A COMPARATIVE STUDY OF WATER QUALITY OF MAJOR RIVERS OF PUNE FOR THREE DIFFERENT SEASONS

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ABSTRACT:-Mula, Mutha and Pavana are the three major rivers of Pune on which the city mainly survives. In view of this, maintenance of quality of these waters is imperative and hence needs regular auditing. Present report is an investigation into the water quality of these river waters carried out at different locations during all three seasons in the year 2015 taking into consideration 18 physico-chemical parameters. Water samples were collected from nine different locations covering all the three rivers. The combined effect of various physico-chemical parameters is studied through calculation of Water Quality index for all these samples. Water quality of Khadakwasla was found to be good whereas for majority of the locations it is medium irrespective of the season in which it is studied, which is in agreement with the previous studies. At Yerwada and Aundh the water samples showed bad quality during all the seasons irrespective of the seasonal variations which speaks about the high pollution levels at these locations. It has been concluded from this work that seasonal variation does have an impact on water Quality Index (WQI) and serves as an indicator for the pollution levels in the waters of Pune.

Key words: **water quality index,summer,monsoon,winter,Mula,Mutha, Pavana, water parametres**

INTRODUCTION :

Mula, Mutha and Pavana are the main sources of water for the populations in and around Pune. Many industries discharge their wastes directly into these rivers, undermining the water quality. The water quality restoration and maintenance in these rivers has been a great challenge to the authorities and environmentalists concerned [1]. In view of this, assessment of water quality of these rivers is highly important. The quality of water is a function of many physico-chemical parameters like Temperature, Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Nitrates, Phosphates and pH [2-3]. However, these parameters do also depend on the environmental conditions. Hence, seasonal variations play an important role in bringing about changes among these parameters which in turn formidably affect the water quality of the rivers [4-5]. Literature studies clearly indicate that the level of pollution was more during pre-and post-monsoon seasons [6]. Present investigation is an attempt to understand the impact of summer, winter and monsoon as seasons on the water quality of river waters of flowing in and around Pune. A study about the influence of different seasons on the water quality is well documented [7]. Water quality is generally studied by evaluating the composite effect of various physico-chemical parameters on the river waters. A widely-accepted index worldwide that reflects this overall influence on water quality is Water Quality Index (WQI) [8]. The aim of the present investigation under the title is to study the water quality of the three rivers of Pune by probing the samples collected from different sampling stations and analysing them the reasons for the obtained results. A total of 9 sampling locations stations were selected for water sampling and eighteen water parameters were analysed at these locations for assessing the water quality.

MATERIALS AND METHODS:

As stated earlier, river water samples were collected for all three seasons by recording water parameters for a period of three months for each season in the year 2015 for all the three seasons.

Table 1 The details of sampling stations

Station No	Name of the Sampling Station	Name of the River
S1	Panshet Dam	Mutha River
S2	Khadakwasla Upstream	Mutha River
S3	Khadakwasla Downstream dam	Mutha River
S4	Mulshi Dam	Mula River
S5	Paud	Mula River
S6	Pavana Dam	Pavana River
S7	Bevad Ovhal	Pavana River
S8	Aundh	Mula River
S9	Yerwada	Mula-Mutha

The physico-chemical analysis of various water parameters Mula, Pavana and Mutha River waters were conducted to analyse the effects of pollution for different locations starting from Khadakwasla to Yerwada. Various station points were selected for sampling. A total of 9 locations are were selected along the stretch of river the details of which are tabulated in Table 1 below. 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 namely pH, Temperature,BOD, COD, DO, MPN, Nitrate, Phosphate, Turbidity,Total Solids,Free Co_2, Chlorides,Total Alkalinity, Total Hardeness, Electrical Conductivity, Calcium, Magnesium and Sodium following standard methods APHA – AWWA – WPCF (1989) [9]. Of these nine most significant water parameters viz,pH, Nitrates, Phosphates, DO and Turbidity were used to calculate the WQI, using a renowned method of calculation [10,11].

Results and Discussion:

Parameter wise results of the study of all three reasons are presented and discussed in the following paragraphs.

Temperature:

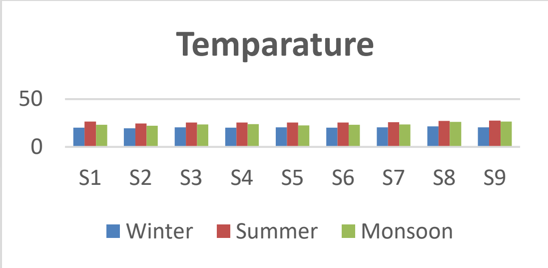

Fig.1 Variation of temperature for different samples

Temperature of water is a significant decisive physical parameter in determining the electrical conductivity, pH and dissolved ions present in each of the water samples. It does have an effect on the alkalinity, chemical and biological reactions and chemical equilibrium of water. As temperature increases, Dissolved Oxygen content dwindles [12]. In the present investigation, average temperature observed for the summer season was . The temperature for different samples from S1 to S9 varied between 19 ̊**C** and 21 ̊**C** for winter, 24 ̊**C** to 27 ̊**C** for summer and 22 ̊C to 26 ̊C for monsoon respectively. Fig.1 shows graphical variation of temperature at various sampling stations for all three seasons.

pH:

pH is an essential parameter as it determines the acidity and alkalinity of waters. [13]. The pH ranged between 5.5 and 8.0 for S9 and S3 respectively. This maximum value of pH was observed for S3 in winter and minimum was recorded at S9 during summer. The decrease in pH during summer with increasing temperature may be due to increase in the process of photosynthesis and sometimes it may also be attributed to maximum algal formation and contaminants as in S8 and S9[Ref] . It is a well known fact that both highly acidic and highly basic nature of waters reduces the quality of water. This is the reason why the water quality at locations like Yerawada (5.9) shows degraded quality of water flow. Fig.2 shows graphical variation of pH at various sampling stations for all three seasons.

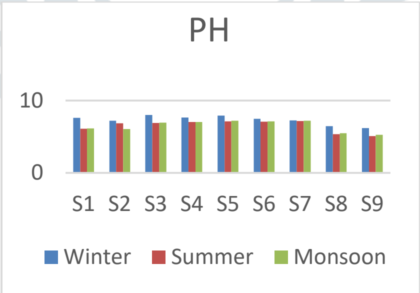

Fig.2 Graphical variation of pH at various sampling stations

BIOLOGICAL OXYGEN DEMAND (BOD):

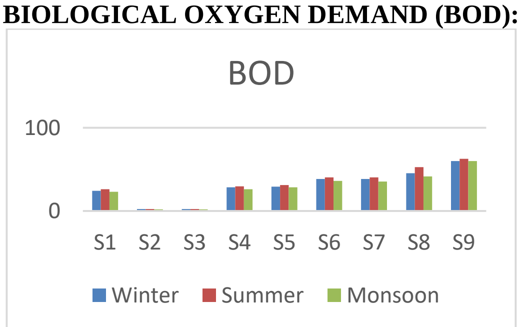

Fig.3 Graphical variation of BOD at various sampling stations

BOD is one of the significant water parameters in evaluating the water quality as well as WQI. The BOD limits per BIS should not exceed 6mg/L [14]. BOD is a parameter used to assess the required oxygen level in stabilizing the domestic and industrial wastes. In the present report, the observed ranges of BOD were 2mg/L at S2 i.e.,Khadakwasla, during winter upstream and 62.7 mg/L at S9 in summer (Yerawada). It has been observed that, BOD values were in general low during winter and monsoon where as comparatively high values were observed during summer season for almost all samples. It may be noted that, the BOD values were high for almost all the sample stations from S4 to S9 during all seasons indicating the presence of various biological species in these stations. Fig.3 shows graphical variation of BOD at various sampling stations for all three seasons.

FECAL COLIFORM (MPN):

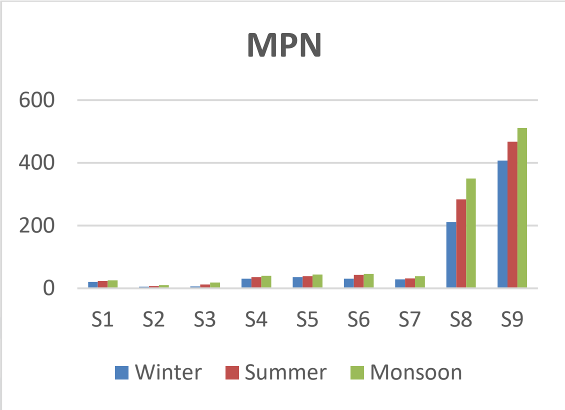

Fig.4 Variation of MPN at various sampling stations

Fecal coliform also known as Most Probable Number (MPN) is another parameter that is used as an indicator to know the safety levels of water by the presence of bacteria in the given water sample [15]. It varied between 4.4 MPN/100ml at S2 to 510 MPN/100 ml of water at S9 during winter and monsoon seasons respectively. At both S8 and S9 the MPN values are on higher side indicating considerably concerning pollution levels at these locations. The fecal colioform levels have gradually increased from winter to summer and to monsoon. In all, at S2 is observed to be apparently the safest irrespective of the seasons. The variations of season wise MPN at all selected locations are represented in Fig.4

DISSOLVED OXYGEN (DO):

DO measurements refer to the pollution levels in water as its levels indicate the favourability of growth and multiplication of aquatic life. The DO levels are also read as the measure of degree of organic pollution of water. The Oxygen levels were high at Khadakwasla stand at around 8 mg/L, but fell considerably at Yerwada to 2.2 mg/L. The DO levels were observed to be highest during monsoon due to rain fall as well as well mixing of runoff from streams where in both the cases, well aerated waters mix with river waters. The DO levels were minimum during summer mostly due to addition of domestic wastes. Such results were perfectly in agreement with the earlier reports [16,17]. The DO values at different locations are graphically displayed in Fig.4.

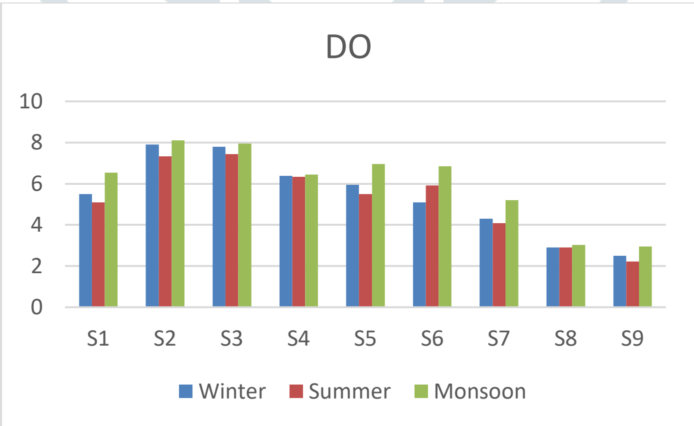

Fig.5 Variation of Dissolved Oxygen (DO) at various sampling stations

CHEMICAL OXYGEN DEMAND (COD):

It is another Physico-Chemical parameter that indicates the degree of pollution in surface waters. When COD and BOD are high in magnitude, water bodies are subjected to eutrophication near city areas due to treated or untreated discharges. This leads to decline in oxygen levels of these waters [18]. COD was recorded to be minimum for S2 (8.9 mg/L) and maximum for S9 (112.3 mg/L). The COD values were observed to be higher at all sampling locations as compared to BOD and displayed the same trends. The COD values for all stations were graphically displayed in Fig.6. When the COD and BOD levels were high the DO levels were found to be low as also reported by some of the earlier researchers [19]. DO depletion rates were maximum between S* and S9 which showed high values of BOD and COD probably due to inflow of waste wayers in the rivers. As discussed earlier, DO content was lower during summer and higher during monsoon while BOD as well as COD contents were higher during summer showing a perfect correlation among these parameters as observed before [20].

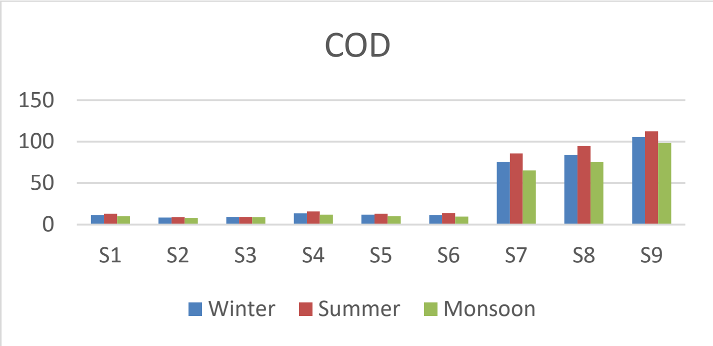

Fig.6 Variation of Dissolved Oxygen (COD) at various sampling stations

PHOSPHATES:

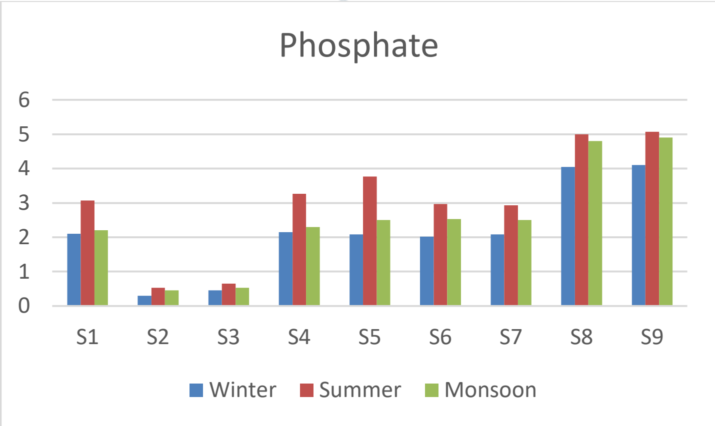

Fig.7 Variation of phosphates at various sampling stations

Phosphate levels are indicative of domestic sewage. Phosphates feed the algae present in water bodies and are responsible for their uncontrolled growth. Their growth in water ecosystems leads to imbalances leading to destruction of other forms of life besides producing harmful toxins [21]. The observed values for phosphates ranged between 0.3 mg/L and 5.1 mg/L in winter and summer respectively at S2 and S9. The greenish untidy algaeic growth was apparently seen at the locations like Aundh and Yerwada supporting the high phosphate levels recorded at these stations. Generally also, from the results obtained it may be concluded that the phosphate levels are higher during summer due to domestic sewage and lower during winter. The phosphate variation at different sampling stations is graphically represented in Fig.7 for different seasons.

NITRATES:

Nitrates in water play significant role in maintaining its quality since excess levels of nitrates in it can create conditions that make it difficult for aquatic life. Similar to phosphates nitrates also nurture the unchecked growth of algae in waters as they act as source of food [22]. Chemical sewage from industries, and agricultural run-off due to use of plant fertilizers contribute to nitrates in waters. Nitrate concentration exceeding 45mg/L also causes blue baby syndrome in infants. S2 and S9 have recorded 0.02 and 5.1 mg/L in winter and summer respectively. The general trends in various seasons for different samples were similar to that of phosphates. Enrichment of nutrients like nitrates and phosphates lead to eutrophication. High levels of nitrates are indicators of chemically polluted waters [Peter 1998]. In the present investigation the nitrate levels of all stations were very much within the limits. The season wise nitrate variation at different sampling stations is graphically represented in Fig.8.

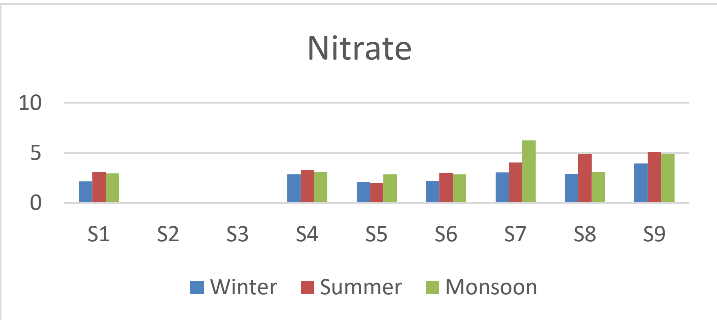

Fig.8 Variation of nitrates at various sampling stations

TURBIDITY:

Particulate matter in suspension causes turbidity in fluids. The suspended particulate matter in water makes the water opaque and alters the scattering property of light in the liquid. As the pollution increases, the amount of particulate matter increases leading to increase in the turbidity of water [20]. S2 and S9 observed 1.25 during winter, where as S9 recorded is 5.3 NTU during monsoon. It has been observed that due to rain fall and river water run off containing silt, fine sand particles, organic matter and clay the turbidity levels of all the samples during rainy season was high of which S8 and S9 have even crossed the WHO limits. The turbidity levels at different sampling stations are graphically represented in Fig.9.

TOTAL SOLIDS:

Total solids constitute dissolved and suspended colloidal solids in each water sample. NaCl, silt and planktons are examples of these. Water run-off from soil and rocks besides agricultural fields contribute to TS. Excess of these in water samples is a matter of concern [21]. In the present study, the TS values recorded are very high. Highest and lowest values of TS were recorded as 192 and 1250

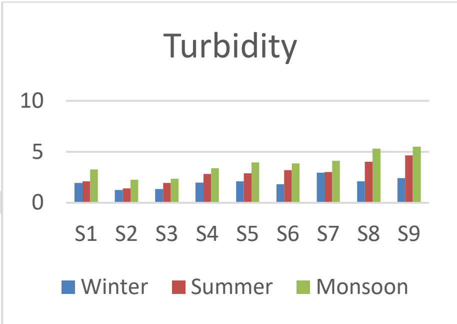

Fig.9 Variation of turbidity at various sampling stations

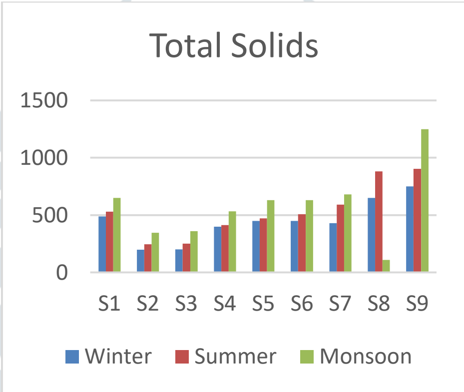

Fig.10 Variation of turbidity at various sampling stations

ppm respectively at Khadakwasla and Yerawada. These values were in sync with those obtained for turbidity maintaining a positive correlation with this water parameter. TS values for all stations are season wise represented graphically in Fig.10

FREE CO_2:

In the present study free co_2 content was found to be higher in summer and lower in winter. Greater free carbon dioxide values were recorded during summer with a value of 38 mg/L at S9. Minimum free co_2 was recorded

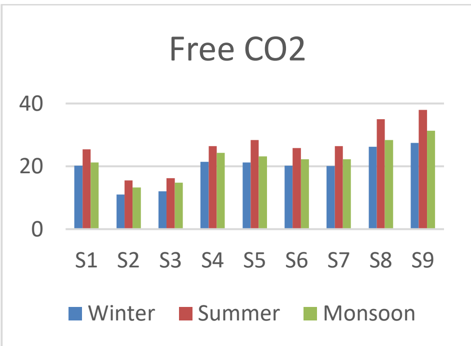

Fig.11 Variation of Free Co_2 at various sampling stations.

during winter with 11 mg/L at S2 as shown in Table 1. It has been observed by researchers [23] that due to oxidation of sewage free co_2 was high in summer. In the present study the free co_2 content was more at S8 and S9 and less in S2 and S3 in all seasons due to domestic waste water. Concentration of free co_2 is higher in polluted waters as compared to fresh water bodies. It may observed here that free co_2 and temperature showed inverse relation with DO. Free co_2 values for all stations are season wise represented graphically in Fig.11

CHLORIDES:

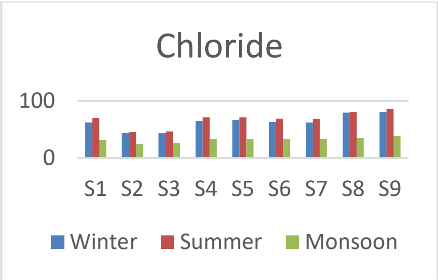

Fig.12 Variation of Free Co_2 at various sampling stations

Chloride concentration was observed to be more during summer and monsoon at 85.5 mg/L at S9 and 23.8 at S2 respectively. Higher chloride levels are due to reduced flow of domestic wastes [24]. Lower chloride concentration was due to dilution during rainy season. Similar observations were earlier recorded [25,26]. In this investigation chloride values for all samples were under permissible limits. Chloride values for all stations are season wise represented graphically in Fig.12

Total Alkalinity (TA):

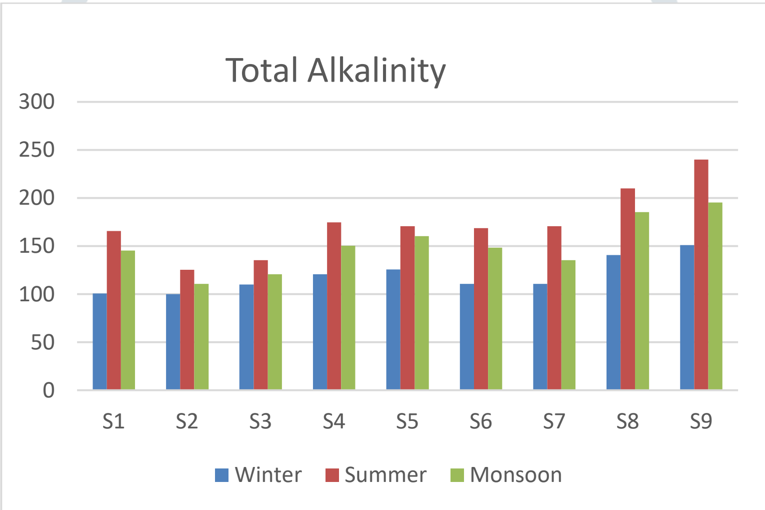

Fig.13 Variation of Total Alkalinity at various sampling stations

TA was a measure of buffering capacity of water or the capacity of bases to neutralize acids. TA was minimum at S2 and maximum at S9 100 to 240 mg/L respectively in monsoon and summer. This might be due to presence of excess of free co_2 produced due to degradation of organic matter [27,28]. Mula river water content displayed higher values of alkalinity which may be attributed to sewage waste [29]. TA values for all stations are season wise represented graphically in Fig.13

TOTAL HARDNESS (TH) :

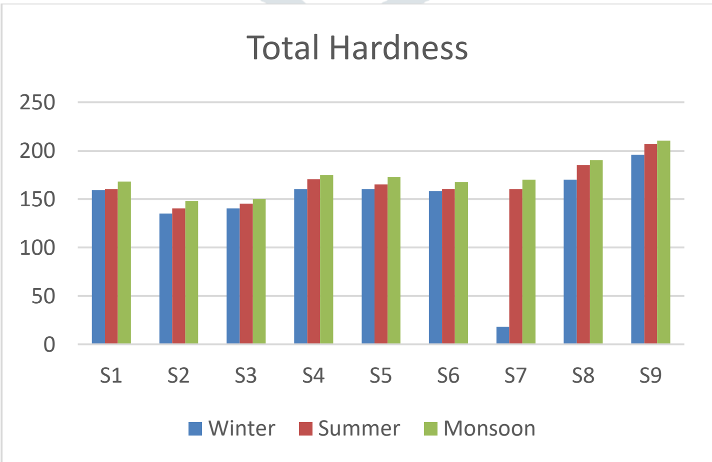

Fig.14 Variations of Total Hardness at various sampling stations

TH is the property of water which prevents the lather formation with soap and increases the boiling point of water. TH values were observed to be minimum during monsoon and maximum in summer and stand at 135 at S2 and 210 at S9 respectively. Earlier studies have also predicted similar trends[30,31]. Higher values of of TH may be because of low water levels and high rates of evaporation [[25]. Enhanced values of TH some times are also attributed to domestic activities like washing animals, vehicles and clothe in agreement with the existing reports [32]. Domestic and industrial wastes through sewages and drains are also reasons for the increased TA and TH values. The TH values for all samples are represented by Fig.14 graphically for all three seasons.

CONDUCTIVITY :

It is a measure of how well water can conduct electricity. It is a characteristic of water which gives a measure of solute concentration and dissolved materials present in the waters of the reservoir. It may also be perceived as an implicit measure of presence of inorganic solids such as sulphates phosphates,chlorides and nitrates . It was observed in the present study that conductivity was maximum at S9 in summer with 1.95 µs/cm and recorded minimum at S2 with a value of 0.432 µs/cm. As conductivity increases with increase of temperature due to increased mobility and dissolution of salts in the water, summers in general recorded greater values of conductivity. This parameter also was observed to be more for the contaminated waters for similar reasons, this is the reason why irrespective of seasons S8 and S9 displayed greater conductivities.

CALCIUM, SODIUM AND MAGNESIUM:

Variations of Calcium, Sodium and Magnesium at various sampling stations are responsible for the hardness behaviour of water. Calcium is one of the most abundant substance in the natural waters and is highly important as a regulator for the physiological functions of various biological species. It has explicit impact on pH and carbonate system. Washing detergents mainly contribute for the increased levels of calcium. The calcium values in the present report vary from 30.2 to 70.5ppm which are recorded at S2 during winter and S9 during monsoon. Natural water in general has Magnesium as a co-constituent along with calcium though exists in lower quantities vis-à-vis Calcium. It does also contribute for hardness and is responsible for the scale formation in boilers. A maximum of 38.1 ppm in monsoon at S9 and a minimum of 18.1 at S2 during winter. Sodium is naturally occurring water constituent but exists in further lower concentrations as compared to Ca and Mg. Unlike these salts, it is highly soluble in water. It is observed that 8.5 ppm at S2 in winter and a maximum 20.4 at S9 during monsoon. High concentrations of sodium lead to cardiovascular diseases in human so their levels need to be contained. In all, all the three salts showed the same kind of trends with respect to seasonal variations.

Though, all the aforesaid parameters do separately have an impact on the quality of water, it is very difficult to get an immediate inference about the water quality from these parameters. In view of this, the index of water quality including all the aforesaid parameters is a parameter that is calculated for assessing the samples S1 to S9 according to NSF.WQI is discussed briefly in the following paragraphs.

WATER QUALITY INDEX:

As discussed earlier, water quality is often evaluated through the calculation of water quality index (WQI). The synergetic effect of all the aforesaid parameters is incorporated in the calculation of this parameter. This is taken as a standard parameter to gauge the water quality worldwide. As interpretation of various complex Physico-Chemical water parameters and their correlation is cumbersome and tedious, such a single index to determine the water quality is not only handy but also highly important. Commonly used water quality Index (WQI) was developed by the National sanitation foundation (NSF) in 1974 [33]. Then NSF WQI was developed to give a standardized method for comparing the water quality of various bodies of water. NSF water quality index was found by using weighted factor of individual parameter and sub-index of each water quality parameter.

The sub-index is based on their respective testing values which can be determined by water quality index calculator or water quality index curve of relative parameters.

$WQI = 0.17\ I_{DO} + 0.11 I_{pH} + 0.1\ I_{dT} + 0.071_{TD}$----for all parameters.

Of all the parameters, the NSF WQI uses nine water quality parameters to evaluate water quality.

Dissolved Oxygen (DO), Fecal Coliform (MPN),pH, Biological Oxygen Demand (BOD)(5-day),Temperature Change, Total phosphates, Nitrate, Turbidity, Total Solids.

One of the major merits of WQI is that it can incorporate data from a number of water quality parameters into a mathematical equation that rates the health of water quality with number [34]. WQI in this work is determined using an established method of calculation of WQI in agreement with

Table 2. Results of season-wise WQI for water samples at different locations

SNo	Winter	Summer	Monsoon	Classification of samples		
S1	62	52	54	M	M	M
S2	76	74	74	G	M	M
S3	76	72	72	G	M	M
S4	61	59	58	M	M	M
S5	60	56	57	M	M	M
S6	61	54	55	M	M	M
S7	59	49	49	M	B	B
S8	42	33	36	B	B	B
S9	38	30	31	B	B	B

that developed by NSF in 1974 [35-39].The obtained season-wise data for these parameters is given in Table 2 and graphically represented in Fig.15

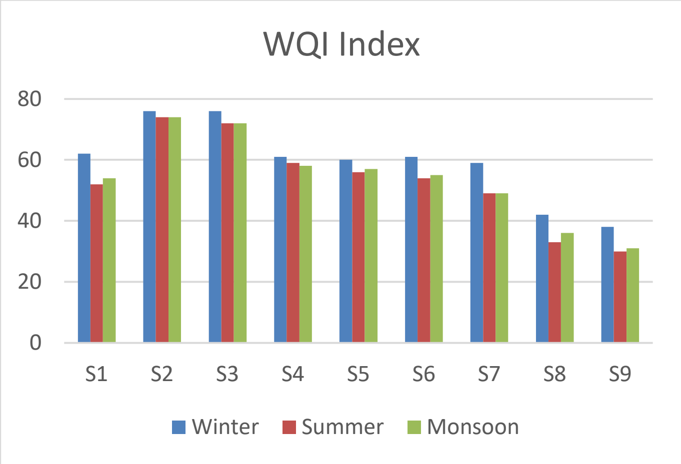

Fig.15 WQI for different samples for all three seasons

From Table 2 it may be understood that, S2 recorded the highest WQI of 76% and the same for S9 is the lowest with a value of 38% during winter season. The WQI is reduced to half for the latter as compared to S2 which may be mainly attributed to pollution based on human interference. In all the seasons, S2 and S3 displayed highest WQI. The WQI of the samples S1 to S6 showed medium quality and S7 to S9 showed bad quality for both summer and monsoon seasons. Higher values of WQI recorded for S2 and S3 are attributed to greater values of DO and lower values of phosphates and nitrates besides being a little alkaline in terms of chemistry. Also, the water samples at these stations were less turbid as compared to the other samples. The phosphates and nitrates values obtained for the studied winter are a little higher vis-à-vis other seasons. This resulted in low value of WQI as compared to winter and spring.

CONCLUSION:

The WQI values have varied between average to excellent in the spring season and the same altered between medium to good quality water in the summer. The effect of season on different parameters is understandable from Table 2. However, the composite effect of all these parameters on the water quality referred to as the WQI was affected considerably in summer. Another very important observation was that, turbidity is maximum in the summer due to the prevalent hot conditions in the environment. This is justified since the rate of evaporation in water is greater leading to enhanced conditions of turbidity. This further, contributes to reduction in WQI. This is one of the reasons for the show up of relatively lower WQI values in the samples studied.

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