CHAPTER – IV
ANALYSIS OF NON-SPECIFIC CHEMICAL PARAMETERS
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ANALYSIS OF NON-SPECIFIC CHEMICAL PARAMETERS

The non-specific chemical parameters studied are total hardness, alkalinity, chemical oxygen demand (COD) and dissolved oxygen (DO).

4.1 Experimental Procedure

4.1.1 Total Hardness (TH)

Principle

The presence of calcium and magnesium ions causes hardness in water. Polyvalent ions of some other metals like strontium, iron, aluminum, zinc and manganese if present also contribute towards hardness of water. The concentrations of these ions being very low in natural water, hardness of water is measured in terms of concentrations of only calcium and magnesium ions (as CaCO₃ & MgCO₃) which are present in considerable quantities when compared to other ions.

Ca²⁺ and Mg²⁺ ions form a wine red coloured complex with eriochrome black – T at pH - 10.0. However, EDTA (ethylene diamine tetra acetic acid) has more affinity towards Ca²⁺ and Mg²⁺ ions. Therefore when EDTA is added to water sample with eriochrome black-T indicator, the former complex is broken down and a new complex is formed. The end point of this reaction is the conversion of wine red colour to blue colour.

Procedure

50 cm³ of sample were taken in a conical flask and 1 cm³ of ammonia buffer solution and 2 drops of eriochromeblack-T indicator were added. The sample was titrated against standard 0.01M EDTA solution till colour changed from wine red to blue.
Calculation

\[
\text{Volume of EDTA consumed x 1000}
\]
\[
\text{Hardness in terms of CaCO}_3 \text{ (mg/L)} = \frac{\text{----------------------------------------}}{\text{Volume of sample taken.}}
\]

4.1.2 Total Alkalinity (Carbonates and Bicarbonates)

Principle:

Total alkalinity is the measure of the capacity of water to neutralize strong acid. The alkalinity in waters is generally due to the presence of salts of carbonates and bicarbonates, phosphates, nitrates, borates and silicates along with hydroxyl ions in the free state. However, most of the water samples are rich in carbonates and bicarbonates with a little concentration of other alkalinity imparting ions.

Total alkalinity in terms of carbonates and bicarbonates can be estimated by titrating the sample with a strong acid first to pH 8.3 using phenolphthalein indicator and then further to pH 5.4 and 4.2 with methyl orange (or mixed) indicator. In the first case, the value is called phenolphthalein alkalinity (PA) and in the second case it is the total alkalinity (TA). The values of carbonates, bicarbonates and hydroxyl ions are computed from these two values.

Procedure

100 cm\(^3\) of the water sample were taken in a conical flask to which 2 drops of phenolphthalein indicator were added. The sample was then titrated against concentrated 0.1NHClsolution till the pink colour disappeared. (if however, no pink colour developed on addition of phenolphthalein, it indicated that PA = O). To the same sample, 2 to 3 drops of methyl orange indicator were added and the titration was continued further till the yellow color changed to pink at the end point.

The first titration with addition of phenolphthalein if and when pink color developed gave the PA value while the second titration gave the total alkalinity (TA) .
Calculation

PA as CaCO₃ (mg/L) = \frac{Ax \text{ N of HCl x 1000 x 50}}{\text{Volume of sample}}

TA as CaCO₃ (mg/L) = \frac{B \text{ x N of HCl x 1000 x 50}}{\text{Volume of sample}}

Where A = volume in cm³ of HCl consumed when phenolphthalein was used as indicator

B = total volume in cm³ of HCl consumed when methyl orange was added in the second titration.

4.1.3 Dissolved Oxygen

DO was determined using Winkler’s Iodometric method.

Principle

Manganese sulphate reacts with the alkali (NaOH or KOH) to form a white precipitate of manganese hydroxide. In the presence of oxygen, the manganese hydroxide gets oxidized to a brown colored compound. When iodide is added to manganic ions in presence of a strong acid, manganic ions are reduced and iodide gets converted into iodine equivalent to original concentration of oxygen in the sample. The liberated I₂ can be titrated against sodium thiosulphate solution using starch as indicator. The chemical reactions involved are:

\[
\begin{align*}
\text{MnSO}_4 & \rightarrow \text{Mn}^{2+} + \text{SO}_4^{2-} \\
\text{Mn}^{2+} + \text{OH}^- & \rightarrow \text{Mn(OH)}_2 \downarrow \\
\text{Mn(OH)}_2 + \frac{1}{2} \text{O}_2 & \rightarrow \text{MnO}_2 + \text{I}_2 + \text{H}_2\text{O} \\
\text{MnO}_2 + 4\text{H}^+ + 2\text{I}^- & \rightarrow \text{Mn}^{2+} + \text{I}_2 + 2\text{H}_2\text{O} \\
2 \text{Na}_2\text{S}_2\text{O}_3 + \text{I}_2 & \rightarrow \text{Na}_2\text{S}_4\text{O}_6 + 2 \text{NaI}.
\end{align*}
\]
**Procedure**

The water sample was taken in a glass stoppered bottle (BOD bottle) of known volume (100-300 cm³), carefully avoiding any kind of bubbling and trapping of air bubbles in the bottle after placing the stopper. One cm³ (or 2 cm³ if volume taken is 300 cm³) each of MnSO₄ solution and alkaline KI solution were added and shaken well after stoppering to mix the solution thoroughly. Passage of air was avoided. The bottle was kept aside for 10-15 minutes for the precipitate (white, Mn (OH)₂) to settle down. After this, 2 cm³ of conc. H₂SO₄ was added to dissolve the precipitate. The solution was then titrated with standard 0.025N sodium thiosulphate solution with starch as indicator.

**Calculation**

\[
\text{DO, mg/L} = \frac{(\text{cm}^3 \times N) \text{ of titrant} \times 8 \times 1000}{\text{Volume of water sample taken}}
\]

**4.1.4 CHEMICAL OXYGEN DEMAND (COD)**

**Principle**

COD is the measure of oxygen consumed during oxidation of the oxidizable organic matter by a strong oxidizing agent. Potassium dichromate in presence of sulphuric acid is generally used as the oxidizing agent. The effect of chlorides is neutralized by refluxing the sample with potassium dichromate and sulphuric acid in presence of mercuric sulphate (silver sulphate is used as a catalyst). The excess K₂Cr₂O₇ is titrated against ferrous ammonium sulphate using ferroin indicator. The amount of dichromate consumed is proportional to the oxidizable organic matter present in the sample.
**Procedure**

20 cm³ of the water sample was taken in a 250 -500 cm³ COD flask. To this 50 cm³ of distilled water and 10 cm³ of 0.25N K₂Cr₂O₇ solution were added along with a pinch of Ag₂SO₄ and HgSO₄ solids and 30 cm³ of concentrated H₂SO₄ acid. The mixture was refluxed for two hours and then cooled. The condensate was washed down with distilled water to make the final volume to about 140 cm³. Two to three drops of ferroin indicator were added. The solution was then titrated against 0.1N ferrous ammonium sulphate solution.

A blank with distilled water, using the same quantities of the other reagents was also carried out. The end point was the sharp colour change from blue green to reddish brown.

**Calculation**

\[
\text{COD, (mg/L)} = \frac{(b-a) \times \text{N of FAS} \times 8 \times 1000}{\text{Volume of sample}}
\]

Where \(a\) = cm³ of titrant with sample

\(b\) = cm³ of titrant with blank.

**4.2 Results and Discussion**

**4.2.1 Total Hardness**

Hardness is defined by the total concentration of calcium and magnesium ions in water. On the basis of hardness, water can be classified as

<table>
<thead>
<tr>
<th>Type</th>
<th>Range of hardness</th>
</tr>
</thead>
<tbody>
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<td>Soft water</td>
<td>0-60 mg/L</td>
</tr>
<tr>
<td>Moderately hard</td>
<td>60 – 120 mg/L</td>
</tr>
<tr>
<td>Hard</td>
<td>120- 18 mg/L</td>
</tr>
<tr>
<td>Very hard</td>
<td>&gt; 300 mg / L</td>
</tr>
</tbody>
</table>
The present study indicates that the hardness of water in the towns studied ranged from moderately hard to hard, being in the range of 120 – 250 mg/L. The hardness was more apparent in monsoon and summer seasons. The desirable limit for hardness according to WHO is 300 mg/L. In that context, the water samples at all the sites of all the towns showed a range of hardness below the desirable limit.

The monthly variation of total hardness is shown in Fig 4.1 and Fig 4.2 while the average seasonal values are given in Table 4.1. The graphical depiction of the average seasonal variation is shown in Fig 4.3.

In Ahmadabad, the total hardness ranged from 169 (± 12.0) mg/L in May 2012 to a maximum value of 285 (± 10.5) mg/L in November 2011. Seasonally, the average hardness was almost the same at 193 (± 24.4) mg/L, 187.33 (± 16.25) mg/L and 199.7 (± 33.65) mg/L during winter, rainy and summer seasons respectively.

In Arasur, the average seasonal value was highest (179 ± 17.04 mg/L) during the rainy season while it was the least during winter season at 137.0 ± 23.8 mg/L (Fig 4.3). The monthly variation as indicated by Fig 4.1 was maximum in the month of September 2012 at 213 (± 8.0) mg/L and least in the month of October 2011 with a value of 93 (± 6.2) mg/L.

During the twelve month period of study the total hardness ranged from 110 (± 2.58) mg/L to 206 (±12.5)mg/L at Ghaemabad. The maximum hardness value was exhibited in the month of February 2012 (206 ± 12.5 mg/L). Seasonally, the hardness value was greatest during winter month at 184.7 (± 31.9) mg/L.

Khampich water showed a hardness value of 135.3 (± 5.0) mg/L during winter, 133.3 (± 29.9) mg/L during rainy and 169.0 (± 11.0) mg/L during the summer season (Fig 4.3). The monthly variation ranged from 100 (± 10.5) mg/L in March 2012 to 180 (± 7.5) mg/L in August 2012 (Fig 4.1).
The river water sample from the location at Khonsar was found to show hardness range between 122 (± 10.4) mg/L in the month of October 2011 and 248 (± 12.3) mg/L in the month of November 2011. The average seasonal hardness was highest during the rainy season at 189.0 (± 18.3) mg/L and least during the winter season (134.3 ± 4.2 mg/L).

In Malga, the water sample of the location showed seasonal average values of 169.3 (± 61.2) mg/L in winter, 190.0 (± 12.8) mg/L in rainy and 172.0 (± 21.2) mg/L in summer season. The monthly variation values ranged from 118.0 (± 10.5) mg/L in the month of October 2011 to 240 (± 8.7) mg/L in February 2012 (Fig 4.2).

Qudejan had a hardness range from 121 (± 9.8) mg/L to 252.0 (± 12.3) mg/L in November 2011 during the twelve month period. Seasonally, the average values ranged from 128 (± 6.2) mg/L in winter to 202 (± 34.8) mg/L in summer.

The seasonal average value of hardness was found to be the least in summer season in Rahmatabad at 148.0 (± 18.2) mg/L while the rainy season showed the maximum value of 193.33 (± 4.04) mg/L (Fig 4.3). The twelve month range was from 927 (± 5.1) mg/L in the months of October 2011 and July 2012 to 197 (± 2.4) mg/L in March 2012.

In Wist the maximum hardness value was seen in the month of November 2011 at 238.0 (± 6.8) mg/L and the least value was in the month of December 2011 at 121.0 (± 3.8) mg/L (Fig 4.2).

Hardness of water is justified by its capacity to form lather with soap. If the soap gives lather easily, the water is termed soft, while it is said to be hard if it cannot lather easily. The total concentration of calcium and magnesium decides the total hardness of water. In the present study the hardness ranged from about 110 mg/L to 285 mg/L over the nine places studied suggesting that the water quality of Kharghabriver ranged from moderately hard (75 to 100 mg/L, Durfor and Becker,1964). The higher values of total hardness in some of
the months in some of the places could be due to the domestic discharges into
the river water along with the anthropogenic activities. The higher rainy
seasonal hardness could be due to leaching of salts and minerals from soils and
agricultural fields.

Fig 4.1: Monthly variation of Total Hardness between period 2011-12 in Ahmadabad, Arasur, Ghaemabad, Khampich, Khonsar

Fig 4.2: Monthly variation of Total Hardness between period 2011-12 in Malga, Qudejan, Rahmatbad, Wist
### Table 4.1 Average Seasonal Variation of Total Hardness (TH) (mg/L)

<table>
<thead>
<tr>
<th></th>
<th>Ahmadabad</th>
<th>Arasur</th>
<th>Ghaemabad</th>
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<th>Khonsar</th>
<th>Malga</th>
<th>Qudejan</th>
<th>Rahmatbad</th>
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*Fig 4.3: Average seasonal variation of Total Hardness*
4.2.2. Alkalinity (Carbonates and Bicarbonates)

The alkalinity in water is due to the salts of carbonates, bicarbonates, phosphates, nitrates, borates and silicates along with free hydroxyl ions. However, the concentration of carbonates and bicarbonates outweigh that of others (which can be considered negligible). Primary source of carbonates is the dissolved carbon dioxide in rain.

The monthly variations of alkalinity are given in Fig 4.4 and Fig 4.5. The average seasonal values are represented in Table 4.2 and graphically in Fig 4.6.

The WHO standards indicate the permissible level of alkalinity to be 200 mg/L. In the present study, alkalinity ranged from a low of 3.5 mg/L to 12.24 mg/L over the 12 month period in the nine places.

In Ahmadabad, the monthly average was 7.08 mg/L with the highest value of alkalinity being 9.7 (±0.82) mg/L in August 2012 and the least value being 4.2 (± 0.55) mg/L in March 2012. The seasonal average values indicated that alkalinity was highest in rainy season at 9.13 (±0.89) mg/L followed by winter season with 6.3 (±0.82) mg/L and then by summer season with concentration of 5.47 (±1.21) mg/L.

The town of Arasur, had a monthly average value of 6.75 (±1.75) mg/L. The maximum value recorded was 9.21 (±1.04) mg/L in September 2012 and a minimum value of 4.07 (±0.98) mg/L in January 2012. The seasonal averages were in the increasing order of winter season (4.59 ±0.66 mg/L), rainy season (6.19 ±0.86 mg/L) and summer season (8.54 ±0.67 mg/L).

Ghaemabad showed a variation range from 4.9 (±0.27) mg/L in April 2012 to 9.6 (±0.88) mg/L in November 2011 with the 12 month average being 7.18 (±1.41) mg/L. During the seasons, winter and summer had almost the same concentration at 7.5 (±0.7) mg/L. Rainy season had an average of 5.24 (±0.46) mg/L.
In Khampich, the monthly average of alkalinity was 8.35 (±1.83) mg/L while the seasonal average were 8.81 (±0.70) mg/L in winter, 7.06 (±0.70) mg/L in rainy and 7.14 (±1.36) mg/L in summer season. The monthly variation ranged from 5.7 (±0.25) mg/L in June 2012 to 12.24 (±1.01) mg/L in October 2011.

Khonsar’s seasonal averages were 5.37 (±2.42) mg/L in winter, 5.46 (±1.45) mg/L in rainy and 7.77 (±1.53) mg/L in summer seasons. The monthly variation over the 12 month period was found to fluctuate from 3.5 (±0.55) mg/L in December 2011 to 10.2 (±0.81) mg/L in October 2011. The monthly average of these values was 6.89 (±2.16) mg/L.

The monthly average of Malga was seen to be 7.57 (±1.93) mg/L. The value over the months fluctuated from 5.66 (±0.48) mg/L in July 2012 to 11.7 (±0.38) mg/L in November 2011. Seasonally, 7.32 (±0.45) mg/L was winter average, 6.70 (±0.90) mg/L was rainy average and 6.49 (±0.85) mg/L was summer average.

In Qudejan, the seasonal variation averages were 5.03 (±0.78) mg/L in rainy season, 5.67 (±2.00) mg/L in summer and 7.97 (±2.23) mg/L in winter seasons. The monthly average, however, was 7.03 (±0.87) mg/L with the highest value recorded being 7.35 (±0.65) mg/L in September 2012 and the least being 6.0 (±0.22) mg/L in October 2011.

Wist exhibited a monthly average of 6.84 (±2.09) mg/L of alkalinity concentration. Monthly values ranged from a minimum of 3.4 (±0.18) mg/L in December 2011 to a maximum of 10.3 (±1.22) mg/L in August 2012. The winter season average was 4.6 (±1.51) mg/L, while rainy and summer seasons averages were 6.07 (±1.62) mg/L and 8.77 (±1.79) mg/L respectively.

In the present study, though there were fluctuations between months in the values of alkalinity (generally in the range of 3.4 mg/L to about 12.8 mg/L considering all the 9 places), the total alkalinity values observed were below the WHO standard of 200 mg/L.
The fluctuations observed in alkalinity would be due to variable discharges from industries, urban and agricultural runoffs. On an average it was found that alkalinity was highest in summer seasons of most towns excepting Khampich, Malga and Qudejan where in the winter averages were highest. The reason for higher alkalinity in summer seasons could be less flow of water in the river coupled with discharge from factories beside the locations of study.

Fig 4.4: Monthly variation of Alkalinity between period 2011-12 in Ahmadabad, Arasur, Ghaemabad, Khampich, Khonsar

Fig 4.5: Monthly variation of Alkalinity between period 2011-12 in Malga, Qudejan, Rahmatbad, Wist
Table 4.2: Average Seasonal Variation of Alkalinity (mg/L)

<table>
<thead>
<tr>
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<th>Ahmadabad</th>
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Fig 4.6: Average seasonal variation of Alkalinity

Places
4.2.3 Dissolved Oxygen (DO)

Oxygen does not dissolve to a great extent in water but its solubility increases with temperature. The rate of oxygen dissolution in polluted water is lesser than that in pure water. So, DO is an important parameter to be assessed in water quality testing which reflects the physical and biological processes taking place in the water. Polluted water have lesser dissolved oxygen which is removed from the water by discharge of the oxygen demanding wastes. The lower the DO values the higher the presence of high organic pollutants. One of the key parameters in water, DO indicates the ability of water to support biological life in water systems. The extent of chemical and physical processes occurring in the water can also be gauged by DO values. The presence of DO in water is due to direct diffusion from air or from photosynthetic activity of autotrophs (Shanthi et al. 2002). DO could potentially indicate the river quality in determining the urban input on river system (Kannel et al. 2007). DO levels are considerably decreased by high pollution load (Singh Namrata, 2010).

The monthly variation values of DO are represented in Fig 4.7 and Fig 4.8. The average seasonal values are given in Table 4.3 and the comparison depicted in Fig 4.9.

In Ahmadabad the DO values in the 12 month period ranged from 3.1 (± 0.5) to 4.95 (± 1.2) mg/L (Fig 4.7). The seasonal average value was highest during the summer season at 4.08 (± 0.75) mg/L and was 3.7 (± 0.6) mg/L and 3.7 (± 0.47) mg/L during winter and rainy seasons. Arasur showed a monthly average DO concentration of 4.48 ± 1.41 mg/L with monthly variation from 2.02 (± 0.52) mg/L in October 2011 to 6.12 (± 1.1) mg/L in June 2012. The winter season average was 3.11 ± 0.61 mg/L while that of summer season was 5.08 ± 1.02 mg/L and that of rainy season was 5.03 ± 1.02 mg/L. In Ghaemabad, the monthly average of DO content was 4.61 ± 0.77 mg/L. Seasonally, the highest average was in rainy season at 5.33 ± 0.75 mg/L, followed by that of summer season at 4.78 ± 0.53 mg/L and then by winter season with 4.43 ± 0.81 mg/L.
In Khampich, the monthly variation ranged from $2.5 \pm 0.22$ mg/L to $5.89 \pm 0.41$ mg/L with a monthly average of $4.28 \pm 0.95$ mg/L. The seasonal averages were $3.67 \pm 1.39$ mg/L in winter, $3.9 \pm 0.1$ mg/L in rainy and $4.53 \pm 0.55$ mg/L in summer. The DO concentrations varied from $0.2 \pm 0.05$ mg/L in December 2011 to $6.1 \pm 1.41$ mg/L in October 2011 with a monthly average value of $3.89 \pm 1.94$ mg/L. The winter average value was $3.1 \pm 2.67$ mg/L, summer average was $3.39 \pm 2.09$ mg/L and rainy season average was $4.67 \pm 1.47$ mg/L. Malga displayed DO average concentration of $4.18 \pm 1.82$ mg/L over the 12 month period of study with monthly values ranging from $1.6 \pm 1.34$ mg/L in August 2012 to $7.2 \pm 1.43$ mg/L in October 2011. Seasonally, the rainy season showed the highest value at $2.37 \pm 1.21$ mg/L. The winter season had a low average at $0.55 \pm 0.39$ mg/L while summer season’s average was $1.2 \pm 1.74$ mg/L.

Qudejan exhibited monthly range from $2.0 \pm 0.41$ mg/L in July 2012 to $6.4 \pm 1.01$ mg/L in February 2012. The 12 month average was $4.02 \pm 1.48$ mg/L. Rahmatabad had a monthly average of $3.75 \pm 1.05$ mg/L while Wist showed 12 month DO average of $3.59 \pm 2.16$ mg/L.

The maintenance of about 5mg/L of DO brings down the nuisance conditions. DO concentration of less than 5mg/L will adversely affect functioning and survival of biological communities. A DO concentration below 2mg/L could lead to death of most fish. (Chapman, 1972) DO levels are important in the self purification quality of the river. A higher level of DO concentration indicates a high aeration rate and rapid oxidation of biological (Suthar, 2010) substances.

Less DO concentration could be due to mixing of high organic compounds from industries near the sampling station. Higher value of DO could be due to mixing of fresh water in river. If nutrients increase in the water, (probably due to leaching of fertilizers), which increases eutrophication stimulating growth of aquatic plants (Patidar, 2009) resulting in decrease in DO concentration.
Temperature plays an important role in determining DO in water. Higher temperature causes lessening of DO (American International 1973). Also, higher organic load and high pollution load deplete DO concentration. Depletion of DO concentration is a pointer towards pollution and indicates deteriorating water quality. In the present study, the DO values ranged generally between 3.0 to 5.0 mg/L. However, in some of the months of some of the towns, the DO values were very much lower than the healthy limit. This could be due to low photosynthetic processes and/or presence of more biota leading to more consumption of DO (Wetzel, 1983).

![Graph 1](image1.png)

**Fig 4.7**: Monthly variation of DO between period 2011-12 in Ahmadabad, Arasur, Ghaemabad, Khampich, Khonsar

![Graph 2](image2.png)

**Fig 4.8**: Monthly variation of DO in between period 2011-12 Malga, Qudejan, Rahmatbad, Wist
Table 4.3 : Average Seasonal Variation of DO (mg/L)

<table>
<thead>
<tr>
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<th>Ahmadabad</th>
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<th>Ghaemabad</th>
<th>Khampich</th>
<th>Khonsar</th>
<th>Malga</th>
<th>Qudejan</th>
<th>Rahmatbad</th>
<th>Wist</th>
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<tr>
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Fig 4.9: Average seasonal variation of Dissolved Oxygen
1.2.4 Chemical Oxygen Demand (COD)

COD gives a measure of the oxygen necessary to oxidize organic substances in water by a strong chemical oxidant, regardless of biological assimilability of that substance. As all organic matter can be oxidized by strong oxidizing agents in acidic media, COD values are greater than BOD values (Kulashrestha and Sharma, 2006). COD values are large if great amounts of biologically resistant organic matter like lignin is present (Khopkar, 1993).

The monthly variations of COD are depicted in Fig.4.10 and Fig. 4.11. The seasonal average values are given in Table 4.4 and depicted in Fig.4.12 graphically.

The average seasonal values of COD for winter season was 0.87(±0.24)mg/L for Ahmadabad. For rainy season it was 0.67(±0.14) mg/L and for the summer season, it was 0.76(±0.21) mg/L. The monthly average was 0.83(±0.76)mg/L. The highest value recorded was 2.0(±0.89) mg/L of COD in October 2011 and the least concentration was 1.17(±0.42) mg/L in August 2012. Some of the months in Ahmadabad did not show any presence of COD.

In Arasur, the monthly average value of COD concentration was 0.16(±0.17) mg/L. The 12 monthly variation ranged from zero concentration to a maximum value of 0.51(±0.11) mg/L. The least value was 0.12 (±0.08) mg/L. Seasonally, the winter average was highest at 0.30 (±0.27) mg/L followed by summer season with 0.09 (±0.08) mg/L and then by rainy season with 0.08 (±0.14) mg/L.

In Ghaemabad, the monthly average value was 0.50(±0.41) mg/L with the highest value of COD at 1.39 (±0.85) mg/L in November 2011 and the minimum value of COD at 0.09 mg/L in August 2012. There was zero concentration of COD in February 2012, June 2012 and July 2012. The seasonal variation in Ghaemabad showed that the summer season had the least COD value at 0.03 (±0.05) mg/L as two of the three months of the season...
had zero COD value. The winter season average was 0.46 (±0.046) mg/L and that of rainy season average was 0.496 (±0.096) mg/L.

Khampich had a monthly average of 0.87±0.52 mg/L. The maximum value was 1.8 (±0.24) mg/L in June 2012 and the least value was 0.72 (±0.13) mg/L. Season wise averages were 1.1 (±0.2) mg/L in winter, 0.4 (±0.69) mg/L in rainy season and 1.36 (±0.45) mg/L in summer season.

In Khonsar, the monthly values varied from a minimum of 0.04 (±0.06) mg/L in November 2011 to 3.6 (±0.38) mg/L in February 2012. Some of the months showed zero concentration. Seasonally, the values varied from 1.7 (±1.81) mg/L in winter to a low of 0.67 (±1.15) mg/L in rainy season. The monthly average was 0.68 (±1.16) mg/L.

Malga showed a variation from 0.13 (±0.14) mg/L in December 2011 to 3.7 (±1.05) mg/L in April 2012 with a monthly average of 1.11 (±1.24) mg/L. The month of July 2012 had zero value. Winter season average was 0.55 (±0.39) mg/L, summer season average was 1.2 (±1.74) mg/L and rainy season average was 2.37 (±1.21) mg/L.

In Qudejan, the maximum COD value was 6.5 (±0.22) mg/L in March 2012 and minimum value was 0.14 (±0.14) mg/L in August 2012. The monthly average was 0.84 (±1.92) mg/L. A couple of months showed zero concentration. In winter season, the average COD value was 0.47 (±0.81) mg/L. In rainy season and summer season, the COD values were 2.24 (±3.69) mg/L and 0.265 (±0.021) mg/L.

In Rahmatabad, many months did not show any COD value whereas the month of April 2012 had 0.56 (±0.19) mg/L and the month of July 2012 had 0.15 (±0.05) mg/L. Monthly average was 0.21 (±0.26) mg/L. The winter season showed zero value while summer season and rainy season had 0.18 (±0.19) mg/L and 0.36 (±0.31) mg/L concentrations respectively.
The town of Wist had a monthly variation from a minimum value of 0.04 (±0.02) mg/L to a maximum value of 0.5(±0.21) mg/L in September 2012. The monthly average was 0.14(±0.15) mg/L. Seasonally, the highest average was 0.19(±0.03) mg/L in summer followed by 0.12(±0.16) mg/L in winter and 0.096(±0.096) mg/L in rainy seasons.

The COD parameter is one of the other parameters along with dissolved oxygen that is an index of fresh water bodies health and hence its pollution load. The desirable limit of COD being 150 mg/L (WHO), in the present study, though there were slight fluctuations of values between months, the values were all well within the permissible limit. The low COD values in most locations of most months in the nine places can be attributed to mixing of fresh water (from rain water, for example) with the river water.
Table 4.4 : Average Seasonal Variation of COD (mg/L)

<table>
<thead>
<tr>
<th></th>
<th>Ahmadabad</th>
<th>Arasur</th>
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<td>0.46</td>
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<td>Summer</td>
<td>av</td>
<td>0.76</td>
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<td>1.36</td>
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</table>

Fig 4.12: Average seasonal variation of COD