result of the correlation analysis also revealed very high negative correlation between nitrate content and colour (-0.9497), nitrate and turbidity **(**-0.964), nitrate and conductivity (-0.97527), nitrate and total dissolved solids (-0.87623), nitrate and dissolved oxygen (-0.86535), Fe and nitrate (-0.944), total suspended solid and nitrates (-0.97134). The result of correlation analysis also revealed high positive correlation between potassium and colour (0.77943), potassium and turbidity (0.71094), potassium and conductivity (0.75727), potassium and total dissolved solids (0.78193), potassium and nitrate (-0.78857), potassium and Fe (0.76395), potassium and total suspended solids (0.77289). Moderate positive and negative correlations were also established while other parameters exhibited low positive and negative correlations.

The correlations were significant at 0.05 level for turidity and colour(0.9897), conductivity and turbidity (0.98995), nitrate and conductivity (-0.97527), total suspended solids and turbidity (0.97304), total suspended solids and conductivity (0.99539),total suspended solids and nitrate (0.97134), total suspended solids and Fe (0.98023). The strong correlation of most of the variables is an indication that any effect on one parameter can affect the other. The negative correlations of some of the variables indicate an inverse relationship between the variables. The very high negative correlation between nitrate and dissolved oxygen (-0.86535) implies that as nitrate increases, dissolved oxygen decreases and vice versa. Increase in nitrate content can result in oxygen depletion in water as a result of bacterial activities in the water which in extreme cases can lead to fish kill (Anyanwu *et al*., 2006). This is a consequence of eutrophication.

## Summary

There is currently, no one single analytical tool that can be used to measure the degree of eutrophication of a given water body. Instead, most experts such as Sawyer (1945) and Vollenweider (1969) are of the view that the best approach is to measure many different parameters and to synthesize the results into a general pattern which will give an over-all, somewhat average degree of the eutrophication of the water. The parameters analyzed in this work are colour, turbidity, total dissolved solids, total suspended solids, total solids, aquatic plant nutrients (potassium, iron, phosphate and nitrate), and the dissolved oxygen content of the river.

From the results, the increase in nitrate values above the critical limit proposed by Sawyer (1945) and Vollenweider (1969) is a pointer to the fact that Anambra River is gradually becoming eutrophic. Furthermore, the substantial amount of phosphates recorded (above the critical concentration) shows that phosphorus is a major nutrient that causes proliferation of aquatic weeds in the river. The process of eutrophication gradually taking place in the river is mostly adduced to nitrate and phosphate contents introduced through such anthropogenic sources as domestic wastewaters, urban drainage, agricultural wastes, and industrial wastes. The two most important nutrients, Nitrate and Phosphate, including the third frequently mentioned element (Iron) recorded high values. The values of nitrate and phosphate either attained or exceeded the critical concentration of 0.3mg/l and 0.01mg/l respectively, which would cause excessive growth of algae and other aquatic plants. The decrease in dissolved oxygen content in Anambra River compared to WHO standard showed that bacterial activity is depleting the oxygen content of the river. This is a serious sign of eutrophication. The high turbidity and total suspended solids' values are other parameters that indicated increasing rate of eutrophication of Anambra River. Though, nitrate is the more abundant of the two most implicated nutrients, both nitrate and phosphate played significant roles in the eutrophication of the river.

## Conclusion

From the general result, including the statistical inference, it has been established that Anambra River is undergoing eutrophication. From the investigation carried out, anthropogenic sources have been noted to be the cause of nutrient enrichment in the river.

The consequences of eutrophication of Anambra River are seen in the appearance and colour of the river as a result of the increased algal bloom. Algal bloom, in addition to affecting the appearance and colour of the river, also releases offensive odours, thereby making the river aesthetically unattractive. This has led to loss of tourism potentials of the water body. The increased vegetation impedes water flow and the movement of boats. The high pollution of the water makes it unsuitable for drinking. Inhabitants using this water are in danger of contracting water borne diseases. The development of anoxic conditions (low oxygen levels) could lead to massive death of fishes and other aquatic organisms.

The realization of the fact that anthropogenic activities are rapidly increasing the amount of nutrients especially nitrates and phosphates in Anambra River shows that there is need for concerted efforts amongst aquatic scientists and all the stakeholders towards the control of eutrophication of the river.

## Recommendations

Based on the findings of this research, the following recommendations are made:

1. Individuals should avoid indiscriminate discharge of refuse while the government on its part should ensure proper refuse management and disposal system.
2. There should be legislation against the use of phosphate in detergents since detergents constitute a major source of phosphate in rivers.
3. The use of fertilizer in agriculture should be minimized since fertilizer is a source of nitrate and phosphates which are the two nutrients implicated as major causes of eutrophication.
4. The discharge of industrial, agricultural and domestic wastes into the river should be discouraged. However, industrial wastes and sewage should be adequately treated before discharge into the environment.

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