Assessment of Spatio-Temporal Variations in Physico-Chemical Characteristics of Mithi River Water Quality of Mumbai, India

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ASSESSMENT OF SPATIO-TEMPORAL VARIATIONS IN PHYSICO-CHEMICAL CHARACTERISTICS OF MITHI RIVER WATER QUALITY OF MUMBAI, INDIA

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Abstract

Spatial and temporal variations in surface water play an important role in water quality and sustainable development. River water quality in Mumbai is rapidly deteriorating due to industrialization and urbanization around the river banks. Hence it is desirable to survey the river water quality to determine the extent of pollution in the water body. The objective of this paper is to assess the seasonal water quality of the highly polluted Mithi river on the basis of surface water standards. A survey of the surface water of Mithi river was performed in an attempt to study the environmental impact of anthropogenic activities and seasonal activities on its water quality. Collected samples were analyzed from five strategic stations of Mithi river for six months representing seasonal variations with respect to pH, temperature, turbidity, conductivity, dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), free CO_2 and ammonical nitrogen (NH_3-N). Analyses results reveal that pH, temperature, NH_3-N and CO_2 are within the permissible limits of MPCB standards for industrial discharge. However the exceptionally high values of BOD, COD, turbidity and significantly low values of DO compared to standards show that the river water has deteriorated to a great extent.

Keywords: Mithi river; spatio-temporal variations; water quality

1. Introduction

Water quality of a river is a global issue especially in transient state developing countries. It is the key indicator of the health of the river. Surface water quality of river water, especially in urban areas is influenced by an array of factors ***(Kazi et al, 2009)***. River water plays major role in carrying municipal and industrial load in the form of suspended and dissolved pollutants from anthropogenic sources ***(Peter et al, 2007)***. Anthropogenic influences mainly impact surface water in the form of sewage, industrial discharges and atmospheric pollution ***(Niemi et al, 1990)***. Municipal and industrial discharges constitute a constant point source of pollution ***(Dan'Azumi et al, 2010)*** while seasonal variations include surface runoffs and precipitation ***(Singh et al, 2004)***. This creates pressure on the aquatic ecosystem resulting in a deterioration of water quality ***(Okoronkwo et al, 1985; Abida et al, 2008; Dan'Azumi et al, 2010)***. Seasonal variations in precipitation, surface runoffs, ground water flow and sea water ingress influence the concentration of pollutants in the river ***(Vega et al, 1998)***. Awareness with regards to water quality and increasing public sensitization has proved insufficient to curb the unpleasant implications of deteriorating water quality in health and economic development ***(Etim et al, 2012)***. The concentration of pollutants is not constant at any location at a given time but addition of the pollutants is predictable and repetitive depending on the area under study. Any interference in the aquatic ecosystem could be highlighted through change in the physical and

chemical characteristics of water ***(Verma et al, 2010)***. Water quality monitoring is essential for better prevention further deterioration and exploitation of the aquatic resources and to check the influence of growing population, urbanization and industrialization on the water body.
Mithi river is a case of Mumbai city where the river is treated like an open drain where sewage, industrial waste and unauthorized hazardous waste is dumped in the river. It is highly influenced from both municipal discharge and industrial effluent as it flows through dense settlements and industrial and office complexes. In earlier days the river acted as a buffer for the excess storm water drain of Mumbai and also balanced the ingress of sea water into the city. It was also a source of drinking water and fishing activities but increased urbanization around the water body has highly impacted the water quality of the river **(*MPCB, 2004*)**. According to the industrial policy on river catchments as per Department of Environment, Govt. of Maharashtra (GR No. NMW-2000/326/22/TB-3 dated 15 July 2000), Mithi river is classified under category A-IV which implies that 500m on either side of the river is to be a no-development zone for any industry except for the green and orange type of industries with pollution control system in place. Currently the river receives 5 MLD of sewage from residential areas of Sakinaka, Kurla and Mahim. This has reduced the carrying capacity of the river resulting in flooding in adjacent areas ***(Singare et al, 2011).*** Illegal, unnatural diversions, commercial encroachments, unauthorized industrial units, unplanned massive commercial development on the bank of the river have culminated in seasonal flooding in the river. Plastic, debris, heavy organic loading and sludge have further reduced the carrying capacity of the river causing water logging in the main course of the river and subsequent flooding in the adjacent low lying areas. The water body is also a source of odor nuisance owing to the septic conditions in the water.
Determination of the extent of pollution in the river is a primary step in taking necessary measures for river restoration. ***(David et al, 1969).*** The present study investigated the water quality of Mithi river, one of the most polluted rivers of Mumbai city with spatial and temporal variations in the physico-chemical parameters of the water at pre-decided locations to understand the pollution load on Mithi river of Mumbai. The parameters chosen were so because they represent the basic factors most affected into manipulation by man and are quite essential for a good management of any water quality.

2. Description of study area

Mithi river (17.8 km length, 7295 ha catchment area) is a seasonal river originating at an altitude of 246 m above sea level from spillway discharges of Vihar and Powai lakes, travelling to the Mahim bay. The watershed of the river is covered with latitude 19°00’ to 19$_{0}$15’N and longitude 72°45’73” E (Toposheet No. 47 A/16).

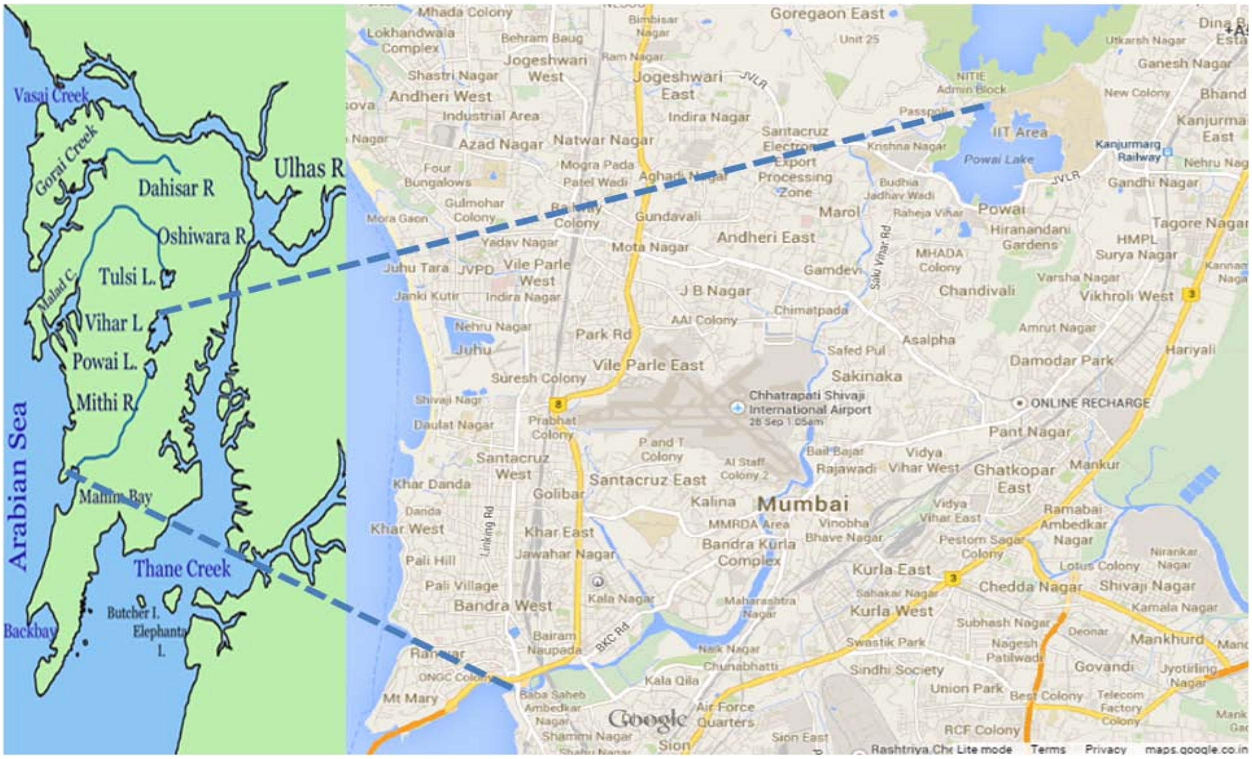

Fig 1: Flow of Mithi river from origin (Powai and Vihar lakes) to confluence (Mahim bay)

From the entire route of the river, five different sampling stations were selected for the purpose of study **(Table 1, Fig 2)**. The reason for selection of these locations is the variation in source of pollution at each point. Mahim creek (Sampling station: Mahim) is the area of confluence of Mithi river with the Arabian Sea. This point is subject to maximum tidal influence and also represents the entire river water pollution as it is the final stretch of the river. Dharavi (Sampling station: Dharavi) and Vakola nalla (Sampling station: Vakola) are the areas surrounded by slum settlements. As a result the water from these areas is subjected to a lot of domestic sewage inflow on a daily basis. The other two sampling stations are located on the upstream (Sampling station: CST2) and downstream (Sampling station: CST3) of bridge on Bandra –Kurla complex. These are industrial zones encompassing automobile spare factories, rubber tyre factories etc. The primary source of pollution in these two points is from industrial sources.

Table 1: Details of sampling locations for determining the status of river

Site Name	Latitude (N)	Longitude (E)
Mahim creek (Mahim)	19^{0}2’53.98”	72^{0}50’17.33”
Dharavi nallah (Dharavi)	19^{0}3’6.69”	72^{0}50’52.46”
Vakola nallah (Vakola)	19^{0}3’56.96”	72^{0}51’13.22”
New mithi bridge (CST2)	19^{0}4’15.03”	72^{0}52’24.29”
CST bridge before airport (CST3)	19^{0}4’29.53”	72^{0}52’17.87”

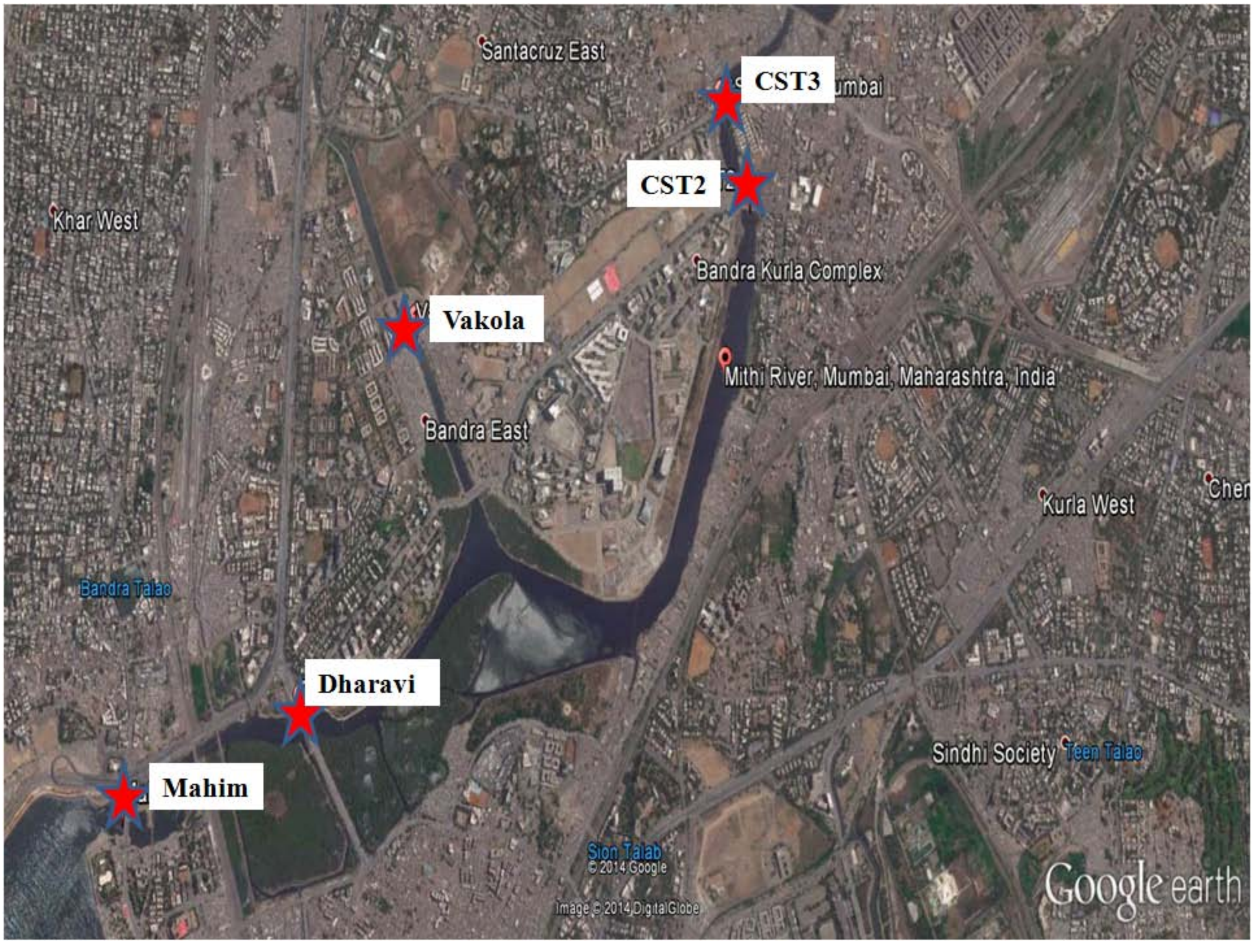

Fig 2: Sampling stations across Mithi river

3. Materials and methods

Mithi river is subject to tidal variation. In order to get a proper idea of the pollution load, the sampling across the stations was carried out in three phases as premonsoon, monsoon and post monsoon. Water samples were collected in duplicates during both high tide and low tide at all sampling points at 0.5m (depth representative of mixed water column) during the months of March, May (premonsoon samples), July, September (monsoon samples) and November, Jaunary (for post monsoon samples) on a tidal basis. The samples were collected in 1 litre polythene and glass (for O&G) bottles previously cleaned with soap and rinsed with distilled water. All the commercial reagents and solvents were procured from Merck (India). The chemicals and reagent were used for analysis were of AR grade. The procedure for calculating the different parameters were conducted in the laboratory. The laboratory apparatus were acid soaked (nitric acid) before the analysis. After acid soaking, they were rinsed thoroughly with tap water and de-ionised distilled water to ensure any traces of cleaning reagents were removed. The pipettes and burette were rinsed with solution before final use.

Collected water samples were preserved at 4˚C from sampling, transportation to laboratory until analysis as per the methodology given in "Standard Methods of Water and Wastewater Analysis **(Table 2)**. The temperature, pH, electrical conductivity, DO of each water sample was measured on site by field instruments including mercury thermometer, digital pH, conductivity and DO meter respectively. All the water samples were analyzed for all the parameters within 24 hours of collection with BOD, COD, NH_3-N and CO_2 determined promptly to prevent errors due to sample deterioration.

Table 2: Water quality parameters with units and analytical methods used

Parameters	Units	Analytical methods
Temperature	˚C	Thermometer
pH	pH unit	pH-meter
Electrical conductivity	**µ**S/m	Conductivity meter
Biochemical oxygen demand (BOD)	mg/L	Dilution and seeding
Chemical oxygen demand (COD)	mg/L	Acid reflux and titration
Dissolved oxygen (DO)	mg/L	Titration
Ammoniacal nitrogen (NH_3-N)	mg/L	Distillation and titration
Turbidity	NTU	Turbidimeter
Free carbon dioxide (CO_2)	mg/L	Titration

Source: APHA, 21st edition

4. Results and Discussion

Comparative study of physico-chemical parameters was summarized for the five sampling stations for three different seasons, i.e., premonsoon, monsoon, and post monsoon. It was observed that there was a considerable change in parameters depending on the season as well as sampling location. As per monsoon cycle there is always an expected change in these parameters due to influence of rain water. However the variations observed in water quality was much more drastic across the sampling stations.

Table 3: Analysis results of physico-chemical characteristics at sampling points

		Mahim	**Vakola**	**Dharavi**	**CST2**	**CST3**
	Range	6.5-7.5	6.5-7.7	7.1-7.6	6.4-7.9	6.4-7.8
	Mean	7.3	7.3	7.4	7.2	7.2
pH	**S.D.**	0.3	0.4	0.2	0.5	0.5
	Range	25-30	26-30	25-29.5	25-30.5	25-30
	Mean	27.6	28.3	27.7	27.4	28.1
Temperature	**S.D.**	1.6	1.4	1.6	2.0	1.8
	Range	16-108	18-110	18-108	36-65	17-65
	Mean	60.3	51.3	68.1	45.1	41.4
Turbidity	**S.D.**	30.7	28.1	25.8	9.0	17.1
	Range	30.3-76	2.2-76	2.6-65	0.9-78	0.8-65
	Mean	47.7	25.3	24.3	14.8	14.7
Conductivity	**S.D.**	14.9	29.4	23.9	22.4	21.5
	Range	0-4.2	0-6.8	0-3.6	0-4.5	0-4.2
	Mean	2.2	1.9	2.0	1.4	1.5
DO	**S.D.**	1.3	2.1	1.6	1.6	1.4

	Range	40-149	46-320	34.6-314	38-187	40-108
	Mean	76.8	122.9	101.9	69.5	60.7
BOD	**S.D.**	31.7	84.2	89.7	39.6	20.7
	Range	114.3-496.7	98.7-711.1	72.1-668.1	165.2-678	181.7-514.3
	Mean	227.8	259.7	217.3	328.2	296.7
COD	**S.D.**	111.6	181.9	195.7	142.0	95.0
	Range	3.8-15.9	4.1-14.2	4.2-10.6	4.4-16.5	4.2-17.6
	Mean	7.9	8.2	7.7	9.7	8.0
NH3-N	**S.D.**	3.9	3.8	1.6	3.7	3.9
	Range	22-44	22-44	22-44	22-44	22-44
	Mean	36.7	36.7	36.7	34.8	34.8
CO2	**S.D.**	10.8	10.8	10.8	11.3	11.3

* S.D.: Standard deviation

pH values of the water samples ranged from minimum 6.5 to maximum 8.0 at all the stations (**Table 3, Fig 3)**. The values were observed to be highest during the months of July and September, considered as the monsoon period. In general, the values of pH were found to be higher during high tide as compared to low tide at Mahim, Dharavi and Vakola due to possibility of ingress of saline water in the river at these sampling locations. The values were found to be similar at CST2 and CST3 areas during both high and low tide. The pH of all the stations remained more or less constant in all the seasons and was within the permissible limits of industrial discharge set by Maharashtra Pollution Control Board, i. e., 6.5 to 8.5.

Temperature is one of the most important parameter related to the health of the water body. The values of temperature are inversely proportional to DO values. Temperature of the water samples ranged from minimum 25˚C to maximum 30.5 ˚C at all the sampling locations (**Table 3, Fig 4)**. The values were observed to be highest during July and September (considered as the monsoon period) and lowest during November and January (considered as the post monsoon period). No effect of tidal influence could be seen at any of the sampling points across the river as the temperature remained constant at Mahim, Vakola and Dharavi during both low and high tides. The variations in temperature at CST2 and CST3 areas can be attributed to the industrial activities in the surrounding areas.

Turbidity is an important factor affecting light penetration in water. It reduces the primary productivity and also affects the marine organisms by blocking their respiratory system. Turbidity of the water sample ranged from minimum 16 NTU to maximum 110 NTU at the sampling stations (**Table 3, Fig 5)**. Major variations in turbidity were observed Mahim, Vakola and Dharavi sampling stations. The reason for this could be the discharge of untreated sewage and addition of suspended matter in the form of garbage at Vakola and Dharavi. This river water further flows to Mahim sampling station, thus explaining the turbidity at this sampling point. The values of turbidity, although high were constant at CST2 and CST3. Tidal variation was evident in Mahim, Vakola and Dharavi sampling stations for turbidity. The values for turbidity were low at these stations during high tide and higher during low tide. This can be attributed to the ingress of sea water at these stations. Seasonal variations were less evident at all the sampling points. The values of turbidity in all the three seasons are very high as compared to the standards set by Maharashtra Pollution Control Board, i.e., 5 NTU.

The conductivity depends on the concentration of ions and its mineral nutrients status. It also depends on various factors such as low rainfall and high temperature. Conductivity of the water was carried out to find out the extent of saline water ingress into the estuarine part of the river. The range of conductivity varied from minimum value of 0.8 µS/cm to maximum value of 76 µS/cm. Values of conductivity were highest at Mahim followed by Dharavi and Vakola sampling stations (**Table 3, Fig 6)**. Mahim showed highest conductivity range from 30.3 to 76 µS/cm with mean conductivity of 47.7 µS/cm. Conductance of the samples varied with seasons. The values of conductivity were lowest during July and September (considered as monsoon period) and highest during March and May (considered as premonsoon period). This decrease in conductivity during monsoon can be attributed to the dilution effect of rain water during monsoon season. In the premonsoon season, the total volume of water decreases, as a result the conductivity increases. Tidal influence was evident in the values of conductivity at Mahim, Vakola and Dharavi as the conductivity was higher during high tide and lower during low tide. This is mainly due to the greater ingress of sea water into the river water at high tide. The difference in electrical conductivity of the sampling points can be attributed to the tidal influence of sea water in the river. The proximity of the sampling points to the sea in the descending order is Mahim, Dharavi, Vakola, CST2 and CST3. This is confirmed by the gradual decrease in the conductivity readings at these points. High conductivity levels may be due to several other factors including untreated wastewater infiltration, wastewater from sewage treatment plants, wastewater from septic systems and drain field on-site wastewater treatment and disposal systems.

Dissolved oxygen is a very important parameter that determines the overall health of the ecosystem. The aerobic aquatic organisms like phytoplankton and fish require dissolved oxygen for their respiration. DO of water is influenced by and is inversely proportional to the temperature and salinity. This means that more is the salinity of the water, lesser is the dissolved oxygen. With a reduction in the concentration of dissolved oxygen the system becomes hypoxic and results in reduction of productivity of the water body. The DO values ranged from minimum of 0 mg/L to maximum of 6.8 mg/L. The values were highest during July and September (considered as monsoon period) and lowest during November and January (considered as post monsoon period) **(Table 3, Fig 7)**. A reason for the increase in the dissolved oxygen during monsoon is the dilution of the river water as more fresh water adds to it in the form of rain. DO values were found to be tidally influenced at Mahim, the values were lower in high tide and higher at low tide. At all other sampling stations, DO values were higher during high tide at Vakola and Dharavi sampling stations whereas the values were not influenced tidally at CST2 and CST3. In case of Vakola the found dissolved oxygen is around 7 and is highest amongst all the selected stations. DO values were lowest at CST2 and CST3 sampling stations during post monsoon (0 to 0.5 mg/L). Observed dissolved oxygen for post monsoon at all the stations was below 1 mg/L. These are very low as compared to the WHO standard of 5 mg/l required for sustaining aquatic life. The low concentrations of dissolved oxygen indicate a high BOD which in turn indicates a very high load of organic matter in the water. This is possibly due to sewage, industrial organic waste and other untreated waste water. When a water body gets polluted and anaerobic conditions set in, the water becomes unsuitable for any practical use. Dissolved oxygen levels should be always maintained above 0 mg/L to avoid anoxic conditions for industrial, commercial and aesthetic use of the water ***(Mackay et al, 1969).***

BOD is a very important biological parameter to determine the organic loading in the water body. The values of BOD varied from minimum of 34.6 mg/L to maximum of 320 mg/L **(Table 3, Fig 8)**. The average BOD values were high at Vakola (123 mg/L) and Dharavi (102 mg/L) sampling stations as compared to other points due to ingress of organic loading in the form of sewage from human settlements at these stations. The values were lower at CST2 (70 mg/L) and CST3 (61 mg/L) areas due to dominance of industrial activities. BOD concentrations were found to be lowest during monsoon as compared to pre monsoon and post monsoon. It is probably due to the reason that fresh water inflow and dilution of the river water decreases the organic matter load in the water. Also the concentration of organic loading was observed to be higher at high tide for almost all stations. This can be attributed to the reason that the DO values are comparatively higher in low tide. When compared to CPCB standards of BOD, i.e. 30 mg/l water quality of the river shows non-compliance of BOD values indicating heavy pollution. Those water bodies having BOD more than 6 mg/l are identified as polluted water bodies. ***(CPCB: Water Quality Assessment, 1.3 Polluted River stretches).*** The source of organic and microbial pollutants present in the water can be accounted for the presence of severe organic waste and sewage.

COD is another parameter used to determine the organic loading in water. The COD values of the water ranged from a minimum of 98.7 mg/L to a maximum of 711.1 mg/L **(Table 3, Fig 9)**. COD values were found to be the highest at sampling stations CST2 and CST3. It can be argued that the industrial activities around these sampling points are the reason for the high values of COD. Although the values of COD at all the stations were high, Mahim and Dharavi showed least COD values as compared to other points. Periodic tidal flushing could be another reason for reduction in these values. In general, COD values were seen to be tidally influenced as the values were higher during high tide and lower during low tide. Influence of fresh water dilution is also evident as the values were lower during monsoon season as compared to pre monsoon and post monsoon. The ratio of BOD: COD gives an indication of the degradable organic compounds in water. The average ratio of BOD: COD at Mahim, Vakola, Dharavi, CST2 and CST3 was 0.35, 0.48, 0.48, 0.20 and 0.25 respectively. A ratio of >=0.5 indicates biodegradable organic compounds. As the ratio was observed to be less at CST2 and CST3, it can be inferred that the water was high in refractory or non-degradable organic compounds. The values were close to 0.5 in areas of Dharavi and Vakola as the water was rich in degradable organic matter in the form of sewage.

Ammonia (NH_3) occurs naturally in water bodies arising from the breakdown of nitrogenous organic and inorganic matter in soil and water, excretion by biota, reduction of nitrogen gas in water by microorganisms and from gas exchange with the atmosphere. The source of NH_3 is essentially domestic waste water. It is also discharged into water bodies by some industrial processes and also as a component of municipal or community waste. At certain pH levels, high concentrations of NH_3 are toxic to aquatic life and therefore detrimental to the ecological balance of water bodies. The values of NH_3-N ranged from 3.8 mg/L to 17.6 mg/L **(Table 3, Fig 10)**. the values were generally low during monsoon due to dilution of river water with monsoon precipitation. The high values of NH_3-N throughout could be attributed to the industrial activities at CST2 and CST3 and the addition of sewage at Vakola and Dharavi areas. The values of ammonical nitrogen were found to be low as compared to the MPCB standards of 50 mg/l.

Free carbon dioxide (CO_2) refers to CO_2 gas dissolved in water. Surface waters normally contain less than 10 mg/l free CO_2. The free CO_2 of the water sample remained more or less constant irrespective of the seasons with a minimum value of 22 mg/L to a maximum of 44 mg/L at all stations **(Table 3, Fig 11)**. Dilution effect of rain water could be observed as the free CO_2

concentration was found to be lower during monsoon (22 mg/L) as compared to other seasons. The reason for this is the comparative increase in the DO values during monsoon. Dilution also reduces the organic load per ml due to which the BOD reduces. In the rest of the seasons the free CO_2 was found to be 44 mg/l. When the oxygen concentration in waters containing organic matter is reduced, the carbon dioxide concentration rises. The rise in carbon dioxide makes it more difficult for fish to use the limited amount of oxygen present. The results show that the river water is highly polluted and the high organic load results in anoxic conditions in the river.

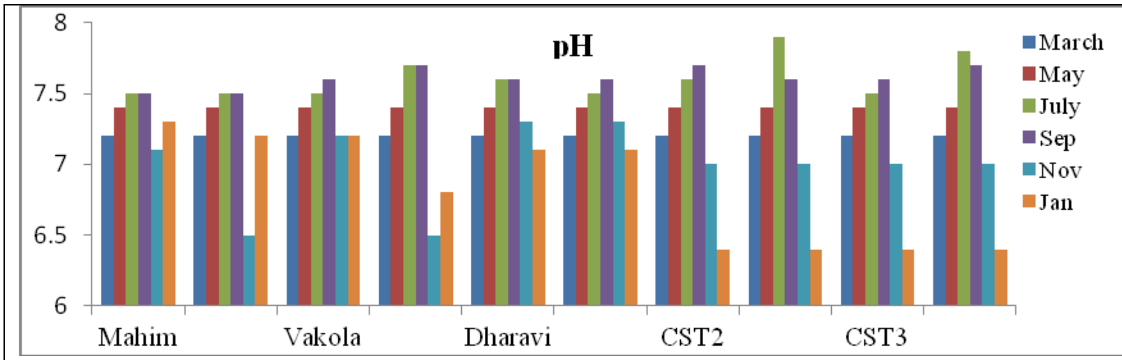

Fig 3: pH of river at sampling stations

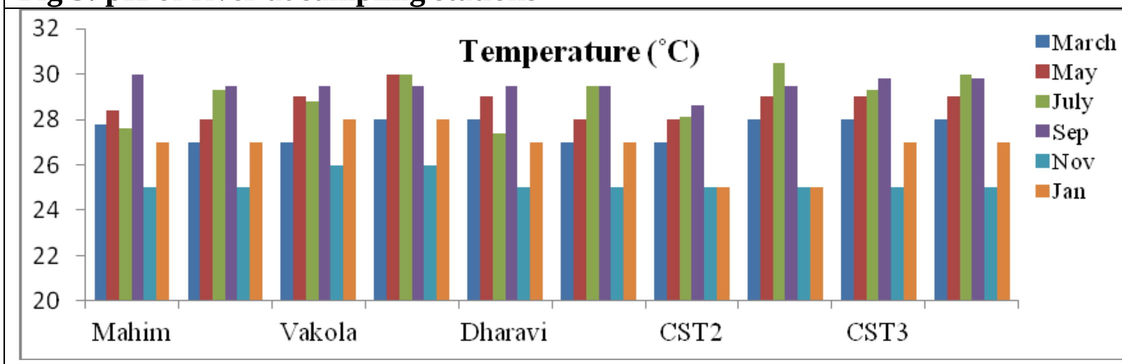

Fig 4: Temperature (˚C) of river at sampling stations

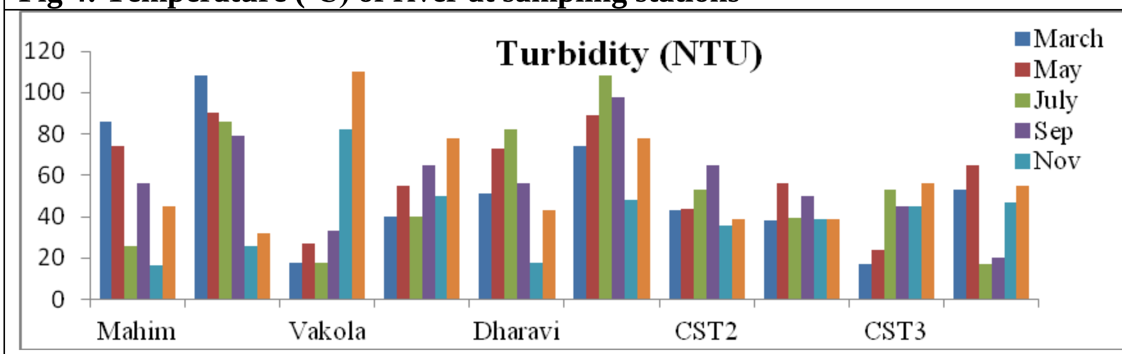

Fig 5: Turbidity (NTU) of river at sampling stations

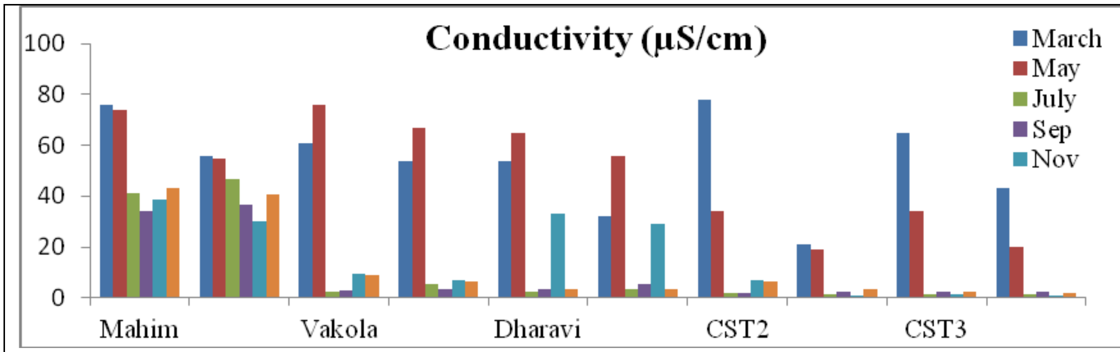

Fig 6: Conductivity (µS/cm) of river at sampling stations

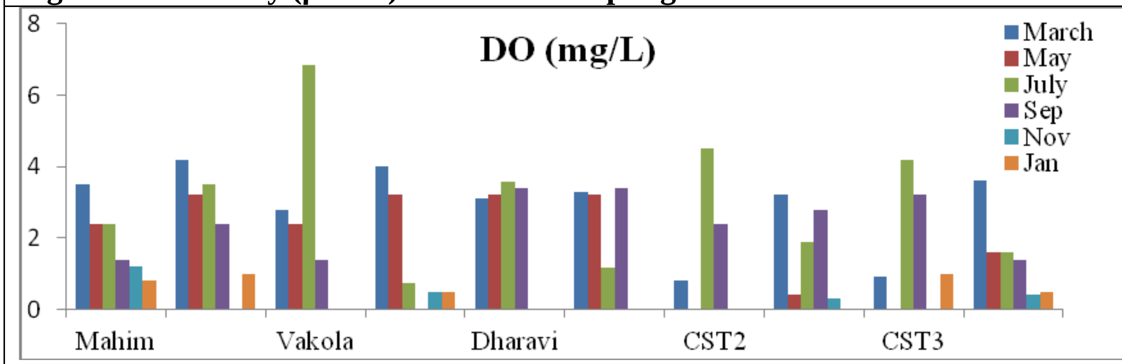

Fig 7: DO (mg/L) of river at sampling stations

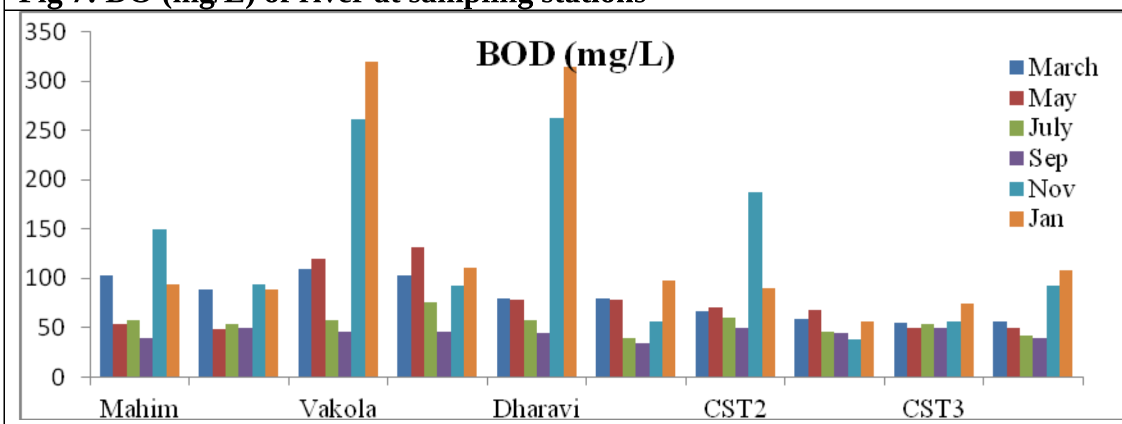

Fig 8: BOD (mg/L) of river at sampling stations

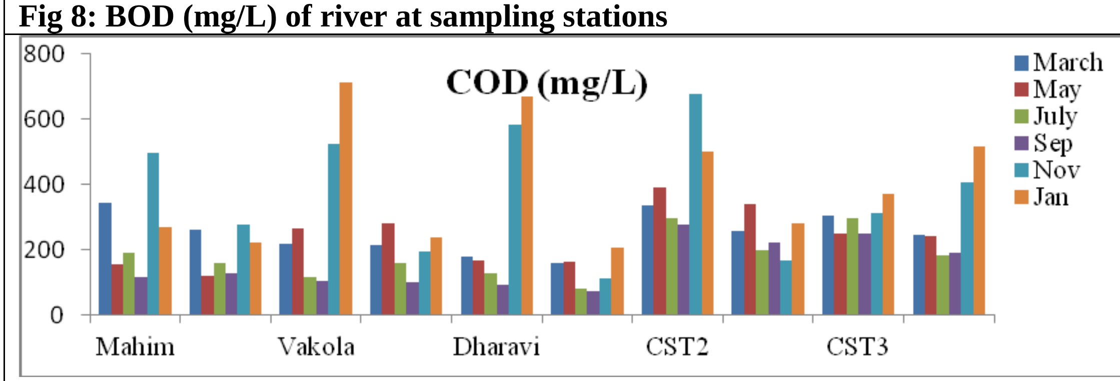

Fig 9: COD (mg/L) of river at sampling stations

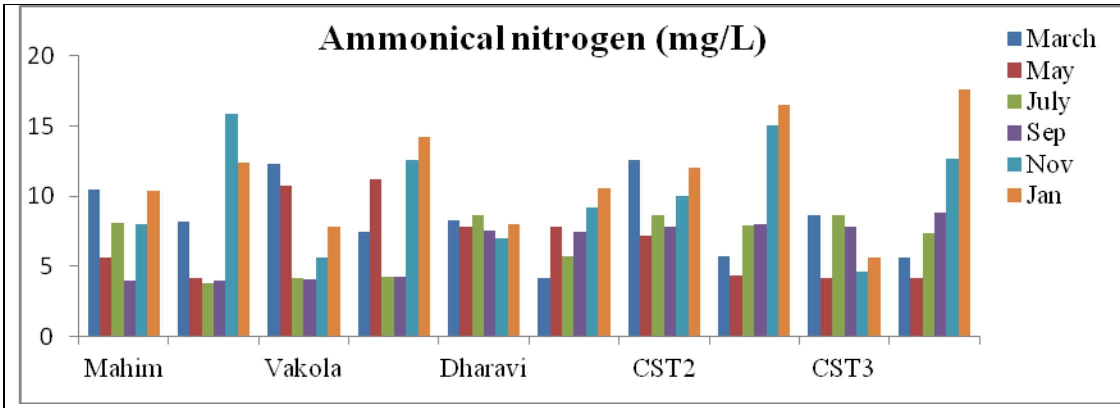

Fig 10: Ammonical nitrogen (mg/L) of river at sampling stations

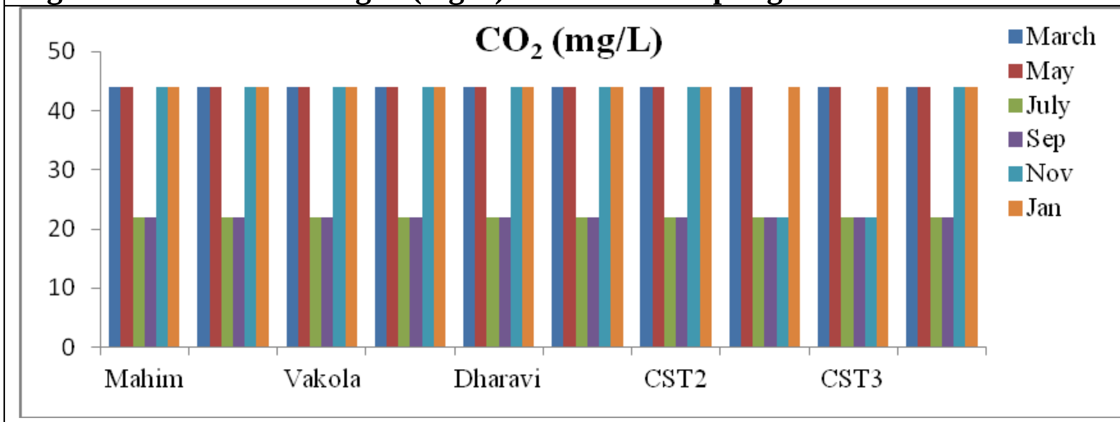

Fig 11: CO_2 (mg/L) of river at sampling stations

5. Conclusions

The overall water quality was found to be within MPCB standards for industrial discharge with respect to pH. The pH was around neutral at all stations. The values of temperature were also within similar values at all the five stations. The turbidity of the water was found to be highly fluctuating depending on sampling stations and season. These values were also very high as compared to the MPCB standards of 5 NTU. The values of conductivity showed variations according to sampling stations. The influence of sea water was maximum at Mahim, followed by Dharavi and Vakola. Dissolved oxygen was very low at all sampling stations. Organic loading in the form of BOD and COD was very high at all the sampling points due to industrial effluent and discharge of sewage. The values of BOD and COD were very high at all sampling points as compared to MPCB standards of 30 mg/L to 250 mg/L. Ammoniacal nitrogen values were lower as compared to the MPCB standards of 50 mg/L. In summary, the studied physico-chemical parameters reveal that the water is neither fit for drinking purposes without any form of treatment nor for various other surface water usage purposes. It is clear from the analysis that industries and domestic wastewater discharge have negative impact on water resources near the industrial area. Serious water quality deterioration has taken place. Based on the water quality analysis, the water quality was found unfit for bathing, contact water sports and commercial purposes.

6. Recommendations

The deterioration of environmental quality at various points in the river requires urgent remedial measures to improve the water quality. Major recommendations required for the improvement in water quality are given:

- Immediate closure of all unauthorized activities discharging industrial effluent along the river course.
- Provision of septic tanks for individual hutments or combined sewage treatment plants along the residential settlements along the river stretches.
- Provision of garbage collection and disposal systems at regular stretches to prevent citizens from dumping trash in the river.
- Dredging of the entire length of the river to clear blocked stretches and to improve the carrying capacity of the river.
- Provision of buffer strips along both the banks of the river for proper maintenance and management.

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