Hazard Evaluation and Health Risk Assessment of a Major River in Ondo Nigeria State

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ABSTRACT

Regular monitoring of water bodies for pollution is necessary to prevent the depletion of aquatic plants and animals that serve as food to man. This study was carried out in the Ogbese River, situated along the Akure - Owo expressway, Ondo state, Nigeria. The physicochemical parameters were determined using the standard method while the heavy metal concentration in the river was determined using an Atomic Absorption Spectrophotometer. The pH, Total Dissolved Solid (TDS) and Electrical Conductivity are within WHO recommended limit. The Dissolved Oxygen (DO) ranged between 2.9 mg/L to 4.2 mg/L with an average value of 3.74 ± 0.04 mg/L, which indicates depletion of Oxygen. The heavy metal concentrations with slightly higher ranges than WHO limits are Ni, and Pb with a range of 0.07 mg/L to 0.12 mg/L, and 0.016 mg/L to 0.042 mg/L respectively. The Average Daily Intake (ADI_i) of metals if the water is consumed and ingested are Cd 6.0 x 10^{-4} mg/kg, Ni 2.9 x 10^{-3} mg/kg, Pb 8.0 x 10^{-4} mg/kg, and Cu 7.9 x10^{-3} mg/kg body weight. The Target Hazard Quotient (dermal) (THQ_d), if used to bathe and shower are Cd 2.4 x 10^{-3} mg/kg, Ni 1.16 x 10^{-3} mg/kg, Pb 3.2 x 10^{-4} mg/kg and Cu 1.1 x10^{-1} mg/kg body weight. The Hazard Index (HI) for Cd, Ni, Pb, and Cu are 0.273, 0.146, 0.457, and 0.308 respectively. Ogbese river is polluted with some metals which is due to non-point sources.

Keyword: Hazard, Metals, Risk, River, Water.

INTRODUCTION

Rapid deterioration in water quality is due to increasing population pressure, rapid urbanization, establishment of industries, agricultural activities and inadequate sanitation facilities. These makes water resources to be contaminated by a variety of chemicals and pathogenic micro-organisms[1].

The health risk that are associated with contaminated river water if consumed or used to bathe have been assessed and categorised as carcinogenic and non-carcinogenic [2,3]. The route to human body could be through ingestion and dermal route [4,5].

Ogbese-River is one of the major rivers in Ondo state, Nigeria [6]. The activities around the river makes it susceptible to change in quality. Many studies have been carried out on Ogbese-River, as it flows through many communities. Untreated sewage, agricultural and commercial activities are the sources of pollution [7]. Health issues, such as kidney, heart, and stone problems, are caused by the hardness. This occur as a results of the presence of carbonates, bicarbonates, chloride, calcium and magnesium[8]. Trace elements contamination in surface water is a serious health issue of great concern[9]. The trace elements contaminated water biomagnified and adversely affects the human health [10]. The sediments of major rivers in Ondo State was studied using African catfish (Clarias gariepinus) from Ogbese-River as an indicator of pollution[11]. Ogbese river was classified using water quality index (WQI) but the study did not address human health risk involved when consumed or used to bathe[12]. The objective of this study is to assess possible hazard that is likely to occur as a results of continuous use of the water.

MATERIALS AND METHOD

The Study Area:

The study site is Ogbese-River along the Akure-Owo expressway in Ondo state. The area lies within Longitude 5º 21' E to 5º 25' E and Latitude 7º 15' N to 7º 17' N. The river has its source from Awo-Ekiti in Ekiti State and flows through Ogbese in Ondo State to Edo State. The Ogbese community is about 10 km east of Akure, the Ondo State capital. Some of the activities going on near the river course include cattle grazing with indiscriminate waste disposal on the river course, farming at subsistence level and some sacrificial activities.

Chemicals and Reagents

All reagents were of analytical grade. Hydrochloric acid and nitric acid (65% Merck, Darmstadt, Germany). All glassware and polyethylene bottles were washed, rinsed and soaked in 10% HNO_3 (v/v) for 48 h and rinsed with distilled water. The glass wares were rinsed again with doubly deionized water and finally dried in oven before use.

Sampling Collection

Ten (10) sampling points at 200 m interval were selected along the river course across 2-kilometre distance and were collected in triplicates. Samples meant for trace element determination were collected into cleaned 2.5

L plastic keg and preserved with 2 ml of 0.1M nitric acid.

***Sample Digestion and analysis*:** Samples were digested in aqua- regai and analysed for trace elements using a Bulk Scientific Atomic Absorption Spectrophotometer[13]. Elements determined are lead (Pb), zinc (Zn), iron (Fe), cadmium (Cd), manganese (Mn), cupper (Cu), nickel (Ni). The physicochemical parameters such as total dissolved solid (TDS), pH, salinity, dissolve oxygen (DO) and electrical conductivity (EC) were determined on site using portable meter (Hanna model).

Health Risk Assessment

The health riskwas assessed using Average Daily Intake (ADI_i), Target Hazard Quotient (dermal) (THQ_d), and Hazard Index (HI).

$$ADIi = \frac{C \times IR \times EF \times ED}{BW \times AT} \quad \text{----------} \quad (1)$$

Where ADI_i is the Average Daily Intake

C is the concentration of metals (mg/L water).

IR is the ingestion rate (2L/day).

EF is the exposure frequency (365days/year)..

ED is the exposure duration (70 years).

BW is the average body weight (70 kg).

AT is the average time (70 years x 365 days).

Target hazard quotient THQi was calculated as

$$THQ_i = \frac{ADIi}{RfD} \quad \text{---------} \quad (2)$$

Where THQ_i, Target Hazard Quotient (ingestion)

RfD = reference dose

$$THQ_d = \frac{ADI}{RfD} \times 10 - 3 \quad \text{----} \quad (3)$$

Where THQ_d, Target Hazard Quotient (dermal)

$$HI = ADI_i + THQ_i + THQ_d \text{ --------} \quad (4)$$

Where HI = Hazard Index

RESULTS AND DISCUSSION

The pH range of 6.53 to 7.08 with mean value of 6.81 ± 0.16 was recorded in Ogbese river (Table 1). Temperature varied between 24.5°C and 26.4°C with the mean value of 25.87 ± 0.59°C. These results were similar to the findings of previous researchers [14].

Table 1: Range of Physicochemical parameters and heavy metals in Ogbese river, along Akure-Owo road

Parameters	Units	Min	Max	Mean ± SD	W.H.O Standard
pH		6.53	7.08	6.81 ± 0.16	6.5 – 8.5
Temperature	^{0}C	24.5	26.4	25.87 ± 0.59	NA
TDS	mgL^{-1}	84	91	84.7 ± 2.21	250
DO	mgL^{-1}	2.9	4.2	3.74 ± 0.41	6.0
Conductivity	µScm^{-1}	167	192	170.6 ± 7.56	NA
Salinity	mgL^{-1}	ND	0.1	0.01 ± 0.001	NA
Cu	mgL^{-1}	0.155	0.374	0.275 ± 0.06	2.0
Cd	mgL^{-1}	0.01	0.032	0.022 ± 0.008	0.003
Fe	mgL^{-1}	0.177	0.362	0.244 ± 0.06	0.3
Ni	mgL^{-1}	0.078	0.12	0.100 ± 0.01	0.02
Mn	mgL^{-1}	0.096	0.426	0.203 ± 0.09	0.5
Pb	mgL^{-1}	0.016	0.042	0.029 ± 0.009	0.01
Zn	mgL^{-1}	0.595	1.02	0.849 ± 0.13	3.0

Key: NA- not Available ND- not Detected

TDS varied from 84 to 91 ppm with average value of 84.7 ± 2.21 mgL^{-1} while DO ranged from 2.9 to 4.2 mgL^{-1} with average value of 3.74 ± 0.41 mgL^{-1}. Low DO value indicated reduction in survival rate of biological life in the river. The Electrical conductivity, EC ranged between (167 - 192 µS) is within allowable limits recommended by WHO.

The concentration of Cu ranged from 0.15 to 0.37 mgL^{-1} with the average value of 0.275 ± 0.06 mgL^{-1}, Cd concentration ranged from 0.01 to 0.03 mgL^{-1} with the average value of 0.022 ± 0.008 mgL^{-1}. These values exceeded 0.003 recommended by WHO. Fe concentration ranged from 0.177 to 0.362 mgL^{-1} with the average value of 0.244 ± 0.06 mgL^{-1}. Ni concentration ranged from 0.78 to 0.12 mgL^{-1} with the average value of 0.100 ± 0.01 mgL^{-1}. Lower value of Ni was reported from Ologe river, Lagos State of Nigeria [15]. This is surprising because Lagos river is expected to be more polluted than Ogbese river due high volume of industrial and human activities. Mn, concentration ranged from 0.096 to 0.426 mgL^{-1} with the average value of 0.203 ± 0.09 mgL^{-1}. Pb concentration ranged from 0.016 to 0.042 mg/L with the average value of 0.029 ± 0.009

mgL^{-1}. Wasike et al.[16], reported higher value of lead from from River Kuywa, Kenya and was attributed to inflow of industrial wastes. Zn concentration ranged from 0.595 to 1.02 mg/L with mean values of 0.849 ± 0.13 mgL^{-1}. All Cd concentrations in the water exceeded WHO limit in drinking water.

The presence of these metals in the river may occur due to waste metal merchants which engaged in picking waste metals from dumpsites, aggregate them in a location for a long time before packing them away. Washing of metals by erosion from such sites to the river body may elevate metal concentration in the river. Seepage of industrial wastes, dumping of sewage directly into the river, runoffs of refuse dump by rain into the river and percolation of water through iron-containing rocks nearby before flowing into the river may also be responsible for the observation . The risk associated with toxic metals in water through fish and aquatic organisms to mam is of great concern [16].

There is no significant difference in values recorded across up-stream, mid-stream and downstream of the river for pH, Temperature, Total Dissolved Solid (TDS), DO, Cd, Cu, Fe, Ni, Pb and Zn (Table 2). The value of conductivity recorded was significantly higher in downstream section of the river. This can be attributed to the accumulation of dissolved ions in the down stream section of the river. The Mn concentration was significantly higher in the upstream section of the river with the average concentration value of 0.299 ± 0.046 mgL^{-1}.

Table 2**:** Mean concentration values of heavy metals in water samples collected at Ogbese river using Duncan Multiple Range Test.

Parameters	Up – Stream	Mid - Stream	Down Stream
pH	6.71± 0.195a	7.03±0.025a	6.63±0.089a
Temp ^0C	24.8±0.600a	25.6±0.497a	25.2±0.208a
TDS (mgL^{-1})	87.3±1.76a	85.7±0.882a	88.3±1.76a
DO (mgL^{-1})	3.47±0.371a	3.17±0.176a	3.97±0.088a
Conductivity (μSCm^{-1})	168±0.882a	185±4.04a	172±2.603b
Cd (mgL^{-1})	0.015±0.007a	0.014±0.006a	0.018±0.016a
Cu (mgL^{-1})	0.311±0.027a	0.249±0.031a	0.268±0.043a

Fe (mgL^{-1})	0.247±0.041a	0.217±0.022a	0.282±0.049a
Ni (mgL^{-1})	0.098±0.017a	0.113±0.024a	0.099±0.068a
Pb (mgL^{-1})	0.031±0.009a	0.031±0.008a	0.038±0.009a
Zn(mgL^{-1})	0.748±0.098a	0.875±0.084a	0.821±0.073a
Mn(mgL^{-1})	0.299±0.046b	0.183±0.034ab	0.137±0.023a

Parameters with different letters across the row indicates significant ($p<0.5$) difference

Strong positive correlation $P<0.05$ was recorded between pH and conductivity (r = 0.566), pH and Zn (r = 0.558), TDS and Cu (r = 0.563), Cu and Mn (r = 0.564) (Table 3). However, negative correlation was recorded between pH and DO (r = -0.573), pH and Fe (r = -0.506), TDS and Ni (r = -0.454), Fe and Zn (r = -0.573), Ni and Mn (r = -0.519). Those with positive correlations implies that as the level of one increases, the level of others also increases while negative correlation showed that the two parameters have nothing in common.

Table 3: Pearson Correlation for the parameters in water

	pH	Temp	TDS	DO	Conductivity	Cd	Cu	Fe	Ni	Pb	Zn	Mn
pH	1											
Temp	0.238	1										
TDS	-0.056	0.011	1									
DO	0.573	0.614	0.032	1								
Conductivity	0.566	0.327	-0.327	-0.374	1							
Cd	0.055	-0.457	-0.300	0.240	0.270	1						
Cu	0.007	-0.200	0.563	0.026	-0.411	-0.314	1					
Fe	-0.506	-0.265	0.095	-0.105	-0.172	0.260	-0.317	1				

Ni	-0.122	-0.179	-0.454	0.235	-0.115	-0.352	-0.370	-0.332	1			
Pb	-0.239	0.372	0.375	0.095	0.108	-0.399	0.064	-0.048	-0.253	1		
Zn	0.558	-0.083	0.396	0.007	0.423	0.018	0.492	-0.573	-0.312	0.129	1	
Mn	0.320	-0.180	0.106	-0.356	-0.206	0.151	0.564	-0.192	-0.519	-0.204	0.108	1

P <0.05

Table 4: Principal Component Analysis (PCA) of the data generated from analysis Ogbese river

	Component 1	Component 2	Component 3	Component 4	Component 5
pH	0.016	**0.755**	**0.508**	-0.278	0.081
Temp	-0.218	-0.095	**0.827**	0.399	-0.080
TDS	**0.605**	0.018	-0.024	**0.615**	0.122
DO	-0.109	-0.091	-0.943	0.143	-0.047
Conductivity	-0.589	**0.595**	0.357	0.052	0.327
Cd	-0.238	0.033	-0.327	-0.431	**0.803**
Cu	**0.900**	0.223	-0.115	0.164	-0.069
Fe	-0.148	-0.807	0.175	0.114	**0.461**
Ni	-0.434	-0.023	-0.237	-0.277	-0.807
Pb	-0.037	0.023	0.055	**0.873**	-0.039
Zn	0.235	**0.872**	-0.089	0.282	0.186
Mn	**0.747**	0.122	0.229	-0.411	0.261
Initial Eugene value	2.934	2.494	2.141	1.836	1.414
% Variance	24.451	20.779	17.838	15.297	11.781

The Principal Component Analysis (PCA) showed five different components, with components 1 where TDS, Cu and Mn contributed 24.451% of the variation observed (Table 4). This showed that Cu and Mn are from the same sources. Component 2 consists of Zn, Conductivity and pH as significant contributor to 20.779% of the variations observed. Component 3 represents 17.838% of the variation observed which was caused by pH and Temperature. The Dissolved Oxygen and Pb contributed to the 4^{th} components which represents 15.297% of the variation observed. The fifth component consists of Cd and Fe which represent 11.781% of the variation observed.

Table 5: Hazard Evaluation of metallic elements present in river Ogbese

Metals	Average Daily Intake (ADIi) mg/kg	Target Hazard Quotient THQi	Target Hazard Quotient THQd	Hazard Index HI
Cd	0.0006	0.2727	0.0024	0.2729
Ni	0.0029	0.145	0.00116	0.146
Pb	0.0008	0.4571	0.00032	0.4573
Cu	0.0079	0.1975	0.11	0.3075

The average daily intake of metals if the water is consumed and ingested are Cd 6.0 x 10^{-4}, Ni 2.9 x 10^{-3}, Pb 8.0 x 10^{-4}, and Cu 7.9 x10^{-3} mg/kg body weight. The target hazard quotient (dermal) if used to bathe are Cd 2.4 x 10^{-3}, Ni 1.16 x 10^{-3}, Pb 3.2 x 10^{-4}, and Cu 1.1 x10^{-1} mg/kg body weight. The hazard index HI are Cu 0.2729, Ni 0.146, Pb 0.4573 and Cu 0.3075. THQi is greater than THQd for all the elements investigated.

CONCLUSION

The study of Ogbese river showed that the physicochemical parameters are within WHO limit and slight pollution by metals such as Cd, Ni and Pb could be due to improper dumping of wastes and other non-point sources. The risk is greater through ingestion of the water than through dermal. Regular monitoring of river Ogbese is necessary to protect human health through food chain. People should be made to pay

fine for dumping wastes into the water body. Preventive measures should be enforced to protect our water bodies.

CONFLICT OF INTEREST DECLARATION

There is no conflict of interest associated with this work

ACKNOWLEDGEMENT

Mr S. O. Omoyajowo is acknowledged for his support during sampling and analysis.

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