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Impact of Industrial and Urban Sewage on Stream Water Quality: A Case Study of River Damodar near Durgapur, West Bengal, India

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ABSTRACT

In this work attempt was made to assess the effect of industrial effluents and urban domestic sewage on water quality of the river Damodar near Durgapur, a major industrial city located on left bank of the concerned river. Data generated by West Bengal Pollution Control Board (WBPCB) on twenty water quality parameters observed every month for a period of 4 years between 2014 and 2017 in pair from two stations, one is at upstream and other at downstream side of the Tamala Nala confluence. Paired Sample t-Test was conducted to compare the value of each parameter observed from two distinct stations and its non-parametric counterpart Wilcoxon Signed Rank Test was also applied for those variables which didn't assume the normality. Out of 20 parameters 14 shows significant difference in their concentration in between up and down stream stations at 5% significance level ($p < 0.05$). The statistical results substantiated by descriptive statistics provide strong evidences to say that the urban and industrial waste water does really have influence in determining the water quality of the river Damodar in West Bengal.

1. Introduction

Quality of river water at a given stretch is determined by both natural and anthropogenic effects. The anthropogenic factors like urban and industrial waste water, mining activity, use of agricultural chemical, dumping of solid waste, exploitation of water resources etc. together constitute the constant polluting sources whereas the natural processes like contamination of geogenic substances which occurs through runoff is a seasonal phenomenon largely affected by climate (Pejman et al., 2009; Shrestha & Kazama, 2007).

A number of works have been reported from many rivers round the globe and India as well (Aruga et al., 1993; Singh et al., 2005; Suresh et al., 2009; Varol & Şen, 2009; Vega et al., 1998). In Indian context what is common in their findings is that the rivers are getting polluted mainly because of rapid urbanization, industrialization, intensive petrochemical-based agriculture, and growing demand for energy etc. (Chatterjee et al., 2010; Jain et al., 2007).

Recently with rapid growth of economy and population the industrial effluent and domestic sewage have become the most common sources of water pollution (Sangodoyin, 1991) which not only affects the utility of this scarce resources but also disrupts the whole environment (Suganthi & Ahamed, 2011; Pillai & Khan, 2016).

Chatterjee et al. (2010) have showcased the evidences from the studies on Indian rivers like Mahanadi, Narmada, Uppanar, Gola, Gomti etc. support this view. It is also worthy to mention that the effect of urban and industrial activities on a river is found to be different depending upon the concentration of industrial units, density of urban population, management strategies adopted thereby etc. So, the pollution analysis of specific river stretch is essential for understanding the anthropogenic effects and formulating strategic plan in view to maintaining the water quality of available flow on sustainable basis.

The present case study has been carried out in view to assess the effect of industrial effluents and urban domestic sewage on water quality of the stretch of river Damodar near Durgapur, a major industrial city and fourth largest urban agglomeration in West Bengal. The area has been the part of Damodar Valley which includes India's most important coal and mica mining fields and has long been an area of active industrial development (Britannica, 2017).

So far, many works have been reported from Damodar Valley but most of these works were done from pollution perspectives i.e., judging the concentration level of a particular pollutant, or assessing the water quality at any point on river channel near any industrial unit or mining spot to know its suitability for a particular use (Banerjee & Ghosh, 2012; Chatterjee et al., 2010; George et al., 2010; A. R. Ghosh & Banerjee, 2012; S. Ghosh, 2011; Mukherjee, 2012; Saha, 2010; Sinha et al., 2013; Verma et al., 2013). Until recently, no initiative has been taken to evaluate the specific role the industrial and domestic waste water together have in determining the water quality of river Damodar. The present study is an initiative toward achieving this objective.

2. The Study Area

Durgapur urban agglomeration which spreads in and around the Durgapur Municipal Corporation is located on left bank of river Damodar, a lower Ganga tributary in Eastern India. It is one of the major industrial cities in Indian state of West Bengal and hosts more than 150 industrial units (MSME, 2012). The Municipal Corporation itself covers an area of 157 km^2 while the Urban Agglomeration extends over the area of 1,615 km^2 with population density of 3600 persons per km^2 (Census of India, 2001).

Almost the entire industrial township of Durgapur city is drained by a small tributary named as Tamla Nala which joins its main river Damodar at Majher Mana village (Fig.1). So, any polluting effect of this urban domestic and industrial waste water on the river Damodar is supposed to be reflected to the immediate downstream side of this Tamla Nala confluence at Majher Mana.

West Bengal Pollution Control Board (WBPCB), a legal autonomous body constituted for the purpose of environmental surveillance makes continuous monitoring of Damodar water quality at this spot. This apex body has another monitoring station named as Durgapur Upstream which is located 12 km upstream of the Majher mana (Fig. 1) and Durgapur City is located in between. If any kind of difference is observed for the water quality in between these two monitoring stations on river Damodar, that could be attributed to this sewage contamination caused by Tamala Nala. Keeping all these in view the stretch of river Damodar near Durgapur Industrial city has been investigated to achieve the objective stated earlier.

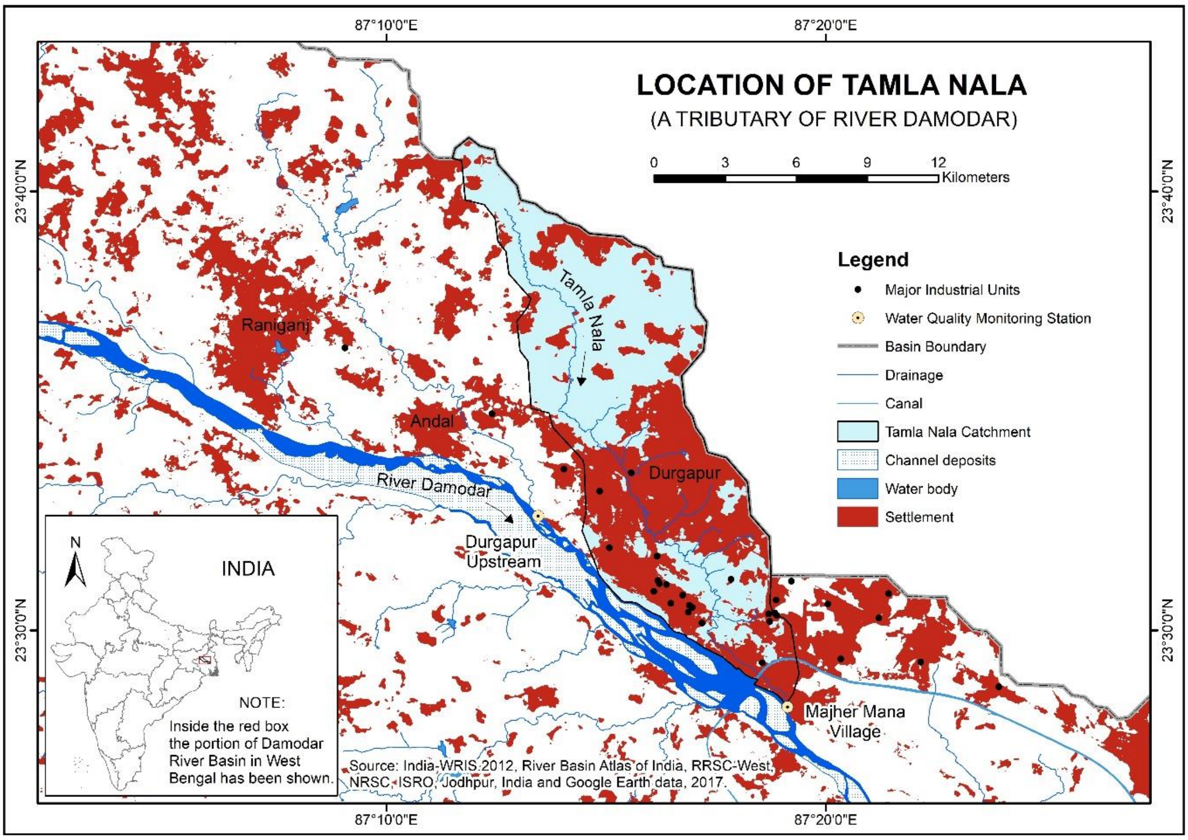

Fig. 1: Location of Tamla Nala catchment which drains the waste water of Durgapur industrial area and outfalls at river Damodar.

3. Database and Methodology

The study was done based on database generated by West Bengal Pollution Control Board (WBPCB), Department of Environment, Govt. of West Bengal as a part of National Water Monitoring Program (NWMP) which was started by Central Pollution Control Board (CPCB), Govt. of India in 1978 under Global Environmental Monitoring System (GEMS) (CPCB, 2007).

The WBPCB makes observation on twenty-six water quality parameters but for the present study twenty parameters have been selected and these include Faecal Coliform (F. Coli), Total Coliform (T. Coli), Turbidity, Total Suspended Solid (TSS), Chlorine (Cl^-), Total Alkalinity (TA), Nitrate Nitrogen (NO_3-N), Calcium (Ca^{2+}), Total Fixed Solid (TFS), Total Hardness (TH), Temperature, Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Dissolved Oxygen (DO), Total Dissolved Solid (TDS), Electrical Conductivity (EC), Fluoride (F^-), Sodium (Na^+), Sulphate (SO_4^{2-}), and pH. Basic reason for their selection is that they are available on regular basis without any missing frequency and censored value.

The observations were made every month in pair from two monitoring stations, one is the Majher Mana village which is located to the immediate downstream side of Tamla Nala confluence with river Damodar while other one named as Durgapur Upstream is located 12 km upstream of the same confluence point (Fig.1) and it was continued for the monitoring period of 4 years between 2014 and 2017 which all together generates 48 cases and 96 data points for each parameter.

The analysis was done by means of hypothesis testing in view to assess the pair-wise differences in mean values of the concerned water quality parameter. Since it is the issue of paired comparison, paired samples *t*-Test was applied for those parameters which were proved to be normally distributed, otherwise Wilcoxon Signed Rank Test which is the non-parametric counterpart of paired samples *t*-Test was used for the same purpose. The main reason for applying two different tests in such cases is that the concerned tests are powerful in the relevant context. However, the data set of each parameter for both the stations was checked separately for normality by using Kolmogorov-Smirnov Test.

This analysis is designed based on the principle that same subject (i.e., flowing water of river Damodar) will show different characteristics in terms of its physical, chemical and biological properties at two different locations (i.e., monitoring stations) and at the same point of time if the industrial and urban sewage discharged though Tamla Nala affects the water of river Damodar in between the two concerned monitoring stations.

4. Result and Discussion

Two water quality monitoring stations – Durgapur Upstream and Majher Mana Village – have been identified as the "Less Polluted" stations (Category – IV, indicating the water is not fit for bathing) based on five-point classification scheme developed by Central Pollution Control Board (CPCB, 2007) which uses BOD and F. Coli value as the classification criteria.

According to Designated Best Use Classification of Surface Water, another use-based classification of surface water introduced by CPCB which uses F. Coli, BOD, DO and pH as the criteria parameter, the water from both the stations are again not fit for bathing. This is mainly due to high concentration of F. Coli which must be 50 MPN/100 ml or less to make the water suitable for outdoor bathing but here the values are extremely high (Table 1). This clearly indicates the contamination of pulp or paper mill effluent, storm sewage and human sewage, all of which are evidenced in the region. Again, it is noticeable fact that the water of Damodar at Majher Mana Village is more degraded than that at Durgapur Upstream in terms of F. Coli concentration which can be attributed to the sewage discharge of Tamla Nala catchment.

Mean BOD value for Majher Mana Village (3.80 mg/l) is a bit higher than the acceptable limit (3 mg/l or less) for outdoor bathing while that of Durgapur Upstream is found to be within specified limit. But COD values for both the stations are quite high though it is higher at Majher Mana than the value at Durgapur Upstream. Mean DO values, on the other hand, are observed to be above the minimum concentration criterion (5 mg/l or more) and it is lower for Majher Mana while pH value is within specified limit of bathing criteria. However, mean difference of all the parameters (except that of T. Coli, Ca^+ and TH) between two stations are indicative of the fact that water quality of river Damodar at Majher Mana has got deteriorated in comparison to that of Durgapur Upstream and it might be due to the influence of Tamla Nala which discharges the urban and industrial sewage of Durgapur city into the main river to the immediate upstream side of Majher Mana Village.

Table 1: Station-wise Mean Value of each Water Quality Parameter

Parameters	Unit	Durgapur Upstream	Majher Mana Village	Parameters	Unit	Durgapur Upstream	Majher Mana Village
BOD	mg/l	2.78	3.80	F. Coli	MPN*/100 ml	7350.00	9687.50
COD	mg/l	8.72	21.38	T. Coli	MPN*/100 ml	20820.83	18000.00
DO	mg/l	8.48	6.69	Ca^+	mg/l	33.23	29.24
Temperature	ºC	28.59	28.71	Na^+	mg/l	20.52	40.10
TDS	mg/l	166.71	305.67	Cl^-	mg/l	35.34	66.90
TSS	mg/l	29.75	384.88	NO_3-N	mg/l	0.48	1.20
TFS	mg/l	117.04	269.46	SO_4^{2-}	mg/l	23.94	39.61
Turbidity	NTU**	21.68	42.34	EC	µs/cm	281.67	490.57
pH	pH Unit	7.89	7.73	TH	mg/l	139.50	114.06
TA	mg/l	133.13	136.79	F^-	mg/l	0.48	0.80

*MPN = Most Probable Number, ** NTU = Nephelometric Turbidity Unit
Source: Computed by author.

Table 2: Result of Normality Test[a]

Parameters	Durgapur Upstream		Majher Mana Village		Parameters	Durgapur Upstream		Majher Mana Village	
	Test Statistic	*p*-Value	Test Statistic	*p*-Value		Test Statistic	*p*-Value	Statistic	*p*-Value
F. Coli	0.254	0.000	0.349	0.000	BOD	0.084	0.200	0.084	0.200
T. Coli	0.335	0.000	0.353	0.000	COD	0.099	0.200	0.115	0.136
Turbidity	0.327	0.000	0.287	0.000	DO	0.102	0.200	0.055	0.200
TSS	0.264	0.000	0.353	0.000	TDS	0.096	0.200	0.096	0.200
Cl^-	0.295	0.000	0.158	0.004	EC	0.068	0.200	0.103	0.200
TA	0.254	0.000	0.158	0.004	F^-	0.108	0.200	0.065	0.200
NO_3-N	0.184	0.000	0.187	0.000	Na^+	0.097	0.200	0.094	0.200

Ca^{+}	0.134	0.031	0.137	0.024	SO_4^{2-}	0.068	0.200	0.064	0.200
TFS	0.084	0.200	0.153	0.007	pH	0.061	0.200	0.074	0.200
Temperature	0.123	0.065	0.188	0.000	TH	0.183	0.000	0.104	0.200

[a]Kolmogorov-Smirnov Test with Lilliefors Significance Correction and *p*-Values less than 0.05 are displayed with grey shaded cell background to indicate that corresponding parameters violate the normality assumptions.

Source: Computed by author.

The result of Normality Test (Table 2) shows that at both the stations 9 parameters namely BOD, COD, DO, TDS, EC, F^-, Na^+, SO_4^{2-}, and pH are proved to be normally distributed at 5% significance level ($p > 0.05$) while eight parameters namely F. Coli, T. Coli, Turbidity, TSS, Cl^-, TA, NO_3-N and Ca^{2+} violet this assumption ($p < 0.05$). TFS and Temperature, on the other hand, follow the normal distribution at station Durgapur Upstream ($p > 0.05$) but at Majher Mana Village they don't ($p < 0.05$) assume so while the opposite is observed for TH.

The normality of the data was checked in order to decide whether to apply parametric or non-parametric test for data analysis. Paired samples *t*-Test was conducted to analyse those 9 parameters (BOD, COD, DO, TDS, EC, F^-, pH, Na^+, SO_4^{2-}) which do not violet the normality assumption. The result shows (Table 3) that there was a significant difference ($p < 0.05$, $df = 47$) in the value of each parameter observed (simultaneously in pair) from two different stations i.e., Majher Mana Village and Durgapur Upstream.

Table 3: Result of Paired Samples *t*-Test

Parameter	Mean of Paired Difference	SE	Lower Boundary	Upper Boundary	*t*	*p*-Value	Result
BOD	-1.025	0.237	-1.502	-0.547	-4.318	0.000	Significant
COD	-12.663	1.895	-16.476	-8.851	-6.682	0.000	Significant
DO	1.792	0.285	1.219	2.364	6.296	0.000	Significant
TDS	-138.958	15.284	-169.707	-108.210	-9.092	0.000	Significant
EC	-208.902	21.001	-251.151	-166.653	-9.947	0.000	Significant
F^-	-0.327	0.026	-0.380	-0.275	-12.516	0.000	Significant
pH	0.164	0.075	0.014	0.313	2.195	0.033	Significant
Na^+	-19.583	2.158	-23.924	-15.243	-9.077	0.000	Significant
SO_4^{2-}	-15.674	1.597	-18.886	-12.462	-9.817	0.000	Significant

Source: Computed by author.

Table 4: Result of Wilcoxon Signed Rank Test

Parameter	*Z*	*p*-value	Result	Parameter	*Z*	*p*-value	Result
TA	-1.763	0.078	Not Sig.	TSS	-5.026	0.000	Significant
Ca^+	-0.717	0.473	Not Sig.	TFS	-5.908	0.000	Significant
TH	-1.710	0.087	Not Sig.	Turbidity	-3.128	0.002	Significant
F. Coli	-0.429	0.668	Not Sig.	Cl^-	-5.075	0.000	Significant
T. Coli	-1.896	0.058	Not Sig.	NO_3-N	-2.529	0.011	Significant
Temperature	-0.159	0.874	Not Sig.	-	-	-	-

Source: Computed by author

Wilcoxon Signed Rank Test was applied for analysing all other parameters which violet the normality assumption. This is worthy to mention that TFS, Temperature and TH have been proved to be normally distributed at one station while at other they have violated this assumption and that is why these three parameters have been analysed by Wilcoxon Signed Rank Test assuming that they do not follow normal distribution. The result (Table 4) shows that there is significant difference ($p < 0.05$) in the concentration level of TSS, TFS, Turbidity, Cl^- and NO_3-N observed at two distinct locations i.e., Majher Mana Village and Durgapur Upstream while TA, Ca^+, TH, F. Coli, T. Coli and Temperature are not.

Another important thing to be noticed, here, is that except DO, pH and T. Coli all other parameters show high mean value at Majher Mana Village compared to their corresponding values at Durgapur Upstream (Table 1) indicating poor water quality of river Damodar at Majher Mana Village as compared to that at Durgapur Upstream. DO and pH are inversely related to the water quality status i.e., their low value is observed for deteriorated water and vice-versa. T. Coli, on the other hand, does not show statistically significant difference in their concentration in between these two stations (Table 4).

It has already been mentioned that Majher Mana Village is located to the downstream side of confluence of Tamla Nala and river Damodar while to its upstream there is second station called Durgapur Upstream with a distance of 12 km in between. There is no other interference to river Damodar in between these two stations but the Tamla Nala which carries the urban and industrial waste water of entire Durgapur city and outfalls at trunk stream Damodar. So, the difference in water quality parameter which is presently inferred from the result of above mentioned two hypothesis tests could be attributed to the sewage contamination caused by Tamla Nala. Descriptive statistics also provide the evidences for getting deteriorated water to the downstream of Tamla Nala confluence. So, there is substantive evidences to say that industrial and urban waste water really does have an effect on water quality of river Damodar near Durgapur city in West Bengal.

Now, question is why then the parameters TA, Ca^{+}, TH, F. Coli, T. Coli and Temperature don't show any significant differences in their concentration level in between the two stations. The major source of TA, Ca^{+}, TH in stream water is the geology and soil which are expected to be uniform in this short stretch of river (Leo, 2017)(USU, 2017) and that is why they don't show significance differences in between two monitoring stations.

There is also some impact of urbanizations on TA. Here, in the present study, Durgapur city does not create any difference in TA concentration in between its upstream and downstream side because Asansol city, another urban agglomeration (not shown in fig. 1) even bigger than Durgapur is located to the upstream side of the study area and diluting the effect of other urban centres to the downstream side.

T. Coli and F. Coli indicate the environmental and recent faecal contamination respectively (WSDOH, 2017). Environmental contamination happens to be a wide scale phenomenon which cannot be captured with much difference within very short distance as observed in the stretch of river Damodar. In the urban area faecal contamination usually occurs due to septic tank failure which is rare in the city like Durgapur and that is the reason why in between up and downstream side of the city such parameters don't show significant difference. No difference in temperature of water between the two stations may be attributed to the fact that in the Tamala Nala catchment there is no thermal power station and the insolation distribution is not expected to vary within this short distance between two monitoring stations.

One thing to be noticed here is that each water quality parameter has been compared in two different locations having different conditions, i.e., Majher Mana Village which manifests the urban and industrial influence and Durgapur Upstream which does not. But Durgapur barrage is located in between these two and it causes decrease in discharge in downstream station i.e., Majher Mana village. This aspect has not been incorporated in this study. Again, seasonal influence on both the stations has been ignored. These are the limitations that the present study carries.

5. Conclusion

The industrial effluent and urban sewage drained from Durgapur industrial area really determine the water quality of the nearby stretch of river Damodar in West Bengal. But the stretch is not extremely polluted rather it belongs to Category – IV which is defined as "Less Polluted" by Central Pollution Control Board, Govt. of India. Not only the sewage, there may be again influence of seasonality of prevailing climate since the Damodar basin area belongs to monsoon climate having well defined wet and dry seasons but evaluation of this seasonal influence is beyond the scope of the present study. Again, the Durgapur Barrage on river Damodar intervenes the river discharge which might have influence on water quality and this latter phenomenon has also been ignored to avoid the complexity of the investigation. Ultimately, how the river water quality responds to all these factors together it is making the scope of further research.

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