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# Impact of urbanization on Nwaorie and Otamiri Rivers in Owerri, Imo State, Nigeria

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**Abstract.** The study examined the effect of urbanization on the water quality of Nwaorie and Otamiri Rivers in Owerri metropolis, Imo State, South-East Nigeria. Water samples were collected from Nwaorie and Otamiri Rivers from four sampling stations up and down stream. Water parameters analyzed using standard procedures were: color, turbidity, temperature, pH, total hardness, total solids, metals (Iron and magnesium), anions (nitrate and ammonia) and Fecal coliform. Results showed increased levels of coloration, iron, ammonia, turbidity and fecal coliform which exceeded the World Health Organization (WHO) permissible limits for drinking water. Increase in these parameters indicated influx of industrial effluent from the nearby industries and indiscriminate disposal of wastes at the bank of the rivers. Application of ANOVA showed various degree of variation in pollutants levels between the two rivers and at different sampling points. River Nwaorie was observed to be more impacted than River Otamiri. High values of iron observed from the study could be deleterious to human health if the river water is consumed without treatment. The study, therefore, recommended proper waste management and disposal as well as effluent treatments in Owerri municipal against pollution of surface water.

**Keywords:** urbanization; pollution; water quality; industrialization; drinking water

## 1. Introduction

Water is an essential natural resource for sustainability of life on earth. The sources of water for any specific purpose are not as important as the suitability of the water for the desired purpose (Osibanjo *et al*. 2011). The phenomenon of urbanization is a consequence of population increase and migration from rural to urban areas and growth-centers. The urban growth rate in Nigeria today is put at 5.8% per annum (NUDP 2004). The process of urbanization impacts rivers in many ways that include alterations to hydrology, morphology, water quality, and habitat and ecology (Schueler 1992). Improper management of vast amount of wastes generated by various anthropogenic activities (Osibanjo *et al*. 2011) and urbanization in developing countries has gradually led to the deterioration of water in recent years. In many regions of the world, especially, those with high population density, river water pollution is becoming increasingly evident. This situation has invariably increased the problem of unsafe disposal of these wastes into the ambient

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environment (Osibanjo *et al*. 2011). Untreated wastes from processing factories located in cities are discharged into inland water bodies resulting to stench, discoloration and a greasy oily nature of such water bodies (Mombeshora *et al.* 1981).

Wastes entering these water bodies are both in solid and liquid forms. These are mostly derived from Industrial, agricultural and domestic activities. As a result, water bodies which are major receptacles of treated and untreated or partially treated industrial wastes have become highly polluted. The resultant effects of this on public health and the environment are usually great in magnitude. The outbreaks of water-borne diseases like cholera, hepatitis, gastro-enteritis, etc, are possible health effects of polluted water (Adesina 1986, Jhingan 1997, Brown *et al*. 2008). In Nigeria, one of the greatest challenges of environmental sustainability and economic development has been the problem of surface water pollution (Ibeh and Mhah 2007). It is estimated that consumable water levels is placed at 1% with ground water also threatened by pollution (Ekhaise and Anyasi 2005, Cornwell 1991). Gbadegesin and Olorunfemi (2007) also pointed out that the scarcity of safe drinking water in the country is responsible for the spread of many water-related diseases.

Open and indiscriminate dumping of solid wastes in drainages and riverbanks is one of the critical problems facing most cities in Nigeria. This practice contributes significantly to environmental degradation caused by incessant flooding in most parts of the cities in recent times (Osibanjo *et al*. 2011). Other notable effects of this practice include proliferation of insects, aesthetic nuisance, bad odor, amongst others (Osibanjo *et al*. 2011). With increasing economic growth and urbanization in Nigeria, the nature and quantity of wastes generated have changed significantly (Osibanjo *et al*. 2011). Most domestic wastes in the country like in many other developing countries now contain modern environmental health hazards' (MEHHs) substances thus posing additional risk to public health (Nweke and Sanders 2009). Unfortunately, the country still lacks adequate technology, resources and manpower required to effectively manage these wastes in an environmentally safe manner (Osibanjo *et al*. 2011). Till date, common means of solid waste disposal in most Nigerian cities still remain open dumping, land-filling in unlined sanitary landfill sites, open burning, incineration, etc. (Adeyemo 2003).

The pollution of Rivers Otamiri and Nwaorie in Owerri municipal area has many factors and this complex issue is brought about by the combination of industrialization and human population explosion. This problem has its roots to indiscriminate disposal of industrial waste, runoff of oil and grease from the increasing filling stations, mechanic workshop and also the dumping of huge amount of refuse in water bodies. Due to the increasing population in Owerri metropolis, there has been an increase in waste generation and also more modern industries are on the increase, but the fact still remains that the waste disposal system has not grown as fast as the waste being generated. This inherent implication of this include among other pollution of fresh water resources in the area. The discharge of municipal, industrial and agricultural wastes into fresh water and the resultant deleterious changes in water ecology have been reported by several researchers (Abida and Hariskrishna 2008, Dan'Azumi and Bichi 2010).

Many factories in Nigeria are located on river banks and use the rivers as open sewers for their effluents. The study area is no exception from this water pollution especially with the population explosion in the area. The potentials for water pollution in Owerri metropolitan area are high and the sources are diverse as the pollutants themselves. The pollution potentials ranges from indiscriminate dumping of refuse close to water bodies, run-off from agricultural lands treated with fertilizers and pesticides and also increase in commercial activities and mechanic workshops. The factors have increased the microbial and physicochemical pollutants in the water sources. This justifies the need for investigation of the water quality status of Nwaorie and Otamiri which are major surface water sources in the area. The aim of this study is to examine the major causes of pollution of the two major rivers (Rivers Otamiri and Nwaorie) within Owerri metropolitan area due to Industrial discharges or as a result of indiscriminate disposal of municipal wastes and transportation of pollutants into these rivers via urban run-offs during heavy rainfall.

## 2. Materials and methods

### *2.1 Description of the study area*

The study area, Owerri is located within latitude 5°10$^1$N to 5°57$^1$N and longitude 7°28$^1$E to 5°35$^1$E and covered an area of about 24.88 $km^2$ (See Fig. 1). The area has an annual rainfall of 1900-2900 mm and monthly minimum temperature of 25°C and maximum temperature of 35°C. Owerri municipal area has a tropical wet and dry climate. The north - east trade wind causes the dry season as it advances south wards while the south-west trade wind causes the rainy season as it moves inland towards the north. Dry season starts from November to early March while the rainy season starts from March to October and reaches their peak in September after the “little dry season (LDS) otherwise known as August break”. Owerri is located in the rain forest zone. The rainfall is characterized by high rainfall in most of the rainy months of the year.

There are various land use patterns in the study area which include residential, commercial and administrative land-uses. The built up of the town is within the confluence of the Nwaorie and Otamiri Rivers. The commercial, market and traditional housing district are both in the less elevated central and southern parts of the town are high density residential district. Low density residential area and public establishments and major educational institutions are concentrated in the north east axis of the town. Manufacturing industries are distributed though the largest of them is located near the Nwaorie River along the highway, North of the town. Owerri among other areas in the southeastern Nigeria is made up of the tertiary geological formation succession. This is built on the coastal plain sand formation during the Miocene epoch of the Cenozoic era. The sediments of the coastal plain are particular, and consolidated and sandy.

The study area lies at the northern section of the eastern coastal lowland, which is characterized by southward dipping slope. To the southwest of the town, the terrain is flat while tolling hills runs in a north south direction to the east at about an elevation of 30m. The vegetation of the basins can be described as secondary forest. The vegetation cover shows a varied combination of different types of plant group which reflect the extent of interference by man on the original vegetation cover. In some parts of the study area, the vegetation cover is marked by the frequent occurrence of the umbrella tree *(Musanga decropoides*). The southern part of both Owerri is relatively undisturbed. The forest is dense and consists of 3 layers; high dominant trees, low dominant trees, shrubs and herds all interwoven by lianas and climbers. Tress here attains the heights of between 25-30 meters. The major occupation of the people is agriculture and small-scale industries.

### *2.2 Sample collection*

The sampling sites were carefully selected to include upstream and downstream regions (Fig. 1). Water samples were collected from 0.3 m of River Nwaori below the water surface with a 500 ml plastic bottle up-stream (NW1) and downstream (NW2) and Otamiri River up-stream (OT1) and


Fig. 1 Owerri showing samples stations (Source: Adapted from Ministry of Lands and Survey, Owerri, Imo State)

downstream (OT2). Samples were collected from where the natives abstract drinking water. Up-stream sampling was done at Nwaorie at Maria Assumpta Avenue and down-stream at Nwaorie at Nekede Bridge. Up-stream sample of Otamiri Rwas done at Egbu road while the down-stream was sampled at Wetheral Road. The samples were collected and labeled for easy identification.

### *2.3 Analysis of samples*

The physico-chemical analyses of water samples were performed using standard analytical methods for the examination of water and wastewater (APHA 1998). Parameters with extremely low stability such as temperature and pH were determined on the *in situ*. These were then assessed immediately for physical characteristics such as temperature, turbidity, total dissolved solids, conductivity, pH, color, smell and taste.

#### *2.3.1 Determination of pH*

The pH of the water samples was determined using the Hanna microprocessor pH meter. It was standardized with a buffer solution of pH range between 4 and 9.

#### *2.3.2 Measurement of temperature*

This was carried out in-situ at the site of sample collection using a mobile thermometer. This was done by dipping the thermometer into the sample and recording the stable reading.

#### *2.3.3 Determination of ammonia ($NH_3$)*

Ammonia content of water samples was determined by the standard procedure as described by APHA (1985).

#### *2.3.4 Determination of turbidity*

This was determined using a standardized Hanna H198703 Turbidimeter. The samples were poured into the measuring bottle and the surface or the bottle was wiped with silicon oil. The bottle was then inserted into the turbidimeter and the reading was obtained and recorded in Formazim Turbidity Units (FTU), a unit used to measure the clarity of water.

#### *2.3.5 Determination of Total Solids (TS) by gravimetric method*

10 mL of the samples were measured into a pre-weighed evaporating dish which was then dried in an oven at a temperature of 103 to 105°C for two and half hours. The dish was transferred into a desiccators and allowed cool to room temperature and was weighed. The total solid was represented by the increase in the weight of the evaporating dish.

$$Total\ solids\ (mg/L) = \frac{(W2 - W1)\ mg\ x\, 1000}{mL\ of\ \ sample\, used} \tag{1}$$

Where,
$W1$ = initial weight of evaporating dish,
$W2$ = final weight of the dish (evaporating dish + residue).

#### *2.3.6 Determination of Total Dissolved Solids (TDS) by gravimetric method*

A portion of water was filtered out and 10mL of the filtrate measured into a pre-weighed evaporating dish. Following the procedure for the determination of total solids above, the total dissolved solids content of the water was calculated.

$$Total\ dissolved\ solids\ (mg/L) = \frac{(W2 - W1)\ mg\ x\, 1000}{mL\ of\ \ filtrate\, used} \tag{2}$$

Where,
$W1$ = initial weight of evaporating dish,
$W2$ = final weight of the dish (evaporating dish + residue).

### *2.3.7 Determination of total hardness*

25 mL of the samples was placed in different clean 250mL conical flask. To this were added 3mL of ammonium chloride in concentrated ammonia buffer ($NH_4CL$/conc.$NH_3$) and 2 drops of Eriochrome Black T indicator. This was titrated against 0.01M EDTA solution until there was a color change from violet to blue.

$$Hardness\ in\ mg/L\ \ CaCO_3 = \frac{V\ x\ M\ \ x\,1000}{mL\ of\ \ sample\ \ used} \tag{3}$$

Where,
$M$ = Molarity of EDTA Used,
$V$ = Volume of EDTA used.

### *2.3.8 Determination of nitrate*

The brucine method was used for the estimation of Nitrate - Nitrogen (APHA 1998). The method is based on the principle that brucine in acidic medium reacts with Nitrate ($NO_3$) to produce a yellow color at elevated temperatures. Ten millimeters of water to be tested was measured into a test tube before gently adding sulphuric acid, $H_2SO_4$. The test tube content was cooled in a water bath for twenty minutes and 0.2 mL of brucine sulphate was added and properly mixed. The sample was then allowed to boil for 25 min in a water bath. The boiled sample was removed and allowed to cool in a cold bath. Four millimeters of this sample was placed in a corvette and values read off at 410 nm using a spectrophotometer model 121D. This procedure was repeated using a blank sample of distilled water which was used as the reference reading to compare. The quantity of Nitrate ($NO_3$) was calculated as follows.

$$C = \frac{A}{a} \qquad \text{(APHA 1998)} \tag{4}$$

Where,
$C$ = Concentration of N-$NO_3$ in sample,
$A$ = Measured absorbance for the sample,
$a$ = Molar absorptivity.

### *2.3.9 Coliform test and isolation of microorganisms*

The three-tube procedure using lactose broth (Hammad and Dirar 1982, Fawole *et al.* 2002, Bakare *et al.* 2003, Lateef 2004) was used for the detection of coliform and determination of the Most Probable Number (MPN) of coliform bacilli, 0.1, 1.0 and 10ml of each sample were used to inoculate the lactose broth in five replicates using the McCrady table following standard methods (APHA 1985). For the detection of faecal coliform bacteria, production of acid and gas reflected through the color change of the indicator incorporated into the lactose broth and accumulation of gas in the inverted Durham tube inserted in the broth, was taken as positive indication (D'Auriac *et al.* 2000). Inocula from tubes showing positive results were cultured into MacConkey broth and incubated at 37°C for 48 hours. These tubes were placed on Eosin-Methylene Blue (EMB) agar and incubated as before. Colonies grown on EMB plates were selected and finally identified on the basis of morphological, cultural and biochemical characteristics for the isolation of *Escherichia coli* (APHA 1992). At the end of incubation, distinct colonies of bacteria reflected through the colonial morphology were picked and purified to obtain pure cultures. They were then subjected to routine primary and biochemical tests. The isolates were identified based on the schemes and description of Bergey's methods (Buchanan and Gibbons 1974) for bacteria and Mislivec *et al.* (1992) for fungi. The colonies were identified on plates based on morphological features.

#### *2.3.10 Determination of iron and magnesium*

To assess the levels of the iron, a portion of all the water samples (50 ml) were initially subjected to fixing using concentrated nitric acid and concentrated hydrochloric acid in a ratio of 1:10 respectively. This was done in order to digest particulate matter inside the sample by heating carefully in a water bath to obtain thick yellow solution, and later was cooled and made up to 100 ml with distilled water. After this fixing, the samples were directly analyzed using the Bulk Scientific AAS. JENWAY 6310 spectrophotometer and JENWAY PFP-7 flame photometer was used to determine magnesium.

### *2.4 Statistical analysis*

The one-way analysis of variance (ANOVA) a parametric statistic was used to determine whether there is any significant difference in the water quality parameters between the two rivers. The statistical tool is used to test whether the means of two or more independent groups are equal by analyzing comparisons of variance estimates (Heiman 2003). The choice of a One way ANOVA is based on the fact that there is only one independent variable (water quality parameters) with two conditions (sample locations). ANOVA test was performed using SPSS Version 16.0.

## 3. Results and discussion

The results of the various analyses are summarized in Tables 1 and 2. Apart from Nwaorie at Maria Assumpta, all the water sources exceed the highest permissible limit for color as outlined by the World Health Organization (WHO 2004). During the rainy season, flowing waters exhibit turbulence, resulting in the unsettling of suspended particulate matters (SPM). Turbidity levels for the various sampling points showed variation. While Nwaorie River at Maria Assumpta falls within permissible limit, Nwaorie at Nekede Bridge exceeded permissible limit by 25 Formazim Turbidity Units (FTU). This is not the case with Otamiri River. The high coloration recorded in Wetheral may be to attributed to the heavy socio-economic, including mechanic village. Otamiri River at Wetheral is used by commercial motor cyclist for washing of their motor cycle. Turbidity levels of Otamiri at both sampled points (i.e., Otamiri at Egbu and Otamiri at Wetheral Road) exceeded the tolerable limits. Turbidity is a function of the degree of turbulence. Results of turbidity obtained for Otamiri correspond with its color values. The very high turbidity value obtained for Nwaorie River at Nekede Bridge may be attributed quarry activity close to the catchment.

The temperatures of sampled rivers showed high values all of which exceeded the W.H.O highest permissible limit for drinking. Nwaorie at Nekede Bridge recorded the highest temperature value of 32°C, while in Maria Assumpta temperature value was recorded at 31.5°C. Otamiri River

Table 1 Results for chemical and non-metallic parameters

| Parameters | NW1 | NW2 | OT1 | OT2 | WHO |
|---|---|---|---|---|---|
| Colour (Hazen Unit) | 5 | 10 | 20 | 20 | 5 |
| Turbidity (FTU) | 4 | 35 | 10 | 30 | 5 |
| Temperature (°C) | 31.5 | 32 | 30 | 29.5 | 25°C |
| pH | 5.6 | 5.8 | 5.4 | 5.2 | 7.0-8.5 |
| Total Hardness mg/l | 38 | 47 | 40 | 41 | 100 |
| Iron Fe (mg/l) | 0.5 | 0.3 | 0.02 | 0.4 | 0.1 |
| Ammonia (mg/l) | 0.3 | 0.2 | 0.2 | 0.04 | 0.02 |
| Nitrate (mg/l) | 0.8 | 0.8 | 0.9 | 0.7 | 10 |
| Magnesium (mg/l) | 26 | 27 | 20 | 25 | 30-150 |
| Total solids (mg/l) | 38 | 37 | 80 | 10 | 500 |
| Fecal coliforms IMP/100ml | 170 | 210 | 150 | 150 | 1 mpn / 100 ml |

Table 2 Descriptive statistics of observed water quality parameters in study area

| | Color | Turbidity | Temp | pH | Total hardness | Fe | Ammonia | $NO_3$ | Mg | TS | FC |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $\bar{x}$ | 13.75 | 19.75 | 31.4 | 5.65 | 41.5 | 0.305 | 0.21 | 0.8 | 24.5 | 21 | 170 |
| SD | 8.83 | 0.35 | 0.56 | 0.07 | 1.41 | 0.13 | 0.127 | 0 | 2.82 | 23.3 | 28.3 |
| SE | 6.25 | 0.25 | 0.4 | 0.05 | 1.0 | 0.095 | 0.09 | 0 | 2.0 | 16.5 | 20 |

where; SD is standard deviation from mean; SE is standard error

at Wetheral road recorded the lowest temperature of 29.5°C and 30°C at Egbu road. Very hot or cold water is not desirable; temperature affects the properties of water such as viscosity, density and surface tension. It follows thus that River Nwaorie will be of less viscosity as well as with low surface tension. Evapotranspiration over River Nwaorie as well as Otamiri at Egbu road will be high.

Result of analysis show that pH levels of Rivers Nwaorie and Otamiri fall within desirable range. Nwaorie at Maria Assumpta recorded pH value of 5.6 and at Nekede Bridge pH rose to 5.8. pH value of River Otamiri at Egbu road was recorded as 5.4 and declined to 5.2 at Wetheral road. The results of pH for the sample stations indicate that the rivers are acidic and tend to be corrosive. According to Ose (1990), low pH in water may result from the existence of compounds like chloride of Iron or aluminum, which hydrolyze in excess water to produce solution. The acidic nature of these rivers maybe attributed to the geological conditions of the Imo Shale, which characterize the study area. In addition the acidic nature of these rivers may suggest pollution from acid rain due to heavy presence of production industries in the Owerri metropolis. When acid waters come into contact with certain chemicals and metals, they often make them more toxic than normal (APHA 2005).

Total hardness showed variation from sampling point to another and from rivers to rivers. Nwaorie River at Maria Assumpta had a Total hardness of 38 mg/l while 47 mg/l at Nekede Bridge. In Otamiri River, total hardness varied slightly. At Egbu Total hardness was recorded as 40 mg/l and 41 mg/l at Wetheral road. Total hardness levels of the two rivers show the rivers fall within desirable limit, indicating the river water is soft.

Table 3 Analysis of variance extent of variation in observed water quality

| Source of variation | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between groups | 205.6933 | 1 | 205.6933 | 0.085552 | 0.772922 | 4.351243 |
| Within groups | 48085.95 | 20 | 2404.298 | | | |
| Total | 48291.64 | 21 | | | | |

Results of Iron concentration in the study area showed that Nwaorie at Marie Assumpta Avenue recorded the highest concentration of 0.5mg/l, followed by River Otamiri at Wetheral with Fe value of 0.4 mg/l. Nwaorie at Nekede Bridge recorded Fe level of 0.3 mg/l, while the lowest level was recorded in Otamiri at Egbu (0.02 mg/l). Apart from Otamiri River at Egbu, other sample points exceeded the desirable limit of WHO. The high level of Fe in Nwaorie River reflect the high concentration of manufacturing Industries which are located near the river along the high way, north of the town. For example, Fuason Industry which is located along the bank of Nwaorie River at Maria Assumpta dispose of water processes from aluminum zinc and other waste into the Nwaorie River. The nitrate, magnesium and Total solid levels for the samples stations fall within range recommended by World Health Organization (WHO).

The results of Ammonia showed that Nwaorie at Maria Assumpta Avenue recorded 0.3 mg/l, 0.2 mg/l at Nekede Bridge. Otamiri River at Wetheral road recorded an ammonia level of 0.04 mg/l. when these values are compared with World Health Organization (WHO) permissible level was observed that ammonia is a source of pollutant in Owerri.

Fecal coliform counts for the different sample points showed variations and in all exceeded the

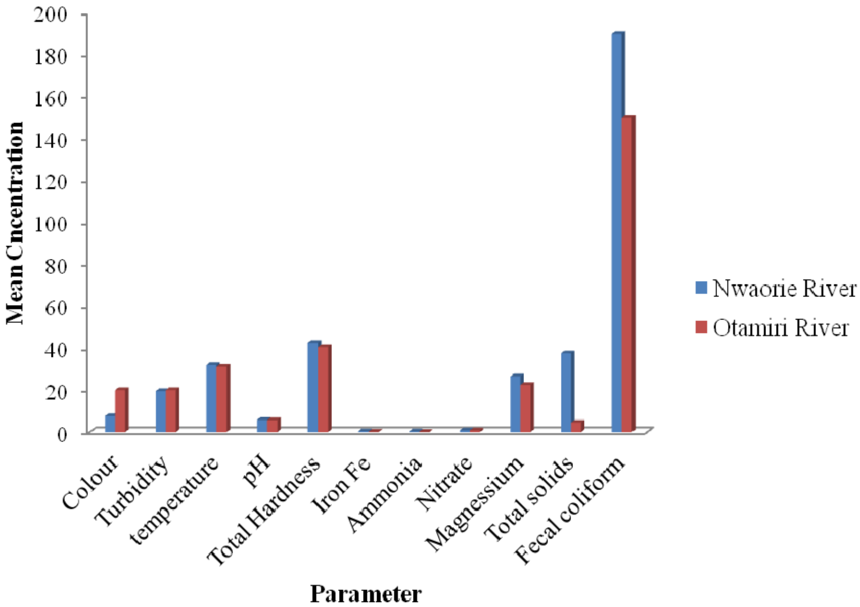


Fig. 2 Mean distribution of physicochemical parameter and heavy metals in Nwaorie and Otamiri Rivers

WHO permissible limit for drinking water. Nwaorie River at Maria Assumpta Avenue recorded 170 mpn / 100 ml. At Nekede fecal coliform count increase to 210 mpn / 100 ml. fecal coliform counts in Otamiri River was constant at both Egbu road and Wetheral road. The very high level of fecal coliform counts in Nwaorie at Nekede confirms the growing population of the town. Nekede is characterized by heavy commercial and high density residential land uses. Increased fecal coliform in these rivers may also result from urban sewage systems from homes, restaurants, institutions (especially, Alvan Ikoku collage of Education, Federal Medical Centre etc.) which empty effluent into these rivers. Generally, the high rates of fecal coliform and ammonia in all the water samples are as a result of intense farm practice along the river catchments.

A one-way ANOVA was conducted at 0.05 level of confidence to explore the extent of variation in the observed water quality between the two rivers (Table 3). Statistically significant differences in water quality were found between Rivers Nwaorie and Otamiri.

These variations suggest that these rivers are characterized by varying pollutant generating activities. From analysis River Nwaorie has higher pollution potential than Otamiri Rivers although this reflects that degree of urbanization and population distribution (Fig. 2). From the figure apart from color level, levels of other pollutants investigated are high in River Nwaorie.

## 4. Conclusion

From observation it is evident that Rivers Nwaorie and Otamiri contain various forms of pollutants. These pollutants are mostly from sewage and industrial discharge, indiscriminate disposal of domestic waste into and/or along the river courses. Using the One way Analysis of variance, ANOVA our study found that there is variation in the extent of pollution in both rivers as well as statistically significant difference in pollutant generating activities.

## Recommendations

Since pollution of surface water sources is prevalent with urbanization and industrialization, the government should as a matter of duty ensure the legislation to address water pollution be passed. To enforce this legislation and make it effective requires an institution or authority to handle the affairs of Nwaorie and Otamiri Rivers, including quarry activity. While Owerri population is on the increase, solid waste generation is expected to rise. There is need for sustainable solid waste management, requiring re-use, recycling and recovery.

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