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Impact of Physico-Chemical and Biological Parameters of Water Quality on Fish Survival in Warri River, Southern Nigeria

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ABSTRACT

The study examined the impact of physico-chemical and biological parameters of water quality on fish survival in Warri River in Southern Nigeria. It is an empirical research work that involved field collection of water samples from six sampled sites along the course of the river and laboratory analysis of the water samples collected. The result was compared with approved water standard for fish survival. The analysis showed that variations exist in the physico-chemical and biological parameters examined. Thus, such parameters as pH, conductivity, temperature, turbidity, DO, BOD, hydrocarbon, TSS, alkalinity, bicarbonate, coliform, magnesium, calcium, and lead fell within the recommended water quality standard for fish survival while parameters such as ammonia, nitrate, COD, chloride, zinc, and iron were above the recommended standard. However, the quality of water from Warri River does not differ significantly from the approved water standard for fish survival at r = –0. 0414, hence the water is good for fish breeding and fish survival. Period testing of the river water and routine monitoring of human activities being carried out from time to time within the catchment area of the river were recommended to help check impairments and address issues of fish kills and boost fish production in the area.

Keywords: impact, physico-chemical, parameters, water, quality, survival, fish

INTRODUCTION

Many aquatic organisms especially fishes are sensitive to the amount of physico-chemical and biological constituents of the water they live in. Changes in the amount of temperature, pH, conductivity, turbidity, dissolved oxygen, biochemical oxygen demand, ammonia, nitrate, coliform, magnesium, calcium, lead, zinc, amongst other parameters affect the survival of fish in surface and sub-surface water.

Water bodies will naturally show changes in temperature seasonally and daily. However, man-made changes to stream water temperature will affect fish's ability to reproduce. Many rivers will exhibit vertical temperature gradients as the sun will warm the upper water while deeper water will increase in temperature as the river flows downstream through urban, industrial and agricultural areas. For example, a river in forested headwaters will be at a suitable temperature to determine whether it is increasing or decreasing in order to account for its impact on fish survival.

Also, in water bodies such as lakes, rivers and streams, high turbidity levels can reduce the amount of light reaching lower depths, which can inhibit growth of submerged aquatic plants and consequently affect species which are dependent on them. This phenomenon has been observed regularly throughout the Chesapeake Bay in the eastern United States (USEPA, 2005). For many mangrove areas, high turbidity is needed to support certain species such as to protect juvenile fish from predators. For most mangroves along the eastern coast of Australia, in particular Moreton Bay, turbidity levels as high as 6 Nephelometric Turbidity Units (NTU) are needed for proper ecosystem functioning (McIsaac, David, Gertner, & Goolsby, 2001).

In natural waters, the pH scale runs from 0 to 14. A pH value of 7 is neutral; a pH less than 7 is acidic and pH greater than 7 represents base saturation or alkalinity. Changes in the pH can be indicative of an industrial pollutant, photosynthesis or the respiration of algae that is feeding on contaminants (Warrick, 2003). Most ecosystems are sensitive to changes in pH and the monitoring of pH has been incorporated into the environmental laws of most industrialised countries (WHO, 1996). pH is typically monitored for assessments of aquatic ecosystems such as the survival of fish, health, recreational waters and drinking water sources.

More so, in surface water, the concentration of dissolved oxygen is of concern to the survival of fish. In general, waters contaminated with fertilizers, suspended materials or petroleum by-products, micro-organisms such as bacteria will break down the contaminants. The oxygen will be consumed and the water will become anaerobic. Typically, DO levels less than 2mg/l will kill aquatic lives especially fishes (Dupree, 2004).

To maintain good growth, fish must have an optimum level of nitrate for survival. On surface water, nitrate will become toxic to fish at about 30mg/l. nitrate pollution will cause eutrophication of a stream where algae and aquatic plant growth will consume the oxygen and increase the total suspended solids of the water. Eutrophication is usually the result of nitrate and phosphate contamination and is a significant reduction of water quality (McIsaac, 2003).

Also, in unpolluted water, trace amounts of ammonia are present from the reduction of atmospheric nitrogen by aquatic microrganisms. Natural seasonal fluctuations can occur from the death and decay of phytoplankton, bacteria and other aquatic organisms. The bottom anoxic waters of rivers may contain higher levels of ammonia as the decayed material settles at the bottom. Natural unpolluted waters can be 0mg/1 to 3mg/l higher concentrations correspond to pollution and can be toxic to fishes.

In general, other physico-chemical and biological parameters such as calcium, magnesium, iron, zinc, potassium, ammonia and total coliform are studied in the light of their impact on fish survival. These parameters coupled with the effects of geologic and anthropogenic inputs including mismanagement of resources have impacted changes, either negatively or positively on the water quality for the survival of fish. An understanding of the hydrology and physico-chemical and biological indices of surface water will not only be useful in assessing fish survival but will also permit a better insight into the life cycle of the fish community.

Warri River flows from Utagba- Uno, covering a surface area of about 255sq.km with a length of about 150km (Netherlands Engineering Consultants (NEDECO), 1961) and runs in a south-west direction passing through Amai, Otorho–Abraka, Oviorie and Ovu Inland and southwards through Agbarho to Otokutu and Ugbolokposo (Egborge, 2001). It stretches to Effurun and forms a "W" shape between Effurun and Warri. The Warri River also flows through such settlements as Enerhen, Igbudu, Ovwian and Aladja. The Warri River empties its water into the Atlantic Ocean through the Forcados estuary (see figure 1). The inhabitants of these settlements depend on the water from the river for domestic, recreational, transportation, fishing, agricultural, and industrial purposes. However, impairments as a result of geologic and anthropogenic activities of man on the quality of water from the river have been reported. These may have had a negative impact on the quality of water from the river for human uses and consequently on the survival of fish and other marine organisms. This study therefore seeks to examine the impact of physico-chemical and biological parameters of water quality on the survival of fish in Warri River, Southern Nigeria in order to determine whether these parameters adversely influence the growth of fish along the course of the river.

Prevailing Trend

The production of fish from inland waterways is under threat from excessive concentration of physico-chemical and biological parameters of water quality. Accordingly, toxic pollutants, such as heavy metals, phenols, and insecticides that have direct and indirect adverse effects on aquatic biota have found their way into surface water bodies either through run-offs or through geologic and anthropogenic activities of man. Most of the industries located along the course of the river discharge their wastes directly or indirectly through run-off into the river. Also, auto-mechanics, abattoir waste, domestic sewage, and refuse also find their way into the river body; thus leading to an increase or decrease in the physico-chemical and biological indices of the water. This variation in the amount of physico-chemical and biological parameters of the water could lead to a decrease or increase in fish breeds along the course of the river. However, of detrimental consequences were the numerous complaints from fishermen of low fish catches along the course of the river. According to the Global Environment Monitoring Systems, sewage, toxic metals, industrial, and agricultural chemicals are the main sources of river pollutants. The need to assess those pollutants whether they are increasing or decreasing in the light of water quality for the survival of fish along the Warri River underscores the need for this study.

Aim and Objectives

The aim of the study was to access the impact of physico-chemical and biological parameters of water quality on fish survival in Warri River, Southern Nigeria. Specifically, the study sought to:

1. Assess the quality of water along the course of the river.
2. Ascertain if the quality of water from the river is good for fish survival in the area or not.
3. Suggest ways on how to check the variation in water quality (if any) and hence achieve sustainable fish production along the course of Warri River.

Hypothesis

Ho: There is no significant relationship between the physico – chemical and biological indices of water quality from Warri River and approved water quality standard for fish survival.

METHODOLOGY

The study is an empirical research work. It involved field collection of water samples along the course of Warri River and laboratory analysis of the water samples collected.

Method of Data Collection

The river was divided into three sections – the upper course, middle course and lower course and two sampling points, each chosen from each section (Figure 1). A total of six sampling points were used for the study. The sampling points were chosen from settlements located along the course of the river through the simple random sampling technique. The six sampling points were chosen from the three sections of the river fore even representation of all sections of the river and for a full coverage of the entire river. The sampling points were Utagba-Uno and Ukabi in the upper course, Ovu and Agbarho in the middle course and Warri and Ode–Itsekiri in the lower course.

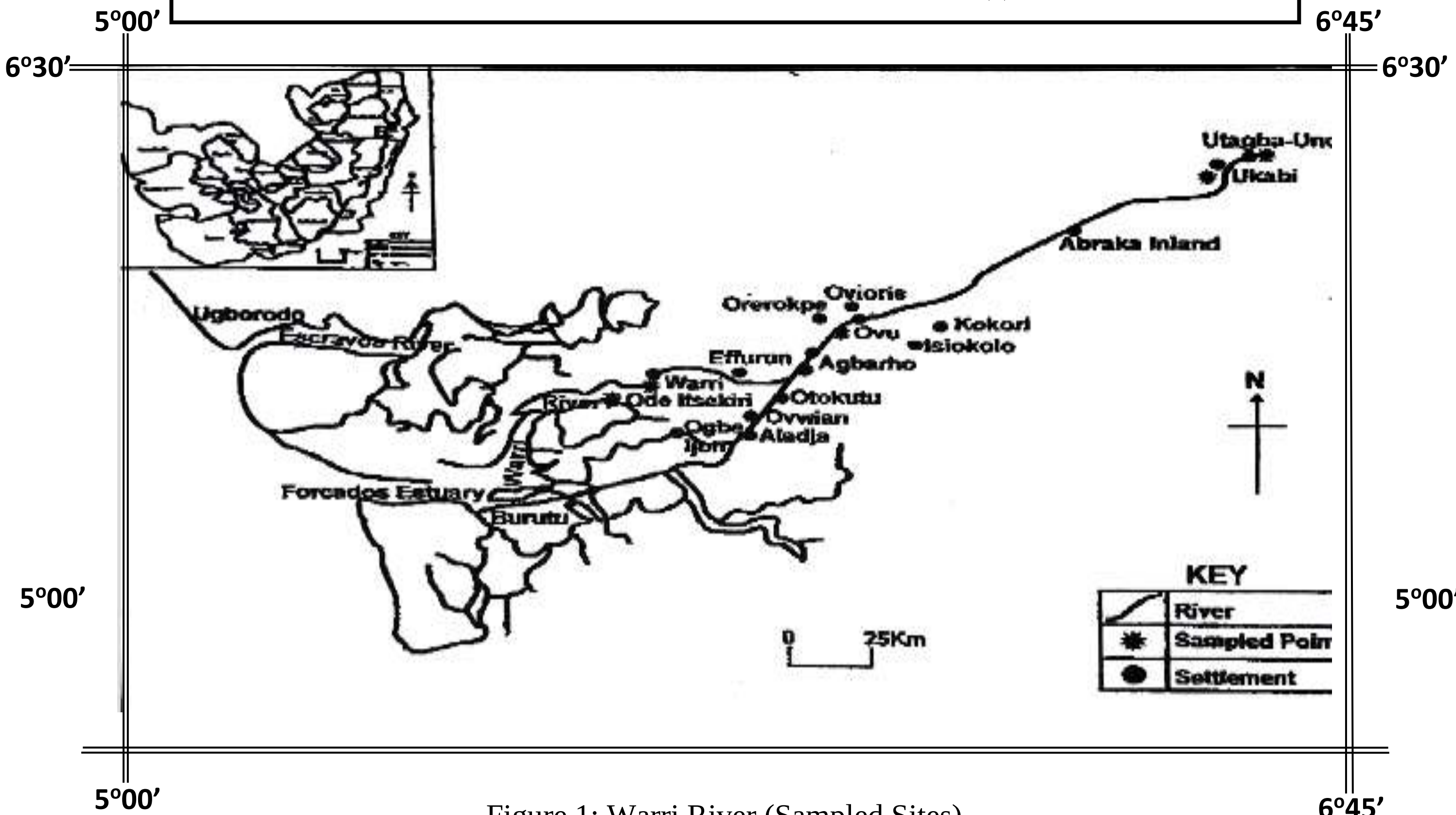

Figure 1: Warri River (Sampled Sites)

Source: Fieldwork, 2020.

The systematic random sampling technique was used for the collection of water samples along the course of the river at varied measured distances using a 2–litre sterilised plastic can for the collection. The water samples were collected early in the morning between 7am and 10am to reduce the effect of temperature on the collected samples. All the water samples were collected from the upper, middle, and lower courses of the river. A total of 12 water samples each were collected from the six (6) sampling points at an average of one sample each month from January, 2020 to December, 2020. The water samples were collected from the surface and sub-surface of the river. All collected water samples were securely corked, labeled, and stored in ice-packed container before transporting them to the laboratory for analysis. This was done within 6 hours of collection. All collected water samples were allowed to settle down before any form of laboratory analysis was carried out on them. This was to eliminate any form of turbidity influence on test.

The materials that were used for the analysis include: a pH meter, turbidity meter, sterilised beakers, conical flask, pipette, burette, measuring cylinder, spectrophotometer, hot plate, sterile plastic, metric dishes, and reagents such as potassium chromate, indicator solution, stock nitrate solution, concentrated nitric acid, buffer solution, ammonium acetate, stock iron solution, and some improvised equipment such plastic containers and coolers. The apparatus and reagents are standardised equipment recommended and validated by the World Health Organisation (WHO, 2010), United States Environmental Protection Agency (USEPA, 2002), and the Nigerian Industrial Standard (NIS, 2007) for testing water quality. The United States Department of Agriculture and Cooperative Extension Services (USDACES, 2002) standard was used as impact criteria. The posited hypothesis was tested using Pearson Product-Moment Correlation Coefficient (r).

RESULTS AND DISCUSSION

The minimum, maximum, and mean values of the analysed water quality parameters of Warri River are summarised in Table 1 in order to maintain a balance between the analysed water quality indices and approved water quality standard for the survival of fish along the course of the river.

Table 1 Physico-Chemical Characteristics for the Survival of Fish in Warri River

Parameters	Water Quality Values			Standard Water Quality Criteria for Fish	Remarks
	Min	Max	Mean		
pH	5.883	6.98	6.70	6.5 – 10.0	Satisfactory
Conductivity (us/em)	35.42	626.11	318.72	400us/cm	Satisfactory
Temperature (0C)	27.50	30.61	28.80	0^0 - 30^0C	Satisfactory
Turbidity (NTU)	5.12	21.39	9.72	20,000NTU	Satisfactory
DO (mg/1)	3.41	6.24	5.07	5mg/1	Satisfactory
BOD (mg/1)	2.38	4.97	3.48	3.0 – 6.0mg/1	Satisfactory
Ammonia (mg/1)	4.15	6.15	4.71	0.0125mg/1	Not Satisfactory
Nitrate (mg/1)	0.96	4.52	2.21	0.03mg/1	Not Satisfactory
Hydrocarbon (mg/1)	4.72	16.04	9.86	200mg/1	Satisfactory
TSS (mg/1)	4.64	28.71	12.27	80mg/1	Satisfactory
COD (mg/1)	10.42	70.41	27.91	3.0 – 6.0mg/1	Not Satisfactory
Alkalinity (mg/1)	29.46	65.41	43.08	10 - 400mg/1	Satisfactory
Bicarbonate (mg/1)	10.11	43.58	20.91	100mg/1	Satisfactory
Chloride (mg/1)	0.09	0.36	0.23	0.04mg/1	Not Satisfactory
Coliform Count (100ml)	15.40	58.46	33.24	200/100mg/1	Satisfactory
Magnesium (mg/1)	3.95	36.67	13.26	Needed for buffer system	Satisfactory
Calcium (ppm)	7.36	30.89	11.41	160ppm	Satisfactory
Lead (ppm)	<0.001	0.002	0.001	0.03ppm	Satisfactory
Zinc (ppm)	0.16	1.42	0.76	0.05ppm	Not Satisfactory
Iron (ppm)	0.24	2.01	0.86	0.15ppm	Not Satisfactory

Source: Fieldwork, 2020

As shown in Table 1, pH values in Warri River range between 5.83 at Warri to 6.98 at Ovu with a mean value of 6.70 while conductivity values which range from 35.32us/cm to 626.11us/cm with a mean value of 318.72us/cm were recorded in the area. Temperature along the course of the river ranges from 27.50^{o}C to 30.61^{o} and a mean value of 28.80^{o}c was recorded in the area. Also, along the course of Warri River, turbidity values of 3.48NTU to 21.39NTU were recorded. In terms of dissolved oxygen (DO), the recorded values range from 3.41mg/1 to 6,24mg/1 with a mean value of 5.07mg/ while biochemical oxygen demand (BOD) values range from 2.38mg/1 to 4.97mg/1 with a mean of 3.84mg/1. These recorded values of pH, conductivity, temperature, turbidity, DO, and BOD are in line with the work of Egborge (1994), Ofem et al. (2011), Dupree (2004), and Asuquo (1999) who obtained similar results in their separate studies of water quality of fish survival. These results are satisfactory and are in line with approved water quality standard for fish survival. These values according to Egborge (1994) are suitable for fish breeding especially catfish and tilapia, which are found in the waters of the Niger Delta region of Nigeria.

However, in Warri River, ammonia values range from a minimum of 4.15mg/1 to a maximum of 6.15mg/1 with a mean value of 4.y1mg/1 while nitrate values range from a minimum value of 0.96mg/1 to a maximum value of 4.52mg/1 and a mean value of 2.21mg/1. The high values recorded for ammonia and nitrate are not satisfactory for the survival of fish. But according to Rottman and Shireman (2003), natural waters such as rivers, ammonia may never reach dangerous high levels because of the low densities of fish. This implies that the mean value of 4.71mg/1 recorded in the area as against 0.0125mg/1 standard criterion for the survival of fish may not affect the survival of fish along the course of the river. Notwithstanding, the high values of nitrate recorded in the area may lead to algae bloom and eutrophication (Egborge, 1994).

In Warri River, hydrocarbon values vary from 4.72mg/1 to 16.04mg/1 with a mean value of 9.86mg/1 while total suspended solids (TSS) values vary from 4.64mg/1 at Utagba-Uno to 28.71mg/1 at Warri. A mean value of 12.27mg/1 was however recorded in the area. These values are satisfactory and fall within the approved standard water quality criteria for fish breeding. Furthermore, alkalinity values range from 29.46mg/1 to 65.41mg/1 with a mean value of 43.08mg/1 along Warri River. These values corroborate the works of Ofem et al. (2011) in a similar study along Ikwori Lake, South-Easter, Nigeria. Also, bicarbonate values vary from 10.11mg/1 to 43.58mg/1 with a mean value of 20.91mg/ in the area. However, chloride values recorded in the area were high, ranging from a minimum of 0.09mg/1 as against 0.04mg/1 approved standard for fish survival.

In the study area, coliform values vary from a minimum of 15.40/100ml to a maximum of 58.46/100ml with a mean value of 33.24/100ml. This value is satisfactory and shows no high level of faecal pollution of the river water. Also, the amount of magnesium recorded along the course of Warri River varies from a minimum of 3.95mg/l to a maximum of 36.67mg/l with a mean value of 13.26mg/1. These values are satisfactory and are needed as buffer for fish production along the course of the river. Also, the mean values of lead (0.001ppm) and calcium (11.41ppm) found along the course of the river are satisfactory and suitable for fish production in the area. However, the mean values of zinc (0.76ppm) and iron (0.85ppm) are higher than the approved standard of 0.05ppm and 0.15ppm for zinc and iron respectively. The implication of this is that excess zinc has a depressive effect on the tissue of different species of fish found in the area (Mungan, 2008) while excess concentration of iron affects the reproduction and feeding habits of fish (Andromeda, 2011).

Test of Hypothesis

The hypothesis which states that "there is no significant relationship between the physico-chemical and biological indices of water quality from Warri River and approved water quality standard for fish survival was tested using the Pearson Product-Moment Correlation Coefficient (r) as shown in Table 2.

Table 2: Pearson Product-Moment Correlation Coefficient (r) Determination

X	Y	X-M_X	Y-M_Y	(X-M_X)^2	(Y-M_Y)^2	(X-M_X) (Y-M_Y)^2
10.0	6.70	-1064.866	-20.960	1133938.799	439.324	22319.637
400	318.72	-674.866	291.060	455443.612	84715.894	196426.335
30	28.80	-1044.86	1.140	1091744.174	1.299	-1191.095
20000	9.72	-18925.134	-17.940	358160711.112	321.894	-339517.857
5	5.07	-1069.866	-22.590	1144612.456	510.310	24168.318
6.0	3.48	-1068.866	-24.180	1142473.724	584.675	25845.224
0.0125	4.71	-1074.836	-22.950	1155309.240	526.705	24667.933
0.03	2.21	-874.866	-25.450	1155271.621	647.705	27354.620
200	9.86	-994.866	-17.800	765389.862	316.842	15572.652
80	12.27	-1068.866	-15.390	989757.612	236.854	15311.032
6.0	27.91	-674.866	0.250	1142473.724	0.062	-267.163
400	43.08	-974.866	15.420	455443.612	237.775	-10406.394
100	20.91	-1074.826	-6.750	950362.987	45.563	6580.392
0.04	0.23	-974.866	-27.430	1155250.124	752.408	29482.521
100	33.24	-1074.866	5.580	950362.987	31.136	-5439.701
0.00	13.26	-914.866	-14.400	1155336.112	207.361	15478.119
160	11.41	-914.866	-16.250	836979.112	264.064	14866.612
0.03	0.001	-1074.836	-27.659	1155271.621	765.023	29728.932
0.05	0.76	-1074.816	-26.900	1155228.628	723.613	28912.594
0.15	0.86	-1074.716	-26.800	1155013.675	718.243	28802.432

X values
$\sum = 21497.312$
Mean = 1074.866
$\sum(X - M_X)^2 = SS_X = 377306374.792$
Y values
$\sum = 553.201$
Mean = 27.26
$\sum(Y - M_Y)^2 = SS_Y = 92046.701$
X and Y combined
N = 20
$\sum(X - M_X)(Y - M_Y) = -244157.547$
r calculation
$r = \sum((X - M_X)(Y - M_Y))/\sqrt{((SS_X)(SS_Y))}$
$r = 244157.547/\sqrt{((377306374.792)(92046.701))}$
$r = -0.0414$; $r^2 = 0.0017$
The value of r is –0.0414. Therefore, the relationship between the variables is weak. There is a negative correlation. This implies the rejection of the null hypothesis and the acceptance of the alternative hypothesis, which signifies that there is a significant relationship between the physico-chemical and biological parameters of water from Warri River and approved water quality standard for fish survival. Conclusively therefore, the quality of water from Warri River is favourable for the survival and breeding of fish in the area.

Findings
Based on the aims and objectives of the study, the following findings emerged:
1. There is a variation in the concentration of physico-chemical and biological parameters of the water samples examined along the course of Warri River.

2. The values of pH, conductivity, temperature, turbidity, DO, BOD, hydrocarbon, TSS, alkalinity, bicarbonate, coliform, magnesium, calcium, and lead are within the approved water quality standard for fish survival and are therefore favourable for fish survival along the course of Warri River.
3. The level of concentration of ammonia, nitrate, COD, chloride, zinc, and iron are above the recommended standard for the survival of fish. As a result, they do not favour the breeding and survival of fish in the area.
4. The quality of water from Warri River is in line with the approved standard of water quality for fish survival; hence the concentration of physico-chemical and biological parameters examined along the course of the river favours the breeding and survival of fish in the area.

CONCLUSION

The study discovers that variations exist in the concentration of physico-chemical and biological parameters of the water quality along the course of Warri River. The variation is caused by geologic and anthropogenic activities of man within the catchment area of the river. Despite these variations, most of the parameters examined fell within the approved water quality standard for the survival of fish. Thus, the water from Warri River in the parameters examined amongst other factors is favourable for the survival of fish, hence fish breeding and production are encouraged along the course of the river.

RECOMMENDATIONS

The following are additional precautionary measures for improving on the present state of the water from the river in order to ensure maximum fish production along the course of the river for the benefit of mankind:

1. The river's water should be monitored from time to time through periodic testing to ascertain if the concentration of the physico-chemical and biological parameters are increasing or decreasing.
2. Anthropogenic activities of man such as industrial, agricultural and mining, including wastewater generation be monitored to check impairments caused by them on the water body.
3. Indiscriminate fishing and use of chemicals along the course of the river should be discouraged to allow for the growth of fingerlings before actual harvest is carried out.

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