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Use of Water Pollution Index to Assess the Levels of Dissolved Organic and Inorganic Substances in Nworie River Owerri, Imo State Nigeria

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Abstract

The use of water pollution index to assess the contributions of organic and inorganic parameters in the pollution level of Nworie River was studied in the month of October, 2014. An index represents the results of generated field data in a simple and generalised way by mathematically combining sets of values obtained. The pollution indices of water and sediment samples during dredging of the river in 2010 and in this present study were presented and comparisons made. This investigation surveyed the following parameters for both surface water and sediment samples: pH, Temp, Phosphate, Nitrate, Sulphate, Iron and Lead, while turbidity, conductivity, Alkalinity, Carbonate, Hardness, DO, BOD_5 TSS, were included in surface water analysis. Three sampling stations along the stretch of the river were selected*: Federal Medical center, Akanchawa Road* and *Egbeada* and standard methods were adopted for their sampling and analysis. The result of the analysis indicates that turbidity and total suspended solids exceeded the standard limits for surface water, while iron exceeded that for sediments. A DO of 5.7mg/l shows that the river could sustain aquatic life. The results of the computed pollution index revealed that the index of organic parameters was 0.42 while that of inorganic was 0.34.During the dredging of the river in 2010 organic parameters had an index of 0.48 while inorganic had 0.30.For sediments, organic variables had a score of 0.08 while inorganic had 0.02 score. During the dredging in 2010, the index of organic parameters for sediments was 0.13, while for inorganic vsariables it was 0.053.The pollution indices strongly implicated pollution by organic wastes which were higher during the dredging of Nworie River.

Keywords: Pollution index, organic, inorganic, Nworie River.

INTRODUCTION

Nworie River is a first order stream that runs about a 5km course across Owerri metropolis in Imo state, Nigeria before emptying into another river, the Otamiri River (Umunnakwe, *et al*., 2011). It flows through some establishments that discharge their untreated waste into it. The river acts as a source of drinking water, fishing and other domestic uses for the inhabitants. Its watershed is subject to intensive human and industrial activities resulting in the discharge of a wide range of pollutants both organic and inorganic (Acholonu *et al*,. 2008). Organic materials are found in domestic sewage, municipal wastewaters and effluent of certain industries e,g, food processing and paper production. These materials are washed into water bodies to cause pollution. They are biodegradable and are easily oxidized by making use of the dissolved oxygen in water which soon depletes. Many inorganic materials and salts are known to enter water bodies by discharge from municipalities, industries and farmlands. They all cause pollution (Ademoroti,1996).There are some reducing inorganic compounds e.g, sulphide, trioxosulphate (IV) ions etc and lower chlorides e.g. iron (II) chloride which are oxygen demanding. The water DO will oxidize them to the corresponding tetraoxosulphates and iron (III) chloride. This activity lowers the water DO leading to adverse effects on the aquatic animals. Organic wastes are of plant or animal origin and includes food waste(cooked and uncooked), vegetables, fruit debris, bones and human waste; while inorganic substances are of mineral origin and include salt, iron, calcium, sulphur among others. Studies on the assessment of the physicochemical variables of Nworie River are therefore necessary to understand its environmental and health effects. Nnaji and Duru, (2006) working on Nworie River prior to the dredging activity analysed parameters such as Ph, TDS, TSS, DO, Nitrate, Total Hardness, phosphate, Calcium and Lead and found they exceeded safe limits. They concluded that Nworie River was polluted and posed a health threat to Owerri residents. Alinnor and Obiji (2010) working on the heavy metal content of fish samples from Nworie River, identified Fe, Cd, Mn, in fish species *Tilapia guineesis* whereas Pb and Hg were below detection level. Umunnakwe *et al.,2011* in their preliminary assessment of some physicochemical parameters during dredging of Nworie River revealed that the water was acidic (pH 5.2) and not fit for human consumption. The study further shows the Pb and Fe values in the sediment samples (0.4331mg/l and 0.4867 mg/l) exceeded the safe limits of WHO; while the low levels of the nutrients N and P and the mean DO value of 5.633 mg/l indicated that the dredging project supported aquatic biodiversity. Pollution Index (PI) is a way of assessing pollution levels by putting into considerations the joint effect of all polluting parameters. According to Lutz, (2004) an index is a number that is created by mathematically combining a set of numbers. The index does not represent a particular measurement but it can be used to make comparisons more simple and intuitive.

Water Quality Index (WQI) as a Water Quality Management Option.

The progressive research on how to improve polluted water quality have led to the development of models for the determination of water quality known as water quality index (WQI). A quality index is a unitless number that ascribes a quality value to an aggregate set of measured parameters. Water quality indices generally consist of sub index scores assigned to each parameter by comparing its measurement with a parameter – specific rating curve, optionally weighted and combined into a final index (Yagow and Shanholtz, 1996). According to Cude, (2001), water quality index is a single number which expresses water quality by integrating measurement of carefully selected water quality parameters. The index was developed for the purpose of providing a simple, concise and valid method for expressing the significance of regularly, generated laboratory data.

Whereas water monitoring for different purposes is well defined (e.g. recreation, water use, irrigation etc), the overall water quality is sometimes difficult to evaluate from a large number of samples, each containing concentrations for many parameters (Chapman, 1992). Although any monitored parameters could be analyzed either alone or grouped according to a common feature, such analysis provides partial information on the overall quality (Pesce and Wunderlin, 2000). The use of water quality indices (WQI) is a simple practice that overcome many of the problems and allow the public and decision makers to receive water quality information. This type of information is meaningful to the public who want to know about the state of their local water bodies and for managers and policy makers who require concise information about those water bodies.

According to Lutz, (2004) an index is a number that is created by mathematically combining a set of numbers. The index does not represent a particular measurement but it can be used to make comparisons more simple and intuitive. Water quality indices combine several different water quality parameters and can be used to show both water quality variation spatially and temporally. The particular parameters used to develop a water quality index are picked based on historical information, ecological importance, human use, seasonal fluctuations and other considerations. Water quality indices can be developed for particular uses e.g aquatic life preservation, agricultural uses, recreation uses, drinking water uses among others.

Some of the computed water quality Indices include those of:

1. Brown *et al*., (1970) whose model was based on the various uses of the river and their relevant Physicochemical parameters. The geometric mean in the form of a multiplicative model was proposed in this model which was later modified by Bhargava, (1983). The modified form of this has been used to classify Gangar River by Bhargava, (1983). A similar index was also used by Egborge and Jolomi, (1986), to classify Warri river; Ikpe, (1999) to classify sections of the Sombreiro river and Edoghotu, (1998) to classify Okpoka creek.

The modified mathematical model is expressed as

$$WQI = \left[\prod_{i=1}^{n} fi\,(pi) \right]^{1/n} X\ 100$$

Where n = numbers of variables considered more relevant to a particular use of the creek. Fi(pi) = sensitivity function of the variable and include the effect of the weighting of the ith variable to creek use under consideration.

2. U.S National Sanitation foundation (NSF) developed water quality indices in 1970 based on the Delphi approach using a panel of 142 persons from throughout the United States with expertise in various aspects of water quality management (Canter, 1996). The investigators subsequently averaged the curves from the respondents to produce a set of "average curves" one for each pollutant variable. The aggregate WQI was calculated using either a weighted linear sum of the sub-indices (WQIa) or a weighted product aggregation function (WQIm). These are expressed mathematically as follows.

$$NSF\ WQI_a = \sum_{i=1}^{n} w_i I_i$$

$$NSF\ WQI_m = \prod_{i=1}^{n} I_i^{w_i}$$

3. The British Colombia Water Quality Index developed by the Canadian Council of Environment Ministers (CCME) reduces the technical water quality information to a simple description of the state of water quality (Rocchini, and Swain, 2001). The CCME water quality index provide a broad overview of environmental performance. This index is based on three attributes of water quality that relate to water quality objectives: Scope, F1, Frequency, F2, Amplitude, F3.
The index is given by the formular
$$(Index)^2 = (F_1)^2 + (F_2)^2 + F_3/_3)^2$$
The result is simplified by assigning it to a descriptive category but this depends on the water bodies and variables being dealt with through a process of comparing the index rank to expert opinion about the water body. The ranking procedure is shown as follows Excellent: (CCME WQI value 95-100) – water quality is protected with a virtual absence of threat or impairment; conditions very close to natural or pristine levels.
Good: (CCME WQI value 80 –94) – Water quality is protected with only a minor degree of threat or impairment, conditions rarely depart from natural or desirable levels.
Fair: (CCME WQI value 60 – 79) – water quality is usually protected but occasionally threatened or impaired, conditions sometimes departs from natural or desirable levels.
Poor: (CCME WQI value 0 –44) – water quality is almost always threatened or impaired; conditions depart from natural or desirable levels.
4. Pesce and Wunderlin, (2000) verified the usefulness of water quality indices to assess the water quality from multiple measured parameters by using two water quality indices; subjective and objective (WQI_{sub} and WQI_{obj}) and minimal (WQI_{min}). This index was used to evaluate the spatial and seasonal changes in the water quality from the Suquia River in Cordoba City (Argentina) and nearby locations.
The minimal index was developed using only three parameters; turbidity, dissolved oxygen and conductivity or dissolved solids. The subjective or objective took into consideration twenty parameters. In each of the above methods, the construction of WQI requires first a normalization step where each parameter is transformed into a 0 – 100% scale with 100 representing the highest quality. The next step was to apply weighting factors that reflect the importance of each parameter as an indicator of the water quality. The so constructed WQI gives a number that can be associated with a quality percentage they concluded.
The subjective water quality index, WQI_{sub} was calculated using the formular.

$$WQI_{sub} = \frac{K\,\Sigma\,Ci \times Pi}{\Sigma\,Pi}$$

Where K is a subjective constant, Ci is the value assigned to each parameter after normalization and Pi is the relative weight assigned to each parameter.

The minimal index (WQI_{min}) was calculated using.

$$WQI_{min} = \frac{C_{DO} + C_{cond} + C_{turb}}{3}$$

Where C_{DO} is the value due to dissolved oxygen after normalization (descriptive statistics); C_{cond} is the value due to conductivity after normalization and C_{turb} the value due to turbidity after normalization.

5. Obunwo, (2003) also developed an index for the classification of a fresh water stream in the Niger Delta, Minichinda stream. He used the ratio BOD/NO3 over the sampling stations for both dry and wet season. Stream stretches with ratios of less than 4 are potable whereas those with ratios greater than 4 are not potable.
6. Another important form of index to assess water quality was that developed by Diese, (2006). This index was developed by choosing eight test factors (i.e eight parameters) and the results were rated for each water test using some rating scales. To calculate the water quality index for the water, the mean scores were added together and divided by total number of the parameters i.e. eight.

7. Umunnakwe *et al*.,(2007) investigated the possibility of developing water quality index based on three parameters, temperature, turbidity and dissolved oxygen to monitor changes in the characteristics of Woji (Trans Amadi) Creek, a brackish water system in order to provide cost effective water quality assessment rapidly and reliably. Results from ratios of these related parameters with dissolved oxygen were analysed to obtain simple trends that reflect water quality profile reasonably and was effectively used to monitor water quality changes. Dissolved Oxygen, DO is a critical factor for aquatic life since fishing is a key activity in the Woji Creek.

Materials and Methods

Area of Study: Nworie River watershed is subject to intensive human and industrial activities resulting in the discharge of wide range of pollutants. The river is used for various domestic applications by inhabitants of Owerri. When the public water fails, the river further serves as a source of direct drinking water, especially for the poorer segment of the city. Occasionally children bath in the river. Nworie River is polluted by organic wastes as result of inefficient waste management in Owerri. Sources of dissolved inorganic into the river include compounds of Potassium, sulphur, phosphate, salt and Sodium carbonate.

Design of Sample Collection and Procedure: Three sample stations were established after a reconnaissance visit to river. The criteria for the choice of sampling at the different stations along the stretch of the river was for comparative studies. Station one is the *Federal Medical Center* where household and medical waste are discharged. Station two is the Akanchawa road where biodegradable and non biodegradable wastes are discharged. Station three is at Egbeada where municipal waste and sewage are discharged. Samples of water and sediments were collected in 1 litre glass container from these stations during the rainy season in the month of October. These samples were labelled, packed inside an ice cooled container and transported to Ministry of Petroleum and Environment (UNIDO/RAC) laboratory for analysis. Standard analytical methods were used for all the physiochemical and biological analysis (APHA, 1992).

Physiochemical and Biological Analysis: In situ measurement of pH and conductivity for water sediment was taken in the field during sampling with pH meter (Suntex model TS-2). Other parameters were analysed in the laboratory with the use of spectrophotometer (Hach DR/2010), using their various specific methods.

Analysis of Data: Statistical tools such as mean, standard deviation and variance were used to analyse the data obtained to ascertain how representative and close the data obtained were. Two way analysis of variance were used to show the significant different between the samples and the stations. Correlation analysis was carried out to show the relationship among the physiochemical and biological parameters.

Development of Pollution Index

The pollution index was calculated by finding the average ratio of metal concentration to the tolerance levels or above the level that it become unsafe to the environment or human health. It was calculated thus;

Pollution Index (PI) = $\frac{I}{n} \quad \frac{M1}{(TL)1} + \frac{M2}{(TL)2} + \frac{M3}{(TLn)}$

where;

M_1, M_2 .... Mn is the average concentration of the parameters

TL_1, TL_2 .... TLn is the tolerable levels for each parameter.

“n” is the number of parameters considered .

A pollution index of more than 1.0 indicates that average concentration of the parameter is above the permissible limit and therefore has adverse effect.

Table 1
SURFACE WATER SAMPLES

S/N	Parameters	WHO standard	Mean	Range	Sampling Stations/Results		
					FMC	Akanchawa road	Egbeada
1	pH	6.5-8.5	6.4	6.49 -7.08	6.65	6.49	7.08
2	Temperature ^{o}c	Ambient	30.6	30.4-30.8	30.8	30.4	30.6
3	Turbidity NTU	50	112.2	61.7-133,0	142.0	133.0	61.70
4	Conductivity (µS/cm)	100	60.84	68.5-81.2	78.50	81.20	68.50
5	Phosphate (mg/l)	5	0.163	0.080-0.250	0.160	0.080	0.250
6	Nitrate (mg/l)	40	6.217	5.17-7.420	7.420	5.170	6.060
7	Sulphate (mg/l)	250			<0.001	<0.001	<0.001
8	Alkalinity (mg/l)	200	12.57	12.40-12.70	12.40	12,60	12.70
9	Carbonate (mg/l)		0.02	0.014-0.023	0.023	0.018	0.014
10	Hardness (mg/l)	150	53.67	41.90-56.80	56.80	62.30	41.90
11	DO (mg/l)	4.0	5.7	5.20-6.30	5.60	5.20	6.30
12	BOD (mg/l)	40	3	2.70-3.20	3.20	2.70	3.10
13	TSS (mg/l)	50	263.3	70-380	380	340	70
14	Iron (Fe) (mg/l)	0.3			<0.001	<0.001	<0.001
15	Lead (Pb) (mg/l)	0.03			<0.001	<0.001	<0.001

Table 2
SEDIMENT SAMPLES

S/N	Parameters	WHO Standard	Mean	Range	Sampling Stations/Results		
					FMC	Akanchawa road	Egbeada
1	pH	6.5 – 8.5	7.35	7.15 -7.64	7.15	7.27	7.64
2	Temperature ^{o}c	Ambient	26.67	26.4 – 27	26.4	26.6	27.0
3	Phosphate (mg/l)	5	0.85	0.070 -1.400	0.070	1.080	1.400
4	Nitrate (mg/l)	40	2.44	1.980 – 3.010	2.340	3.010	1.980
5	Sulphate (mg/l)	250	0.027	<0.01 – 0,070	0.010	<0.001	0.070
6	Iron (Fe) (mg/l)	0.3	2.432	1.188 – 2.735	3.373	1.188	2.736
7	Lead (mg/l)	0,05			<0.001	<0.001	<0.001

Table3
Mean of measured physiochemical and biological parameter of the surface water sample of Nworie River for the month of July,2010.

Parameter	WHO Standard	Mean	Range	Partially dredged	Dredged	Undredged	Standard deviation
pH	6.5-8.5	5.897	5.65-6.22	5.65	5.82	6.22	0.293
Conductivity (µs/cm)	100	113.000	84-155	100	84	155	37.242
TSD(mg/l)	250	56	47-76	50	42	76	17.776
TSS(mg/l)	50	18.333	13.26	26	16	13	6.808
turbidity NTU	50	42.333	2-73	73	52	2	36.474
Nitrate (mg/l)	40	9.033	4.7-12.4	12.4	4.7	10	3.939
Phosphate (mg/l)	5	2.427	0.35-1.72	1.72	0.56	0.35	2.303
Sulphate (mg/l	250	8.4000	2-13.1	13.1	10.1	2	5.742
Alkalinity (mg/l)	200	24.933	14.9-37.4	37.4	14.9	22.5	11.446
Chloride (mg/l)	200	12.533	8.5-16.2	16.2	12.8	8.5	3.807
DO(mg/l) BOD(mg/l	4.0	5.633	4.6-7.0	5.3	4.6	7.0	1.234
Calcium (ca mg/l)	70	0.727	0.08-1.9	1.9	0.2	0.08	1.018
Magnesium (mn mg/l)	0.5	0.217	0.01-0.6	0.6	0.04	0.01	0.332
Lead (Pb mg/l)	0.05	0.0433	0.02-0.08	0.08	0.03	0.02	0.032
Iron (Fe mg/l)	0.3	0.4100	0.27-0.62	1.62	0.48	0.29	0.7193
Zinc (Zn mg/l)	<1.0	0.567	0.4-0.7	0.6	0.4	0.7	0153
Manganese (Mn mg/l)	0.4	0.733	0.05-0.07	0.07	0.05	0.1	0.0252
Chromium (Cr mg/l)	0.1		BDL	BDL	BDL	BDL	
Copper (Cu mg/l)	0.3	0.8110	0.19-1.24	1.24	1.003	0.19	0.551
TOC (%)	5	BDL	BDL	BDL	BDL	BDL	
Aluminium (Al mg/l)	0.2	0.91	0.69-0.91	0.91	0.72	0.69	0.110
Cadmium (Cd mg/l)	0.003	0.046	0.02-0.052	0.046	0.052	0.02	0.173

Table 4: Mean of measured physiochemical and biological parameters of the sediment samples of Nworie River for the month of July, 2010.

Parameter	WHO Standard	Mean	Range	Partially dredged	Dredged	Undredged	Standard deviation
pH	6.5-8.5	5.243	5.24 – 5.67	5.36	5.24	5.67	0.222
Conductivity (µs/cm)	100	111.8000	104.00-118.80	112.6	104.0	118.8	7.432
Nitrate(mg/l)	40	0.3400	0.16-0.59	0.59	0.27	0.16	0.223
Phosphate(mg/l)	5	1.8500	1.65-2.08	2.08	1.65	1.82	0.217
Sulphate (mg/l)	250	1.8733	1.03-2.36	2.23	2.36	1.03	0.7332
Chloride (mg/l)	200	1.5300	1.30-1.82	1.82	1.47	1.30	0.2651
Calcium (ca mg/l)	70	0.377	0.14-0.62	0.37	0.62	0.14	0.24007
Magnesium (Mg mg/l)	0.5	0.0403	0.03-0.05	0.04	0.051	0.03	0.01050
Lead (Pb mg/l)	0.05	0.4343	0.26-0.61	0.61	0.433	0.26	0.17500
Iron (Fe mg/l)	0.3	0.7967	0.29-1.62	1.62	0.48	0.29	0.7193
Zinc (Zn mg/l)	<1.0	0.3567	0.003-0.75	0.75	0.32	0.003	0.3763
Manganese (Mn mg/l)	0.4	0.0457	0.00-0.08	0.081	0.062	BDL	0.04163
Copper (Cu mg/l)	0.3	0.9867	0.02-1.52	1.42	1.52	0.021	0.8387
TOC (%)		0.5467	0.34-0.68	0.62	0.34	0.68	0.18148
Aluminium (Al mg/l)		0.8433	0.24-1.26	1.03	1.26	0.24	0.53501
Cadmium (Cd mg/l)		0.0467	0.03-0.06	0.061	0.049	0.026	0.01528

Computation of Pollution Index Values

Using the Pollution Index Formular (PI) = $\frac{I}{n}\ \frac{M1}{(TL)1} + \frac{M2}{(TL)2} + \frac{M3}{(TLn)}$ the results of various sub indices of the parameters were given below:

Table 5 **Surface water (2014)**

Parameter	Mean value	Sub index
pH	6.4	0.9
Temp	30.6	1.09
Turbidity	112.23	2.2
Conductivity	60.84	0.608
Phosphate	0.163	0.033
Nitrate	6.217	0.155
Sulphate	<0.001	
Alkalinity	12.567	0.0629
Carbonate	0.02	
Hardness	53.67	1.073
DO	5.7	1.425
BOD5	3	0.075
TSS	263.33	5.267
Iron	<0.001	
Lead	<0.001	

Table 6 **Sediment (2014)**

Parameter	Mean	Sub index
pH	7.35	1.131
Temp	26.67	0.953
Phosphate	0.85	0.17
Nitrate	2.44	0.061
Sulphate	0.027	0.000108
Iron	2.432	8.106
Lead	<0.001	0.02

Table 7 **Surface water (2010)**

Parameter	Mean	Sub index
pH	5.897	0.907
Conductivity	113.00	1.13
TDS	56	0.224
TSS	18.333	0.3667
Turbidity	42.333	0.817
Nitrate	9.033	0.226
Phosphate	2.427	0.485
Sulphate	8.4000	0.034
Alkalinity	24.993	0.125
Chloride	12.533	0.062
DO	5.633	1.408
Calcium	0.727	0.010
Magnesium	0.217	0.434
Lead	0.0433	0.866
Iron	0.4100	1.367
Zinc	0.567	0.567
Manganese	0.733	1.833
Copper	0.8110	2.703
Chromium	BDL	
TOC	BDL	
Aluminium	0.91	4.55
Cadmium	0.046	1.533

Table 8 **Sediment (2010)**

Parameter	Mean	Sub index
pH	5.243	0.807
Conductivity	111.800 1.118	
Nitrate	0.3400	0.009
Phosphate	1.8500	0.37
Sulphate	1.8733	0.007
Chloride	1.5300	0.008
Calcium	0.377	0.005
Magnesium	0.0403	o.o806
Lead	0.4343	8.686
Iron	0.7967	2.656
Zinc	0.3567	0.3657
Manganese	0.0467	0.117
Copper	0.9867	3.289
Aluminium	0.8433	4.216
Cadmium	0.0467	15.567
TOC	0.5467	

Tables 1 and 2 showed the concentrations of the physicochemical and biological variables from surface water and sediment samples. Tables 3 and 4 showed the concentrations of the physicochemical and biological variables from water and sediment samples during dredging operation in 2010; while tables 5, 6,7 and 8 showed the computed pollution indices for surface water and sediments samples in the study period and during dredging in 2010.For the surface water, the mean of the measured parameters were within the standard limits with the exception of turbidity and TSS; while only Iron exceeded the limits for sediments(2.43mg/l).There was an increase in turbidity and TSS from the recorded values during dredging in 2010 with highest concentrations at FMC(142 NTU, 380mg/l respectively).This is an indication of increased sediment load which reduces the depth of the river thus endangering those aquatic species requiring specific depth for survival. Besides, the loaded rivers are murky or clouded and thus reduces light penetration. This phenomena is attributed to inefficient waste management in Owerri(Acholonu,2008).A rapid increase in turbidity and TSS attaining values of 11,398 NTU and 8,200mg/l respectively was reported after dredging of Warri River(Ohiamani,2008).

The Pollution indices were calculated by combining sets of organic and inorganic parameters to determine sub index unitless numbers and ranked the organic and inorganic variables in the total waste mix. For the surface water, index calculations during dredging in 2010 based on organic parameters like Total Dissolved Solids, Nitrates, Phosphates, Sulphates and DO gave an index of 0.475; while inorganic parameters such as TSS, Turbidity, Alkalinity, Chloride, Calcium, Magnessium and Zinc gave pollution index of 0.30.The mathematical calculation is as follows:

$$\text{P.I for organic} = \frac{1}{5}\left[\frac{56}{250} + \frac{9.333}{40} + \frac{2.427}{5} + \frac{8.4000}{250} + \frac{5.633}{30}\right] = 0.475$$

$$\text{P.I for inorganic} = \frac{1}{7}\left[\frac{18.333}{50} + \frac{42.333}{50} + \frac{24.933}{200} + \frac{12.5331}{200} + \frac{0.727}{70} + \frac{0.217}{0.5} + \frac{0.567}{1}\right] = 0.30$$

During the present study, calculation for organic variables based on Phosphate, Nitrate, DO and BOD gave an index of 0.4215, while inorganic parameters based on conductivity and alkalinity gave an index of 0.34.The mathematical calculations were as follows;

$$\frac{1}{4}\left[\frac{0.163}{5} + \frac{6.217}{40} + \frac{5.7}{4} + \frac{3}{40}\right]$$

PI = 0.4215.

For inorganic PI calculations based on conductivity and Alkalinity gave 0.34

$$\left[\quad\right]$$

$$PI = \frac{1}{2} \quad \frac{60.84}{100} + \frac{12.567}{200}$$

PI = 0.34.

For sediments, organic parameters based on phosphate, nitrate and sulphate gave an index of 0.077, while the mathematical combinations for inorganic parameters gave an index of 0.02. Similarly using the same formula the indices for sediments during dredging for organic parameters was 0.129 and inorganic parameters was 0.0527.

The values of the indices were below 1 which is an indication they were not toxic. This agrees with the results 0f the analysis where all those parameters did not exceed the standard limits set by world Health Organization, WHO. From the computed values of the indices, the organic variables had higher sub index scores than inorganic variables indicating that they contributed more in the overall waste mix of Nworie River. This agrees with the work of other researchers that Nworie River was polluted by organic wastes (Nnaji & Duru, 2006, Umunnakwe *et al*.,2011, Acholonu *et al*.,2008)

Conclusion

The discharge of untreated waste from different sources of intensive human activities into Nworie River altered the water quality as shown by the result of analysis. However most of the analyzed variables were within the standard limit set by World Health Organization. The mean pH of 6.4 for the surface water shows a bit of slight acidity (though 5.82 during dredging). The mean turbidity and TSS recorded the highest values at Federal Medical Center (142NTU, 380mg/g respectively). The mean Iron value of 2.43mg/l for sediment exceeded the standard limit set by World Health Organization. The comparison of the results in this present survey to values obtained during the dredging of the river in 2010 indicates that the water quality is deteriorating as a result of continuous poor waste management in Owerri. Most of these wastes are from organic sources. The study further showed that pollution index based on the ratio

(PI) = $\frac{I}{n} \quad \frac{M1}{(TL)1} + \frac{M2}{(TL)2} + \frac{M3}{(TLn)}$ can reasonably be used as an index for monitoring the effect of poor municipal waste discharge in Nworie River and contributions by various classes of waste.

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