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Application of Water Pollution Indices in the Comparative Assessment of Two Rivers in the Niger Delta Region of Southern Nigeria

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Abstract

The comparative assessment of two rivers, Warri River (Delta State) and Ule River (Edo State), in the Niger Delta region of Southern Nigeria was carried out between the months of January and June, 2016 across wet and dry seasons using two pollution indices of water quality index (WQI) and physical pollution index (PPI). Results from this study when compared with existing standards revealed the pollution state of the two rivers as occasioned by anthropogenic activities and flooding from the surrounding watershed. While WQI values for Warri River ranged from 440.9071-1077.9974 for station 1 and 4222.3909-1067.7317 for station 2, WQI values for Ule River ranged from 175.1432-482.4832 and 199.1039-416.4238 for stations 1 and 2 respectively. The PPI values of Warri River ranged from 27.919-99.030 for station 1 and 29.851-82.284 for station 2 while PPI values for Ule River ranged from 6.491-10.632 for station 1 and 6.829-11.381 for station 2. Warri River recorded the highest mean WQI of 714.9793±125.7361 for station 1 and 704.5335±105.198 for station 2and highest mean PPI values of 67.455±12.364 for station 1 and 57.633±9.602 for station 2compared to Ule River with lower mean WQI values of 316.045±49.076 for station 1 and 294.795±32.837 for station 2 and lower mean PPI values of 7.998±0.734 for station 1 and 8.367±0.940 for station 2 respectively. The wet season has more influence on the quality of both water bodies. The findings of this investigation reveal that the water is not fit for drinking and other domestic purposes.This is a signal to the Government and Environmental Protection Agencies (EPA)to promulgate laws restricting industries and individuals from dumping waste materials into the water bodies. Proper means of waste disposal in the environment should also be developed so as to conserve and preserve the aquatic ecosystems.

Keywords: Pollution, anthropogenic, watershed, water quality index, physical pollution index.

Introduction

The Niger Delta area of Nigeria is an area with abundant oil and gas resources which makes it an important region as it accounts for a major part of the nation's income (Chukwuemeka, *et al.*, 2013). However, the exploitation of these natural resources are not without their attendant consequences on the water bodies which are the immediate recipients of the waste products or spills emanating from the industries mining them. To this end, water bodies affected in the Niger Delta region become unsuitable for use. Aquatic biodiversity is lost and aesthetic value of the affected water bodies is also eliminated. In addition, a lot of anthropogenic activities like washing, commercial activities, oil bunkering and pipeline vandalism (which brings about a release of hydrocarbon chemicals) from the surrounding watershed find their way into the rivers through flooding during wet season and then give rise to pollution, which as at present is of great concern to the world at large. As a result of this influx of several pollutants in the water bodies, nutrient levels are raised, eutrophication sets in, oxygen is depleted and water bodies become polluted and unfit for domestic use like drinking and in some cases, outbreak of diseases occur (Kwadzah and Iorhemen, 2015).

The purpose of this study is to apply the use of some pollution indices (water quality index (WQI) and physical pollution index (PPI) to compare and assess the health state of two Niger Delta rivers, with a view to:

(a) Ascertaining the quality of the water on the basis of WQI of each of the stations in the two rivers.

(b) Comparing the pollution status of the rivers.

(c) Ascertaining the suitability of the water for domestic use in the area.

(d) Suggesting ways to improve the water quality for the use of the community.

Several authors have reported the water quality assessment of some Nigeria rivers. These include the investigations of Ekhator*et al.*(2015), on water quality index of Osse River, Ushurhe*et al.* (2014), on River Ase, Etim*et al.* (2013), from different sources in the Niger Delta region, Onwugbutu-Enyi*et al.* (2008), on Bodo Creek, in the lower Niger Delta Basin, Ideriah*et al.* (2010), on Amadi Creek, Portharcourt, Rim-Rukeh*et al.* (2006), on Orogodo River, Agbor and Ayobahan*et al.* (2014), on Benin River, Nigeria. Some physical pollution index reports on some other water bodies include, Ekhator and Ihimire (2016), on some selected rivers in Edo State, Umunnakwe (2015), on Nworie River, Owerri, and Abua and Ajake (2014), on Adiabo River, Cross River State, Nigeria.

Study Area

Warri/Forcados Estuaries form part of the creeks cutting across the southern coastline of Nigeria. Parts of the freshwater zones of this river which are stations I (Nigeria Port Authority,NPA) and station 2 (Bennet Island) were sampled for this study. The river flows through the mangrove swamp forest area carrying along decaying organic matter. Station 1 is a beehive of activity comprising commercial activities and speed boat repairs. The commercial activities reduce as one progresses to station II. Around the stretch of the river are markets, Nigeria National Petroleum Company (NNPC) refinery, different sales points, etc.

Ule River is located along Afuze road, Edo state. Two stations were equally sampled along this river. Station 1 is plagued with swimming, bathing and washing activities and it's also very close to the community market, making it possible for indigenes to access. Station 2 is located within a recreation center which makes it less disturbed apart from little swimming activity that takes place by few tourists.

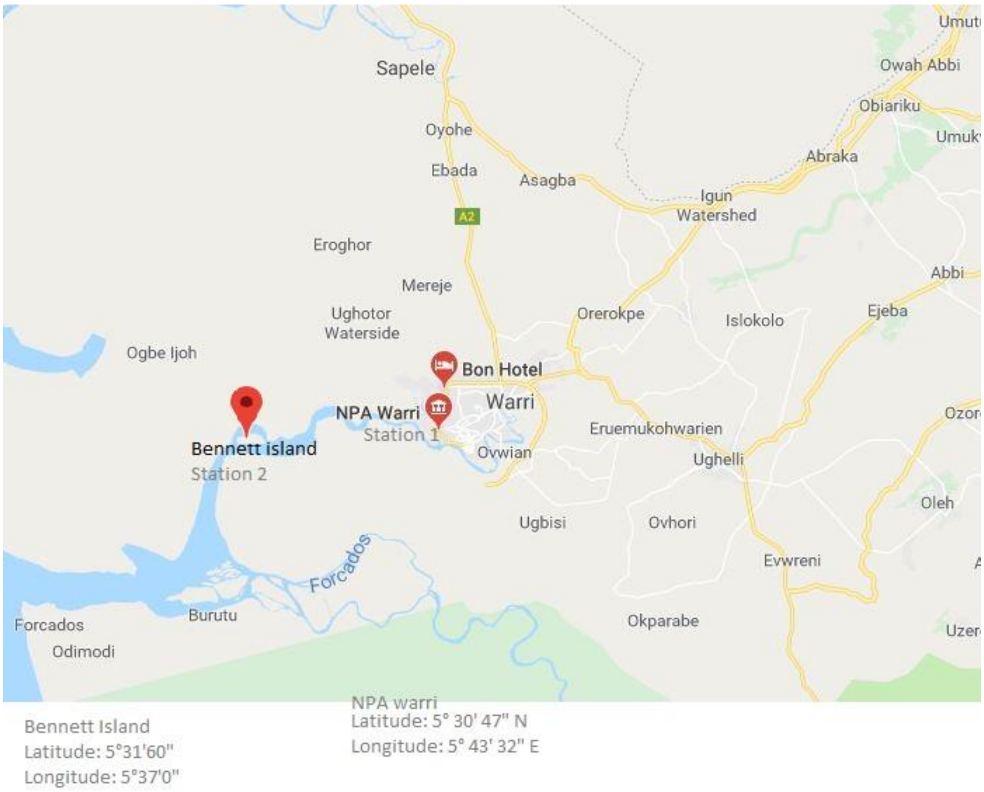

Fig. 1(a): Map of Warri River showing sampled stations

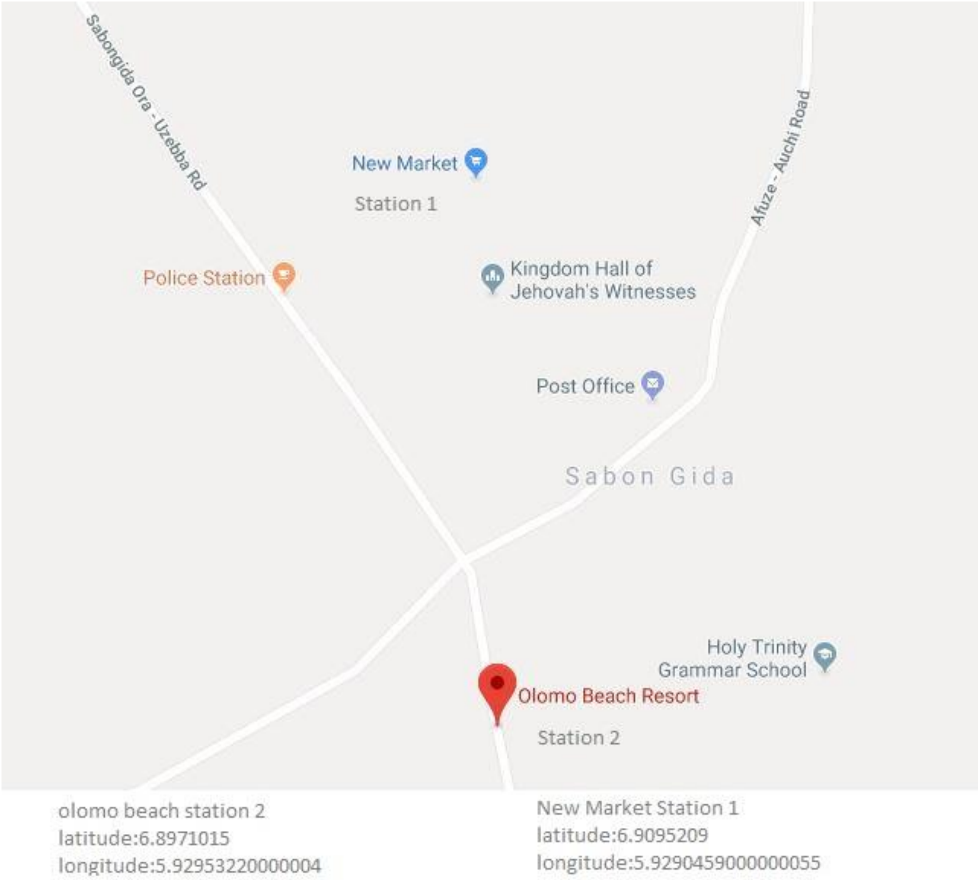

Fig. 1 (b): Map of Ule River showing sampled stations

Materials and Methods

The water samples from the two Niger Delta Rivers were collected from the open water using a 1 liter plastic container in each station on monthly basis for a period of six months across twostations in Warri River,Delta State andUle River, Edo State,respectively from January 2016 to June 2016 in both dry and wet seasons.

Physico-chemical Analysis

Samples for physico-chemical analysis were taken to the phycology laboratory, University of Benin for analysis. The methods described by America Public Health Association (APHA, 1998) were used for physical and chemical analysis.

Calculation for water quality index

In calculating the water quality index (WQI) in this investigation, nine parameters were chosen. The WQI was calculated using the standard drinking water quality recommended by World Health Organization (WHO). The process of calculation is as follows;

(I) Selection of water quality index parameters: Parameters were selected on the basis of their importance.

(II) Assignment of weight: Each parameter has been assigned weight (w_i) according to its importance in the overall quality of water for drinking purpose. The maximum weight of 5 was assigned to nitrate as a result of its importance in water quality measurement.

(III) Relative weight (W_i) : This was calculated using the equation

$$W_i = \frac{w_i}{\sum_{i=1}^{n} w_i}$$

Where, W_i= relative weight,

w_i = is the weight of each parameter

n = number of parameters

(IV)Quality rating scale (q): This was calculated by dividing the concentration of each water sample by its respective standard and the result multiplied by 100.

$$q = C_i/S_i \times 100$$

Where C_i =Concentration of each chemical parameter in each water sample.

S_i= WHO standard for each chemical parameter.

However, for the purpose of getting quality rating of pH and dissolved oxygen, the expression below was used.

$$q=(V_i-V_{io})/(S_i-V_{io})\times 100$$

Where q_i=quality rating for the i^{th} water parameter

V_i=Estimated value of the i^{th} parameter at a given station (i.e. the concentration)

S_i=Standard permissible value of the i^{th} parameter

V_{io}=Ideal value of i^{th} parameter in a pure water.

Note: Ideal value in most cases V_{io}=0 except in certain parameters like pH and dissolved oxygen. Calculation of quality rating for pH is 7 while dissolved oxygen is14.6mg/l

(V) WQI: The overall WQI is calculated by the equation:

$$WQI=\Sigma q_i W_i / \Sigma W_i$$

The suitability of WQI values for human consumption is contained in the table 1 below

Table 1: Water quality index (WQI) classification based on WQI values

Water quality index levels	Description
<50	Excellent
50-100	Good water
100-200	Poor water
200-300	Very poor (bad) water
>300	Unsuitable (unfit) for drinking

(Ramakrishniah*et al*. (2009)

The pollution index of the water bodies was determined from the equation below.

$$(PPI) = \frac{\frac{pH}{9} + \frac{\text{Total hardness}}{45} + \frac{\text{Conductivity}}{3} + \frac{TDS}{1440}}{4}$$

(Boluda*et al.*, 2001)

Table 2: Water quality classification based on pollution index Pollution index standards

Pollution index	Status
PI:<1	No pollution
PI:1-2	Slightly polluted
PI:2-3	Moderately polluted
PI:3-5	Strongly polluted
PI:>5	Seriously polluted

(Caerio*et al.*, 2005, Amadi*et al.*, 2012)

Results and Discussion

Results

Mean values of parameters studied in Warri River with electrical conductivity and total hardness being the highest are presented in table 3. Table 4, represents the calculation table for results of all WQI values obtained in the study. Table 5 and 8 show the WQI values for Warri and Ule Rivers respectively, while the PPI values of both rivers are revealed in tables 6 and 9 respectively. Table 7 shows the mean summary of physico-chemical parameters of Ule River from January to June 2016.

Table 3.Mean values of physico-chemical parameters of Warri River from January to June 2016.

Parameters	Station 1	Station 2
pH	6.767±0.171 (6.20-7.20)	6.617±0.140 (6.20-7.00)
Turbidity (NTU)	58.333±13.388 (29.00-100.00)	59.000±11.228 (30.00-100.00)
Electrical conductivity (EC) (μS/cm)	694.500±141.023 (236.00-1059.00)	581.830±110.002 (260.00-862.00)
Total dissolved solids (TDS) (mg/l)	342.330±66.913 (130.00-512.00)	311.670±57.493 (135.00-432.00)
Dissolve oxygen DO (mg/l)	46.000±8.119 (26.00-80.00)	43.333±5.402 (27.00-60.00)
Total hardness(mg/l)	1698.30±122.377 (1350.0-2140.0)	1606.00±86.879 (1350.0-1860.0)
Phosphate (mg/l)	0.267±0.030 (0.16-0.36)	0.275±0.015 (0.24-0.34)
Sulphate (mg/l)	22.833±6.374 (0.00-41.00)	17.833±5.810 (0.00-34.00)
Nitrate (mg/l)	0.073±0.016 (0.03-0.13)	0.078±0.014 (0.04-0.13)

Table 4. Example of calculation of water quality index (WQI) for Warri River January (station 1)

PARAMETER	Actual measured value	WQ Standard (S_I)	Weight	Relative weight (W_i)	Quality weight (Q_I)	Weight values (W_IQ_I)	
pH	7.1	6.5-8.5	4	0.1176	6.7	0.788	
Turbidity (mg/l)	97	1	3	0.0882	9700	855.54	
EC(μS/cm)	885	500	4	0.1176	177	20.8152	
TDS (mg/l)	426	500	4	0.1176	85.2	10.0195	
DO (mg/l)	26	5	4	0.1176	120.83	14.2096	
Total hardness(mg/l)	1810	200	3	0.0882	905	79.821	
Phosphate(mg/l)	0.24	10	1	0.0294	2.4	0.07056	
Sulphate(mg/l)	27	200	3	0.0882	13.5	1.1907	
Nitrate	0.11	50	5	0.147	0.22	0.03234	
Total				0.9114		982.4869	
							982.4869
							0.9114
						1077.9974	

Table 5. Summary of water quality index (WQI) across months in Warri River from January to June 2016

Months	Station 1	Station 2
January	1077.9974	904.4104
February	796.4265	647.3531
March	440.9071	422.3909
April	465.4385	431.0590
May	442.0206	754.2560
June	1067.0854	1067.7317
Mean WQI Total	714.9793±125.7361	704.5335±105.198

There was a gradual decrease in WQI values of Warri River from January to March of the dry season followed by a rise in values in the wet months of April to June in station 2,while increase in station 1 started from the month of May (fig.2). The highest value of 1077.9974 was recorded in station 1 in January while the lowest value of 422.3909 was recorded in station 2 in the month of March.

Fig.2. Water quality index values of Warri River

Table 6. Mean physical pollution index (PPI) of Warri Riverfrom January to June 2016.

Months	Station 1	Station 2
January	84.076	82.284
February	84.494	81.516
March	78.376	67.955
April	99.030	52.751
May	27.919	29.851
June	30.839	31.446
Mean PPI total	67.455±12.364	57.633±9.602

The physical pollution index values of Warri River in station 2 decreased across the dry season from January across March to April and May in the wet season with an increase observed in June. Station 1 recorded a similar trend, however with an increase in the month of April (99.030) followed by a decline in the month of May and a gradual rise in June during the wet season (fig.3)

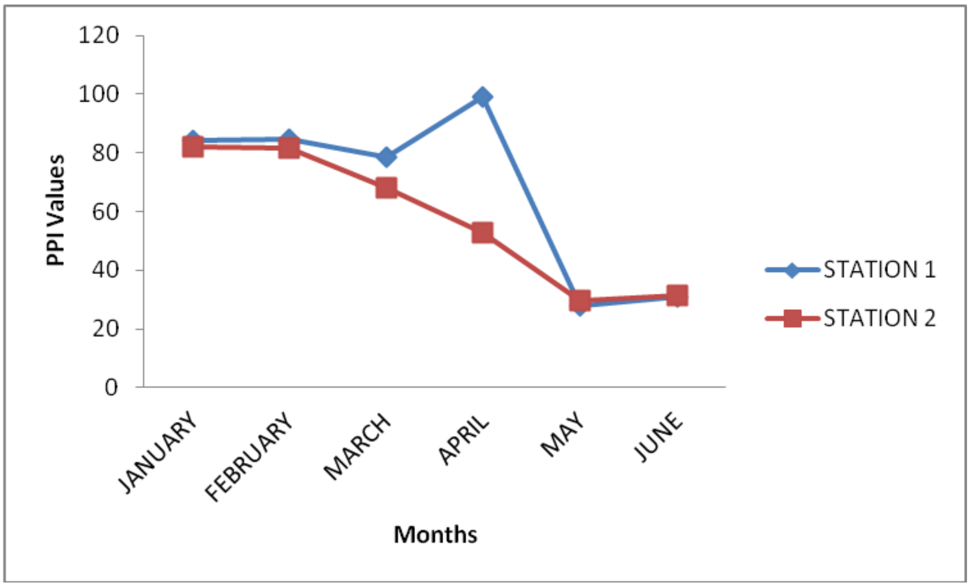

Fig.3 Physical pollution index values for Warri River

Table 7. Mean summary of Physico-chemical parameters of Ule River from January to June 2016.

Parameter	**Station 1**	**Station 2**
Total hardness (mg/l)	752.50±57.756	768.75±88.065
PO_4 (mg/l)	0.494±0.0812	0.425±0.1093
$S0_4$(mg/l)	0.75±1.389	1.00±1.069
NO_3 (mg/l)	0.056±0.021	0.051±0.025
pH	6.575±0.388	6.638±0.358
Turbidity (NTU)	34.62±23.730	16.62±8.798
EC (µS/cm)	39.97±21.839	41.64±24.071
TDS (mg/l)	57.38±114.389	61.00±121.851
DO(mg/l)	65.500±113.252	45.562±25.787

Table 8.Water quality index (WQI) values for Ule River from January to June 2016.

Months	Station 1	Station 2
January	175.1432	299.3841
February	418.6395	357.6244
March	223.3165	245.4397
April	248.6046	250.4591
May	482.4832	416.5438
June	348.0886	199.1039
Mean WQITotal	316.045±49.076	294.795±32.837

There were variations in the WQI readings recorded for stations 1 and 2 in Ule River throughout the dry and wet season (fig 4). The highest value of 482.4832 was recorded in the month of May while the lowest of 175.1432 was recorded in the month of January.

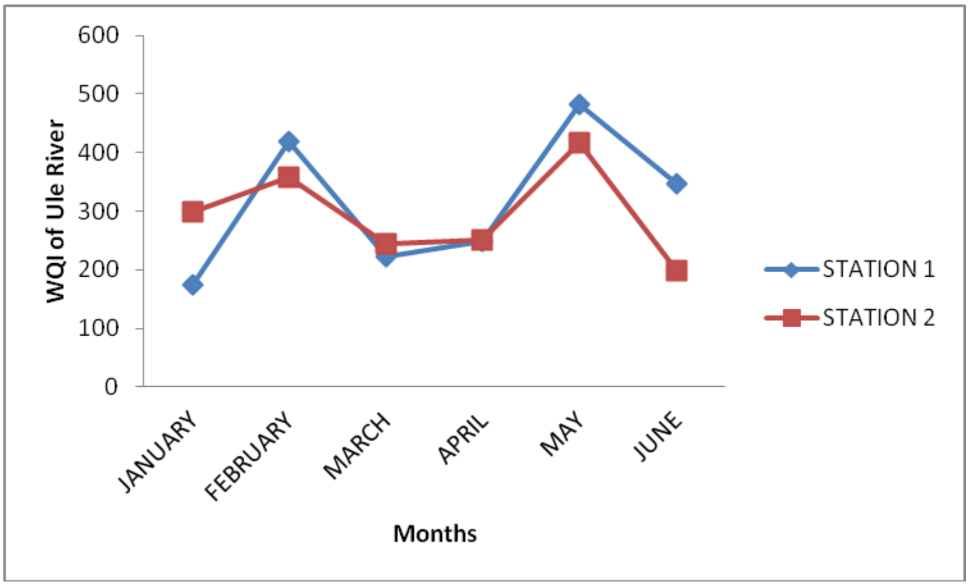

Fig.4 WQI of Ule River from January to June, 2016

Table 9. PPI values of Ule River from January to June 2016

Months	Station 1	Station 2
January	7.059	7.543
February	6.98	6.829
March	6.879	7.242
April	6.491	6.051
May	9.947	11.381
June	10.632	11.156
Mean PPI total	7.998±0.734	8.367±0.940

PPI values of Ule River were fairly constant in the dry months of January to March followed by an increase in the wet months of May and June. Almost similar values were recorded for both stations. Highest value of 11.381 was recorded in June in station 2 while the lowest of 6.051 was recorded in station 2.

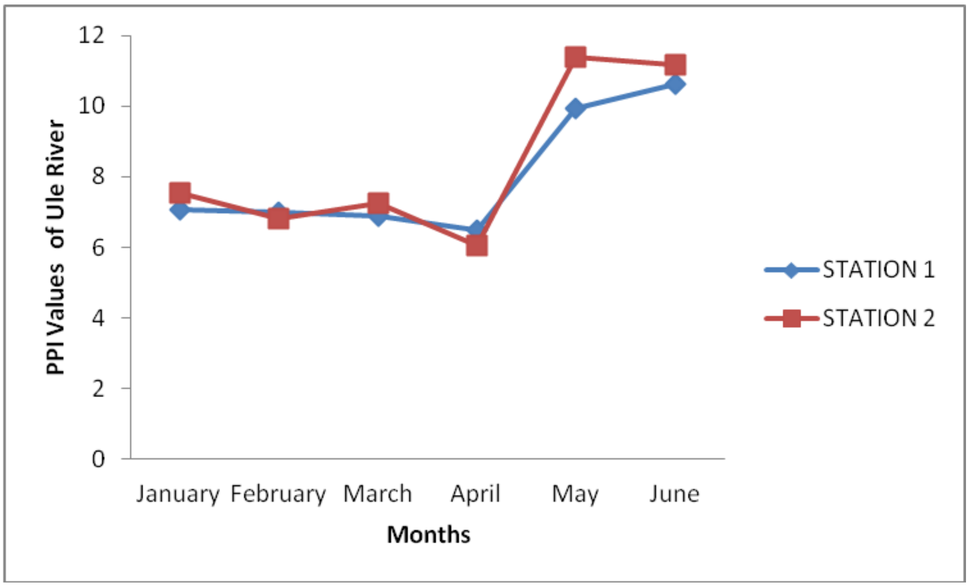

Fig.5. PPI values of Ule River from January to June, 2016

3.2 Discussion of Results

From the study, it was observed that both Warri River (Delta State) and Ule River (Edo State) reflected low water quality when compared with the standards of both indices. Warri River however recorded higher values of both WQI and PPI possibly due to the large nature of the river which makes it a thoroughfare for large vessels and speed boats, thereby increasing the turbidity and total dissolved solids (TDS) levels. Moreso, the militant activities like pipeline vandalism which accounts for hydrocarbon chemicals in the river during wet season and pollutants from speed boat repairs along the bank of the river could have impaired the water. Fig.2 shows a decline in WQI values for Warri River during the dry months of January to March followed by an increase in the wet months of April to June. This is corroborated by the PPI values where the dry months recorded a gradual decrease as well before an increase in the wet months from May and June, an indication that the wet season brought in more pollutants from the markets, factories and industries in the surrounding environment.

Aghoghovwia (2008), on assessment of industrial and domestic effluent on fish species also observed that Warri River being an inland water body, receives sewage and effluents from markets, factories and industries around the river which are capable of affecting the physical, chemical and biological components of the water as a result of the presence of organic and inorganic substances present in the pollutants.

Chapman (1996) equally reported that heavy rainfall and run off with high suspended particles could lead to organic matter pollution. Waziri and Ogugbuaja (2012) further pointed out that large amount of rainfall and river flow could also be responsible for influx of allocthonous materials into the water. The high values of WQI and PPI recorded in the dry months for Warri River could be due to the ever mixing and turbulent nature of the river because of its importance to the Nigeria economy as large vessels with goods travel through it all year round. Movement of these large vessels results in turbulence and wave actions which cause the water to have contact with the swampy areas thereby washing in solids, organic matter and other waste products into the river as the water flows back. Moreso, tidal action from the sea during the dry season could also bring about increased total dissolved solids (TDS) arising from an increase in the dissolved substances and salts that possibly can affect the quality of the water. This is in line with the investigation of Opute (2000), on his work on Warri River when he observed that the water way of Warri River is affected by strong tidal action especially in the dry season months. The possibility of pollution in dry season was also highlighted by Ewa *et al*. (2013), on the assessment of water quality of Calabar River, that sources of pollution of water in dry season include agricultural and industrial waste as well as inorganic and organic waste from households. In addition, the vegetation around the Warri River as well as the swampy areas ensures availability of dissolved substances and organic matter into the water throughout the year when the water reaches them. The freshwater zones of the Warri River sampled (stations 1: NPA and station 2: Bennett Island) are areas of activity comprising numerous speedboats used to navigate the waterway and the presence of commercial activities to satisfy the needs of travelers. The speedboats go along with the refuse produced by the passengers in the boat and these are later washed into the river in the process of cleaning the boat. All these negatively affect the water body overtime. Digging of sand from the water also takes place in these freshwater zones along the water way by the locals in the surrounding community which render these areas of the water turbid. Wind mixing, wave action and turbulence bring about increased total dissolve solids (TDS) and conductivity as recorded in this study.

Ule River (Edo State) recorded lower values compared to Warri River being a smaller river and not so much subjected to the nature of disturbance experienced by the larger river except for the direct pressure exerted by the inhabitants of the surrounding areas who come to dump waste materials into the water at station 1. Moreso, washing of clothes done by the inhabitants who use the river as a washing base also impair the river. Etim*et al*. (2013) supported this by observing that smaller rivers are prone to pollution by human defecation and dumping of untreated waste. Since the river is a lotic water body, station 2 inside the recreation center possibly contains some of these pollutants in addition to the swimming activity carried out by visitors. The allocthonous materials brought in by flood from the surrounding watershed may have accounted for the increased WQI and PPI values in both stations. The mean total PPI recorded is a reflection of the composition of the surrounding watershed. This is in line with the observation of Ekhator and Iloh (2015) on their investigation on the effect of watershed operations on the limnology of River Niger (Illushi community), that as far as there are operations and activities in the surrounding watershed of which the wastes from such activities will eventually have direct or indirect contact with the water, there may be tendency for pollution. Galadima*et al*. (2011) corroborated this point when they stated that daily market operations like buying and selling in local communities produce reasonable amount of different wastes which are dumped into fresh water. These local markets include shops and roadside markets and 90% of these kinds of markets are available in Nigeria. The various wastes like banana peels, empty cans, food items, etc., in addition to the refuse generated during weekly or community market where rural dwellers and their city associates gather for commercial activities, all find their way into the rivers in a community as their final destination either during flooding or willful disposal of wastes into them by inhabitants of the community. These reduce the aesthetic value and water quality of the rivers. Ekhator and Ihimire (2016) on the physical pollution index of some selected rivers in Edo State, reported that all the rivers in the local communities studied were slightly, moderately and seriously polluted; an indication of the prevalence of the aforementioned reasons in the catchment areas. The impact of watershed operations on water bodies have also been buttressed by Okeke and Adinna (2013), when they stated that land uses can bring about chemical, physical and biological pollution which jeopardize water quality. Amadi*et al*. (2010) on water quality index (WQI) of Otamiri and Oramiriukwa Rivers also observed that enrichment of elements in the water body which consequently bring about increased or reduced WQI and PPI values are as a result of different human operations going on along the river bank.

The effect of these pollutants from the watershed bring about eutrophication and can make the water smell badly, unfit for drinking and domestic purposes and may become toxic to aquatic life. Adebayo and Adediran (2005) asserted that levels of dissolved oxygen (DO), pH, hardness and suspended solids are known to affect the survival of fish in the river.

From the study of the two rivers, it is clear that the low water quality observed from the calculation of the WQI and PPI is not as a result of the nitrate and phosphate parameters in the environment as these have low values; giving an indication of low agricultural activity and low fertilizer residue in the surrounding. Olajire and Imeokparia (2000), on the water assessment of Osun River had reported that agricultural activities were major source of water pollution as it accounts for high ammonia and phosphate concentration. The implication on this study therefore, is that domestic and industrial discharges, incursions of water into the swampy areas, commercial activities, flooding and digging of sand from bottom sediment other than agricultural activities accounted more for the low water quality of Warri River. This was strengthened by the findings of Aghoghovwia (2011) on the physico-chemical characteristics of Warri River, that the level of pollution observed in the river was as a result of the pollutants in discharges from NNPC Jetty, Warri market, Udu bridge market, Ugbolokposo dredging site and others. On the other hand as well, flooding and indiscriminate dumping of waste into the water other than agricultural activities may have affected the water quality in Ule River.

The revelation from this study is the nonchalant attitude and uttermost disregard for aquatic ecosystems and their biodiversity which the populace of the various areas investigated display towards water bodies. Many people take the water body as the final sink for all manner of refuse and junks with the belief that it is “no man’s land” and as such, they cannot be accountable for whatever impact their actions have on the aquatic environment in as much as they have pushed the problem far away from their immediate surroundings. Little do they know that a negative bounce back awaits them all when outbreak of diseases occur and water bodies become unfit for drinking and domestic purposes.

4.0Conclusion and Recommendation

From this study, it is clear that the waters in both rivers are unfit for drinking and other domestic purposes unless when treated. The result obtained from this study is a signal to the Government and Environmental Protection Agencies (EPA) with regard to human activities around water bodies in the Niger Delta regions and their effects on the quality of the water, humans and aquatic biodiversity, to promulgate laws restricting industries and individuals from dumping waste materials into the water bodies. Proper means of waste disposal in the environment should also be developed so as to conserve and preserve the aquatic ecosystems.

One may not be able to completely stop the human activities in the surrounding watershed that influence the water body. However, regular physico-chemical analysis of rivers can be carried out to ascertain the quality of water.

Proper monitoring of human activities along the bank of rivers should be done to minimize the generation of refuse and nutrients into the water body. This means that the Environmental Protection Agencies should be in active operation of protecting the water bodies and environments in general.

Public enlightenment in both print and electronic media can be done by the government to expose the populace to the dangers of polluting the aquatic ecosystems.

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