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RESEARCH ARTICLE

STATUS OF WATER QUALITY OF MINI RIVER, VADODARA

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ABSTRACT

Fresh water is essential for healthy living. River water is used for various purposes such as bathing, drinking, community water supply, irrigation etc. This natural resource is being polluted by disposal of industrial waste sewage and human activities which affect the quality of river water. In the present study an attempt has been made to study water quality parameters and pollution status of Mini River of Vadodara region (Gujarat). For this study the water samples were collected from pre-selected sampling stations during December to March 2015 and important physico-chemical parameters such as Temperature, Conductivity, pH, DO, BOD, COD, Salinity, TSS, TDS, Phosphate, Nitrate-N, Nitrite-N, Total nitrogen, Silicates, Sulphate, Flouride, Dissolved Petro-Hydrocarbon were analyzed. The values of COD at all stations was within Permissible limits prescribed by CPCB. The value of salinity and DO were beyond permissible limits in some samples. On the basis of this study it was concluded that water of Mini River is moderately polluted due to discharges of industrial waste, domestic sewage and agricultural run-off and required more efficient management to conserve this river.

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INTRODUCTION

Industrial development results in the generation of industrial effluents, and the release of untreated or treated effluents result in water, sediment and soil pollution (Fakayode and Onianwa 2002, Fakayode 2005). High level of pollutants mainly organic matter in river water cause an increase in biological oxygen demand (Kulkarni 1997), chemical oxygen demand, total dissolved solids, total suspended solids and fecal coli form. These make water unsuitable for drinking, irrigation or any other use (Hari 1994). In India, Central Pollution Control Board have identified about 150 polluted stretches along various rivers based on Bio-Chemical Oxygen Demand levels (a key indicator of organic pollution). Of those 150 stretches, 28 are in Maharashtra, 19 in Gujarat, 12 in Uttar Pradesh, 11 in Karnataka and 9 in Tamil Nadu. In China, over the last 50 years, there has been a 73% increase in pollution levels from hundreds of cities, in the main stream of the Yangtze River. The annual discharge of sewage and industrial waste in the Yangtze River has reached about 25 billion tons, which is 42% of the country's total sewage discharge, and 45% of its total industrial discharge. Pollution and industrial development goes together. Though there are steps initiated to reduce the pollution be it water or air, but would take some time before the signs of improvement in the nature is visible. There are trends in developing countries to use sewage effluent as fertilizer as it is considered a source of organic matter and plant nutrients and serves as good fertilizer (Riordan 1983,Patil *et al.,* 2012).

There is regular monitoring of the major rivers, but the smaller ones are generally not monitored, that are equally important source of water for the residents along its course. Further, these small rivers end up draining into the major river before entering into the sea. The present paper tried to enumerate the status of one of the small and lesser known rivers, Mini river located in north-west of Vadodara city. The river passes from Savli, industrial areas of Ranoli, GSFC and Nandesari Industrial Estate. Currently, the Nandesari Industrial Estate has 250 small scale industries that produce organic and inorganic chemical compounds, pharmaceuticals and drugs (Misra, 2002). Previously water quality in the mini river was anlysed for the locations adjoining the industrial area (Patel *et al.,* 2013), but the entire stretch was not done. The present study was done for the entire riverine stretch from its beginning till it entry into the Mahi river.

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Study area

The river originates in the Savli taluka and traverses a total length of 35 Km before draining into River Mahi. Rainfall in this area ranges from 850 to 1050 mm. The region is characterized by the moderate subtropical monsoonal type of climate (Srivastava *et al.,* 2011). A total number of 8 stations were considered for sampling and the details of each station are shown in the map. Stations 1 to 3 represent the upstream. Station 4 to 8 passes through the industrial cluster, first through the Manjusar Industrial area and then Nandesari Industrial estate. There are small towns along the course of the river that release untreated sewage directly into the river. Due to this, the water at station 1 to 3 is blackish in colour. After station 4 onwards, there is release of treated industrial effluents directly into the river and fishy odour is reported. At station 6, mortality of fish was reported which is indicative of highly stress condition.

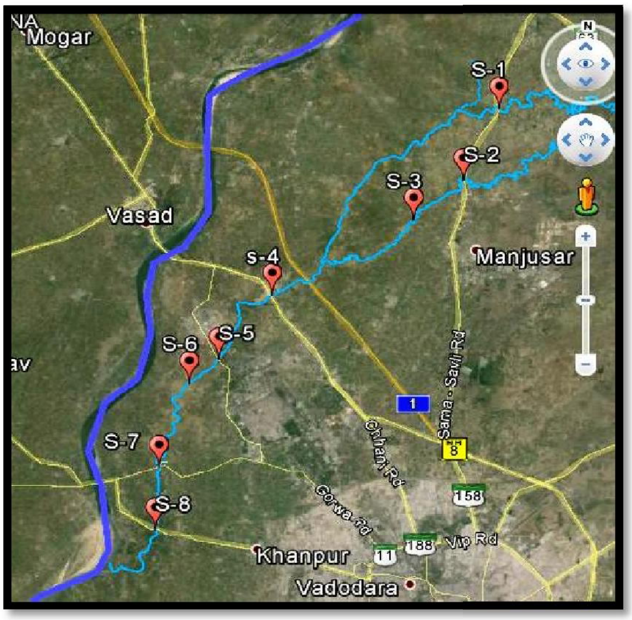

Figure 1. Location map of study area

MATERIALS AND METHODS

A total of 18 water parameters were analysed using standards methods (APHA). Surface water samples were collected from each location in the morning hours in triplicates during the month of January 2015. For analysis of DO, the water samples were collected in a 300 ml BOD bottle and fixed on site using $MnSO_4$ and Alkaline Iodide-Azide solution. For rest of the parameters, water samples were collected in one litre plastic bottle and brought to the laboratory. All the parameters were analysed within 4 hours of sample collection using the standard methods (APHA). For statistical analysis of the data, Pearson correlation coefficient and cluster analysis was performed.

RESULTS AND DISCUSSION

The temperature of Mini River water ranged between 15.5°C to 19.5°C. There was steady increase in the water temperature from station 1 to station 8. The water temperature is in optimum range (Mishra and Patel 2001; Yadav 2003) and due to sampling in winter season the water temperature recorded was below 20°C. The pH values in the present study varied from 7.64 to 8.56 and the values were within permissible limits as per CPCB. The pH values declined downstream of station 6. Previous study (Patel and Parikh, *et al.,* 2013) reported pH in the range of 6.5 to 8.5 of Mini river. Thus, the present study indicates improvement in the pH levels attributed to steps taken for industrial discharges. The conductivity recorded at all stations was in the range of 467.5µS (station 2) to 2080 µS (station 8). The highest conductivity value was recorded downstream to station 5 *viz*., station 6, 7 and 8 (Table 1). There is positive correlation (P significant at 0.5 level) between conductivity, salinity, TDS and these have contributed to positive ions resulting in high conductivity value. This indicates influence of sea at stations downstream of station 5. The chlorides levels was also high at station 6 (1038.67 mg/l), station 7 (2034.88 mg/l) and station 8 (2298.5 mg/l). Higher levels of chloride indicate influx of sea water during the high tide. A close look into the map would reveal that the Mini river drains into the Mahi river, which is at a distance of 40 km from the sea. The tidal amplitude of Gulf of Khambhat is high about 11 m (Mishra *et al*., 2014). Due to construction of barrage across Mahi river, there is intrusion of sea water upto station 6 of Mini river. The TDS values recorded minimum 258 mg/L at station 1 and maximum 1551 mg/L at station 8. As per the Indian standards, the permissible limit of TDS in fresh water is 1000 mg/L (Deshkar *et al*., 2014). In the present study, the values were above the permissible limits at station 6, 7 and 8. Attributed to sea water intrusion as mentioned above. The DO values ranged from 4 mg/L (station 2) to 9.84 mg/L (station 4). Low DO value at station 2 is attributed to high TSS value due to discharge of domestic sewage. A drop in DO value was recorded at station 2, which is related with high discharges as inferred from higher TSS value in the same station. At station 6 also, drop in the DO levels was reported which coincided with the sighting of dead fish at this station. As per the Indian standard DO prescribed in warm water is 6 mg/L to 9.5 mg/L in cold water for survival of various aquatic species (Deshkar *et al.,* 2014). In this case the DO levels were too low at station 2 and 6 resulting in death of fish at the latter stations. The BOD values recorded at all stations were in the range of 12.8 mg/L (station 2) to 136.4 mg/L (station 3). The levels of BOD exceeds the water quality standards limits of GPCB ie., 30 mg/L. BOD level indicates higher contamination at site 3 which keeps on decreasing as on moves downstream attributed to dilution factor. COD values were well within the permissible limits and ranged from 40 mg/L at station 5 and 7 to 120 mg/L at station 8. The COD levels of station 6 (100 mg/l) was recorded higher than station 7 (40 mg/l). This clearly indicates presence of organic pollution at all the locations across the Mini river. The nearby villages and human settlement dischrage the domestic effluents directly into the stream adding to pollution. The nitrite values recorded minimum 0.03 mg/L at station 5. The maximum values was recorded at station 6 (0.158 mg/L) and at station 7 (0.192 mg/L).Higher values of nitrite indicate reduced state of nitrates and higher microbial activity in the water. The nitrate values found ranged from 0.02 mg/L (station 6) to 0.165 mg/L at station 8.

Table 1. Result of water quality Parameters

No.	Parameters	CPCB Limits	Stations							
			1	2	3	4	5	6	7	8
1	Temperature (°C)	-	16.5 (16-17)	18.5 (18-19)	15.5 (15-16)	17.5 (18-17)	17.5 (18-17)	16 (16-16)	19.5 (20-19)	19.5 (19-20)
2	pH	5.5-9.0	8.26 (8.6-7.91)	8.04 (8.19-7.89)	8.05 (7.94-8.15)	8.56 (8.46-8.67)	8.53 (8.68-8.38)	7.77 (7.8-7.73)	7.64 (7.7-7.58)	7.69 (7.83-7.54)
3	Conductivity (µS)	2000	515 (570-460)	467.5 (445-490)	677.5 (655-700)	600 (700-500)	630 (630-630)	1217.5 (1425-1030)	1970 (2350-1590)	2085 (2550-1610)
4	Salinity (mg/L)	1000	161.6 (149.8-173.3)	152.6 (95.7-209.4)	220.3 (169.7-270.9)	197.8 (186.0-209.5)	206.7 (167.9-245.61)	1876.3 (3330.1-422.5)	3676 (6532.1-819.9)	4152.2 (7556.7-747.6)
5	TDS (mg/L)	1.5	0.26 (0.27-0.24)	0.28 (0.25-0.30)	0.43 (0.38-50.38)	0.35 (0.38-0.30)	0.36 (0.32-0.39)	0.76 (0.82-0.69)	1.28 (1.48-1.06)	1.55 (1.69-1.40)
6	DO (mg/L)	-	9.7 (9.6-9.8)	4.0 (0-8)	9.22 (8.64-9.8)	9.84 (10.7-8.9)	9.22 (8.64-9.8)	4.72 (4.32-5.12)	7.84 (9.1-6.5)	7.36 (12.6-2.0)
7	BOD (mg/L)	30	72.4 (51.2-93.6)	12.8 (18.4-147.2)	136.4 (92.8-180)	83.2 (99.2-67.2)	67.6 (38.4-96.8)	67.2 (86.4-48)	72 (86.4-57.6)	57.6 (73.6-41.6)
8	TSS (mg/L)	100	0.05 (0.042-0.059)	0.020 (0.035-0.048)	0.004 (0.0011-0.0073)	0.019 (0.00025-0.038)	0.008 (0.0005-0.015)	0.012 (0.0045-0.02)	0.010 (0.004-0.015)	0.009 (0.0101-0.0089)
9	Nitrites (mg/L)	-	0.017 (0.015-0.018)	0.016 (0.015-0.016)	0.056 (0.065-0.046)	0.028 (0.031-0.025)	0.030 (0.029-0.03)	0.068 (0.107-0.208)	0.079 (0.131-0.252)	0.086 (0.15-0.022)
10	Nitrates (mg/L)	100	0.138 (0.18-0.07)	0.128 (0.17-0.05)	0.229 (0.26-0.19)	0.197 (0.22-0.12)	0.174 (0.22-0.07)	0.175 (0.2-0.2)	0.245 (0.22--0.249)	0.249 (0.29-0.23)
11	Total Nitrogen (mg/L)	-	0.135 (0.13-0.14)	0.136 (0.13-0.14)	0.129 (0.12-0.14)	0.133 (0.13-0.4)	0.13 (0.13-0.13)	0.131 (0.131-0.13)	0.134 (0.131-0.136)	0.135 (0.132-0.137)
12	Phosphate (mg/L)	-	0.074 (0.072-0.078)	0.096 (0.07-0.11)	0.08 (0.07-0.08)	0.11 (0.11-0.12)	0.09 (0.08-0.11)	0.13 (0.10-0.16)	0.31 (0.38-0.23)	0.32 (0.38-0.27)
13	Total Phosphate (mg/L)	-	0.126 (0.12-0.132)	0.160 (0.164-0.156)	0.162 (0.144-0.18)	0.160 (0.18-0.14)	0.17 (0.173-0.178)	0.28 (0.24-0.32)	0.60 (0.66-0.53)	0.67 (0.76-0.59)
14	Silicates (mg/L)	-	0.034 (0.033-0.035)	0.031 (0.03-0.031)	0.026 (0.029-0.023)	0.029 (0.029-0.028)	0.023 (0.025-0.021)	0.024 (0.025-0.023)	0.052 (0.057-0.047)	0.039 (0.055-0.023)
15	Sulphates (mg/L)	400	2.86 (2.89-2.83)	2.64 (2.63-2.66)	4.71 (4.39-5.03)	3.44 (3.8-3.08)	3.52 (3.39-3.66)	8.02 (8.26-7.78)	10.71 (8.44-12.98)	11.02 (9.06-12.98)
16	COD (mg/L)	250	60	100 (0-0)	80 (0-80)	60 (0-60)	40 (0-40)	100 (60-100)	40 (0-40)	120 (0-120)
17	Flourides (mg/L)	2.0	1.007 (0.94-1.07)	0.992 (0.96-1.03)	0.846 (0.94-0.75)	1.153 (1.11-1.19)	1.106 (1.06-1.154)	0.949 (0.78-1.11)	1.085 (0.86-1.31)	1.107 (0.9-1.28)
18	Dissolved Petro-Hydrocarbon (mg/l)	-	2.94	3.18	3.18	3.48	3.55	3.67	3.67	5.21

Table 2. Correlation between water quality parameters

Parameters	Temperature	pH	Conductivity	Salinity	TDS	DO	BOD	TSS	Nitrite	Nitrate	Total Nitrogen	Phosphate	Total Phosphate	Silicate	Sulphate	COD	Flouride	Dissolved Petrohydrocarbon
Temperature	1																	
pH	-.351	1																
Conductivity	.619	-.793*	1															
Salinity	.646	-.811*	.996**	1														
TDS	.633	-.786*	.994**	.992**	1													
DO	-.194	.556	-.170	-.224	-.175	1												
BOD	.318	.609	-.169	-.166	-.165	.670	1											
TSS	-.274	.224	-.319	-.285	-.334	.338	.453	1										
Nitrite	.303	-.800*	.914**	.888**	.910**	-.156	-.443	-.453	1									
Nitrate	.327	-.464	.754*	.701	.763*	.282	-.126	-.486	.841**	1								
TotalNitrogen	.655	-.246	.211	.287	.231	-.299	.315	.351	-.136	-.230	1							
Phosphate	.062	-.096	.117	.151	.103	.309	.466	.899**	-.088	-.155	.514	1						
TotalPhosphate	.725*	-.760*	.986**	.988**	.990**	-.163	-.081	-.317	.857**	.737*	.310	.129	1					
Silicate	.733*	-.576	.700	.712*	.672	.018	.189	.073	.460	.474	.589	.437	.747*	1				
Sulphate	.503	-.834*	.987**	.978**	.976**	-.217	-.303	-.356	.958**	.760*	.107	.057	.950**	.627	1			
COD	.039	-.489	.226	.275	.303	-.625	-.554	-.200	.299	.024	.250	-.129	.234	-.155	.264	1		
Flouride	.682	.262	.283	.292	.282	.259	.723*	-.083	-.018	.145	.391	.100	.352	.342	.167	-.308	1	
DissolvedPetrohydrocarbon	.583	-.483	.795*	.802*	.847**	-.134	-.016	-.394	.716*	.625	.191	-.040	.820*	.310	.757*	.500	.427	1

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

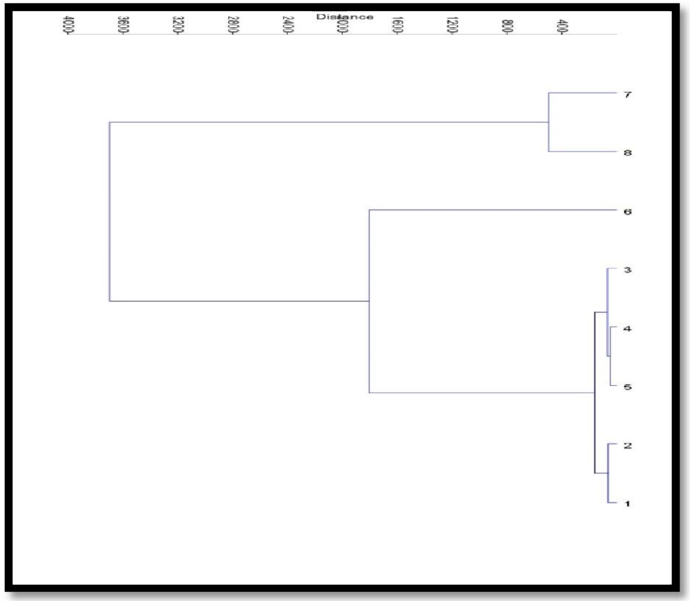

Figure 2. Cluster analysis of Sampling Stations of Mini River

These values were within the permissible range of GPCB (50 mg/l). The higher nitrate values at the downstream stations are due to addition of pollution and its magnification as the river flows. The total nitrogen values ranged from 0.13 mg/L (station 1) to 0.364 mg/L at station 8 respectively. Overall the nitrite, nitrate and total nitrogen values increased as one moved downstream of the river. This is due to increase in pollution load across the gradient. The phosphate values recorded ranged from 0.075 mg/L at station 1 to 0.326 mg/L at station 8. There is clear increase in the inorganic phosphates four times as one moves down the river. The major source of inorganic phosphates is the industrial effluents and input of effluent from the industrial area. The recommended maximum value of the Total Phosphate in the river is 0.1 mg/L (Water Quality Criteria*,* Environmental Studies Board, National Academy of Sciences, 1972). The observed value of the phosphate in the present study is high and unfit for agriculture purpose as well. The total phosphate values ranged from 0.126 mg/l (station 1) to 0.6795 mg/L (station 8). Here also the total phosphates increased by 5 times at the last station as compared to first station. This indicates presence of both domestic and industrial discharges in the downstream stations especially station 7 onwards. Silicate values was noted in the range of 0.023 at station 5 to 0.052 mg/L at station 7. The maximum values were recorded at station 7 and 8 which was 0.052 and 0.042 mg/L respectively. Sulphate values recorded in the range of 2.65 mg/L at station 2 to 11.02 mg/L at station 8.The standard for the Sulphate concentration in the river water from effluent discharge is prescribed as 100 mg/L (MOEF, 1993). Thus in the present study the sulphate values were within the permissible limits. The highest level was recorded at station 6, 7, 8 (8.02 mg/L, 10.71 mg/L, 11.02 mg/L respectively) which are downstream stations. Fluoride levels was recorded high at all stations in the ranged from 0.846 (Station 3) to 1.153 mg/L (Station 4) which was within the permissible limits (1.9 mg/l). The higher fluoride concentration leads to flourosis and the water is unfit for drinking (Fawell *et al.,* 2006). PHC values observed were in the range of 2.94 mg/L (Station 1) to 5.21 mg/L (Station 8). The values of PHC increased downstream indicative of hydro-carbon pollution. The presence of refinery and its discharges have influenced the high PHC values. Pearson's correlation was performed to understand the correlation between all physico-chemical parameters. Chloride showed positive correlation with Total phosphate ($P \leq 0.01$), nitrite and PHC content. This is due to the fact that there is increase in the all above mentioned parameters as one moves down the riverine system. High concentration of Total nitrogen,Total phosphorous ion affect the conductivity which influence the concentration of chlorinity (Deshkar *et al*., 2014).

Fluoride showed negatively correlation with Total suspended solids ($P \leq 0.05$) and positively correlated with BOD levels ($P \leq 0.05$). There is no direct relation between fluoride content and TDS or BOD levels. In this case it happens that there could be some industry releasing fluoride into the waters that has impacted and the relation was observed. PHC showed positive correlation with chloride, Total dissolved solids and Total phosphate ($P \leq 0.05$). This may be due to influence of industrialization which releases high amount of phosphate into the water. Crude oil is used to make petroleum products, which can contaminate the environment (Gustafson, 2007). PHC are made up of a variety of organic compounds and the amount of carbon availability to potential degrade the species in large. This results in large microbial demand for inorganic nutrients especially Nitrogen and Phosphorous. Nitrate gives significant positive correlation ($P \leq 0.05$) with nitrite values. The higher nitrate values indicate conversion of nitrites, unstable form to stable form which is also readily available for absorption to the plants. Cluster analysis was performed for all the parameters and the results showed classification of the stations in three distinct categories A, B and C. Category A includes station 1 to 5 and the water quality in these stations are similar. Category B includes station 6 which lies in between Category A and C and therefore act more of ecotone zone. At this point the tidal influence finishes and there is confluence of fresh water and marine water. Category C includes station 7 and 8. At these stations there is presence of sea influence and also the nutrient status is almost 2-5 times compared to category A. Therefore, category C is also distantly related with category A.

Conclusion

The Mini river is one of the polluted rivers and though is a small tributary of Mahi river, the water finally reaches the estuarine region. There is need to tackle the problem of pollution not only in the large major rivers but also in the smaller rivers that form part of the large riverine system. With the expansion of village population and generation of sewage, there is need to install STP at even village level to check the pollution of major rivers and curtail the degradation of the estuarine life.

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