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STUDIES ON WATER POLLUTION OF MULA, MUTHA AND PAWANA RIVERS IN SUMMER SEASON IN THE PUNE CITY REGION

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ABSTRACT

With increasing urbanization and industrialization, human beings are introducing new and complex chemicals without any rigorous bioassessment of their toxicity. Pune, which is situated at 18°31' N and 73°51' E, is the city with three rivers (Mula, Mutha, and Pavana) flowing through heart of the city. Nineteen sampling stations were selected downstream of non-polluted sites on all the three rivers. The river water samples were collected for a period of four months in the summer season from first week of February 2006 to end of May 2006, as the problem of water pollution is grave during summer season due to various factors like low water flow in the river and evaporation. The collection of samples was made fortnightly. The analysis of water samples was carried out for various physical and chemical parameters like pH, DO, BOD, hardness, calcium, magnesium, sodium, potassium, nitrates and nitrites etc. The analysis depicted heavy pollution of the river waters as BOD was high with lower or absence of DO at some sites. The nitrates, nitrites, sulphates, phosphates and sodium also showed high values at highly polluted sites.

INTRODUCTION

Studies on river water quality is an essential step to protect this useful natural water resource. The addition of organic matter or sewage results in depletion of oxygen and increase in carbon dioxide owing to bacterial degradation. The direct addition of nutrients enhance algal growth and other biological growths, which when die and decompose, further deplete oxygen (Gunale 1981).

Impact India Foundation and Thermax Ltd. carried out the water quality assessment of Mula, Mutha and Pavana rivers in 1997. The results from 1976 to 1994 clearly indicated that there is gradual deterioration of the river water quality. In all these three rivers gradual lowering of dissolved oxygen (DO) was reported indicating increasing load of biodegradable matter, and increasing values of BOD. This has resulted in increasing eutrophication, which has brought changes in biological community such as algal blooms and rapid growth of aquatic weeds like water hyacinth. Patil et al. (2003), Lahiri et al. (2002), Maity et al. (2004) and Goel & Bhosale (2001) have also carried out studies on pollution of various rivers in India and indicated that these rivers are polluted mainly because of the human impact.

Information on physico-chemical properties of Pavana, Mula and Mutha rivers, flowing across Pune city, is meagre in recent years, hence it was proposed to investigate these rivers during the summer season when the pollution level is maximum.

MATERIALS AND METHODS

The River Mula emerges at Deoghar, 70 km west of Pune and meets Pavana at Dapodi. The Pavana has its source in the Western Ghats and flows for a distance of 65 kms to meet Mula. The Mula then

joins the Mutha at Sangam and together they flow as the Mula- Mutha as a single river for a distance of 56 km to meet Bhima river, which later merges into Krishna river and falls into the Bay of Bengal.

The physical and chemical analysis of Mula, Pavana, Mutha and Mula-Mutha river waters were conducted and the results were calculated as mean of all the readings.

Collection of Water Samples

The river water samples were collected fortnightly in cleaned 1.5-L plastic bottles for a period of four months in the summer season from first week of February 2006 to end of May 2006. Samples were collected taking care to prevent formation of air bubbles, and bottles were corked tightly under the surface of water. The analysis of water samples was done for various physical and chemical parameters like pH, turbidity, DO, BOD, COD, hardness, calcium, magnesium, sodium, potassium, nitrates and nitrites etc. following the standard methods APHA-AWWA-WPCF (1989).

Sampling Stations

To study the extent of pollution, nineteen sampling stations were selected in about 20 km stretch of River Mutha, about 15 km of River Pavana, 10 km of River Mula and 15 km stretch of the River Mula-Mutha. While selecting the sampling points, the objective of monitoring and accessibility were considered.

Sites at Mutha River

A1-Khadakwasla: This is the most unpolluted site on the River Mutha.

A2-Vitthalwadi: Due to the increasing residential complexes and growth of villages, more and more sewage is getting added into the river water.

A3-Rajaram Bridge: This site is located just downstream of the above site (Vitthalwadi) and hence the sewage discharge problem magnifies in this zone.

A4-Mhatre Bridge: The water quality improves slightly at this station as water flows for certain distance and duration, self-purification is observed and direct discharge is not practised.

A5-Balgandharva: Water quality here at downstream area of Deccan Gymkhana is slightly same as that at Mhatre Bridge.

A6-Before Sangam; This is a station on the Mutha river just before the confluence of Mula and Mutha. At this spot heavy pollution and disagreeable odour exist.

Sites at Mula River

B1-Aundh (Spicer College): Slight pollution exists here due to domestic waste added from the Aundh village and Spicer college campus.

B2-Sangvi: After Pavana and Mula Sangam; there are no specific polluting agents before this spot and Mula remains practically unpolluted.

B3-Bopodi Bridge: At this site there is heavy pollution from surrounding domestic sewage entering the river directly without treatment.

B4-Khadki: Downstream of the above site (Bopodi bridge) is an oil engine factory, a biscuit and food processing plant and many other factories, which may be responsible for the heavy pollution.

B5-Holkar Bridge: The high explosive and ammunition factory is situated near this site and discharge wastewater in the river water. There is also addition of sewage from Khadki area.

B6-Before Sangam: This site on Mula river is just before the confluence of Mula with Mutha. Also as the residential complexes increase in this area, sewage is the most common waste added in this region.

Sites at Pavana River

C1-Thergaon: At this site the water shows little organic pollution and is comparatively a non-polluted site.

C2-Sangvi: Pavana before meeting Mula; most of the wastes coming from the Pimpri-Chinchwad industrial and domestic complexes is let into the Pavana through small channels before this site at various locations.

Sites at Mula-Mutha River

D1-After Sangam: This site is after confluence of Mula and Mutha rivers and here dilution factor may act to reduce the pollution. Here, holy flowers are added in river as a part of the cremation ritual, which increases organic load of the river.

D2-Bundgarden: Some chemical factories are situated upstream, which may be a reason for pollution in this area.

D3-Koregaon Park: It is heavily polluted due to residential complexes.

D4-Mundhwa Bridge: The conditions here seem to improve at the downstream sites and self-purification creates better conditions.

D5-Manjari: At this site, all the values show decreasing trend compared to all other sites and this suggests that the self-purification is responsible in reducing the pollution load.

RESULTS AND DISCUSSION

The results of the study are depicted in Table 1.

Colour: Colour of water is indicative of the degree of pollution caused by humus materials, peat, tannins, metallic substances, weeds and protozoa. Industrial wastewaters also contribute to colour. Yellow colour is indicative of the presence of organic matter. At Khadakwasla, the water was clear and colourless. As the river entered the city, it developed a greenish to blackish colour. At Sangam, black sludge was also seen surfacing the water as also reported by the studies carried out by Impact India Foundation and Thermax Ltd. in 1997. The colour quality slightly improved till Manjari.

Temperature: Temperature of water is an important parameter in determining the pH, electrical conductivity and dissolved ions present in water. Temperature affects the chemical equilibrium of water, alkalinity, and chemical and biological reactions. Dissolved oxygen content decreases as temperature increases. The average temperature observed for the summer season was 25.6°C. The temperature ranged from 24.4°C to 26.75°C.

Turbidity: Turbidity is caused by particulate matter in suspension. It is an expression of the optical property of the sample containing insoluble substances which cause the light to scatter. Suspended matter as clay, silt, organic matter and plankton also contribute to turbidity. The average turbidity for the rivers water observed was 57.6 NTU. The turbidity increased as the pollution increased. The plankton in the river is also contributing to turbidity as they grow and further decay in water.

pH: pH is an essential parameter as it determines the acidity and alkalinity of waters. The pH at non-polluted area i.e., Khadakwasla was 8.54. This pH turns into an acidic side as organic matter content

of the river and pollution goes on increasing. Lowest pH was found near highly polluted Sangam area. The pH again tends to become alkaline as the river travelled to Manjari (7.18) where most of the organic utilization had been occurred during flow.

Electrical conductivity: Conductivity gives an idea of the total solids content of water. The EC was low at Khadakwasla (0.07 mS/cm) and Thergaon sites (0.168 mS/cm). This was due to low salts as these were non-polluted areas. The EC went on increasing to the Sangam sites where it became highest (0.433 and 0.5 mS/cm). The EC then again went on decreasing as the organic matter was degraded in the process of flow and the ions either were precipitated, sedimented or formed compounds. EC decreased to 0.343 mS/cm at the Manjari site.

Dissolved Oxygen (DO): DO measurement is indicative of pollution levels and is necessary for maintenance of favourable conditions for growth and multiplication of aquatic life. It also reflects the degree of organic pollution of water. It is an indication of water with respect to balance between oxygen consuming and oxygen producing processes. The oxygen levels were high at Khadakwasla (8.8 mg/L), but fall considerably (0.0 mg/L) at Sangam suggesting that the river is overloaded with organic matter. At Thergaon site on River Pavana, high DO of 7.62 mg/L was observed, which decreased later as organic matter got added and oxygen was utilized. After the confluence of Mula and Mutha rivers, the DO remained low (0.03 mg/L), but slightly went on increasing (2.96 mg/L) towards Manjari. Gunale (1981) has reported highest DO for Mula-Mutha as 10 mg/L in non-polluted area and lowest at Sangam as 2.07 mg/L. Mathur et al. (1987) carried out physico-chemical study of River Ganga and reported that the DO values go on increasing because of self-purification of the river water after pollution.

Biochemical Oxygen Demand (BOD): BOD is important to measure the pollutional strength of domestic and industrial wastes in terms of oxygen utilisation. The suggested BOD for surface waters is 2 mg/L, which was not observed at any of the sites. BOD went on increasing with pollution in all the rivers. Similar results were reported by Gunale (1981) for Mula-Mutha river.

Total Hardness (as $CaCO_3$): Total hardness indicates the concentration of Ca and Mg ions. Hardness is due to natural accumulation of salts from contact with soil, or it may enter through industrial effluents and domestic sewage. Hardness was low at Khadakwasla and Thergaon sites, but increased at sites with organic loading.

Calcium and Magnesium: The presence of calcium in water is due to its passage through or deposits of limestone, dolomite, gypsum and other gypsiferous materials. Ca and Mg are major scale forming substance in raw water. Human body requires approx. 0.7-2.0 g of Ca per day as a food element, but high Ca content is undesirable for household uses as washing and bathing etc. as it tend to form incrustations on cooking vessels and water heaters. Calcium values showed a fluctuation from 12.83 mg/L to 52.375 mg/L. The values increased for the river Mutha and Pavana gradually. The calcium values for Mula-Mutha river went on increasing at all sites but decreased slightly at Manjari.

The values for magnesium ranged from 6.6-33.61 mg/L. The magnesium values were lowest at Khadakwasla. Magnesium increased at Vitthalwadi, then decreased gradually at before Sangam.

Sodium: The concentration of sodium ranged from 4.1-26.48 mg/L. The lowest concentration existed at Khadakwasla and highest at Mundhwa. The concentration of sodium increased gradually from Khadakwasla to the Sangam site on the Mutha river. The concentration at Aundh on Mula river was 23.27 mg/L, which later decreased at the confluence of Pavana and Mula, but from there it again

increased gradually. At Thergaon on the River Pavana, the concentration was low (6.61 mg/L). The concentration at Mula-Mutha river was high, which reduced slightly at next sites but again increased at Mundhwa and reduced at Manjari.

Potassium: Potassium is an essential nutritional element. The values of potassium concentration ranged from 6-31.87 mg/L. The concentration of potassium went on decreasing as the pollution levels go on increasing. The potassium concentration was increased at Manjari.

Sulphate: Sulphates occur as a result of leaching from gypsum and other minerals. Various municipal treatment processes use alum (aluminium sulphate) as a coagulant. The concentration of sulphates as SO_4 ranged from 36-348 mg/L. The concentration of sulphates increased with increasing pollution. The tolerance limit for sulphate in surface waters used for irrigation is 1000 mg/L. Values of sulphates for the rivers are low, and hence it is suitable for irrigation.

Chloride: Any increase in chloride concentration over the normal values indicates pollution. The limit for chloride in surface waters is 250 mg/L. The values for chlorides ranged from 1.87-29.06 mg/L. The concentrations of chlorides increased gradually at Mutha river. At Mula river, the chlorides showed slight variations at various sites. Chlorides increased from Thergaon to Sangvi on Pavana river. Similar results were also reported by Gunale (1981). He reported chloride concentrations in the range of 11.4-36.4 mg/L for various sites in Pune. Chlorides are toxic to most plants, so they should be checked for irrigation waters. The tolerance limit for surface waters used for irrigation is 600 mg/L, and values in Rivers Mula and Mutha are quite low, so the rivers water can be suitably used for irrigation without any hazard from chlorides.

Nitrate: The addition of wastewaters from chemical, fertilizer manufacturing and sewage contribute to nitrate. Nitrate concentration above 45 mg/L may cause methaemoglobinaemia (blue baby) in infants, a disease characterized by blood changes. The nitrate values varied from 0.173-4.57 mg/L. Higher values of nitrates were observed at Mhatre bridge suggesting sewage addition at locations upstream. The values then went on reducing to before Sangam site on river Mutha. The values at the River Mula went on increasing gradually till Holkar bridge and reduced slightly before Sangam. This suggested that the decomposition of organic matter may be responsible for decreased values before Sangam or there was raw sewage discharge, which was not decomposed. In the Mula-Mutha river, values of nitrates were high after Sangam and went on reducing for later sites suggesting that organic load has decreased, but they were slightly increased at Manjari.

Nitrites: Ammonia arises from aerobic and anaerobic decomposition of organic matter. It is an indication of fresh pollution by nitrogenous wastes and it is undesirable even in traces. Nitrites are formed by action of bacteria upon ammonia and organic nitrogen. The concentrations for nitrites varied from 0.062-5.94 mg/L. The concentration was lowest at Manjari and highest at Rajaram bridge, suggesting heavy decomposition of organic matter and addition of sewage at upstream locations. The values of nitrites decreased at Sangam for both Mula and Mutha rivers, whereas the values of nitrites for Mula-Mutha and Pavana rivers remained comparatively low, suggesting lesser pollution in these two rivers.

Phosphate: Phosphate is useful in determining whether the pollution is due to domestic sewage. The range observed for phosphate was 0.096-4.35 mg/L. The lowest value was observed at Khadakwasla and highest after Sangam. The values at river Mutha increased gradually except at Rajaram bridge. In river Mula also the values were increased. This suggested that organic pollution went on increasing in both Mula and Mutha rivers. Phosphate values were high after Sangam and reduced at further

Table 1: Physico-chemical characteristics of the mula-mutha river at sampling sites

Parameters	A1	A2	A3	A4	A5	A6	B1	B2	B3	B4	B5	B6	C1	C2	D1	D2	D3	D4	D5
Physical Parameters																			
Movement	0.024	0.024	0.073	0.43	0.11	0.13	0.02	0.014	0035	0.017	0.021	0.011	0.034	0.016	0.06	0.07	0.05	0.07	0.02
Temperature	24.4	24.7	26.3	25.4	26.2	25.8	25	26.7	25.5	25.5	26.2	25.2	24.5	26.5	25.8	25.8	25.8	25.5	26.2
Turbidity	4	36.3	20	55	43.3	100.3	35.5	114	88.5	63.5	52	47.5	24.8	74.8	93.7	50	70.7	47	73.7
Chemical Parameters																			
pH	7.56	7.12	6.86	6.92	6.84	6.65	7.12	7.12	7.02	6.88	6.93	6.83	6.58	7.13	6.66	6.77	6.88	7.04	7.02
EC	0.098	0.34	0.36	0.37	0.38	0.41	0.52	0.54	0.44	0.51	0.48	0.42	0.17	0.49	0.39	0.41	0.41	0.45	0.46
BOD	42.0	80.7	76.3	150.5	93.8	146.0	182.1	348.7	251.5	182.5	163.4	177.8	23.4	316.3	423.2	26.8	101.9	109.5	114.8
Hardness	40	136	128	108	109	94.7	190.7	138	129.3	142.7	137.3	137.3	70.8	123.2	121.3	122.7	124	116.7	126.7
Calcium	12.8	33.7	41.1	32.1	33.1	30.5	52.4	40.9	40.6	43.8	45.9	44.3	21.0	40.9	36.1	36.1	39.3	41.7	40.2
Magnesium	6.6	24.9	21.1	18.4	18.5	15.6	33.6	23.8	21.7	24.0	22.2	22.6	12.1	20.2	20.9	20.2	22.5	17.3	21.4
Sodium	4.1	16.1	16.9	20.1	21.5	25.6	23.3	16.5	22.9	23.9	23.4	24.7	6.6	8.7	24.9	25.0	23.4	26.5	24.4
Potassium	21.7	12.7	11.8	8.7	8.5	6.0	10.5	8.13	8.7	9.6	9.6	10.0	31.9	9.3	19.3	18.6	18.4	15.8	18.7
Sulphates	36.0	164.7	134.7	110.3	132.3	154.6	204.5	312	131	348	334	406.5	71.3	264.3	250	258.3	208.3	272.8	336.7
TDS	320	440	440	580	460	300	300	450	440	300	340	160	46	330	230	530	240	320	310
TSS	150	190	210	300	182	350	260	542	460	380	360	200	128	215	178	250	390	300	460
Fixed VS	250	427.3	399.8	571.5	666.7	899.3	533.3	786.7	826.7	443.3	616.7	560	532.2	319.2	645.6	465	655	316.2	254.2
Free CO_2	15.4	30.8	19.8	28.6	35.2	39.6	29.3	39.01	48.1	31.4	25.5	25.3	8.6	24.1	67.1	34.0	32.8	41.1	36.7
Total CO_2	80.5	196.2	179.9	201.1	200.6	198.0	224.1	219.5	207.7	181.6	174.5	186.0	92.7	182.6	261.3	218.2	208.5	213.8	236.7
Nitrates	0.17	0.24	2.40	4.57	1.7	0.49	0.35	0.51	0.40	1.23	1.73	1.23	0.13	0.39	1.32	0.66	0.53	0.32	0.66
Nitrites	0.03	0.52	5.94	0.67	3.68	1.53	0.05	0.34	0.157	2.31	5.83	1.53	0.03	0.26	0.21	0.07	0.03	0.99	0.06
Phosphate	0.09	1.33	1.05	2.23	2.80	3.60	1.52	1.58	1.45	2.15	3.45	2.55	0.14	0.61	4.35	3.049	0.14	1.01	3.94

All values are expressed in mg/L except pH, electrical conductivity, temperature, movement and turbidity.
Movement is expressed as m/s, EC as mS/cm and turbidity as NTU; All values are mean of three determinants.

sites suggesting decrease in pollution. However, values were slightly increased at Manjari. Similar results were observed by Gunale (1981) who found the range in 0.113-0.982 mg/L.

Total Dissolved Solids, Total Suspended Solids: Mineral matter is in dissolved condition like the carbonates, bicarbonates, sulphates, chlorides and nitrates of Ca, Mg, Na, K along with traces of Fe and Mn. Silica also form an important constituent of dissolved solids. The values were below the limits as the suggested (TDS 500 mg/L). TDS values vary according to pollutants added. The undissolved matter i.e., silt, clay, organic matter, algae, bacteria and fungi forms TSS. Suspended solids also are seen due to natural process of erosion, sewage and industrial effluents. There was great variation in values of these two parameters at different sites.

Free CO_2: It is a normal component of natural waters. It is dissolved in water in varying amounts and dissolution depends on temperature, pressure and mineral content of water. Polluted waters acquire CO_2 by biological oxidation of organic matter.

Carbon dioxide increased in Mutha river with increasing pollution levels. It was high at the Bopodi bridge, but went on decreasing up to Sangam on river Mula. The concentration of CO_2 reduced in the Mula-Mutha river. CO_2 should not exceed 6 mg/L for fish growth. Hence, from values of CO_2, we can conclude that water is not suitable for fish growth except at Khadakwasla and Thergaon.

CONCLUSION

These rivers were unpolluted at the point where they entered the city, but got progressively polluted due to the wastes from industries and city sewage. As a result, there was gradual deterioration of the water quality; thus, affecting the overall characteristics and flora and fauna of the rivers. The significant findings are as follows:

The physical parameters like turbidity and colour increased with increasing pollution in the city and then decreased to the farthest point. The dissolved oxygen decreased with increasing pollutant load and recovered slightly due to self-purification capacity of water.

The BOD and COD both were low initially, but increased with increased organic loading, but again decreased as the organic matter got reduced and utilized. The alkalinity also showed a similar trend.

The sodium levels increased as pollution increased, but potassium level decreased as pollution increased. Sulphates and chlorides increased with increase in pollution. Values of phosphate have also increased with organic load.

Nitrates and nitrites depict the pollution that has taken place at upstream sites as they are formed due to heavy biological activity. Values of high nitrates and nitrites were observed at Rajaram bridge and Mhatre bridge on Mutha river and Holkar bridge on Mula river, indicating pollution load added in the upstream areas. Free CO_2 and values of TS, TDS, TSS increased with increase in pollution.

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