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Determination of Water Quality Index for Otamiri River Chokocho Rivers State

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Abstract

This study examined the water quality of the Otamiri River, which is located in the state of Rivers, Nigeria. The objectives of the study were to gain an understanding of the concentrations of pollutants (such as ammonia, PH, COD, turbidity, dissolved oxygen, Zinc Cadmium, and Lead) and to determine the Water Quality Index (WQI) of the river in order to ascertain whether or not the water is safe to drink. During the course of the study, ten water samples were collected from ten different places, and their coordinates were determined by utilizing a Global Positioning System (GPS) between the hours of 6 and 7 each morning. The WQI analysis was carried out using the Excel application tool, employing equations 2.1, 2.2, 2.3, and 2.4. The drinking water quality standards established by the World Health Organization (WHO) and the WQI rating published by Robert and Icka [1] served as references for the analysis. Results showed that the river had 96.19 for March, 69.65 for April, 64.67 for May, 57.75 for June, 64.33 for July, and 51.22 for August, implying that the Otamiri River was unsafe for drinking purposes for March, April and May with WQI values of 90.19, 69.65 and 64.67 respectively while in June, July.

Keywords: Water quality index, Global positioning system, Water, Pollutants.

1 | Introduction

Water is a resource that can be replenished, and it is absolutely necessary for the continuation of all forms of life, the manufacturing of food, the growth of the economy, and the maintenance of general health. It is impossible to find a suitable replacement for the majority of the functions it performs, it is challenging to disinfect, and it is expensive to transport; it is unquestionably a one-of-a-kind gift from nature to people [2].

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According to Gupta [3], water is one of the natural resources that can be redirected, transported, stored, and recycled, making it one of the most managed resources. Water pollution occurs when dangerous elements like chemicals or bacteria are introduced into a stream, river, lagoon, sea, aquifer, or any other body of water [4]. This causes the water quality to deteriorate, making the water hazardous to human health or the environment [5].

A river is considered polluted when dangerous chemicals of any kind, physical, chemical, or biological, make their way into its body. In this sense, pollution can refer to any of these types of contamination. Because of the detrimental effects that these pollutants (which can originate from either a point source or a non-point source) have on the biological and physicochemical qualities of the river, they are no longer suitable for use by humans.

The capability of water to sustain a wide variety of applications and activities is what we mean when we talk about the quality of the water. Each use of water will have its own unique set of physical, chemical, and biological features; for instance, limitations on harmful material concentrations for drinking water or temperature and pH range restrictions for water use to support habitats [6]. These characteristics will vary depending on the application of water.

The World Health Organization (WHO) standard, the Environmental Quality Standard (EQS), and the European Commission Standard (ECS) are all examples of safe drinking water standards, which are shown in *Table 1*.

Table 1. Drinking water quality standards [7].

Parameter	**Drinking Water Quality Standard**		
	WHO	**EQS**	**ECS**
pH	6.5 - 8.5	6.0 - 8.5	6.5 - 8.5
TDS (mg/l)	1000	1000	1000
Iron (mg/l)	0.3	0.3 - 1.0	0.2
Sodium (mg/l)	200	200	175
Chloride (mg/l)	250	150 – 600	250
Sulphate (mg/l)	400	400	25
Fluoride (mg/l)	1.5	1	1.5
Arsenic (mg/l)	0.05	0.05	0.05
Ammonium (mg/l)	1.5	0.5	0.5
Nitrate (mg/l)	10	10	10
Phosphate (mg/l)	-	6	5
Potassium (mg/l)	-	12	10
Endrin (mg/l)	0.2	-	0.2
Heptachlor (μmg/l)	0.1	-	0.1
DDT (μmg/l)	1	-	0.1

The components of surface and subsurface water bodies in the drainage basin are impacted by environmental variables (such as geological, topographical, meteorological, hydrological, and biological), which change with seasonal fluctuations in runoff amounts, wind patterns, and water levels. These environmental aspects include geology, topography, meteorology, hydrology, and biology.

Large natural shifts in water quality can be seen even when only one waterway is in play. A variety of factors can cause these shifts. The influence that human activity has on the quality of water also has a substantial impact. The construction of dams, the draining of wetlands, and the redirection of flow are all examples of hydrological alterations that have contributed to some of these consequences. Activities that contribute to pollution, such as the intentional or inadvertent discharge of residential, industrial, and other wastes and urban runoff into watercourses, as well as the distribution of chemicals on agricultural land in the drainage basin, are more apparent [5]. Urban runoff contributes significantly to water pollution.

Water quality index

According to Lumb et al. [8], WQI is simply a weighted average of selected ambient pollutant concentrations often linked with different water quality classes. Udeh [9] presented a strategy for condensing large volumes of data on water quality into simple terms and indicators (such as good) for the purpose of uniform communication to managers and the general public.

This can tell us if the overall quality of water bodies threatens the many users of water, such as those who utilize it as a habitat for aquatic life, as irrigation water for agriculture and cattle, for enjoyment and beautification, and as drinking water supplies. The WQI may be calculated based on a number of physicochemical properties, including dissolved oxygen, pH, total dissolved solids, hardness, calcium, magnesium, total alkalinity, and electrical conductivity. Dissolved oxygen is one of the most important of these characteristics. When calculating the WQI of a river, in addition to the pollutants indicated above and any others that could be relevant, other pollutants are not specified above. It can also be taken into consideration. This study aims to determine the WQI of the Otamiri River in Chokocho Rivers State, Nigeria.

2 | Material and Methods

2.1 | Study Area

The Chokocho axis of the Otamiri River, located in Etche Local Government in Rivers State, was the focus of this research project. It is situated at a longitude of 7°03'32" east of the meridian and a latitude of 4°59'33" south of the equator. The Egwi community is located to the north of the research area, the Rumuakuru village is located to the south, and the Okoroagu and Chokocho communities are located to the east and west of the study area, respectively. The Otamiri River begins its journey at Egbu and continues to Ozuzu in Etche, Rivers State. From there, it travels through Owerri, Nekede, Ihiagwa, Eziobodo, OlokwuUmuisi, Mgbirichi, and Umuagwo before finally emptying into the Atlantic Ocean.

From its origin in Egbu, until it meets with the Uramiriukwa River close to Emeabiam, the river travels a distance of around 30 kilometres. The Otamiri watershed is around 10,000 square kilometres (3,900 square miles) in size and gets annual precipitation of between 2,250 and 2,500 millimetres (89 to 98 inches). The watershed is mainly covered with deteriorated rainforest vegetation since the typical temperature throughout the year is 27 degrees Celsius (81 degrees Fahrenheit).

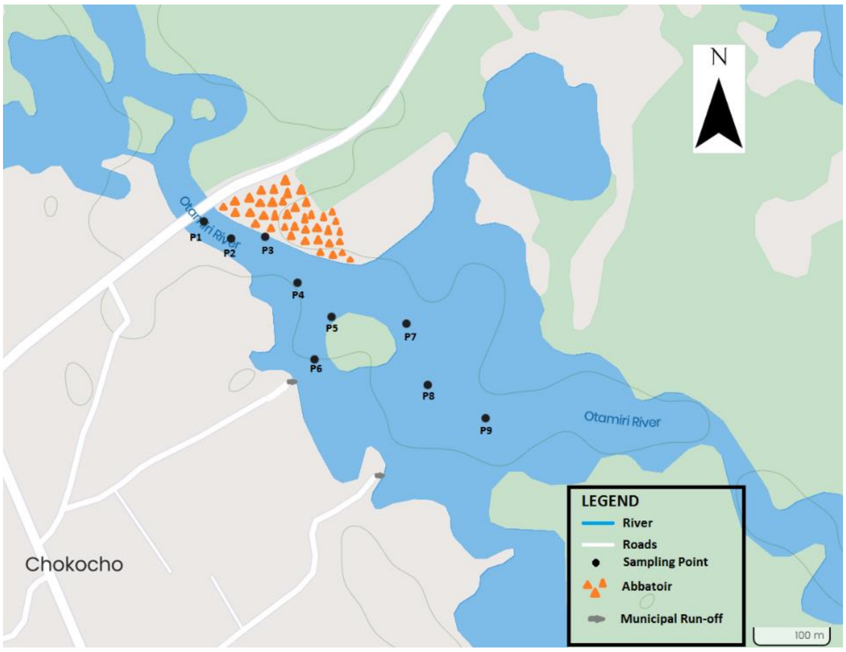

Fig. 1. A map showing the sample points in the study area of the otamiri river (source: Google Maps).

2.2 | Equipment

The following items were utilized in the conduct of the study: two canoes, canoes, hand gloves, safety boots, a life jacket, glass and plastic sampling bottles, a notebook, a GPS, a stopwatch, a thermometer, floating object (table tennis balls), five-meter-long bamboo sticks, one hundred meters of tape, preservatives, labels, marker pens, a sample storage container, and ice packs. The WQI was determined by applying the following relation to the data:

The WQI of any water body can be expressed mathematically as

$$\mathrm{WQI} = \mathrm{W_i} \times \mathrm{V_i}, \tag{1}$$

where

Wi = unit weight of factor.

Vi = the WHO's maximum acceptable limits.

Furthermore, the unit weight factor (Wi) can be expressed using mathematical relationships in *Eqs. (2)* and *(3)*.

$$\mathrm{W_i} \propto \frac{1}{\mathrm{V_i}}, \tag{2}$$

$$\mathrm{W_i} = \frac{k}{\mathrm{V_i}}, \tag{3}$$

where

k = constant of proportionality.

The value of k can be derived using *Eq. (4)*.

$$k = \frac{1}{\sum_{i=1}^{n} \frac{1}{\mathrm{V_i}}}. \tag{4}$$

The table below referenced after calculating the WQI to come up with the grade.

Table 2. WQI rating [1].

WQI	Rating of Water Quality	Grade
0-25	Excellent water quality	A
26-50	Good water quality	B
51-75	Poor water quality	C
76-100	Very poor water quality	D
Above 100	Unsuitable for drinking purposes	E

2.3 | Sampling Technique

The sampling of points was carried out with the assistance of a GPS, which was used to determine the spots' respective coordinates. Before the water sample was taken, the points were marked by attaching and labelling a bamboo stick. This was done before the water sample was taken. Before the sample was taken, the vials and tops were thoroughly washed five times each. This is a vital fact that must be stated. Using the tape measure, we measured 100 meters downstream from where we were and used it to establish our position. In addition to recording the coordinates, samples were obtained. This process was carried out for each of the nine places of sampling. Immediately following the collection of each sample, it was placed in a container containing ice to inhibit any microbial activity. The samples were then sent to the laboratory for analysis as soon as the process of collecting water samples was finished.

The samples were taken between 6.30 and 7 a.m. since the river is in its natural form at that time and was free from the effect of anthropogenic activity. This allowed for the most accurate results possible. In order to collect data for both the dry and rainy seasons, the sampling was carried out every six months, beginning in March 2020 and ending in August 2020.

Following the measurement and marking of 10 meters down the middle of the river with bamboo sticks, the surface velocities were determined by dropping a table tennis ball into the water and timing how long it took for the ball to cover the distance using a stopwatch. This process was carried out five times, and the mean velocity was computed and logged for each iteration.

2.4 | Nature and Sources of Data

A combination of primary and secondary data was used for the study. Primary data were generated by analyzing samples obtained from the river both in situ and in the laboratory. Secondary data and assumptions were obtained from textbooks and relevant scientific and engineering journals.

2.5 | Parameter Testing Procedure

Because of their frequent association with wastewater from an abattoir, ten (10) physicochemical characteristics were investigated and analyzed. The parameter and the standard test technique that was employed in the process of determining the concentration of the contaminants that were found in the sample are presented in *Table 3*. The level of total hydrocarbons, also known as THC, was analyzed during the first month of the study to assess whether petroleum contamination was present in the river. This precaution was made so that there would be no contact between the pollutants from the slaughterhouse and those from the oil refinery.

Table 3. A summary of parameters and standard tests done in the laboratory.

S/No	Parameter	Standard Test Procedure	Abbreviation
1	pH	American public health association - 4500 -H+B	APHA 4500-H+B
2	Turbidity	American public health association - 2130B	APHA 2130B
3	Total suspended solids	American public health association - 2540B	APHA 2540D
4	Ammonia	American society for testing and materials D 1426	ASTM D 1426
5	Chemical oxygen demand	American public health association - 5220B	APHA 5220C
6	Biochemical oxygen demand 5	American public health association - 5210B	APHA 5210B
7	Dissolved oxygen	American public health association - 4500 - O G	APHA 4500-O G
8	Zinc	American public health association - 3111B	APHA 3111B
9	Cadmium	American public health association - 3111B	APHA 3111B
10	Lead	American public health association - 3111B	APHA 3111B

3 | Results and Discussion

In order to conduct the WQI analysis, the software program Excel was utilized, and the *Eqs. (1)-(4)* were utilized. In addition, the Drinking Water Quality Standard established by the WHO was referred to throughout the study. To choose the boundaries of the parameters utilized in the WQI calculation, reference was made to *Table 1* as a foundation for making our selections.

Total Suspended Solids (TSS) were not included since the WHO Drinking Water Quality Standard did not establish a limit for the TSS criterion. This is a crucial point to remember because it explains why TSS were not included. The findings of the investigation of the WQI are shown in *Table 4*. The results of the WQI study are broken down into more specific categories and may be seen in *Tables 4-9*.

Table 4. Summary monthly WQI for otamiri river.

Month	WQI	Rating of Water Quality	Grade
March	96.19	Very poor water quality	D
April	69.65	Poor water quality	C
May	64.67	Poor water quality	C
June	57.75	Poor water quality	C
July	64.33	Poor water quality	C
August	51.22	Poor water quality	C

Table 5. March 2020 WQI results for otamiri river.

Parameters	WHO Standard (Sn)	1/Sn	∑1/Sn	K=1/ [∑1/Sn]	Wi=K/Sn	Ideal Value (Vo)	Mean Concentration (Vn)	Qn=l(Vn-Sn)/(Sn-Vo) l	Qn×100	Wi×Qn
Ph	8.5000	0.1176	135.0260	0.0074	0.0009	7.0	6.1	0.6000	60.0000	0.0523
Turbidity (NTU)	5.0000	0.2000	135.0260	0.0074	0.0015	0	2.7	0.5400	54.0000	0.0800
Ammonia - NH4+ (mg/l)	1.5000	0.6667	135.0260	0.0074	0.0049	0	0.2385	0.1590	15.9008	0.0785
BOD5 (mg/l)	5.0000	0.2000	135.0260	0.0074	0.0015	0	0.5111	0.1022	10.2222	0.0151
COD (mg/l)	20.0000	0.0500	135.0260	0.0074	0.0004	0	0.9300	0.0465	4.6500	0.0017
Dissolved Oxygen - DO (mg/l)	8.0000	0.1250	135.0260	0.0074	0.0009	14	4.8778	1.5204	152.0370	0.1407
Zinc - Zn (mg/l)	3.0000	0.3333	135.0260	0.0074	0.0025	0	0.0213	0.0071	0.7111	0.0018
Cadmium- Cd (mg/l)	0.0300	33.3333	135.0260	0.0074	0.2469	0.0000	0.0404	1.3481	134.8148	33.2812
Lead - Pb (mg/l)	0.0100	100.0000	135.0260	0.0074	0.7406	0.0000	0.0084	0.8444	84.4444	62.5394
		135.0260			1.0000				WQI=	96.1907

Table 6. April 2020 WQI results for otamiri river.

Parameters	WHO Standard (Sn)	1/Sn	∑1/Sn	K=1/ [∑1/Sn]	Wi=K/Sn	Ideal Value (Vo)	Mean Concentration (Vn)	Qn=l(Vn-Sn)/(Sn-Vo) l	Qn×100	Wi×Qn
pH	8.5	0.1176	135.0260	0.0074	0.0009	7	5.5667	0.9556	95.5556	0.0833
Turbidity (NTU)	5	0.2000	135.0260	0.0074	0.0015	0	2.3778	0.4756	47.5556	0.0704
Ammonia - NH4+ (mg/l)	1.5	0.6667	135.0260	0.0074	0.0049	0	0.2394	0.1596	15.9630	0.0788
BOD5 (mg/l)	5	0.2000	135.0260	0.0074	0.0015	0	0.6556	0.1311	13.1111	0.0194
COD (mg/l)	20	0.0500	135.0260	0.0074	0.0004	0	121.2556	6.0628	606.2778	0.2245
Dissolved Oxygen - DO (mg/l)	8	0.1250	135.0260	0.0074	0.0009	14	5.2000	1.4667	146.6667	0.1358
Zinc - Zn (mg/l)	3	0.3333	135.0260	0.0074	0.0025	0	0.0210	0.0070	0.7000	0.0017
Cadmium- Cd (mg/l)	0.03	33.3333	135.0260	0.0074	0.2469	0	0.0079	0.2630	26.2963	6.4917
Lead - Pb (mg/l)	0.01	100.0000	135.0260	0.0074	0.7406	0	0.008444444	0.8444	84.4444	62.5394
		135.026			1				WQI=	69.64501

Table 7. May 2020 WQI calculation for otamiri river.

Parameters	WHO Standard (Sn)	1/Sn	∑1/Sn	K=1/[∑1/Sn]	Wi=K/Sn	Ideal Value (Vo)	Mean Concentration (Vn)	Qn=l(Vn-Sn)/(Sn-Vo) l	Qn×100	Wi×Qn
pH	8.5	0.118	135.026	0.00741	0.00087	7	5.4111	1.0593	105.926	0.0923
Turbidity (NTU)	5	0.200	135.026	0.00741	0.00148	0	1.1778	0.2356	23.556	0.0349
Ammonia - NH4+ (mg/l)	1.5	0.667	135.026	0.00741	0.00494	0	0.1739	0.1159	11.593	0.0572
BOD5 (mg/l)	5	0.200	135.026	0.00741	0.00148	0	2.1656	0.4331	43.311	0.0642
COD (mg/l)	20	0.050	135.026	0.00741	0.00037	0	140.5556	7.0278	702.778	0.2094
Dissolved Oxygen - DO (mg/l)	8	0.125	135.026	0.00741	0.00093	14	3.5189	1.7469	174.685	0.1617
Zinc - Zn (mg/l)	3	0.333	135.026	0.00741	0.00247	0	0.0233	0.0078	0.778	0.0019
Cadmium-Cd (mg/l)	0.03	33.333	135.026	0.00741	0.24687	0	0.0068	0.2259	22.593	5.5773
Lead - Pb (mg/l)	0.01	100.000	135.026	0.00741	0.74060	0	0.0079	0.7889	78.000	58.4250
		135.026			1				WQI=	64.6748

Table 8. June 2020 WQI calculation for otamiri river.

Parameters	WHO Standard (Sn)	1/Sn	∑1/Sn	K=1/[∑1/Sn]	Wi=K/Sn	Ideal Value (Vo)	Mean Concentration (Vn)	Qn=l(Vn-Sn)/(Sn-Vo) l	Qn×100	Wi×Qn
pH	8.5	0.118	135.026	0.00741	0.000871	7	6.8278	0.1148	11.481	0.0100
Turbidity (NTU)	5	0.200	135.026	0.00741	0.001481	0	0.6622	0.1324	13.244	0.0196
Ammonia - NH4+ (mg/l)	1.5	0.667	135.026	0.00741	0.004937	0	0.4468	0.2979	29.785	0.1471
BOD5 (mg/l)	5	0.200	135.026	0.00741	0.001481	0	27.6939	5.5388	553.878	0.8204
COD (mg/l)	20	0.050	135.026	0.00741	0.00037	0	113.1222	5.6561	565.611	0.2094
Dissolved Oxygen - DO (mg/l)	8	0.125	135.026	0.00741	0.000926	14	2.5261	1.9123	191.231	0.1770
Zinc - Zn (mg/l)	3	0.333	135.026	0.00741	0.002469	0	0.0300	0.0100	1.000	0.0025
Cadmium-Cd (mg/l)	0.03	33.333	135.026	0.00741	0.246866	0	0.0028	0.0933	9.333	2.3041
Lead - Pb (mg/l)	0.01	100.000	135.026	0.00741	0.740598	0	0.0073	0.7300	73.000	54.0637
		135.026			1				WQI=	57.7538

Table 9. July 2020 WQI calculation for otamiri river.

Parameters	WHO Standard (Sn)	1/Sn	∑1/Sn	K=1/[∑1/Sn]	Wi=K/Sn	Ideal Value (Vo)	Mean Concentration (Vn)	Qn=l(Vn-Sn)/(Sn-Vo) l	Qn×100	Wi×Qn
pH	8.5	0.118	135.026	0.00741	0.000871	7	6.5311	0.3126	31.259	0.0272
Turbidity (NTU)	5	0.200	135.026	0.00741	0.001481	0	0.1000	0.0200	2.000	0.0030
Ammonia - NH4+ (mg/l)	1.5	0.667	135.026	0.00741	0.004937	0	0.7197	0.4798	47.978	0.2369
BOD5 (mg/l)	5	0.200	135.026	0.00741	0.001481	0	53.2222	10.6444	1064.444	1.5767
COD (mg/l)	20	0.050	135.026	0.00741	0.00037	0	85.6889	4.2844	428.444	0.1587
Dissolved Oxygen - DO (mg/l)	8	0.125	135.026	0.00741	0.000926	14	1.5333	2.0778	207.778	0.1923
Zinc - Zn (mg/l)	3	0.333	135.026	0.00741	0.002469	0	0.0300	0.0100	1.000	0.0025
Cadmium-Cd (mg/l)	0.03	33.333	135.026	0.00741	0.246866	0	0.0028	0.0933	9.333	2.3041
Lead - Pb (mg/l)	0.01	100.000	135.026	0.00741	0.740598	0	0.0081	0.8078	80.778	59.8239
		135.026			1				WQI=	64.3252

Table 10. August 2020 WQI calculation for otamiri river.

Parameters	WHO Standard (Sn)	1/Sn	∑1/Sn	K=1/[∑1/Sn]	Wi=K/Sn	Ideal Value (Vo)	Mean Concentration (Vn)	Qn=l(Vn-Sn)/(Sn-Vo) l	Qn×100	Wi×Qn
pH	8.5	0.118	135.026	0.00741	0.000871	7	6.5800	0.2800	28.000	0.0244
Turbidity (NTU)	5	0.200	135.026	0.00741	0.001481	0	0.1000	0.0200	2.000	0.0030
Ammonia - NH4+ (mg/l)	1.5	0.667	135.026	0.00741	0.004937	0	0.3711	0.2474	24.741	0.1222
BOD5 (mg/l)	5	0.200	135.026	0.00741	0.001481	0	36.4889	7.2978	729.778	1.0809
COD (mg/l)	20	0.050	135.026	0.00741	0.00037	0	62.0778	3.1039	310.389	0.1149
Dissolved Oxygen - DO (mg/l)	8	0.125	135.026	0.00741	0.000926	14	3.1889	1.8019	180.185	0.1668
Zinc - Zn (mg/l)	3	0.333	135.026	0.00741	0.002469	0	0.0300	0.0100	1.000	0.0025
Cadmium-Cd (mg/l)	0.03	33.333	135.026	0.00741	0.246866	0	0.0028	0.0933	9.333	2.3041
Lead - Pb (mg/l)	0.01	100.000	135.026	0.00741	0.740598	0	0.0064	0.6400	64.000	47.3983
		135.026			1				WQI=	51.2170

4|Discussion

In *Table 3*, it was shown that the Study River had a very poor water quality with a WQI of 96.19, ranking grade D on a scale specified by Robert and Icka [1]; the primary contributors to the high WQI value are both Cadmium and Lead in March. This was the case during March, with a score of 69.65 on the WQI; the Study

River was placed in the category designated as C for its unsatisfactory water quality in April. In addition, cadmium and lead are the two primary contributors to the elevated WQI. With WQI readings of 64.67, 57.75, 64.33, and 51.22, respectively, the Study River was placed in the C category of the ranking for May, June, July, and August due to its consistently poor water quality.

The elevated WQI was also primarily caused by cadmium and lead, the two primary contributors. The quality of the water affects every facet of human life. According to [8], communities all over the world are struggling with water quality even though the planet's continued existence is dependent on clean water. Inadequate water quality can cause a variety of health problems in people, including but not limited to bacterial infections like cholera, viral diseases like gastroenteritis and poliomyelitis, and other difficulties such as poor reproductive function. Additionally, it may affect animals and plants if utilized for agricultural reasons such as irrigation.

5 | Conclusion

In March, April, and May, the water in the Otamiri River had WQI values of 90.19, 69.65, and 64.67, respectively; however, in June, July, and August, the water in the river became fit for drinking with WQI values of 9.61, 10.43, and 9.74 respectively. A study on the sources of lead and cadmium pollution in the river should be done to determine the root cause of this pollution, as the river serves as a water source for both domestic and recreational purposes. The high WQI values were a result of lead and cadmium pollution. I recommend that this study be done because the river serves as a water source for both domestic and recreational purposes.

Conflicts of Interest

No competing interest among the authors

Acknowledgments

Consent was obtained and preserved by authors As per the University Standard.

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Appendix A

Table 1.A. Data set.

Months	Points (m)	Longitudinal Distance from Effluent Point (m)	Temperature (°C)	Average Velocity (m/s)	pH	Turbidity (NTU)	TSS (mg/l)	NH3-N) (mg/l)	BOD_5 (mg/l)	COD (mg/l)	DO (mg/l)	Zn (mg/l)	Cd (mg/l)	Pb (mg/l)	THC (mg/l)
March, 2020	Control Point (P1)	-100	26.2	0.329	6.2	3.7	6.9	0.164	0.3	1.06	6.3	<0.001	0.025	0.032	<0.001
	Point 2	-50	26.1		5.9	1	2.2	0.62	2.3	1.32	6.5	<0.001	0.055	0.011	<0.001
	Effluent Point (P3)	0	26.4		6.2	3.3	9.3	0.214	0.1	1.25	4.7	0.05	0.061	<0.001	<0.001
	Point 4	100	26.3		6	2.4	6.9	0.16	0.4	0.88	4	0.083	0.073	0.008	<0.001
	Point 5	200	26.6		6.2	2.4	5.2	0.261	0.1	0.81	4.8	0.053	0.044	0.005	<0.001
	Point 6	250	26.7		6.2	3.1	10.4	0.267	0.3	1.25	4	<0.001	0.039	0.007	<0.001
	Point 7	300	26.6		5.8	2.6	7	0.14	0.6	0.44	4.5	<0.001	0.022	0.008	<0.001
	Point 8	400	26.6		6	3	9.4	0.179	0.3	0.75	4.5	<0.001	0.026	0.003	<0.001
	Point 9	500	26.5		6.4	2.8	6.7	0.142	0.2	0.61	4.6	<0.001	0.019	<0.001	<0.001
April, 2020	Control Point (P1)	-100	25.5	0.334	6.3	4.4	9.4	0.246	0.6	120	5.7	0.013	<0.001	<0.001	-
	Point 2	-50	25.5		5.7	1	1	0.176	1.4	117	6.3	0.021	<0.001	<0.001	-
	Effluent Point (P3)	0	25.6		5.6	1.2	1.2	0.331	0.3	82.7	5.3	0.03	<0.001	<0.001	-
	Point 4	100	25.7		5.2	1.4	1.2	0.214	0.5	142	4.6	0.024	<0.001	<0.001	-
	Point 5	200	25.4		5.6	3.6	1.6	0.276	0.2	132	5.3	0.014	<0.001	0.003	-
	Point 6	250	25.3		5.5	2.7	1.3	0.14	0.7	143	4.8	0.036	<0.001	0.006	-
	Point 7	300	25.3		5.4	1.3	4.2	0.253	0.7	97.6	5.3	0.019	0.003	<0.001	-
	Point 8	400	25.4		5.2	3.4	1.3	0.192	0.9	133	4.2	0.017	0.061	0.061	-
	Point 9	500	25.2		5.6	2.4	7.4	0.327	0.6	124	5.3	0.015	<0.001	<0.001	-
May, 2021	Control Point (P1)	-100	25.8	0.347	5.5	1	7.2	0.164	1.62	22.6	2.44	0.015	0.053	0.025	-
	Point 2	-50	26		5.4	1.2	4.5	0.174	1.62	22.4	3.24	0.031	<0.001	<0.001	-
	Effluent Point (P3)	0	26.1		5.5	1.1	12.5	0.127	4.07	157	4.87	0.014	<0.001	0	-
	Point 4	100	26.2		5.4	1.3	9.6	0.219	2.44	166	3.25	0.024	<0.001	<0.001	-
	Point 5	200	26.4		5.2	1.1	9.7	0.229	2.43	170	4.06	0.014	<0.001	<0.001	-
	Point 6	250	26.1		5.4	1.3	10.7	0.1	1.62	176	4.06	0.014	<0.001	0.021	-
	Point 7	300	25.9		5.5	1.2	1.4	0.156	2.44	176	3.25	0.034	<0.001	0.02	-
	Point 8	400	26.2		5.5	1.2	8.2	0.218	0.81	170	3.25	0.035	<0.001	<0.001	-
	Point 9	500	26.1		5.3	1.2	8.2	0.178	2.44	205	3.25	0.029	<0.001	<0.001	-

Table 1.A. Continued.

Months	Points (m)	Longitudinal Distance from Effluent Point (m)	Temperature (°C)	Average Velocity (m/s)	pH	Turbidity (NTU)	TSS (mg/l)	NH3-N) (mg/l)	BOD_5 (mg/l)	COD (mg/l)	DO (mg/l)	Zn (mg/l)	Cd (mg/l)	Pb (mg/l)	THC (mg/l)
June, 2021	Control Point (P1)	-100	25.4	0.359	6.75	0.58	3.608	0.481	3.835	16.1	1.97	<0.003	<0.0028	0.023	-
	Point 2	-50	25.2		6.58	0.68	2.271	0.3615	1.785	12.8	2.42	<0.003	<0.0028	0.016	-
	Effluent Point (P3)	0	25.5		6.59	0.63	6.254	0.422	31.785	126.5	3.185	<0.003	<0.0028	<0.0012	-
	Point 4	100	25.3		6.67	0.73	4.803	0.4865	140.22	307	2.375	<0.003	<0.0028	<0.0012	-
	Point 5	200	25.6		6.83	0.63	4.871	0.462	11.315	101	2.78	<0.003	<0.0028	<0.0012	-
	Point 6	250	25.5		6.98	0.7	5.3575	0.465	31.06	136	2.83	<0.003	<0.0028	0.0019	-
	Point 7	300	25.7		7	0.68	0.7215	0.4635	20.72	120	2.425	<0.003	<0.0028	<0.0012	-
	Point 8	400	25.6		7.1	0.68	4.1015	0.4405	4.375	91.4	2.375	<0.003	<0.0028	0.0017	-
	Point 9	500	25.9		6.95	0.65	4.1395	0.439	4.15	107.3	2.375	<0.003	<0.0028	<0.0012	-
July, 2021	Control Point (P1)	-100	26	0.378	6.6	0.1	0.016	0.798	6.05	9.6	1.5	<0.003	<0.0028	0.032	-
	Point 2	-50	25.7		6.56	0.1	0.042	0.549	1.95	3.2	1.6	<0.003	<0.0028	0.0025	-
	Effluent Point (P3)	0	25.9		6.48	0.1	0.008	0.717	59.5	96	1.5	<0.003	<0.0028	<0.0012	-
	Point 4	100	25.7		6.54	0.1	0.006	0.754	278	448	1.5	<0.003	<0.0028	<0.0012	-
	Point 5	200	25.9		6.55	0.1	0.042	0.695	20.2	32	1.5	<0.003	<0.0028	<0.0012	-
	Point 6	250	26.1		6.53	0.1	0.015	0.83	60.5	96	1.6	<0.003	<0.0028	0.0022	-
	Point 7	300	26.3		6.5	0.1	0.043	0.771	39	64	1.6	<0.003	<0.0028	<0.0012	-
	Point 8	400	25.4		6.5	0.1	0.003	0.663	7.94	12.8	1.5	<0.003	<0.0028	0.030	-
	Point 9	500	26.2		6.52	0.1	0.079	0.7	5.86	9.6	1.5	<0.003	0.028	<0.0012	-
August, 2021	Control Point (P1)	-100	26.4	0.371	6.63	0.1	0.067	0.558	25.8	41.6	5.3	<0.003	0.028	0.039	-
	Point 2	-50	26.3		6.54	0.1	0.094	0.474	18.8	32	4.4	<0.003	0.028	0.0028	-
	Effluent Point (P3)	0	26.6		6.6	0.1	0.061	0.278	50.4	96	3.3	<0.003	0.028	<0.0012	-
	Point 4	100	26.5		6.62	0.1	0.046	0.268	48.5	89.6	3.5	<0.003	0.028	<0.0012	-
	Point 5	200	26.8		6.48	0.1	0.056	0.529	64.7	106	1.4	<0.003	0.028	<0.0012	-
	Point 6	250	26.9		6.58	0.1	0.009	0.036	64.3	102	1.5	<0.003	0.028	0.0029	-
	Point 7	300	26.8		6.51	0.1	0.05	0.44	19.8	32	4.4	<0.003	0.028	<0.0012	-
	Point 8	400	26.8		6.72	0.1	0.082	0.11	25.4	41.6	3.5	<0.003	0.028	0.042	-
	Point 9	500	26.7		6.54	0.1	0.097	0.647	10.7	17.9	1.4	<0.003	0.028	<0.0012	-