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Assessment of Water Quality Parameters along Imo River, Nigeria

Christian Chibundu Odinkemere* and Isiguzo Edwin Ahaneku

Department of Agricultural and Bioresources Engineering, Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria.

Corresponding Author: Christian Chibundu Odinkemere, Department of Agricultural and Bioresources Engineering, Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria.

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Abstract

This study aimed to assess the water quality parameters along Imo River, Nigeria. A total of 18 samples were collected along the Imo River, at three stations viz; Onuimo, in Obowo L.G.A., Ugbo kiri in Isiala Ngwa and Okpala in Ngor Okpala in order to have a comprehensive idea of overall quality variation in the river. The three sampling stations are one kilometer apart from each other. Three samples were collected from each station. This was collected for a period of two seasons viz: Rainy and Dry seasons. Water quality parameters were determined using standard methods. The results of this study revealed that some of the water quality parameters of Imo River, such as Temperature, Biochemical Oxygen Demand (BOD), Electrical Conductivity and Dissolved Oxygen are within the acceptable limit on the standard set by NSDWQ, WHO and FAO. However, Total Dissolved Solids, pH, Turbidity, Total Hardness, E. coli and Feacel Streptococci are above the permissible limits. The river is slightly acidic and polluted with evidence of microbes. The results showed that the river is more polluted in the dry season than in the rainy season. Principal Component Analysis suggested four principal pollution sources: organic and anthropogenic activities (including battery charging), agricultural and residential runoff, nutrient sources, and meteorological factors. The study concludes that while the river's water should not be consumed without treatment, it could be used for irrigation purposes, specifically for crops not consumed raw. It is recommended that regular assessments of the river's water quality be conducted at least triennially.

Keywords: Imo River, Water Pollution, Water Quality Parameters

1. Introduction

Water is a vital resource for sustaining life and ensuring the continuity of various socio-economic activities [1]. It is an indispensable component of ecosystems and plays a significant role in the overall health and wellbeing of human beings, wildlife, and vegetation. In many regions of the world, including Nigeria, water bodies are not only sources of potable water but also play a central role in agriculture, industry, and the environment [1]. The quality of water is a broad concept that can be influenced by several factors [2]. It is determined by a set of characteristics such as physical, chemical, and biological parameters. The World Health Organization suggests that these parameters should fall within certain limits to ensure that water is safe for consumption and other uses. These parameters include but are not limited to turbidity, temperature, pH, total dissolved solids (TDS), biochemical oxygen demand (BOD), oxygen demand (OD), and the presence of various inorganic and organic substances [2]. In Nigeria, the Imo River is a significant source of water for several communities in Imo, Abia, Rivers, and Akwa Ibom states. The river is used for a range of activities such as domestic use, farming, fishing, and sand dredging among others. The anthropogenic activities along the Imo River, including industrial pollution, agricultural runoff, poor waste management, and deforestation, have caused serious concerns about its water quality [3,4]. on the bacteriological quality of Imo River found high levels of pathogenic bacteria indicating pollution from faecal matter [5].revealed that the Imo River's physicochemical properties showed signs of degradation due to anthropogenic activities. However, there is a dearth of comprehensive research on the overall quality of water in the Imo River and the multiple potential pollution sources. Additionally, the water quality standards in Nigeria are frequently not met due to inadequate monitoring and enforcement of regulations [6]. As such, there is a growing need to assess the quality of water sources and promote sustainable water resource management. This study titled "Assessment of Water Quality Parameters Along Imo River, Nigeria" aims to bridge this gap. The assessment of the Imo River's water quality parameters will provide valuable insights for policymakers, environmental scientists, water resources managers, and the communities who rely on the river. This study will contribute to the current knowledge of the water quality in the river and highlight areas that require intervention.

2. Materials and Methods

2.1. Study Area

Imo River is situated between latitudes 5^0 50^I 56^{II} N and $4^0 28^I 14^{II}$ N and longitudes 7^0 14^I 20^{II} W and 7^0 35^I 38^{II} W of Greenwich meridian. It is located in Southeastern Nigeria and flows 242km into the Atlantic Ocean. Its estuary is around 40km wide [7]. The River has a daily discharge of 4 L/sec [8]. with 26,000

ha of wetland. The Imo River tributaries are the Otamiri and Oramirukwa [9]. The Imo River was cleared under the British colonial administration of Nigeria in 1907–1908 and 1911; first to Aba and then to Udo near Umuahia [10]. Figure 1 shows the map of the study area.

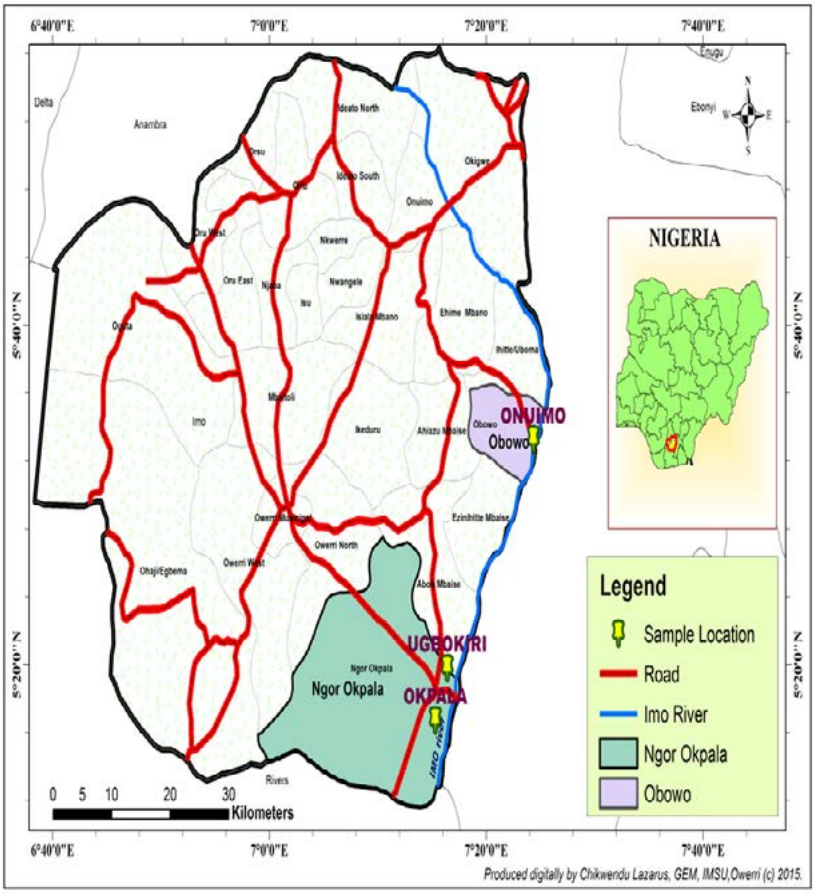

Figure 1: Map of the Study Area

2.2. Climate and Vegetation

The study area falls within the humid tropical rainforest climate. Rainy season begins in April and lasts until October with annual rainfall varying from 1,500 mm to 2,200 mm. An average annual temperature above 20°C creates an annual relative humidity of 75% with humidity reaching 90% in the rainy season. The dry season experiences two months of harmattan from December to February. The hottest months are between January and March. Palm trees, Kaffia palms, bananas, plantain, cassava, yam, cocoyam and maize are grown abundantly in the area. The abundant rainfall and high temperature in the area favours their growth. The vegetation appears more forest-like along river channels and due to intense farming in the area, grasses are taking over the original tropical forest characteristic of the area.

2.3. Water Sampling

A total of 18 samples were collected along the Imo River, at three stations viz; Onuimo (S_1-S_3), in Obowo L.G.A., Ugbo kiri (S_4 - S_6) in Isiala Ngwa and Okpala (S_7 - S_9) in Ngor Okpala in order to have a comprehensive idea of overall quality variation in the River. The three sampling stations are one kilometer apart from each other. Three samples were collected from each station. This was collected for a period of two seasons viz: Rainy and Dry seasons. The selection of the sampling points was necessitated by accessibility, proximity to residential area and topography as these factors are responsible for the quantity and strength of waste dumped into the river via anthropogenic means. Prior to sample collection as part of quality control measures, all the plastic containers (1Litre) used for the sample collection were washed with dilute HCl and rinsed with distilled water. The containers were rinsed three times with the sample water at the point of collection before final water sampling was done. The containers were held at the bottom while filling to avoid contamination of water from fingers or hands [11]. All sample containers were kept in ice boxes and brought to the laboratory for analysis.

The containers were labeled with masking tapes and identification details were written on them according to sampling location as shown in Table 1. The qualitative analyses were carried out at the Soil and Water Laboratories of National Root Crops Research Institute (NRCRI) Umudike, Umuahia, Abia State.

L.G.A	Sample Location	Sample
Obowo	Onuimo	S1
		S2
		S3
Isialangwa	Ugborkiri	S4
		S5
		S6
Okapala	Ngor Okapala	S7
		S8
		S9

Table 1: Sample Locations and Local Government Areas (L.G.A.)

2.4. Test for Bacteriological Quality

The samples collected from the various stations were analyzed for the following bacteriological parameters: E. coli, and Faecal Streptococci. The Membrane Filter (MF) technique was used for the analysis.

2.5. Test for Physico-Chemical Quality

The samples were analyzed for the following physico-chemical parameters: Dissolved Oxygen (DO), Electrical Conductivity (EC), Temperature, Turbidity, Total Dissolved Solids (TDS), pH, Total Suspended Solid (TSS), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Hardness ($CaCO_3$). Standard methods were adopted for the analysis [12].

2.6. Statistical Analysis

In order to quantitatively evaluate the parameters in the river, Person's correlation analysis was applied to the dataset. Statistical methods such as Principal Component Analysis, Factorial Analysis, and Descriptive Analysis were adopted in the interpretation of data. These methods allow identifying the different group of parameters that was correlated and thus can be considered as having a similar behavior and common origin [13]. Since parametric statistical tests require the data to be normally distributed, it was checked whether the data collected from the population is normally distributed by applying Shapiro-Wilk's test (significance level, $\alpha = 0.05$).

3. Results

The results of this study revealed that some of the water quality parameters of Imo River such as Temperature (Figure 2), Electrical Conductivity (Figure 4), Dissolved Oxygen (Figure 9) and Biochemical Oxygen Demand (BOD) (Figure 10) are within the acceptable limit on the standard set by NSDWQ, WHO and FAO. However, Total Dissolved Solid (Figure 5), pH (Figure 7), Turbidity (Figure 3), Total Hardness (Figure 8), E. coli and Feacel Streptococci (Table 2) are above the permissible limits. The results of the statistical summary of the water quality parameters from Imo River are presented in Tables 2 and 3. The correlation analysis of water samples from Imo River are presented in tables 4 and 5. The results further showed that the river is polluted more in dry season than in the rainy season.

Parameters	E. coli (CFU per 100ml)		Faecal Streptococci Count (CFU per 100ml)	
	Season		Season	
	Dry	Rainy	Dry	Rainy
Mean	1.16×10^3	1.6×10^2	3.53×10^2	1.10×10^2
Range	768	30.6	737	51.66
S.D.	438	15.7	421	421
Variance	191450	249	177409	177409
Min	896	151.0	90	90
Max	1664	181.6	759.6	827
NSDWQ [14]	0	0	0	0
FAO [8]	-	-	-	Per 100 ml

Table 2: Statistical summary of bacteriological parameters of water samples from Imo River

Parameters	Mean±Standard Deviation		Standards		
	Rainy Season	Dry Season	NSDWQ [14]	WHO [15]	FAO [8]
Temperature (oC)	25.99 ±0.33	25.08±0.69	-	-	35
Turbidity (NTU)	25.74±8.15	47.12±8.15	5	5	-
EC (µohm/cm)	33.88±5.13	141.17±10.82	1000	1000	2000
TDS	398.67±8.92	473.00±5.41	500	600	-

TSS	440.44±27.4	345.00±7.73	-	-	45
pH	6.41±0.04	6.26±0.10	6.5-8.5	6.5-8.5	5-9
$CaCO_3$	236.11±8.79	211±3.06	150	-	-
DO	2.69±0.13	6.56±0.46	-	5	-
BOD	6.64±0.05	12.78±1.15	-	-	30
All parameters in mg/L except where stated					

Table 2: Statistical summary of bacteriological parameters of water samples from Imo River

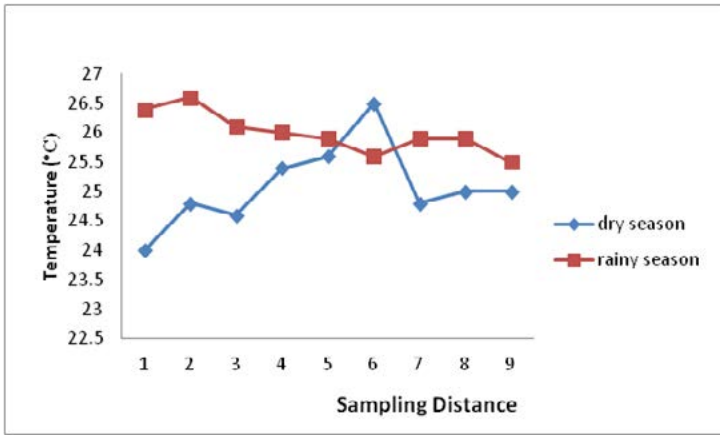

Figure 2: Variation of Temperature with Distance and Season in Imo River.

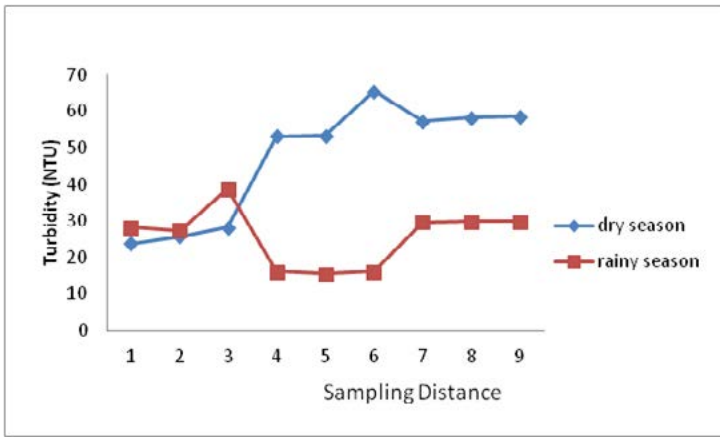

Figure 3: Variation of Turbidity with Distance and Season in Imo River.

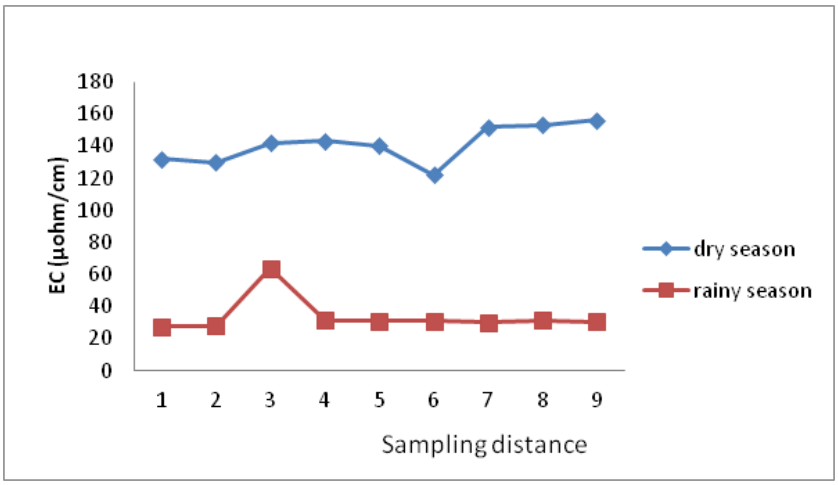

Figure 4: Variation of Electrical Conductivity (EC) with Distance and Season in Imo River

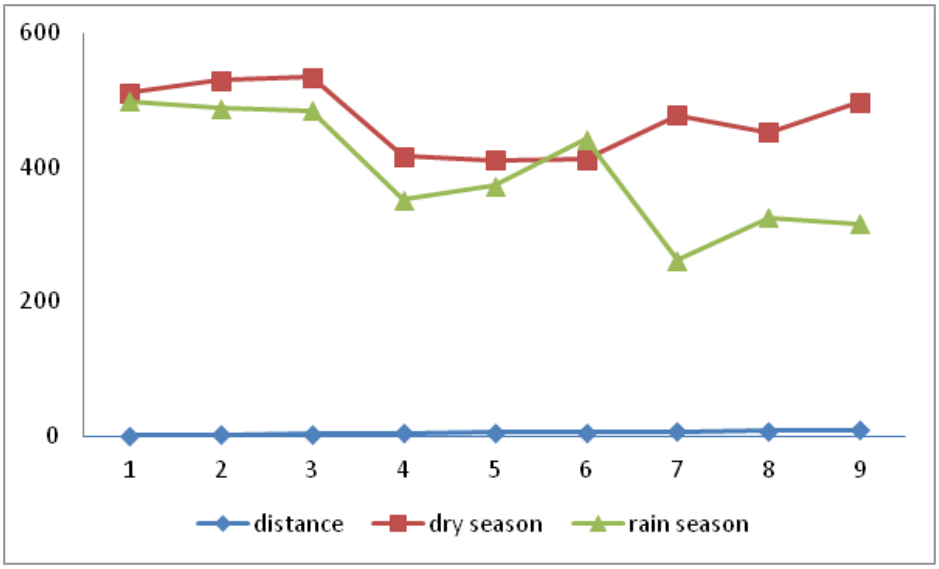

Figure 5: Variation of Total Dissolved Solids with Distance and Season in Imo River.

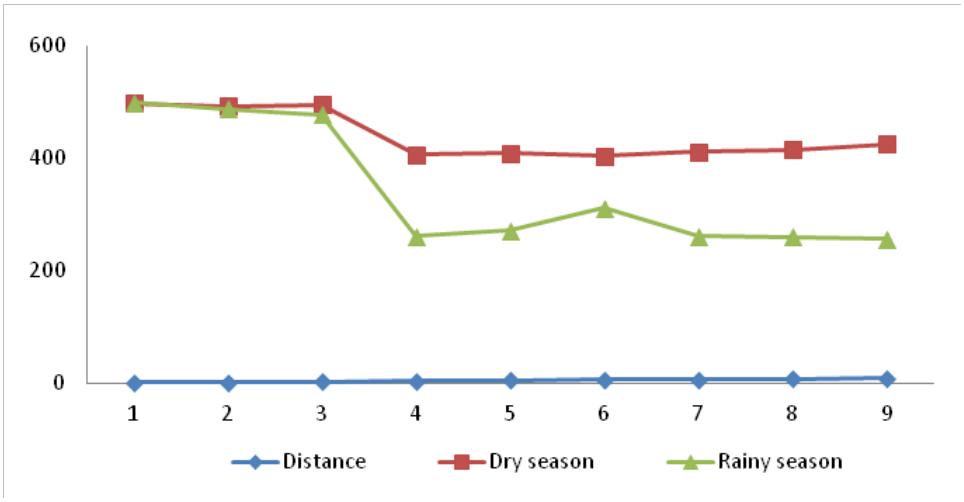

Figure 6: Variation of Total Suspended Solid with Distance and Season in Imo River

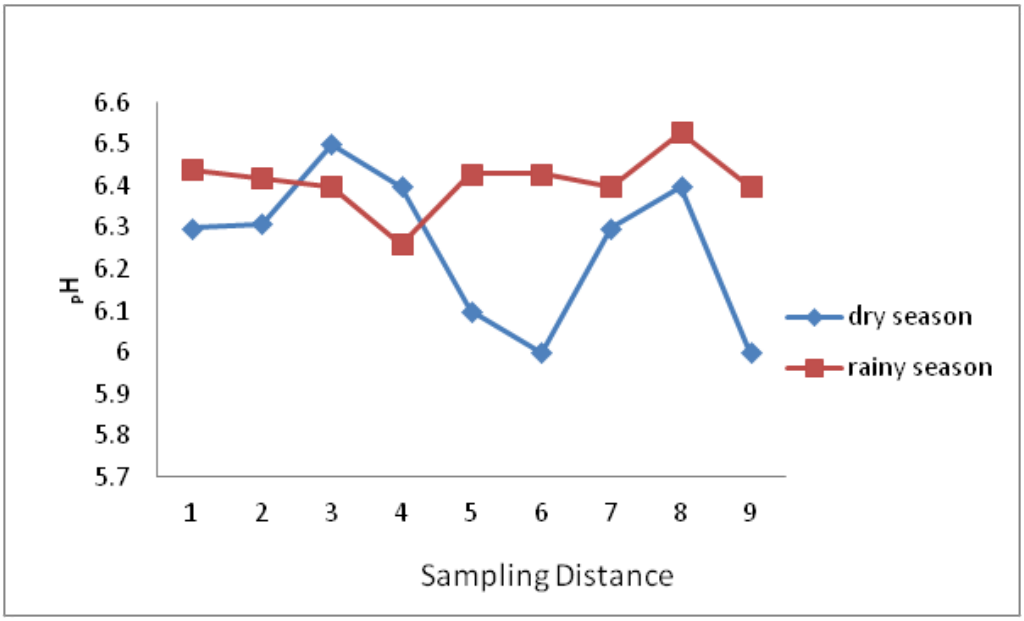

Figure 7: Variation of pH with distance and season in Imo River

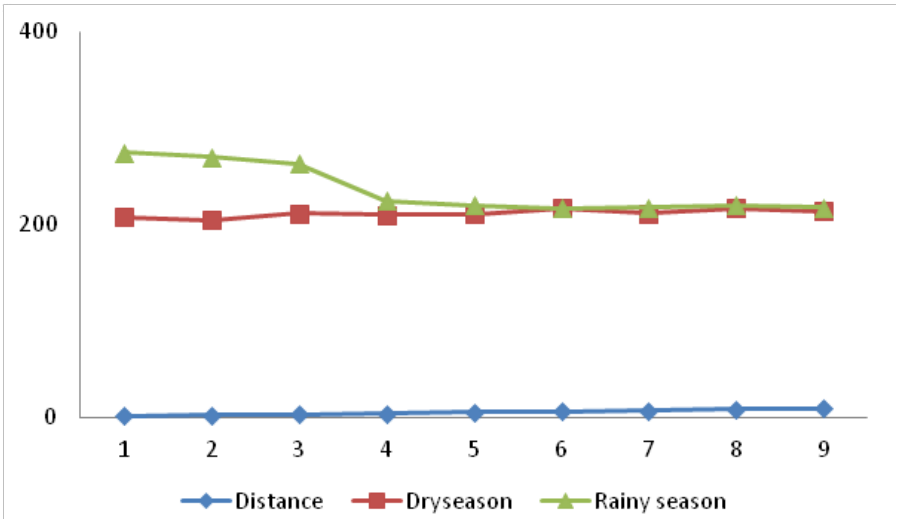

Figure 8: Variation of CaCO3 with distance and season in Imo River

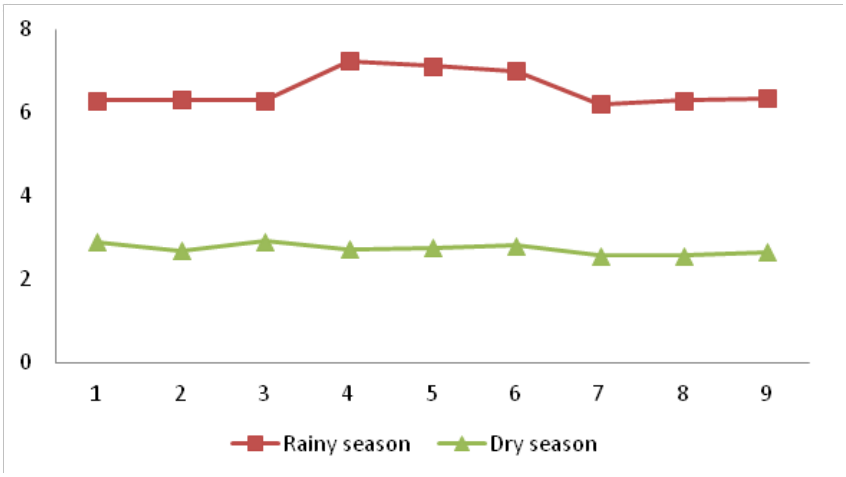

Figure 9: Variation of Dissolved Oxygen with season and distance in Imo River

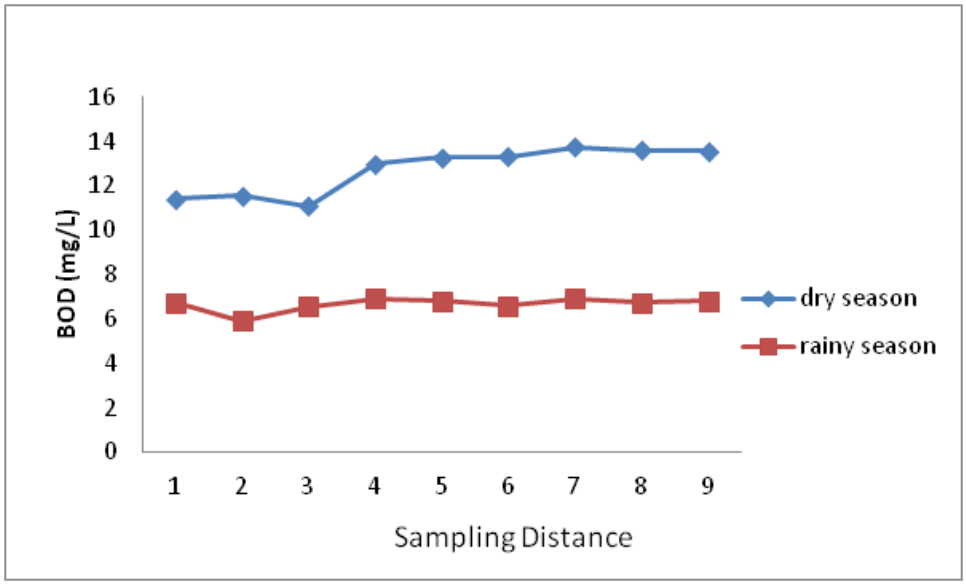

Figure 10: Variation of Biochemical Oxygen Demand (BOD) with Distance and Season in Imo River

Parameters	Temp	Turb	Cond	TDS	TSS
Temp	1				
Turb	-0.121	1			
Cond	-0.706	0.720	1		
TDS	-0.288	0.295	0.524	1	
TSS	-0.269	0.310	0.538	-0.934**	1
**. Correlation is significant at the 0.01 level (2-tailed). * Correlation is significant at the 0.05 level (2-tail)					

Table 4: Correlation analysis of physical parameters

Parameters	pH	CaCO3	O2	BOD
pH	1.00			
CaCO3	.456	1.00		
O2	-.775	-.579	1.00	
COD	-.963**	-.554	.906*	
BOD	-.867*	-.608	.985**	1.00
*. Correlation is significant at the 0.05 level (2-tailed). **. Correlation is significant at the 0.01 level (2-tailed).				

Table 5: Correlation coefficient matrix of chemical parameters

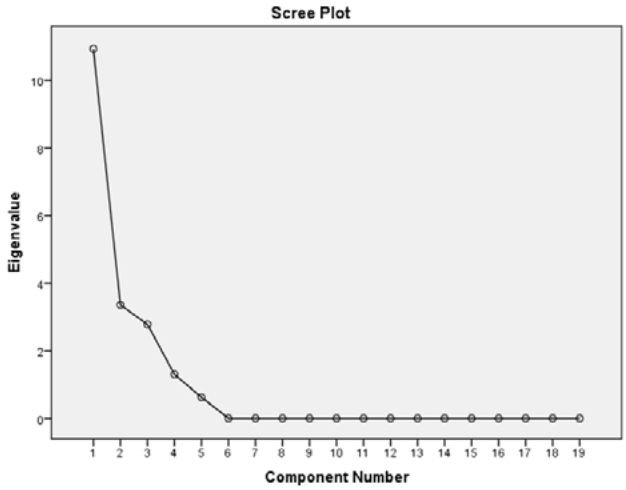

Figure 11: Plot of Eigenvalue Vs Component Number from Principal Component Analysis

	VF-1	VF-2	VF-3	VF-4
COD	0.94	-0.01	0.07	0.33
BOD	0.93	0.18	0.22	0.22
Turbidity	0.91	-0.09	-0.25	0.15
DO	0.81	0.32	0.26	0.13
EC	0.89	0.35	0.23	0.16
pH	-0.87	0.15	0.01	-0.43
TSS	0.32	0.80	-0.28	0.09
TDS	0.25	0.88	-0.08	0.21
$CaCO_3$	-0.46	0.25	-0.82	-0.15
Temperature	-0.46	-0.40	-0.74	0.22
Eigen value	9.12	3.45	2.97	2.84
Total Variance (%)	12.38	5.88	1.59	3.77
Cumulative (%)	12.38	18.26	19.85	23.62

Table 6: Factor loading of parameters on significant Vfs for water quality data set

4. Discussion

The coliform in water could also be an indication of fecal contamination and has been associated with water borne epidemic such as cholera, diarrhea, hepatitis etc. Water source used for drinking and cleaning purposes should not contain any organism of fecal origin. However, the mean values of E. coli are 1.161×10^3cfu per 100 ml and 1.67×10^2cfu per 100 ml for dry and rainy season, respectively (Table 2). These are above the recommended limit for WHO, NSDWQ and FAO. The mean values of faecal Streptococci are 3.53×10^2cfu per 100 ml and 1.10×10^3cfu per 100 ml for dry and rainy season which are also above the recommended limit for WHO, NSDWQ and FAO [15,16]. Nwankwu reported high coliform values in the range of 3100-150,000cfu per100 ml at Iddo area of Lagos Lagoon. The high values observed could be attributed to the storm water runoff from the area and land application of manure in nearby farms. High water temperature enhances the growth of micro-organisms and may increase problems related to taste, odour and colour [2].

The mean values of analyzed samples for Imo River are 25.08°C and 25.99oC for both dry and rainy season respectively. These values are within standard limit of 35°C of FAO, though there is no standard value for WHO and NSDWQ, therefore there is no evidence of thermal pollution and only a marginal difference in temperature between rainy and dry season. The consistent rise in temperature between S1 – S6 as observed in dry season could be attributed to weather condition at the point of sample collection as shown in Figure 2. Turbidity in water is caused by suspended particles or colloidal matter that obstructs light transmission through the water [2]. It may be caused by inorganic or organic matter or a combination of the two. The mean values of turbidity for Imo River are 47.12 NTU and 25.74 NTU for dry and rainy season, respectively. These are above NSDWQ and WHO maximum limit of acceptability level of 5 NTU. This is in agreement with the work of [17-19]. High values observed in the sample may be related as indicator of possible source of microbial contamination [2]. The high values observed in S4-S6 could be attributed to the activities of soil excavators and the depression between dry and rainy seasons are as a result of dilution as shown in Figure 3.

This is a measure of the ability of water to conduct an electrical current. It also measures the salinity of water and depends on the ions present in water. The mean values of EC for Imo River are 141.17µs/cm and 33.88µs/cm for dry and rainy season respectively. These are within the prescribed limit of 1000 µs/cm of NSDWQ, WHO and 2000 µs/cm of FAO. On the basis of EC, the water is fit for both drinking and irrigation purpose [20]. Okeke and Adinna in a study of Otamiri River, Owerri observed a low value similar to the present study. In rainy season as the flow of river increases and led to the dilution of the salinity of the water, while the dry season flow of water, is reduced and result in high concentration (Figure 4). TDS indicates the general nature of salinity of water. Water containing more than 500 mg/L of TDS is not considered suitable for drinking water supplies. The mean values of TDS for Imo River are 473 mg/L and 399mg/l for dry and rainy seasons respectively, and are within the permissible limit of WHO and NSDWQ of 500 mg/L. This agrees with the findings of Abu and Egenonu of surface waters in Zaira [21,22]. TDS values are more in dry season than rainy season due to the discharge sewage effluent from industries as shown in Figure 5.

TSS measures the physical or visual observable dirtiness of a water resource. The mean values of TSS are 440.4mg/l and 345.0mg/l for dry and rainy season respectively. These values are above recommended FAO standard of 45mg/l. Higher values were also reported by Ajibade of River Asa, Ilorin [23]. Okeke and Adinna in similar study reported high TSS concentration of Otamiri, River Owerri [24]. Variation of TSS during the two seasons sampled as shown in Figure 6. Although, pH usually has no direct impact on the consumers, it is one of the most important operational water quality parameters. The mean values of pH of Imo River are 6.26 and 6.41 for dry and rainy season respectively. These values were found outside the range of WHO and NSDWQ standard of 6.5 - 8.5 whereas it is within recommended limit of FAO standard of 5 - 9. This agrees with the work done by Adeboya [25]. of Lagos Lagoon, Abu and Egenonu of New Calabar River [21]. The result indicates that the river is slightly acidic and may not be fit for drinking but may be used for irrigation. The variation of pH during the two seasons sampled is shown in Figure 7.

Hardness is as a result of the dissolution of limestone deposit that underlies most parts of the settlements. However, total hardness is mainly due to Calcium, Magnesium and water containing excess hardness is not desirable for portable water. It also consumes more soap during washing of clothes. The mean values of hardness are 211 mg/L and 236 mg/L for dry and rainy season and are above the permitted limit of 150 mg/L of NSDWQ and WHO. Akinyemi [26]. in a study of Eleyele River in Oyo State observed high hardness values similar to the present study. Hardness seems to be relatively constant during dry season as shown in Figure 8. This is an important water quality parameter for most chemical and biological process in the water column and is essential for aquatic life. The mean values of DO are 6.52 mg/L and 2.69 mg/L for rainy and dry season respectively. The mean value of the dry season is within recommended limit of WHO standard of 5mg/l while the mean value of rainy season shows evidence of pollution. This shows that the river can be effectively used during dry season for both drinking and irrigation [19]. Taiwo reported of a low value of DO in the wet season due to urban runoff on Alakata Stream in Abeokuta. Variation of DO during two seasons sampled as shown in Figure 9.

BOD test is useful in determining relative waste loading. A high value indicates the presence of large amount of organic pollutant and relatively higher level of microbial activities with consequent depletion of oxygen content. The mean values of BOD for Imo River are 12.78 mg/L and 6.64mg/l for dry and rainy seasons respectively, and are within the acceptable limit of FAO standard of 30 mg/L. This agrees with Ogunfowokan [21,27]. Abu and Egenonu with a significant elevation of water indices such as BOD being the impart of pollution from sewage treatment oxidation pond on receiving stream. Variation of BOD during the two seasons sampled is shown in Figure 10. Among the physical parameters, a significant negative correlation was observed between TSS and TDS (P indicating the same source

as shown in Table 4. Tables 4 and 5 showed the degree of linear association between any two or more of the quality parameters as measured by correlation coefficient. A very strong positive correlation exists between with pH, DO, BOD and Pb as well as Cu ($P<0.01$ level), thereby indicating same source. Similarly, Ca showed moderately positive correlation with Mg, Na ($P< 0.05$) level. This is attributed to same origin while a significant negative correlation is an indication of distinct sources for the parameters in the river.

In addition to correlation analysis, principle component analysis/ factor analysis (PCA/FA) of the studied river water samples was performed in order to get an overall impression about assembling the samples in a multidimensional space. The rotated Principal Component Loading (Factors) is detailed in Table 4. Four factor components (Eigenvalue > 1) emerged accounting for 96.7% of cumulative variance. The result in Table 6 shows factor loading of parameters on significant Vfs for water quality data set. These results could be attributed to organic source, and battery charging activities ongoing in the area. Sawmill activities can lead to high BOD and COD [28]. pH of water could be conceived to mainly originate from industrial and discharge of waste in the river [29]. The TSS and TDS values could be attributed to agricultural and residential runoff and leaching to soil contamination. The factor explaining, 15.6% of the total had a moderate positive loading on Temperature and $CaCO_3$. These could be linked to nutrient source.

The scree plot (Figure 9) was applied to determine the member of pcs to be retained to understand the underlying data structure. Based on the screen plot and eigenvalues >1 criterion, four factors were chosen as principal factors explaining 96.7% of the total variance in the data set. The corresponding varifactors (VFs) variable loadings, eigenvalues and explained variances are presented in Table 6.

5. Conclusions and Recommendations

The results of this study revealed that some of the water quality parameters of Imo River such as Temperature, Biochemical Oxygen Demand (BOD), Electrical Conductivity and Dissolved Oxygen are within the acceptable limit on the standard set by NSDWQ, WHO and FAO. However, Total Dissolved Solid, pH, Turbidity, Total Hardness, E. coli and Feacel Streptococci are above the permissible limits. The river is slightly acidic and polluted with evidence of microbes. The results show that the river is polluted more in dry season than in the rainy season. This could be due to increase in evaporation and less dilution due to absence of runoff water. The Principal Component Analysis yielded four factors representing four possible sources of pollution, viz; organic source and anthropogenic activities (battery charging and others), agricultural and residential runoff, nutrient source and meterological factor. The river should not be used for drinking without treatment but may provide good source for irrigation of some agricultural crops especially those that are not consumed raw. There is need for regular assessment of the river at least every three years.

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