Assessment of water quality of the Karala River and suitability for fish production and industrial purposes - an overview

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Abstract

One of the essential natural resources is fresh water. The Karala River is one of the most important rivers inthe Jalpaiguri district. The river water is used for agricultural purposes, household utilities, and fish harvesting. The river receives sewage from Jalpaiguri town, and thus, it is polluted. For assessing the pollution status, the values of parameters such as BOD, COD, chloride, conductivity, dissolved oxygen (DO), hardness, pH, total dissolved solids (TDS), temperature, total Kjeldahl nitrogen (TKN), total solids, total phosphorus (TPP), and total suspended solids (TSS) were measured. Almost all the parameters maintain a strong correlation with each other. The pollution status in terms of WQI of the three sampling stations has been determined, and the river has been designated as medium-contaminated. Some physicochemical parameters are within the recommended range for fish growth, but some parameters like TDS, hardness, TKN, and TPP need special attention. Another important parameter, the Langelier index, which indicates the corrosion power of the water, was determined, and the river was assigned moderately aggressive.

Keywords: Karala River, WQI, Langelier Saturation Index, aggressive.

1.Introduction

Fresh water is one of the most essential natural resources on earth. Humans, animals, and most plant communities depend on freshwater for survival. Fresh water is found in rivers, lakes, ponds, ground waters, and rainwater. Polar ice caps and glaciers in the mountains are also large reserves of fresh water.

Rivers,among all other vitalfreshwater sources, have been found to impact human civilisations significantly.The riversfulfil the demand for water for various uses, including irrigation, domestic, industrial, and aquaculture (Haldar et al., 2014). Fresh water is limited, and the demand for it is increasing day by day (Ravikumar et al., 2011).Moreover, many rivers become polluted as they receive sewage from cities and towns and agrochemicals from agricultural fields.Consequently, the river water's physical, chemical, and biological properties are gradually changing, harming aquatic life (Patra et al., 2011) and human health.The physical, chemical, biological, and radiological characteristics comprise the water quality; thereby, the water quality is changing and becoming unsuitable for use in different sectors. The Karala River is a small, rain-fed tributary of the Teesta River, located in the Jalpaiguri district of West Bengal, India.The river receives sewage from Jalpaiguri town, sewage from Cremation Ghat at Maskalai Bari, and medical sewage from the Jalpaiguri District Hospital. Tea gardeners use the water resourcefor tea plantation and drain the excess water used with a variety of pesticides and fertilisers into this river, thus polluting the river. The name of the river came a few times into the news headlines because of the massive death of the fish, indicatingthe degradation of water quality. The objectives of this paper are to evaluate the water quality and to see the suitability for fish production and industrial uses.

2. Materials and Methods: -

The paper has been made by gathering experimental data and information from other papers published in different years by different authors. However, the data have been modified and processed according to the requirements for this study. The data have been collected from Mandal et al., 2012and many other authors that are suitably cited in the proper places.

2.1 Study area

The study area covers the Jalpaiguri stretch of the Karala River. The river originated from the catchment basin of the Teesta River in the Baikunthapur forest(Mandal et al., 2012) at a latitude of 26º46'41"N and a longitude of 88º32'14"E. The river is 45 km long and flows almost parallelly to the TeestaRiver(Das, 2016) and meets the TeestaRiver at Mandalghat (latitude 26º28'42" N, longitude 88º44'25"E) in the Jalpaiguri district of West Bengal in India. The three sampling stations were (i) S-1, near Maskalai Bari; (ii) S-2, near Sadar Girls School; and (iii) S-3, near Min-Bhaban in Jalpaiguri town.The data collected here are fromthe pre-monsoonal period of2012.

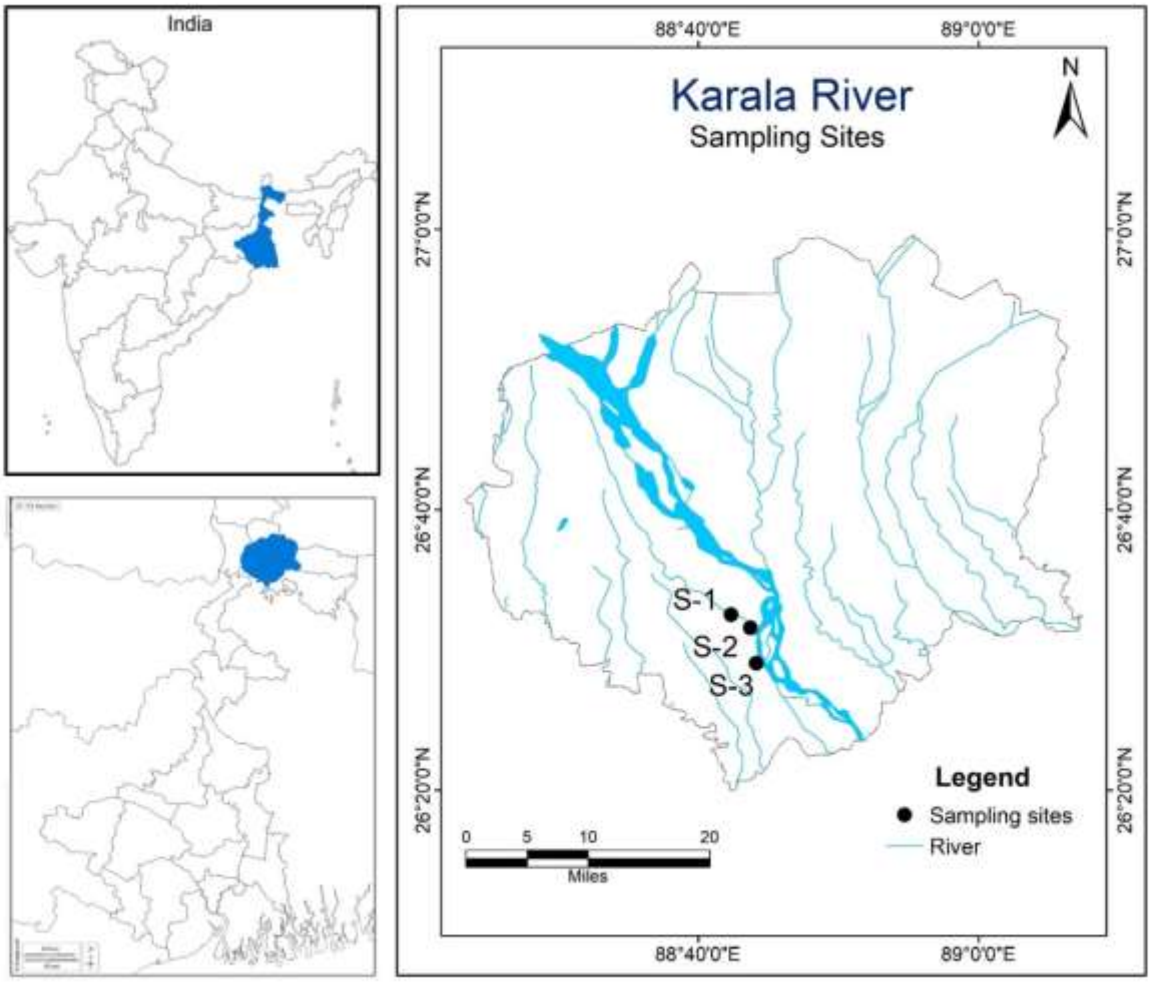

Figure 1: Sampling location in the map

2.2. Water quality analysis for drinking purposes

The river flow varies with the time of the year, climatic situation, and drainage patterns. Like a riverine system, every freshwater body has its own pattern of physical and chemical characteristics which are governed by the drainage basin's climatic, geomorphologic and geochemical conditions(Chapman, 1996).Water quality is described in terms of the concentration and state (dissolved or particulate) of some or all of the organic and inorganic materials in the water, together with some physical characteristics (Bartram and Ballance, 1996). Nowadays, pollution plays a vital role in determining the quality of the water of a river. Pollution of the aquatic environment occurs when humans introduce, either by direct discharge to water or indirectly, some substances or energy that have deleterious effects on the biotic community. The deleterious effects may include hazards to human health, harm to living resources, and hindrance to aquatic activities such as fish production (GESAMP, 1988). The large number of physical and chemical parameters that determine the water quality sometimes makes itdifficult to understand the significance of the parameters instantly. In this situation, the water quality index (WQI) can be used to summarise a large amount of water quality data into a simple term. Thus, WQI allows for comparing the water quality of diverse sources, reporting to policy-makers, and ensuring the perception of ordinary people is consistent.The water quality index is a complex mathematical outcome that aggregates information into a usable form, reflecting the composite influence of the water's significant physical, chemical and biological parameters(Muthulakshmi et al., 2013).

There are numerous specific WQI for a specific region, considering different parameters in water quality assessment, depending upon the utility of the water because many National and International agencies define water quality criteria for various uses. Other water quality indices developed in the world are the US National Sanitation Foundation Water Quality Index (NSFWQI), Canadian Council of Ministers of the Environment Water Quality Index (CCMEWQI), British Columbia Water Quality Index (BCWQI), and Oregon Water Quality Index (OWQI). A few scientists also proposed individual methods, like Smith's method and Bhargav's methods, for the same purpose(Tirkey et al., 2013).The following procedure of Pesce and Wunderlin, 2000 calculated WQI.

$$\mathrm{WQI} = \mathrm{k}\frac{\sum \mathrm{CiPi}}{\sum \mathrm{Pi}}$$

Where k = subjective constant, its value depends on the visual impression of the river. Its value ranges from 0.25 to 1.00. k = 0.25 is assigned for highly contaminated water, 0.5 for moderately contaminated water, and 0.75 for light-contaminated water. Value 1.00 is assigned for apparently good-quality water. Ci is each parameter's normalised value, and Pi is the relative weight value assigned to the corresponding parameter. Values of Ci and Pi can be obtained from the paper authored by Pesce and Wunderlin, 2000.

The value of WQI ranges from 0 – 100 and is classified into five categories. WQI values between 0 – 25 are classified as "very bad"; the values of WQI between 26 – 50 are classified as "bad"; WQI values between 51 – 70 are classified as "medium"; WQI values between 71 – 90 are classified as "good" and the WQI values between 91–100 classified as "excellent"(Jonnalagadda and Mhere, 2001).

2.3. Water quality analysis for fish production: -Fish is an essential source of protein for people.A substantial quantity of fish is needed for daily consumption, much of which is sourced from rivers.Again, fish production depends on the river water's physical, chemical, and biological qualities. Though the overall water quality of the river under study, as predicted by the WQI analysis, is medium contaminated, some individual parameters that profoundly impact the fish's production need to be discussed. Some important parameters that maintain an aquatic healthy environment are temperature, turbidity, pH, alkalinity, hardness, ammonia, nitrite, nitrate, primary productivity, biochemical oxygen demand (BOD), TDS, and plankton population.

2.4 Water quality analysis for Industrial purpose

Langelier Saturation Index is the measure of a solution's ability to dissolve or deposit calcium carbonate and is used to express the corrosivity of water(Langelier, 1936). The index is related to the deposition of calcium carbonate or scale formation. This scale can insulate a system's pipes, boilers, and other components from water contact. When there is no scale formation, the water is aggressive,and corrosion can occur. Both scale formation and corrosion can cause system failures, necessitating repair or replacement.

The Langelier Saturation Index is the difference between the actual pH and pHs, the pH of the solution saturated with calcium carbonate. LI is calculated as -

$LI = pH - pHs$

And pHs is calculated as

$pHs = A + B - C - D$

A is the corresponding value of temperature (in ºC). B, C, and D are the corresponding values of TDS (in mg/L), calcium hardness, and total alkalinity (expressed in mg/L as $CaCO_3$), respectively, given by Langelier.

Table 1: Classification of water quality based on the Langelier index

Corrosive characteristics	Langelier Index	Water types
Highly Aggressive	< -2.0	Not scale-forming water
Moderately Aggressive	-2.0 to 0.0	Balanced water
Nonaggressive	> 0.0	Scale forming water

3. Result and discussion

The water quantity, water flow, pollution status, and values of different parameters have changed significantly over the years. Our common experience is that the worst water quality prevails in the pre-monsoon season because the heavy rain in the monsoon season washes away some pollutants. Therefore, the water quality in the post-monsoon season becomes better than in the pre-monsoon season. This is why we used the values of thephysicochemical water parametersof the pre-monsoon season in this study.The summary of thevalues of variousphysicochemical water parameters ispresented in the following table

Table 2: The analytical values of various physicochemical water parameters

Sl.No	Parameters	Pre-monsoon 2012 (Mandal et al. 2012)		
		S-1	S-2	S-3
1	BOD in mg/L at 26º C	1.43	1.65	1.44
2	Chloride in mg/L	1.483	1.677	1.806
3	COD in mg/L	18.4	17.67	16.38
4	Conductivity in µmho/cm	79.01	91.12	88.17
5	Dissolved oxygen in mg/L	6.76	5.53	6.14
6	Hardness in mg/L	29.27	33.27	31.88
7	pH	7.58	7.24	7.33
8	TDS in mg/L	40.17	46.51	44.92
9	Temperature in ºC	26	26	26.8
10	TKN in mg/L as Ammonia' N'	1.452	1.671	1.439
11	Total solid in mg/L	63.28	83.17	81.58
12	TPP in mg/L as phosphate 'P'	729.52	827.58	790.28
13	Turbidity in NTU	1.555	0.866	1.167

ThepH values of the three sampling stations were in the recommended range. All three BOD values of this analysis fall in the recommended range (Table 3). According to Bhatnagar and Singh, 2010, BOD < 1.6 mgL^{-1} is suitable for optimum fish production. Thisresearch work indicated that the river was in good condition in respect of BOD for fish production.The temperatures of all three sampling stations were also in good concordance with Santhosh and Singh, 2007 and Ezeanya et al., 2015. Total dissolved solids (TDS) values were much higher than the recommended value of 0.13 mgL^{-1} proposed by Ezeanya et al., 2015. Higher values of TDS cause cell damage among the fish. According to Stone and Thomforde, 2004, the desirable range of hardness is 50 - 150 mgL^{-1},and below 20 mgL^{-1} causes stress on the water body. The hardness values did not fall in the desirable range and were close to the stress level. The river neededmanagement actions to upgrade the water qualityregarding hardness values. Bhatnagar and Singh, 2010, and Ekubo and Abowei, 2011, recommended that the DO value ≥ 5.0 mgL^{-1} is suitable for fish culture.

All three DO values of the three sampling stations were above the recommended value, indicating the healthy DO level of this river. According to Stone and Thomforde, 2004, the desirable limit of total ammonia is 0 - 2 mgL^{-1}, and Bhatnagar and Devi, 2013 suggested that < 0.05 mgL^{-1} is safe for many tropical fish species. The values were within the limits of Stone and Thomforde, 2004, but largely exceeded those proposed by Bhatnagar and Devi, 2013. Fishes and aquatic animals may face adverse effects of excessive ammonia. The optimum phosphate concentration for fish production is 0.06 mgL^{-1} (Stone and Thomforde, 2004). Bhatnagar and Devi, 2013 suggested the range as 0.05 - 0.07 mg L^{-1}. The three phosphate values obtained from the sampling stations were much higher than the recommended. The higher phosphate value results in excessive planktonic and algal growth. Consequently, fish production was expected to increase as some species feed on algae and plankton. According to Ezeanya et al., 2015, the standard value of TSS for fish production is 10.0 - 20.0 mgL^{-1}, but the value of the Karala River was slightly higher. The river water needed treatment for productive fish cultivation. The proper coagulant may decrease the TSS level. However, adequate monitoring and subsequent measures are essential inthecase of TDS, hardness, TKN, and TPP.

Table 3: Values of recommended water parameters for fish production

Sl. No		Recommended values	References
1	pH	6.5 - 9.0	Ekubo and Abowei, 2011
2	BOD	<1.6 mg/L	Bhatnagar and Singh, 2010
3	Temperature	25ºC - 30ºC	Ezeanya et al., 2015
4	TDS	0.13 mg/L	Ezeanya et al., 2015
5	Total Hardness	50 - 150 mg/L	Stone and Thomforde, 2004
6	DO	≥ 5.0 mg/L	Bhatnagar and Devi, 2013
7	‘N’- NH_3	< 0.05 mg/L	Bhatnagar and Devi, 2013
8	‘P’- Phosphate	0.01-3.0 mg/L	Bhatnagar and Devi, 2013
9	TSS	10.0 - 20.0 mg/L	Ezeanya et al., 2015

The present analysis shows that the WQI values were 59.00, 56.25, and 57.25 for sampling stations S-1, S-2, and S-3, respectively, which indicatedthe "medium water quality"of the river.

In this analysis, the value of the Langelier Index for sample S-1 was −1.12; for sample S-2, the value was −1.56; and for sample S-3, the value was −1.47. The three values are negative (Table 1), indicating that the water is moderately aggressive and untreated water is unsuitable for industrial purposes. However, proper treatment procedures may make the water suitable for industrial uses.

Table 4: Pearson correlation matrix of various water parameters

	Temp	pH	EC	DO	Turbidity	TDS	TS	Hardness	BOD	COD	Chloride	TKN	*TPP*
Temp	1.000												
pH	-0.262	1.000											
EC	0.284	-1.000	1.000										
DO	-0.005	0.966	-0.960	1.000									
Turbidity	-0.073	0.982	-0.977	0.998	1.000								
TDS	0.277	-1.000	1.000	-0.962	-0.979	1.000							
TS	0.436	-0.983	0.987	-0.902	-0.929	0.985	1.000						
Hardness	0.173	-0.996	0.994	-0.986	-0.995	0.994	0.962	1.000					
BOD	-0.465	-0.733	0.717	-0.883	-0.849	0.722	0.594	0.791	1.000				
COD	-0.934	0.589	-0.607	0.361	0.424	-0.601	-0.729	-0.513	0.118	1.000			
Chloride	0.800	-0.789	0.802	-0.604	-0.657	0.798	0.889	0.730	0.159	-0.961	1.000		
TKN	-0.543	-0.668	0.651	-0.837	-0.798	0.657	0.519	0.733	0.996	0.207	0.070	1.000	
TPP	0.137	-0.992	0.989	-0.991	-0.998	0.990	0.951	0.999	0.814	-0.481	0.704	0.758	1.000

At a significance level alpha = 0.05

The Pearson correlation matrix (Table 4) was calculated using the analytical values of the water parameters to determine the interdependence of one parameter with another. A positive value describes direct proportionality, a negative value indicates inverse proportionality and a zero value indicates no relation, i.e., the two parameters are not dependent. Moreover, if the correlation coefficient (r), r > 0.7,indicatesa strong correlation, r value 0.5 to 0.7indicates a moderate correlation and r < 0.5 indicates a weak correlation (Kumar et al., 2006).Almost all the parameters are strongly correlated except in a few cases. Temperature is not strongly correlated with other parameters except COD and chloride. COD is poorly correlated with DO, turbidity, TKN, TPP, and BOD. Chloride is also poorly correlated with BOD and TKN.

Conclusion

Though the physique of the river is small, its impact on the people of the Jalpaiguri district is tremendous. The river is not free from the clutches of degradation. The WQI analysis designates the river as 'medium contaminated'. Most of the individual water quality parameters are within or very close to the recommended fish production values, but TDS, hardness, TKN, and TPP need proper monitoring. The analysis of the Langelier Index indicates that the water is moderately aggressive for industrial uses.

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