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A STUDY OF PHYSICO-CHEMICAL PARAMETERS OF MITHI RIVER WATER IN MUMBAI METROPOLIS

NAGARSEKAR, A. S.* AND KAKDE, U.B. **
*RESEARCH SCHOLAR,
SHRI.J.J.T UNIVERSITY, JHUNJUNU, RAJASTHAN, INDIA.
**GOVT. OF MAHARASHTRA'S ISMAIL YUSUF COLLEGE,
JOGESHWARI (EAST), MUMBAI 400-060, MAHARASHTRA, INDIA.
* Corresponding author's e-mail: drumeshkakde@gmail.com

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ABSTRACT:

Water plays a very important role in sustaining life. The quality of water acts as a barometer of the environmental health and well being of the human society. In the last 3 to 4 centuries, urbanization and industrialization have progressed affecting water bodies, which are being generally used for discharging domestic and industrial wastes. The river water pollution has an adverse effect on the environmental health and hygiene of people in surrounding areas of the river. It also affects the river water ecosystem.

In order to assess the quality of Mithi River water, four sampling stations along the course of the Mithi River were selected. The sampling points were selected in such a manner so as to ensure substantial pollution, considering the residential units and commercial activities near the sampling points. The investigation has been carried out throughout the year i.e. from October 2011 to September 2012. The physico-chemical parameters viz., pH, E.C., D.O., B.O.D., C.O.D., total hardness, total alkalinity, chlorides, nitrates and phosphates were analysed. It has been observed that some of the parameters substantially exceeded the limits when compared with the standards set by BIS and CPCB. The River water was therefore heavily polluted with number of organic and inorganic pollutants. A mechanism for the continuous monitoring of the river water and efforts to control discharge of waste in the Mithi River are required.

KEY WORD: *Physicochemical parameters, Water pollution, Mithi River, Mumbai, environmental health, hygiene, aquatic life.*

INTRODUCTION:

Water is essential to life on Earth. The importance of clean water was known from the ancient times. The Nomadic Stone Age man wandered around river basins. Water was useful to the people for drinking, cleaning, rearing animals and for agriculture, plantation etc. The greatest civilizations came up around river basins. All the major rivers of the world, Nile River, Indus River, Tigris & Euphrates River each played a major role in the development of World's greatest civilizations viz. The Ancient Egyptian civilization in Africa, Mohenjo Daro civilization in South Asia, Mesopotamian cultures in Europe and Ancient Roman culture.

As civilization progressed man invented new techniques to exploit river systems. As industrialization grew, mass production was started in factories. The industrial units which came up began generating scrap and wastes. The river systems were seen as convenient and cheap way to dispose of the wastes. This had an adverse effect on human health and environment. Though not specifically intended, the process of development vide, urbanization, globalization and industrialization leads to an adverse effect on the ecosystem ***(Tanner et al., 2001).*** In both developing and developed countries, the disposal of human wastes is a great challenge **(*Zimmel et al., 2004).***

Natural sources of water have an inbuilt process to purify water to a certain extent through physical, chemical and biological means. However, these processes cannot handle excess of pollutants which are being discharged into the water bodies. Over population, and related human activities like industrialization, deforestation etc. are causing a change in the delicate water balance ***(Trivedi et al., 1989-90***). In India, clean drinking water is available to only 12% of the people. The rest have to use polluted sources of water, which causes diseases, health & hygiene problems (***Trivedi et al., 2004).*** The importance of clean drinking water cannot but be overemphasized.

Efforts to reduce Water pollution have therefore become a global phenomenon. Point sources of pollution refer to discharge of wastes into water bodies directly by Industrial Units, domestic sewage plants etc. Non point sources refer to indirect pollutants, such as, impurities which settle form air, farm water runoff etc. It is very difficult to indentify non point sources and their remediation is very costly (***Harnova et al., 2003).***

There is an abundance of literature on "Water Quality" of various water bodies, since the problem of "water pollution" has now become a global phenomenon. However, utmost care needs to be taken to ensure that water of adequate quality and in sufficient quantity is provided to the people for domestic and industrial purposes. Due to increase in human population and growth of industries there is a considerable pressure on water bodies; the pollution level are increasing ***(Sahu et al., 1991)***. Various anthropogenic activities like the discharge of domestic wastes, industrial effluents, recreational and municipal wastes have greatly affected physiochemical properties of river waters ***(Panda et al., 1991).*** The use of untreated waste water for irrigational purposes has increased, as a result of lack of good quality of water. The fast reducing availability pure water for domestic or industrial purposes, coupled with its unequal distribution globally, has become a major concern in terms of Management of water quality and quantity ***(Leonard et al., 1971)***. Ecological damage and a serious health hazard are mainly a result of deterioration in the quality of water which is mainly due to human activities, such as, discharge of industrial/domestic wastes, sewage , agricultural run offs, disposal of dead bodies etc. ***(Meitei et al., 2004).***

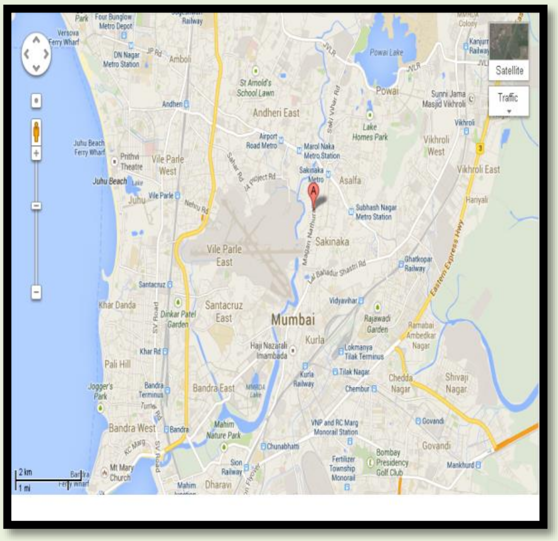
The Mithi River flows through the heart of Mumbai. It is ensconced on both sides by residential units, slums and industrial units. The domestic or industrial wastes are being discharged into the river. In the aftermath of the heavy downpour of 26th July 2005, there was heavy flooding around the airport, BKC and other areas near Mithi River. The inability of Mithi River to drain out the water was blamed for these floods, in which many people lost their lives. Thereafter, various authorities have made efforts to reduce the pollution in Mithi River and control the wastes being discharged. But due to financial/technical reasons, all the suggestions to control wastes and reduce pollution could not be fully implemented. The quality of Mithi River water continues to suffer in the meantime. The present investigations were done with a view to ascertain the current status.

MATERIALS AND METHOD:

Area of Study

The Mithi River flows through the heart of Mumbai City, which is a Metro and a premier city of India. The river has by now become synonymous with all ills which a river may experience. Encroachment of flood plains, storm water drainage, and disposal of untreated sewage and dumping of liquid & solid wastes are the various ills which afflict the River. The hills in the "Sanjay Gandhi National Park", which are at an altitude of 246 Meters above sea level, are the originating place of the River. Thereafter it merges with the overflows of Tulsi, Powai and Vihar lakes and travels downstream for around 18 Kms up to Mahim Bay. All the thickly populated areas like the residential and industrial complexes of Powai, Saki Naka, Kurla, Bandra- Kurla complex and Mahim lie on its path. In its initial stretches the river is narrow, but near the Bandra Kurla Complex it is at its widest. Further, it has a rather steep gradient in its initial stretches, and hence the water flows quite fast. However, on its second leg (say after Andheri), it course goes through a flat region. As a result of this, water and waste accumulate. The picture showing the flow of Mithi River, from origin to destination, is given below:

Figure 1: MITHI RIVER FROM ORIGIN TO DESTINATION



(Source: National Environment Engineering research Institute Report – 2011.)

The process of evaluating the quality of water along the course of Mithi River was carried out by selecting four sampling points along its path. A brief description of the location and the topographical details of each point are given below:

Sr.	Description of sampling point	Latitude	Longitude	Remarks
S1	Airport- Bridge on road from LBS Marg to IA colony (road from behind airport.)	19.08	72.87	Heavy residential area, slums- Airport Waste discharged.
S2	Safed pool	19.09	72.88	Slums, unauthorized industrial units
S3	CST Bridge	19.07	72.88	Thickly populated area. Unauthorized industrial units
S4	Kalanagar Bridge	19.05	72.85	Area surrounded by mangr -oves, acting as city’s oxy-gen lungs. Near “Saleem Ali” bird sanctuary.

Climatic & Topological Factors

The Mithi River empties into the Arabian Sea. At its origin, it is not more than 10 Kms from the Arabian Sea. The area within latitude 19^{o} 00’ to 19^{o} 15’ and longitude 72^{o} 45’ to 73^{o}.00’ E is covered in the water shed of Mithi River ***(NEERI 2011)***.

Chemicals & Regents Used–:

Chemicals and regents of analytical grade (AR) were used for evaluating the presence of various physicochemical parameters. A blank reading was taken to ensure the accuracy of the regents.

Preparation of Water Samples

Water samples were collected on a random basis, in the morning and evenings. Every week, sample collection was done on any two days at random, from the different sampling stations along the flow of Mithi River. Further, the process of drawing samples was carried out in all seasons, from October 2011 to September 2012, to evaluate various parameters. Prior to collection of water sample from surface of the river, the polythene bottles are rinsed 3 to 4 times in the water from where the sample is being collected.

The Equipments /Methods used.

The equipments used and the methods followed for analyzing the different physiochemical parameters, are given in a table.

Sr No.	Parameter	Equipments & Methods
1.	pH	Digital pH meter.
2.	EC(Electrical Conductivity)	Digital Conductometer.
3.	Total Hardness	Complexometric titration using E.D.T.A.
4.	Total Alkalinity	Using Acidimetric titration.
5	BOD (Biochemical Oxygen Demand)	Winkler's method with azide modification.
6.	COD (Chemical Oxygen Demand)	Potassium Dichromate Open reflex method.
7	Chlorides	Standard Silver Nitrate Method
8.	Nitrate	Using UV- Visible Spectrophotometer.
9.	Phosphate	Using UV- Visible Spectrophotometer
10.	DO (Dissolved Oxygen)	Winkler's method with azide modification.

The standard methods prescribed by ***(APHA, NEERI 1991***) were followed for evaluating each parameter.

Quality Control/ Assurance

1. To ensure correct result and avoid errors -
2. Analytical Grade (AR) regents & chemicals were used.
3. Water samples were collected in clean polythene bottles free from impurities, as well as, free from organic matter.
4. Bottles were sealed with paraffin wax in order to avoid contamination during transporting from sampling station to laboratory.

5. Regent blanks were verified to ensure that there are no impurities in the regents due to environmental factors.
6. All glassware ware was washed properly and then soaked in acid bath overnight. In the morning the glass wares washed and rinsed with distilled water.

RESULTS AND DISCUSSION:

The tables showing the seasonal averages for post-monsoon, pre-monsoon and monsoon seasons and the 12 monthly values showing the concentration level of each parameter, along with the charts showing seasonal fluctuations in the concentration levels are given on pages 14-15 & 16-18.

pH: During the study period, the pH of water samples were measured at the sampling station itself, using digital p^H meter. The average concentration levels at each of the four sampling points S1, S2, S3 & S4 in the post monsoon season were 7.42, 7.35, 7.27 & 8.04. In the pre-monsoon season the values at S1, S2, S3 & S4 were 6.18, 6.26, 6.57 & 7.63 respectively. In the Monsoon season the values were 7.25, 7.05, 7.08 & 7.62 at the four sampling stations (All Concentration levels in Nos).

It was observed that throughout the study period the values of pH at S4 were higher than S1, S2 and S3, since S4 is near the sea. The values of p^H indicate a slightly acidic to alkaline content during pre-monsoon season at sampling points I, II & III. At sampling point IV water was slightly alkaline throughout the period of the study. However, all the values of pH were within the permissible limits of (6.5 to 8.5) prescribed by **ISI**. A slightly alkaline pH is preferable in waters as heavy metals are removed by carbonate or bi-carbonate precipitation ***(Ahipathy et al., 2006).***

Electrical Conductivity (EC): The measurement of EC is done immediately after taking the water samples, using digital conductometer. The average concentration levels at each of the four sampling points S1, S2, S3 & S4 in the post-monsoon season were 876, 1043, 1295, and 21.128. In the pre monsoon season the values were 816, 861, 1415 & 20.593. In the Monsoon season the values were 651, 877, 980 & 12.660 (all concentration levels except S4 in µ**S/cms**).

The variation in EC values is due to seasonal variation in the quality of water and the dilution effect in the rainy season. Effects of effluents discharged, human anthropogenic activity have also shown their effect at the different sampling stations. The average value of EC in an unpolluted river is 350 **µS/cms**. It was observed that at all sampling points the values of EC were higher than prescribed limits. However, it was observed that at S4, the value of EC (**S/cms**) was substantially higher as compared to S1, S2 & S3. This could be due to effect of sea water.

Dissolved Oxygen (DO): Dissolved Oxygen is a most important parameter in deciding the health of aquatic systems, including river waters. The D.O value for surface water should be at least in the range of 5-6 mg/L. D.O. below the permissible limit or a lower value of DO indicates a danger to the eco-system of the river. Depletion of DO as a result of sewage disposal into the river is reported by ***Saxena et al., 1966.*** It was reported that dissolved oxygen concentration of at least 5 mg/L is required for maintaining a healthy aquatic life and DO concentration of less than 5 mg/L indicates pollution ***(Khanderkar et al., 1986).***

The water samples were drawn in such a way, so as to avoid air bubbles. Also, the D.O was measured at the sampling point itself using digital D.O Meter. The average concentration levels at each of the four sampling points S1, S2, S3 & S4 in the post monsoon season were 0.65, 0.63, 1.65, & 1.1. In the pre monsoon season the values were 0.3, 0.33, 0.67 & 1.3. In the Monsoon season the values were 0.38, 0.40, 0.72 & 1.43 (All Concentration levels in mg/L).

The variation in D.O. values could be due to many reasons. Our study shows seasonal variation in D.O. values, are affected by industrial, human and thermal activities. D.O. values have found maximum during winter and minimum during the summer. The lower values of D.O. at the sampling point S1 and S2 compared to S3 indicates higher pollution at the site due to anthropogenic activity, disposal of sewage from the surrounding area and effluents from industrial units. At S4, there may be dilution effect due to sea water.

It is clear from the above data that the values of D.O at all the four sampling stations, were much below the required permissible limits for domestic, irrigation and other uses throughout the year. This indicates a high level of pollution. Around all the four sampling points (S1, S2, S3 & S4), there is substantial sewage discharge from nearby housing societies. Besides, near the banks of the river certain, anthropogenic activities, like scrap dealers, drum cleaners, scrap from airport, automobile garages nearby contributes to impurities, which ultimately deplete D.O. levels in water. Due to this, the aquatic life in Mithi River is very adversely affected. Lower value of D.O. is an indication of contamination with organic matter.

Biological Oxygen Demand (BOD*):* Represents the demand of oxygen required by aerobic organisms in water. The presence of organic matter in water increases the biochemical oxygen demand. In unpolluted waters/rivers, the BOD is usually 5 mg/L or lower. Higher value of BOD results in the depletion of D.O. This reduces the availability of oxygen for living organisms, like fish, plants etc. and leads to stress on aquatic plants, animals and ultimately death. River water having BOD values more than 10 mg/L is considered as moderately polluted and when the level is more than 20 mg/L it is said to be highly polluted ***(Paul et al., 1999).*** It has been observed that BOD values are higher in polluted waters and lower in pollution free waters ***(Solanki et al., 2012).*** The average concentration levels at each of the four sampling points S1, S2, S3 & S4 in the post-monsoon season were 205, 276, 167, and 144. In the pre monsoon season the values were 229, 338, 196 & 164. In the Monsoon season the values were 209, 263, 100 & 145 (All concentration levels in mg/L).

On comparison of the seasonal BOD values, it was observed that BOD values were higher during the pre monsoon season than during than the monsoon and post monsoon season. This is due to lower water levels and saturation of impurities. Higher values of BOD at all the sampling locations, as against prescribed levels, indicate that there is significant organic pollution. Also the BOD values were observed to be substantially higher than the prescribed levels.

Chemical Oxygen Demand (COD): Presence of organic matter and chemical compounds in water demands oxygen for oxidization process. COD is a measure of organic pollution of water. It measures indirectly the presence of organic matter in H_2O. Higher values of COD indicate that there is high organic pollution leading to a depletion of dissolved oxygen COD is an indicator of organic pollution in surface water. This is a danger to aquatic ecosystem. The average concentration levels at each of the four sampling points S1, S2, S3 & S4 in the post monsoon season were 299, 360, 766 & 385. In the pre monsoon season the values were 472, 535, 719 & 678. In the Monsoon season the values were 276, 321, 546 & 298 *(All concentration levels in mg/L).*

A seasonal variation in the values of COD at points S1, S2 S3 & S4 was observed. Lower values of COD during the rainy season, compared to pre and post monsoon, were observed. This is due to dilution of water in the monsoon. It was observed that in all seasons, the value of COD at S3, were higher than S1, S2 and S4. Also, comparing the COD values at all the stations (average per season) with the permissible limits (10 mg/L) indicates the high organic pollution.

The sampling stations S2 & S3, are surrounded by industrial units and dense population of slums which discharge sewage, and industrial effluents increasing pollution to a very vulnerable state. Higher COD values in the pre-monsoon may be due to concentration of water as a result of evaporation etc. Lower COD values in the monsoon may be attributed to dilution of water by rain water flows.

Total Hardness: Hardness of water is an important parameter for indicating the suitability for industrial and domestic purposes. Hardness causing cat ions are Ca^{2+} Mg^{2+}, Sr^{2+}, Fe^{2+}, Mn^{2+}. Hardness is also caused by anions OH^-, CO_3^{2-} and HCO_3^{-2}. If the total hardness exceeds 150 mg/L the water is not suitable for fish. The average concentration levels at each of the four sampling points S1, S2, S3 & S4 in the post monsoon season were 186, 298, 283, & 2610. In the pre monsoon season the values were 198, 247, 319& 2452. In the Monsoon season the values were, 180, 250, 239 & 2387 (All concentration levels in mg/L).

During the present study, it was observed that at all the four locations, S1, S2, S3 & S4 water is hard and not suitable for any domestic or industrial use. During the monsoon the values of Total Hardness are lower, as a result of dilution of waters due to rain water; while in the pre-monsoon season it is high as a result of concentration of water due to evaporation. At S4, the values of total hardness obtained were significantly higher as compared to points S1, S2 & S3. This may be due to the effect of sea water.

Alkalinity:

Alkalinity of water is measured in terms of Carbonate, Bicarbonate and hydroxide alkalinity. Total Alkalinity includes all types of alkalinity. The average concentration levels at each of the four sampling points S1, S2, S3 & S4 in the post monsoon season were 203, 205, 209 & 216. In the pre-monsoon season the values were 242, 228, 233 & 237. In the Monsoon season the values were, 176, 210, 185 & 205 (All concentration levels in mg/L).

The total alkalinity values obtained for the sampling stations S1, S2, S3 & S4 reveal that during the pre-monsoon season values are higher compared to the monsoon and post-monsoon. During the monsoon the alkalinity values were minimum indicating a dilution of water. Though the values of alkalinity were higher at S4, as compared to S1, S2 & S3, the differences were not observed to be quite substantial. Further it was observed that alkalinity is due to carbonate and bicarbonate ions but no hydroxide alkalinity is found. Bi-carbonate alkalinity was found to be higher than carbonate alkalinity.

Chlorides:

Chlorides are usually present in water. They are also added in domestic water supply as bleaching agent, to kill micro-organisms. Presence of chlorides in water, above the permissible limit (higher concentration) is an indicator of pollution. The high concentration of chlorides may be due to organic wastes or industrial effluents. They are very harmful to aquatic life. The permissible limit of chlorides in water is (250 mg/L). The average concentration levels at each of the four sampling points S1, S2, S3 & S4 in the post monsoon season were 8431, 10226, 12818 & 18654. In the pre monsoon season the values were 9448, 9942, 14911& 17265. In the Monsoon season the values were, 7263, 10506, 11055 & 16615 (All concentration levels in mg/L).

The present study indicates that the chloride concentration is substantially higher at all the four sampling points as compared to the permissible limits (250 mg/L). Season wise analysis reveals that chloride concentration is highest in pre monsoon than in the monsoon and post-monsoon seasons except at S2 point. Further, it was also observed that throughout the year chloride concentration was higher at S4 than at other sampling points S1, S2 & S3. This is due to the effect of sea water.

Phosphate:

Increase in concentration of phosphate indicates that there is mixing of industrial effluents, sewage water and waste water in the river water. Higher concentration of Phosphates leads to eutrophication. The average concentration levels at each of the four sampling points S1, S2, S3 & S4 in the post monsoon season were 0.144, 0.227, 0.156 and 0.145. In the pre monsoon season the values were 0.165, 0.205, 0.233 & 0.143. In the Monsoon season the values were 0.137, 0.273, 0.135 & 0.166 (All concentration levels in mg/L).

In the present study, no specific season wise variations were observed as far as phosphate is concerned. The location wise analysis also did not indicate that the phosphate concentration at any of the sampling points was higher than at other points consistently throughout the year. This indicates that the phosphate content in water varies with local factors at the sampling point.

Nitrates:

Increased concentration of nitrates in water leads to eutrophication. As per ISI guidelines, the permissible limit for nitrates in water for domestic/industrial use is 45 mg/L. Higher concentration of Nitrates may be due to disposal of untreated sewage, which leads to nutrient loads in water. The average concentration levels at each of the four sampling points S1, S2, S3 & S4 in the post monsoon season were 135.8, 112.2, 160.4 & 107.9. In the pre-monsoon season the values were 182.9, 183.7, 180 & 159.3 In the Monsoon season the values were 101.21 145.9, 107.52 & 100.04 (All concentration levels in mg/L).

It is observed that at all the sampling points and in all seasons, the nitrate concentration is in excess of the permissible limits (45 mg/L). This indicates that there is organic pollution. High level of nitrates in drinking water, which is mainly due to leakage of fertilisers in water affects children and leads to blue baby disease in infants by depriving them of oxygen (**Nash Linda et al., 1993).**

It was observed that in all seasons, the concentration of nitrates was lower at S4 than the other sampling points. Also, it is observed that the nitrate concentration is lower in the monsoon except at S2; while it is highest in the pre monsoon season. This may be due to dilution of water in the in the rainy season and concentration in the summer as a result of evaporation due to heat.

A statistical analysis was carried out for each parameter selected for the study. An “ANNOVA” test was carried out using the data for each parameter. The hypothesis selected for the test that “There is no significant variation”. The tabulated values of F at 5% level of significance, F 2, 6 = 5.14 and F 3, 6 = 4.75 were obtained. If the calculated value of F is more than the tabulated value, the null hypothesis is rejected that means there is significant variation. Alternatively, if the calculated value of F is less than the tabulated value, the null hypothesis is accepted. This implies that there is no significant variation in the data. In the present investigation, it was observed that there was a significant seasonal variation in pH, nitrate, BOD, COD and Total alkalinity. Significant variation was observed at different sampling stations in pH, EC, DO, BOD, COD,TH and chlorides.

CONCLUSIONS:

It is revealed from the results that the concentration levels for several physiochemical parameters have exceeded the maximum permissible limits. It can therefore be concluded that the waters of the Mithi River are substantially polluted due to various pollutants. Therefore, the water cannot be used for any domestic or industrial purposes. Several adverse effects are caused by the polluted water of the "River" on the health & hygiene of the people staying in adjoining areas near the river. It is also ecologically damaging the aquatic life of the River and the Arabian Sea besides it also going to affect the mangrove ecosystem which serves the lungs of the city and Saleem Ali bird sanctuary at Mahim, where migratory birds come for nesting is nearby. Therefore a mechanism for continuous monitoring of the quality of the water of river Mithi is required. Also concentrated efforts are required from all concerned to reduce dumping of industrial and residential wastes in the river waters. The State Government, Municipal Authorities need to work together to achieve this. Broadly, the following suggestions are made to reduce pollution levels in the Mithi River.

a) Strict controls need to be introduced on the disposal of domestic sewage by Housing Societies and residential units. There are many sewage lines which dispose the sewage in the river. The sewage should be treated and then only allow to dispose off.
b) Dumping of garbage into the river should be strictly prohibited.
c) Strict implementation of all the Environmental laws to be followed.
d) Modern sanitation systems should be adopted. Proper lavatories need to be built at different locations to prevent open defecation.

The width of the Mithi River needs to be widened by relocating residential, commercial units, slums which obstruct the course of the river.

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Table 1: Seasonal averages and monthly data of ph, EC, DO, BOD, COD, TH, TAK, Chlorides, Nitrates & Phosphates (Sampling Point S1=Airport, S2=Safed Pool, S3=CST Bridge, S4= Kalanagar)

MONTH/ YR	pH				EC				DO (mg/L)				BOD (mg/L)			
	S1	S2	S3	S4	*S1	*S2	*S3	**S4	S1	S2	S3	S4	S1	S2	S3	S4
Oct-11	7.95	7.92	7.6	8.3	951	1177	1246	19.5	0.9	0.7	0.9	1.3	199	252	157	135
Nov-11	7.8	7.5	7.2	8.1	914	1098	1203	20.71	0.6	0.4	1.2	1	203	271	171	147
Dec-11	7.84	8.1	7.4	8.17	821	976	1353	22.45	0.4	0.6	2.4	0.9	191	267	163	140
Jan-12	6.1	5.9	6.9	7.6	819	921	1378	21.85	0.7	0.8	2.1	1.2	227	308	175	153
Post Mon.	**7.42**	**7.36**	**7.28**	**8.04**	**876**	**1043**	**1295**	**21.1**	**0.65**	**0.63**	**1.65**	**1.1**	**205**	**275**	**167**	**144**
Feb-12	5.93	6.12	6.4	7.92	768	835	1404	21.05	0.5	0.4	1.4	1.8	230	329	189	156
Mar-12	6.2	6.2	6.3	7.41	821	821	1457	21.13	NIL	NIL	0.6	1.6	218	323	193	166
Apr-12	6.4	6.4	6.9	7.7	781	857	1398	19.67	0.1	0.2	0.4	0.6	223	356	196	173
May-12	6.2	6.32	6.7	7.5	895	932	1401	20.52	NIL	0.4	0.3	1.2	243	345	207	162
Pre Mon.	**6.18**	**6.26**	**6.58**	**7.63**	**816**	**861**	**1415**	**20.6**	**0.3**	**0.33**	**0.68**	**1.3**	**229**	**338**	**196**	**164**
Jun-12	6.3	6	6.5	7.3	651	913	1285	12.28	0.2	0.4	0.6	1.6	231	331	213	169
Jul-12	6.8	6.8	6.9	7.5	598	839	981	12.08	0.6	0.3	0.8	1.8	216	281	174	138
Aug-12	7.8	7.6	7.6	7.8	642	901	842	12.5	0.4	0.5	0.6	1.4	198	223	168	143
Sep-12	8.1	7.8	7.3	7.9	713	856	814	13.78	0.3	0.4	0.9	0.9	189	215	163	129
Monsoon	**7.25**	**7.05**	**7.08**	**7.63**	**651**	**877**	**981**	**12.7**	**0.38**	**0.4**	**0.73**	**1.43**	**209**	**263**	**180**	**145**

MONTH/ YR	COD (mg/L)				TH (mg/L)				TAK (mg/L)			
	S1	S2	S3	S4	S1	S2	S3	S4	S1	S2	S3	S4
Oct-11	283	312	702	234	172	312	273	2381	210	186	217	236
Nov-11	276	298	810	355	181	285	280	2576	203	218	203	213
Dec-11	304	356	840	412	224	389	253	3018	184	203	219	215
Jan-12	334	472	712	541	168	205	326	2463	216	212	198	201
Post Mon.	**299**	**360**	**766**	**386**	**186**	**298**	**283**	**2610**	**203**	**205**	**209**	**216**
Feb-12	453	561	651	692	178	212	357	1982	219	220	209	228
Mar-12	472	528	784	713	196	230	318	2350	235	205	231	237
Apr-12	419	491	652	698	206	263	304	2586	272	251	240	251
May-12	543	562	791	612	213	281	297	2891	241	237	252	230
Pre Mon	**472**	**536**	**720**	**679**	**198**	**247**	**319**	**2452**	**242**	**228**	**233**	**237**
Jun-12	349	351	648	392	192	290	315	2671	173	218	179	198
Jul-12	268	301	482	298	168	273	210	2341	180	227	185	213
Aug-12	240	337	503	217	173	213	198	2185	182	194	193	196
Sep-12	247	294	549	284	188	224	231	2352	169	201	185	212
Monsoon	**276**	**321**	**546**	**298**	**180**	**250**	**239**	**2387**	**176**	**210**	**186**	**205**

(*) Data in **µS/cm**
(**)Data in **S/cm**

MONTH/ YR	CHLORIDES (mg/L)			
	S1	S2	S3	S4
Oct-11	8862	10280	11691	19691
Nov-11	8491	10125	11481	17892
Dec-11	7191	10635	13180	17462
Jan-12	9180	9864	14921	19571
Post Mon.	**8431**	**10226**	**12818.3**	**18654**
Feb-12	9430	10215	15387	18342
Mar-12	9762	10870	14681	17431
Apr-12	8615	9561	14230	16850
May-12	9983	9123	15347	16435
Pre Mon	**9447.5**	**9942.25**	**14911.3**	**17264.5**
Jun-12	8160	9594	11233	16540
Jul-12	7980	9916	9852	15721
Aug-12	6159	10283	10371	15740
Sep-12	6754	12231	12762	18457
Monsoon.	**7263.25**	**10506**	**11054.5**	**16614.5**

MONTH / YEAR	NITRATE (mg/L)				PHOSPHATE (mg/L)			
	S1	*S2*	*S3*	*S4*	S1	S2	S3	S4
Oct-11	85	62.5	165	65.4	0.15	0.3	0.16	0.14
Nov-11	103	85.4	150	87.3	0.15	0.2	0.15	0.15
Dec-11	165	139	154	131	0.13	0.2	0.15	0.16
Jan-12	191	163	172	149	0.15	0.2	0.16	0.14
Post Mon	**136**	**112**	**160**	**108**	**0.14**	**0.2**	**0.16**	**0.15**
Feb-12	183	180	168	160	0.15	0.2	0.19	0.14
Mar-12	176	178	171	158	0.17	0.2	0.16	0.14
Apr-12	191	192	189	149	0.16	0.2	0.41	0.15
May-12	182	185	193	170	0.18	0.2	0.17	0.14
Pre Mon	**183**	**184**	**180**	**159**	**0.16**	**0.2**	**0.23**	**0.14**
Jun-12	176	183	186	147	0.14	0.2	0.15	0.15
Jul-12	109	157	97.2	89.2	0.13	0.3	0.13	0.15
Aug-12	53.2	140	58.2	106	0.13	0.3	0.13	0.19
Sep-12	67.2	103	89	58.2	0.15	0.3	0.13	0.18
Monsoon	**101**	**146**	**108**	**100**	**0.14**	**0.3**	**0.13**	**0.17**

FIGURES SHOWING SEASONAL AVERAGES OF pH, EC, DO, BOD

(Sampling Point S1=Airport, S2=Safed Pool, S3=CST Bridge, S4= Kalanagar)

Figure 1: Seasonal Variations in pH

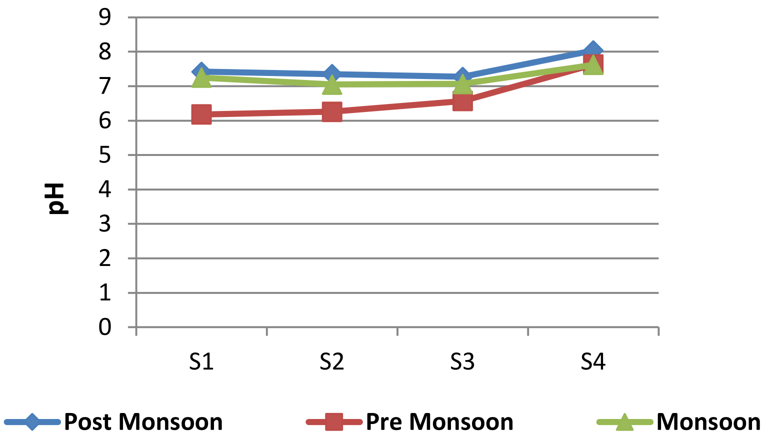
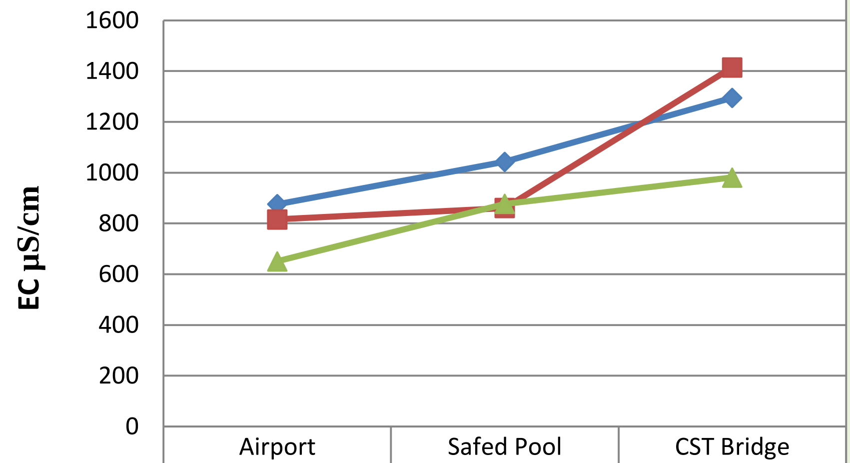
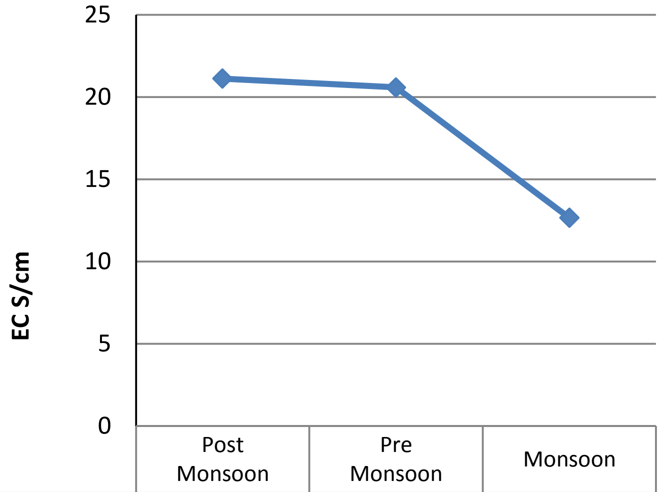


Figure 2A: showing EC of water at three sampling points.



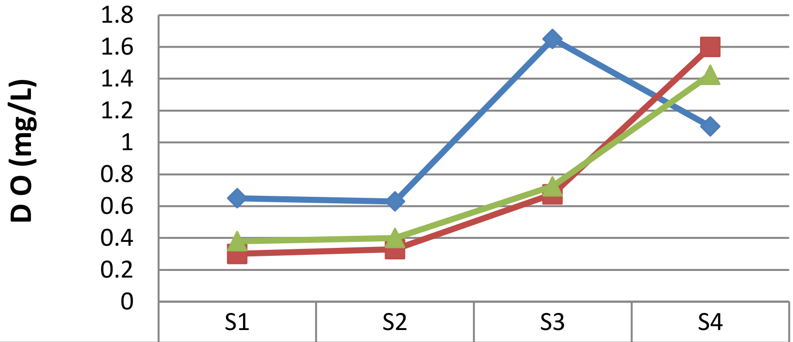
	Airport	Safed Pool	CST Bridge
Post Monsoon	876	1043	1295
Pre Monsoon	816	861	1415
Monsoon	651	877	981

Fig 2B: EC of water at Kalanagar



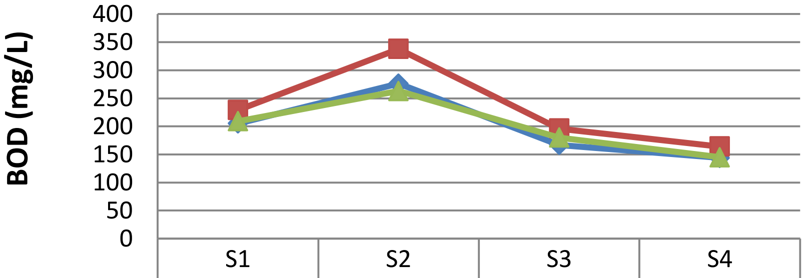
	Post Monsoon	Pre Monsoon	Monsoon
Kalanagar	21.13	20.595	12.66

Figure 3: Seasonal Variations in D O



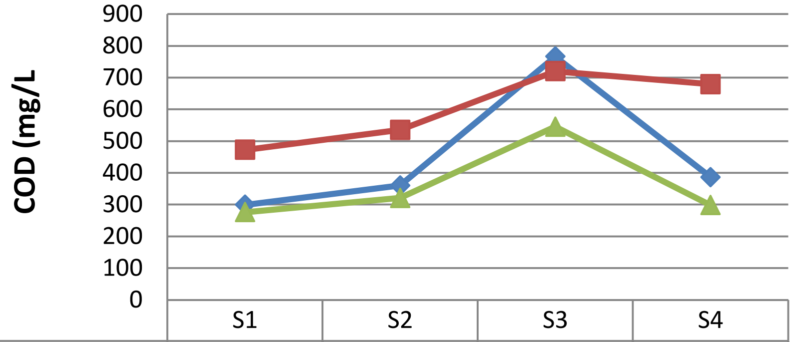
	S1	S2	S3	S4
Post Monsoon	0.65	0.63	1.65	1.1
Pre Monsoon	0.3	0.33	0.675	1.6
Monsoon	0.38	0.4	0.725	1.425

Figure4: Seasonal Variations in BOD



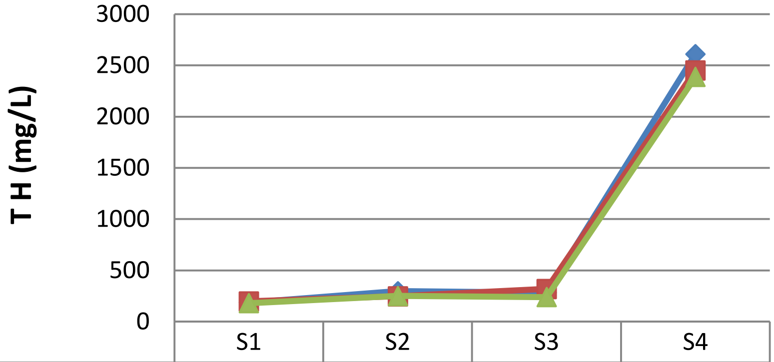
	S1	S2	S3	S4
Post Monsoon	205	276	167	144
Pre Monsoon	229	338	196	164
Monsoon	209	263	180	145

Figure5: Seasonal Variation in COD concentration



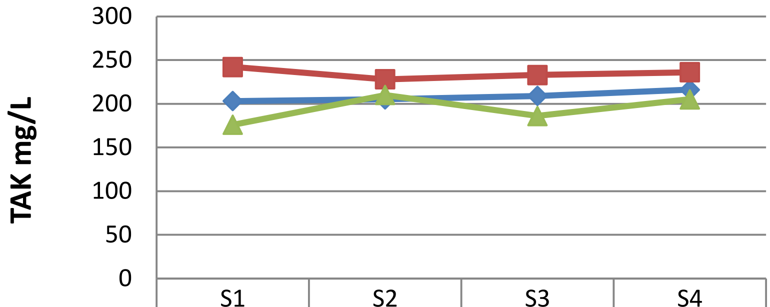
	S1	S2	S3	S4
Post Monsoon	299	360	766	386
Pre Monsoon	472	535	720	679
Monsoon	276	321	545	298

Figure 6: Seasonal Variations in Total Hardness levels



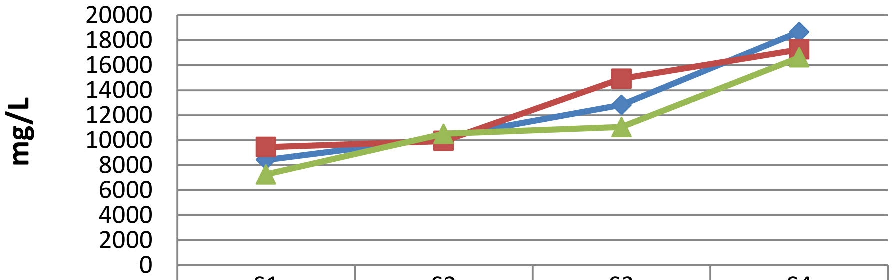
	S1	S2	S3	S4
Post Monsoon	186	298	283	2610
Pre Monsoon	198	247	319	2452
Monsoon	180	250	239	2387

Figure7: Seasonal Variations in alkalinity levels



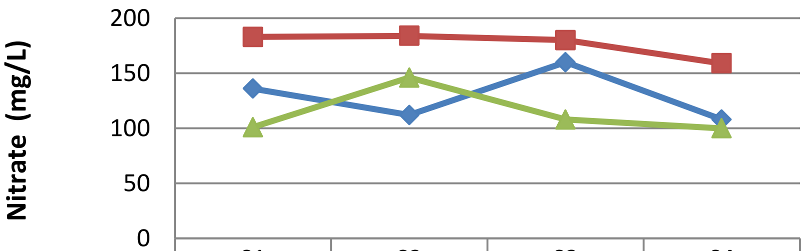
	S1	S2	S3	S4
Post Monsoon	203	205	209	216
Pre Monsoon	242	228	233	236
Monsoon	176	210	186	205

Figure8: Seasonal Variations in Chlorides levels



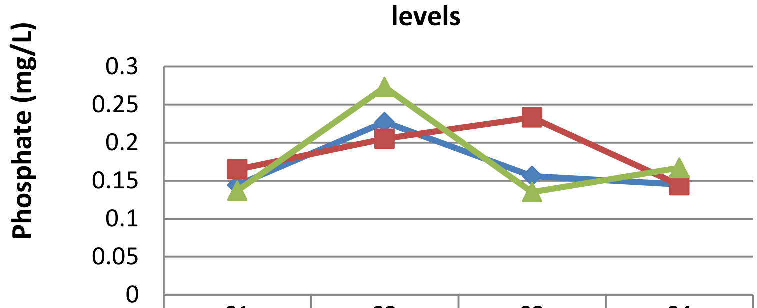
	S1	S2	S3	S4
Post Monsoon	8431	10226	12818	18654
Pre Monsoon	9448	9942	14911	17265
Monsoon	7263	10506	11055	16615

Figure9:Seasonal variations in Nitrate level



	S1	S2	S3	S4
Post Monsoon	136	112	160	108
Pre Monsoon	183	184	180	159
Monsoon	101	146	108	100

Figure 10:seasonal variations in Phosphate concentration levels



	S1	S2	S3	S4
Post Monsoon	0.144	0.227	0.156	0.145
Pre Monsoon	0.165	0.205	0.233	0.144
Monsoon	0.137	0.273	0.135	0.167