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Evaluation of Water Quality of Eleyele River, Oyo State using Water Pollution Index, Heavy-Metal Pollution and Evaluation Index

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Abstract
Water is an essential resource to sustaining life. The quality of water depended on its usage since it could pose public detrimental health and environmental threats. The assessment of water quality is very essential to both public health and aquatic life.
Water Samples were collected at the surface and at 1m depth in triplicates bi-monthly for 6 months from November 2010 to April 2011 at five stations. The following parameters; pH, Temperature, Conductivity, DO, Nitrate, Nitrite, Phosphate and metals; Mg, Fe, Cu, Zn, Cr, Pb, Cd, Ni were analysed according to standard methods. Water Pollution Index (WPI), Heavy-metal Pollution Index (HPI) and Heavy-metal Evaluation Index (HEI) were used to evaluate the water quality and heavy-metal pollution level in the water body.The physico-chemical parameters fall within the range of standards provided by WHO, except for dissolved Oxygen and Conductivity. The levels of the metal followed the trend Mg>Fe>Cr>Pb>Zn at the surface and Mg>Fe>Pb>Zn at 1m depth. Some metals were not detected in the water sample at both levels (Cu, Cd and Ni), Cr however, was detected at the surface but not at 1m depth and the concentration was within limit of the standard. Mg had values within the standard, while, Fe, Zn and Pb had values higher than the WHO standard at both surface and 1m depth. The WPI at the surface was 0.260 and at 1m depth was 0.257. HPI values are 59.68 and 86.34 for both surface and at 1m depth respectively. HEI on the other hand have values at the surface, 6.81 and 1m depth, 7.44. There is a need for conscious effort geared towards improving the quality of water in terms of metal pollution in the water body.
Keywords: *Water Pollution Index, Heavy-metal Pollution Index, Heavy-Metal Evaluation Index, Eleyele*

Introduction

Quality and quantity of freshwater is of great importance to human existence and the survival of all living components in the ecosystem. Water quality issues are complex and diverse and it deserves urgent global intervention (Breabăn, *et. al*., 2012). Water is an essential resource to sustaining life. The quality of water depended on its usage since it could pose public detrimental health and environmental threats (Mukate, *et. al.*, 2019; Hossain and Patra, 2020).

The most available water source for most urban–rural communities in developing countries, including Nigeria, are surface waters (rivers, streams, ponds and lakes) and groundwater (in form of boreholes and hand-dug wells). Surface waters in Nigeria are usually contaminated with domestic, agricultural, and industrial wastes and

it causes many water-borne diseases and ill health to living organisms (Ojekunle, 2000; Ayeni, *et. al*., 2009). The assessment of water quality is very essential to both public health and aquatic life. (Ouyang, 2005). Different water assessment indices have been employed in the evaluation of water quality for human use.

Water Pollution Index (WPI) as developed by Hossain and Patra, (2020) is an integrated tool used for evaluating water quality. It transforms water parameters to a single value index which helps to categorize the quality. It also allows for little changes in the level of any measured parameters to be noticed.

Heavy Metal Pollution Index (HPI) is an effective tool used in determining the quality of water based on its heavy-metal concentrations. HPI is described as a rating that reflects the combined impact of various measured heavy metals on water quality.

Heavy Metal Evaluation Index (HEI) as HPI, provides the overall trend in water quality in terms of heavy-metal and metalloid contamination (Edet and Offiong, 2002).

Materials and Methods

Description of sampling area

The study area was a man-made lake, located on latitude $7^0$20`-$7^0$25`N, longitude $3^0$51`-$3^0$56`E and was constructed by Water Corporation of Oyo State in 1939 by damming River Ona within the Ibadan metropolis. The lake covers part of Eleyele area, Ijokodo, Apete, Awotan, Ologun-eru, Agbaje, Idi-Osan, and the Polytechnic of Ibadan. The Ilajes and Yorubas are the dominant fishing communities at the lake (Olagbemide, 2017). The major livelihood activity at the lake is fishing; others include car washing, block making, laundry, automobile repairing, farming, cassava processing etc.

Field Sampling

Water Samples were collected at the surface and at 1m depth in triplicates bi-monthly for 6 months from November 2010 to April 2011 at five stations. Samples were collected at the surface using sample bottles and at the 1m depth using a Kemmerer water sampler. Water samples were kept in an acid washed polypropylene for metals and a glass bottle for other chemical parameters.

Laboratory Analyses

Water samples collected at both the surface and 1m depth were subjected to chemical analysis. The following parameters; pH, Temperature, Conductivity, DO, Nitrate, Nitrite, Phosphate and metals; Mg, Fe, Cu, Zn, Cr, Pb, Cd, Ni were analysed according to standard methods of APHA/ AWWA/WEF, (1998).

Assessment of Water Contamination

Water Pollution Index (WPI)

WPI is computed using the function:

$$WPI = \frac{1}{n}\sum_{i=1}^{n} PL$$

$$PL = 1 + \left(\frac{I_c - S_d}{S_d}\right)$$

Where PL refers to Pollution Load, S_d is standard or the highest permissible limit for the various variables considered, I_c is observed concentration of the ith parameter, WPI is Water Pollution Index and n is number of parameters. Hossain and Patra, (2020) classified WPI as follows:

Value	Indication
< 0.5	Excellent water
0.5–0.75	Good water
0.75–1	Moderately polluted water
> 1	Highly polluted water

Heavy Metal Pollution Index (HPI)

The Heavy-Metal Pollution Index (HPI) and the Heavy-Metal Evaluation Index (HEI) were used to assess the combined impact of different metals on the overall quality of surface water. In the present study, seven metals (Fe, Ni, Cu, Zn, Cd, Pb, Cr and Mg) were assessed for the calculation of HPI and HEI.

HPI was calculated by these equations (Abdel-Satar, *et. al*., 2017).

$$HPI = \frac{\sum_{i=1}^{n}(Q_I\, W_I)}{\sum_{i=1}^{n} W_I}$$

$$Q_I = \frac{M_I}{S_I}\, X\, 100$$

where Q_i is the sub-index of the ith parameter, W_i is the unit weightage of the ith parameter (mg/l), and n is the number of the considered chemical parameters. M_i and S_i are the concentrations of the monitored ith parameter and the standard maximum allowable values (mg/l).

$$W_I = \frac{1}{S_I}$$

where the weightage unit (W_i) is inversely proportional to the maximum concentration allowed

The critical HPI value is 100, and the HPI values above 100 are reported to cause greater damage to health (Setia, *et. al*., 2020, Tokatlı, and Varol, 2021).

Status category of HPI of water

0-25	Very good
26-50	Good
51-75	Poor
>75	Very poor

Heavy Metal Evaluation Index (HEI)

HEI was calculated by equation

$$HEI = \sum_{i=1}^{n} \frac{H_c}{H_{mac}}$$

where H_c is the monitored value of the ith parameter (mg/L) and H_{mac} the maximum admissible concentration of the ith parameter (Shil and Sing, 2019, Varol and Tokatlı, 2021). The HEI classifies the water as low (HEI < 10), medium (10 < HEI < 20), and highly polluted (HEI > 20) (Rezae, *et. al*., 2019).

Results and Discussion

The results of the physico-chemical parameters and the heavy-metal analysis of water samples are given in the tables below. The physico-chemical parameters fall within the range of standards provided by WHO, (2011) as shown in Table 1, except for dissolved Oxygen and Conductivity. These two parameters were observed to be very low compared with the WHO standard at both the surface and at 1m depth. It has been established that DO and Conductivity decreases with water depth and this was also observed to be true in this study. Levels of DO in a water body is dependent on various factors including the amount of photosynthesis, water temperature and the quantity of dissolved oxygen used up for respiration. Other factors could be decaying organic matter from aquatic plants and algae around the water body, and weather changes. Decaying algae and plants use up dissolved oxygen produced from photosynthesis thereby reducing available DO for aquatic life. Conductivity is one parameter that increases with salinity, therefore freshwater bodies are usually low in conductivity because of their low salinity.

From Table 2, the levels of the metal followed the trend Mg>Fe>Cr>Pb>Zn at the surface and Mg>Fe>Pb>Zn at 1m depth. Some metals were not detected in the water sample at both levels (Cu, Cd and Ni), Cr however, was detected at the surface but not at 1m depth and the concentration was within limit of the standard. Mg had values within the standard, while, Fe, Zn and Pb had values higher than the WHO standard at both surface and 1m depth.

Table 1: Physico-chemical parameters of water at the surface and 1m depth with WHO standards

Parameters	Surface	1m depth	WHO Standard
Ph	6.914	6.804	6.5-8.5
Temperature (^oC)	26.13	26.24	25-32
TDS (mg/l)	151.8	170.4	30-200
Conductivity (µs/cm)	0.308**	0.34**	50-500
DO (mg/l)	1.148**	0.804**	5
Nitrate (mg/l)	0.51	1.006	0.1-3
Nitrite (mg/l)	0.062	0.078	≤0.5
Phosphate (mg/l)	0.036	0.076	0.12

** Values are lower than the recommended standard

Table 2: Heavy-Metal levels in water at the surface and 1m depth with WHO standards

Metals	Surface	1m depth	WHO Standard
Magnesium (mg/l)	7.276	7.494	20
Iron (mg/l)	0.672*	0.564*	0.3
Copper (mg/l)	Nd	nd	2
Zinc(mg/l)	0.0106*	0.0258*	0.01
Chromium (mg/l)	0.041	nd	0.05
Lead (mg/l)	0.02325*	0.026*	0.01
Cadmium (mg/l)	Nd	nd	0.003
Nickel (mg/l)	Nd	nd	0.02

*Values are higher than the standard limit

Table 3: WPI of Water sample at the surface

Water parameters	I_c	S_d	I_c-S_d	$(I_c-S_d)/S_d$	$PL=1+(I_c-S_d)/S_d$	WPI
Ph	6.914	8.5	-1.586	-0.1865882	0.81341176	**0.26014395**
Temperature (^oC)	26.126	35	-8.874	-0.2535429	0.74645714	
TDS (mg/l)	151.8	600	-448.2	-0.747	0.253	
Conductivity(µs/cm)	0.308	500	-499.692	-0.999384	0.000616	
DO (mg/l)	1.148	5	-3.852	-0.7704	0.2296	
Nitrate (mg/l)	0.51	50	-49.49	-0.9898	0.0102	
Nitrite (mg/l)	0.062	3	-2.938	-0.9793333	0.02066667	
Phosphate (mg/l)	0.036	5	-4.964	-0.9928	0.0072	
					2.08115157	

The Water Pollution Index (WPI) is given in Tables 3 and 4, at the surface was 0.260 and at 1m depth was 0.257, both values are (WPI <0.5) classified to be "excellent water" according to the WPI classifications by Hossain and Patra, (2020). HPI values from tables 5 and 6 are 59.68 and 86.34 for both surface and at 1m depth respectively. These values fall below the HPI critical value which is 100. According to the guide provided, HPI value for the water at the surface indicated the water quality is poor and at 1m depth indicated that the water is very poor as regards metal pollution in the water body. HEI on the other hand have values at the surface, 6.81 and 1m depth, 7.44 (tables 5 and 6). Both values are considered to indicate that the water has "low pollution" (HEI<10) from the metals detected in the water body.

Table 4: WPI of Water sample at 1m depth

Water parameters	I_c	S_d	I_c-S_d	$(I_c$-$S_d)/S_d$	$PL=1+(I_c$-$S_d)/S_d)$	WPI
pH	6.804	8.5	-1.696	-0.1995294	0.80047059	**0.25710882**
Temperature (^oC)	26.236	35	-8.764	-0.2504	0.7496	
TDS (mg/l)	170.4	600	-429.6	-0.716	0.284	
Conductivity (µs/cm)	0.34	500	-499.66	-0.99932	0.00068	
DO (mg/l)	0.804	5	-4.196	-0.8392	0.1608	
Nitrate (mg/l)	1.006	50	-48.994	-0.97988	0.02012	
Nitrite (mg/l)	0.078	3	-2.922	-0.974	0.026	
Phosphate (mg/l)	0.076	5	-4.924	-0.9848	0.0152	
					2.05687059	

Table 5: HPI and HEI of Metals at the Water Surface

Metals	Mi	Si	Qi	Wi	QiWi	HPI	Hc/Hmac	HEI
Mg(mg/l)	7.276	20	36.38	0.05	1.819	**59.6797**	0.3638	**6.8088**
Fe(mg/l)	0.672	0.3	224	3.333	746.667		2.24	
Cu(mg/l)		2	0	0.5	0		0	
Zn(mg/l)	0.0106	0.01	106	100	10600		1.06	
Cr(mg/l)	0.041	0.05	82	20	1640		0.82	
Pb(mg/l)	0.02325	0.01	232.5	100	23250		2.325	
Cd(mg/l)		0.003	0	333.33	0		0	
Ni(mg/l)		0.02	0	50	0		0	
				607.217	36238.49			

Table 6: HPI and HEI of Metals at 1m depth of Water

Metals	Mi	Si	Qi	Wi	QiWi	HPI	Hc/Hmac	HEI
Mg(mg/l)	7.494	20	37.47	0.05	1.8735	**86.34239**	0.3747	**7.4347**
Fe(mg/l)	0.564	0.3	188	3.33333	626.6667		1.88	
Cu(mg/l)		2	0	0.5	0		0	
Zn(mg/l)	0.0258	0.01	258	100	25800		2.58	
Cr(mg/l)		0.05	0	20	0		0	
Pb(mg/l)	0.026	0.01	260	100	26000		2.6	
Cd(mg/l)		0.003	0	333.333	0		0	
Ni(mg/l)		0.02	0	50	0		0	
				607.217	52428.54			

Conclusion

Water Pollution, Heavy-metal pollution and Heavy metal Evaluation Index were used to evaluate the water quality and the level of metal pollution in Eleyele water body. The WPI rated the water excellent, the HPI revealed that the water is poor, HEI showed that the water has a low pollution level from metals. There is a need

for conscious effort geared towards improving the quality of water in terms of metal pollution in the water body.

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