Pollution Studies

Physical and Chemical analysis of river Yamuna water

The Yamuna River has been affected by the dumping of toxic effluents by various industries. The water of river Yamuna when it enters Delhi at Wazirabad is much cleaner than when it leaves Delhi at Okhla. Municipal Corporation accounts for 80% of the waste water and sullage falling in to the river, much of it untreated. Several major open drains discharge their untreated toxic wastes in the river, that amounts to 5,51,000 Kilo liters daily carrying about 150 tons of organic matter, 300 tons of dissolved solids and 150 tons of suspended solids. Different researchers have extensively studied the different quality parameters of the rivers in India Atthappan et al., (1992), Gill et al., (1993), Datar and Vashistha, (1998), Sharma et al., (2002), Barik et al. (2004), Gurjar et al. (2005) Toshniwal et al. (2006) and Patil et al (2007). Singh and Gupta (2004) collected different water samples from Yamuna at Mathura and studied the physico-chemical characters like pH, turbidity, DO, BOD, COD, total alkalinity, total hardness and TDS at monthly interval. They observed that most of the parameters were beyond the permissible limits. Mishra and Tripathi (2003) selected five sites at monthly basis from upstream to downstream of river Ganga at Varanasi and analysed the various physico-chemical parameters on seasonal basis.

Temperature measurements were important for understanding the problems of density, Oxygen saturation value and rates of biological degradation. Turbidity tests were important from aesthetic point of view and from the point of economics of treatment. It is a measure of opaqueness of water and interference presented by suspended matter to the passage of light. The turbidity was due to clay, silt, finely divided organic matter and microscopic organisms. The most important health significance of turbidity is that it may harbor pathogenic organisms. Solid matter indicated the physical state of the principal constituents.
Manual removal of waste from the floodplain

Construction of Houses adjacent to river Yamuna
Dissolved Oxygen is a factor which determines whether the biological processes undergoing a change were aerobic or anaerobic. Low values of dissolved Oxygen adversely affected the potability of water and may result in the death of fishes. Organic matter indicated type and extent of pollution, which has its origin in plants and animal matter. The Biological Oxygen Demand is the amount of Oxygen required by Bacteria while stabilizing decomposable organic matter under aerobic conditions. The Chemical Oxygen Demand test was based on the concept that a large majority of organic compounds can be completely oxidized by the action of strong oxidizing agents in acidic medium.

Methodology

Three liters of samples from the river from different sites were collected in six wide mouth bottles of 300 ml. capacities fitted with glass stopper. The bottles were sterilized and were kept unopened until the time of collection. After filling the stopper was replaced immediately. The samples after collection were stored at the temperature of collection and analyzed within six hours of collection. The samples were taken each month and analyzed separately for different pollution parameters. Following criteria had been observed during collecting the samples-

1. The sampling location was representative of the river.
2. No floating material was collected in the bottle.
3. Samples were collected 15 cm below the water surface.

Colour: The colour intensity was observed by naked eye. At all the sites the colour of the sample was observed slightly greenish.

Turbidity: It was calculated with the help of standard Jacksons Candle Turbiditimeter. It consists of three parts i. Calibrated tube, ii. Holder and iii. A Bee wax candle designed to burn within the limits of 114 to 1245 grains /hour. The glass tube and candle were supported in a vertical position so that the centre line of the tube passes through the centre line of the candle. The top of the support of the candle must be 7.6 cm. below the bottom of the glass tube.
The sample was filled in the glass tube until the image of the candle disappeared. The light path was measured from inside bottom of the glass tube in cm. and read the table of turbidity units.

**pH:** It was determined by using Digital pH meter. pH meter was standardized by immersing the electrode in buffer solution of known pH. After rinsing the electrode in distilled water it was immersed in the sample (6-8 cm) to note the pH value after stabilization.

**Alkalinity:**

**Reagents-**

Indicator Phenolphthalein- 0.5 g. Phenolphthalein indicator was dissolved in 50ml of 95% ethyl alcohol and 50ml of distilled water. 0.05 N NaOH was added drop by drop until the colour became pink.

Indicator methyl orange- 0.5 g methyl orange was dissolved in 100 ml of distilled water.

N HCl: It was prepared by taking 8.34 ml conc. HCl and diluted with distilled water to 1.0 liter.

Procedure: 100 ml water sample was taken in a flask and 2 drops oof phenolphthalein indicator was added. The solution turned pink and titrated with the dilute HCl. The end points came with sharp disappearance of pink colour. The volume of dilute HCl was noticed. Now in the same flask 2-3 drops of methyl orange was added and the colour of solution turned yellow. Further titration was continued and a new end point reached when the solution in flask just turned pink. Total alkalinity was calculated by the following formula-

\[
\text{Total alkalinity as CaCO}_3 (\text{mg/l}) = \frac{\text{Total HCl} \times 0.1 \text{ N HCl}}{\text{ml of the sample}} \times 1000 \times 50
\]

**Hardness:** The hardness of the sample was measured by EDTA (Ethylene di tetra acetic acid and its sodium salt) titrimetric method (Water and Waste water Testing by R.P.Mathur, Nem Chand & Bros Roorkee, 1993)
Reagents-
Buffer Solution (pH-10)

(i) 16.9 g Ammonium Chloride was dissolved in 143 ml of Conc. Ammonium Hydroxide.
(ii) 1,179 g Di Sodium EDTA and 0.78 g Mg SO$_4$ 7H$_2$O was dissolved in 50.0 ml of distilled water. Both solutions were mixed and raised to 250.0 ml by adding distilled water.
(iii) Eriochrome Black T Indicator- 0.5 g dye was dissolved in 100 ml of Nitrilotriethanol.
(iv) EDTA titrant (0.01M) - 3.723 g di Sodium salt of EDTA was dissolved in distilled water and rose to 1.0 l.

Procedure: 50.0 ml of sample was taken in a conical flask. 1-2 ml of buffer solution and 1-2 drops of EBT indicator was added in to the flask. The solution turned wine red. The sample titrated against standard EDTA titrant. The sample titrated up to end point when the colour turned from wine red to blue and noted the titrant reading. The Hardness was calculated by using the following formula-

\[
\text{Hardness (mg/l)} = \frac{\text{ml EDTA used}}{\text{ml of sample}} \times 1000
\]

Total Suspended Solids (TSS): 1000 ml. of sample was filtered through oven dried pre-weighted filter paper and residue containing filter paper was oven dried at 103-105C for 12 hours. After cooling the crucible in desiccator, it was weighed and increase in weight is noted. Total solids were calculated as per the following equation-

\[
\text{TSS (mg/l)} = \text{Final weight of filter paper with residue- initial weight of filter paper}
\]

Total Dissolved Solids (TDS): The water sample was taken and filtered through glass filter to remove the suspended particles. 250 ml of clear filtrate was evaporated in an oven at 180C in porcelain disc. The measurement was obtained by the following formula-
TDS (mg/l) = \( \frac{W_2 - W_1 \times 1000}{V} \)

Where-

- \( W_1 \) - Weight of empty disc
- \( W_2 \) - Weight of disc after oven drying
- \( V \) - Volume of the sample taken (ml)

**Total Solids (TS):** It includes both suspended and dissolved solids. It was calculated by using the following formula-

\[
\text{Total Solids (mg/l)} = \text{TSS} + \text{TDS}
\]

**Dissolved Oxygen (DO):**

Reagents-

Manganese sulphate solution- It was prepared by dissolving 364g MnSO\(_4\) in distilled water and diluted to 1 l.

Alkali Iodide azide solution- It was prepared by dissolving 700g KOH and 150 g KI in 1 l. of distilled water and added to above solution.

Starch solution- It was prepared by forming a emulsion of 0.5 g. starch in a beaker with a small quantity of distilled water. This emulsion was poured in 100 ml. boiled distilled water and solution was boiled 5-6 minutes and settled over night. Supernatant was taken as starch indicator.

Sodium thiosulphate solution (0.1 N) -24.82 g. Na\(_2\)S\(_2\)O\(_3\) was dissolved in boiled distilled water and on cooling diluted to 1.0 liter. 0.025 N Na\(_2\)S\(_2\)O\(_3\) was prepared by diluting 250 ml. Na\(_2\)S\(_2\)O\(_3\) stock to 1000 ml distilled water.

Concentrated H\(_2\)SO\(_4\).

**Procedure-** Water sample was collected without bubbling in the 250 ml glass bottle. 2.0 ml each of manganous sulphate and alkali iodide azide solution was added in succession, right at the bottom of the bottle with separate pipette and the stopper was replaced. The bottle was shaken in the upside down direction at least six times. The brown precipitate formed was allowed to settle, 2.0 ml of concentrate sulphuric acid was added and the bottle was shaken to dissolve the brown precipitate. 50.0 ml of solution was taken in a flask and titrated with sodium thiosulphate solution(taken in burettes) till the colour changes to pale straw.2 drops of starch solution was added to the above flask, which changed the colour of the contents from pale to blue solution that was titrated again with thiosulphate solution till the blue colour
disappeared. The total amount of sodium thiosulphate was observed and the dissolved oxygen content of water (mg/l) was calculated by applying the following formula-

$$\text{DO (mg/l)} = \frac{(8 \times 1000 \times N) \times V}{V}$$

Where-

- $V$ = Volume of sample taken (ml)
- $V$ = Volume titrant used
- $N$ = Normality of the titrant

* = 8 is the constant since 1.0 ml of 0.025 sodium thiosulphate solution is equivalent to 0.2 mg of oxygen.

**Biological Oxygen Demand (BOD):**

**Reagents-**

Phosphate buffer (pH 7.2) - 8.5 gm KH$_2$PO$_4$, 21.75gm K$_2$HPO$_4$, 33.4 gm Na$_2$HPO$_4$.7H$_2$O and 1.7gm of NH$_4$Cl were dissolved in 1 litre of distilled water.

MgSO$_4$ solution- 2.25 gm. MgSO$_4$.7H$_2$O was dissolved in 100 ml of distilled water.

FeCl$_3$ solution- 0.2 gm FeCl$_3$.6H$_2$O was dissolved in 1.0 litre distilled water.

Sodium sulphite solution (0.025N) - 1.575 gm Na$_2$SO$_3$ was dissolved in 1 litre distilled water.

**Procedure-** The dilution water was prepared by adding 1.0 ml of each phosphate buffer solution, magnesium sulphate solution, calcium chloride solution, and ferric chloride solution to 1.0 liter distilled water. 2.0 ml water sample was added and aerated. The DO of undiluted sample was determined which designated as DO. The desired percentage mixture was prepared by adding sample in dilution water. One bottle was filled with the mixture and designated as DO1 and the other one with dilution water (blank), which is designated as Dob. Both bottles were incubated at 20 C for 5 days and after incubation, the Do was determined. The BOD was obtained by using the following formula-

$$\text{BOD (mg/l)} = ( (\text{DOB- DO1}) \times 100) - (\text{(DOB-DOo)})$$
Chemical Oxygen Demand (COD):

Reagents:

0.1M Potassium dichromate solution-3.676 gm $K_2Cr_2O_7$ was dissolved in 1 litre of distilled water.
Sodium thiosulphate (0.1 M) - 15.811 gm $Na_2S_2O_3$ was dissolved in 2 litre of distilled water.
Sulphuric acid (2M) - 10.8 ml. of concentrate $H_2SO_4$ was dissolved in 100 ml. distilled water.
1% of Potassium Iodide solution- 10 gm of $KI$ was dissolved in 100 ml. of distilled water.

Procedure- 50.0 ml. of water sample was taken in three, 100 ml flasks (in triplicate). Triplicates of blank were also prepared. 5.0 ml. of $K_2Cr_2O_7$ solution was added to each of the 6 flasks. The flasks were kept at 100 C in water bath for 1 hour. The samples were allowed to cool for 10 minutes and then 5.0 ml. of $KI$ was added. Next 10.0 ml. of $H_2SO_4$ was added in each flask. Content of each flask were titrated with 0.1 M $Na_2S_2O_3$ till the appearance of pale yellow colour. 1.0 ml. of starch solution was then added due to which the solution turned pale yellow to blue and titrated it again until the blue colour disappeared completely. COD was calculated by applying following formula-

\[
COD \text{ of the sample (mg/l) } = \frac{8 \times C \times (B - A)}{S}
\]

Where-
C = Concentration of titrant (m M/l)
A = Volume of titrant used for blank (ml)
B = Volume of titrant used for sample (ml)
S = Volume of water sample taken

Organic Carbon:

Reagents-

Sulphuric acid
0.1N Iodine solution
Potassium sulphate
$CuSO_4$
0.1N Sodium thiocynate

Procedure- 100 ml. water sample was taken in a round bottom flask (Kjeldahl's flask). 30.0 ml. concentrate $H_2SO_4$ was added. Through rubber stopper a thistle funnel was inserted into the Kjeldahl's flask, which dipped
into the sulphuric acid and water mixture. The side tube of Kjeldahl's flask was connected to two washing bottle arranged in series, containing 75.0 ml. of 0.1 N iodine solution and the washing bottles were connected to suction pump. Before inserting the thistle funnel, 4.0 gm. of Potassium Sulphate and 5.0 gm CuSO4 were added to the mixture of sulphuric acid and water sample. The flask was heated with the help of burner till the clear blue colour was obtained. The iodine present in washing bottle was titrated against 0.1 N Sodium thiocynate and the organic carbon was estimated by using the following formula:

One ml. of 0.1 N iodine used = 0.003 gm. of organic carbon

**Ammonical Nitrogen:** In water the nitrogen content was estimated by Kjeldahl method. (APHA, 1998).

Reagents:
- Sodium hydroxide
- 0.04 N H2SO4
- Phenolphthaleine indicator

Procedure- 50.0 ml. of water sample was taken in Kjeldahl flask and neutralized it to pH 7.0. 10.0 ml. of conc. H2SO4, 6.7 gm. K2SO4 and 1.2 ml. HgSO4 solutions were added into the flask. Few glass beads were also added into the flask to prevent bumping. All the materials were digested until the turbid samples were turned straw colour. After digestion, 300 ml. of distilled water and 50.0 ml. of NaOH solution were added into the flask. The flask was connected to the distillation unit. One end of the distillation unit connected to Kjeldahl flask and another end to distillate containing 50.0 ml. of N H2SO4 solution. Again Kjeldahl flask was heated for half an hour. A reagent blank was also carried using all the steps of the procedure. The nitrogen was estimated by titration method, using Phenolphthaleine as an indicator. The nitrogen content present in the sample were calculated by using following equation:

\[ \text{Nitrogen (mg/l)} = \frac{(A-B) \times 280}{\text{ml. of sample}} \]

Where:
- A= Volume of titrant used for sample
- B= Volume of titrant used for blank
Results:
The physico-chemical parameters i.e., color, turbidity, pH, acidity, alkalinity, hardness, TS, TSS, TDS, DO, BOD, COD, organic and ammonical nitrogen from all the five sites were studied monthly from March 2007 to February 2008.

Physico-chemical parameters of Yamuna water samples:

Table 6.1:
Monthly variation in physico-chemical parameters of Yamuna water samples
(Site- Kitham).

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LG-Light green; DG-Dark green; SM-Slighty muddy; M-Muddy
The colour of Yamuna water was observed light green and the maximum value of other physico-chemical parameters i.e., turbidity, pH, alkalinity, hardness, TS, TSS, TDS, BOD, and COD were observed 30.3 NTU, 7.9, 195.0 mg/l, 216.0 mg/l, 1684.0 mg/l, 398.0 mg/l, 1286.0 mg/l, 6.5 mg/l and 14.0 mg/l respectively. The maximum DO was observed 14.0 mg/l, organic carbon and ammonical nitrogen 90.0 mg/l and 22.4 mg/l respectively. The minimum values of different above parameters except DO, were found 22.0 NTU, 6.5, 130.0 mg/l, 206.0 mg/l, 1280.0 mg/l, 254.0 mg/l, 1026.0 mg/l, 2.6 mg/l and 2.3 mg/l respectively. The minimum organic carbon and ammonical nitrogen were observed 63.0 mg/l and 10.6 mg/l. Minimum value for DO was observed 6.0 mg/l in 2007-08.
Monthly variation in pH of Yamuna water samples (Site- Kitham).

Months of study 2007-2008

Monthly variation in turbidity of Yamuna water samples (Site- Kitham).

Months of study 2007-2008
Monthly variation in turbidity of Yamuna water samples (Site- Kitham).

Monthly variation in hardness of Yamuna water samples (Site- Kitham).
Monthly variation in TS of Yamuna water samples (Site-Kitham).

Monthly variation in TSS of Yamuna water samples (Site-Kitham).
Monthly variation in TDS of Yamuna water samples (Site- Kitham).

Monthly variation in DO of Yamuna water samples (Site- Kitham).

Months of study 2007-08
Monthly variation in BOD of Yamuna water samples (Site- Kitham).

Months of study 2007-08

Monthly variation in COD of Yamuna water samples (Site- Kitham).

Months of study 2007-08
The colour of Yamuna water was observed light green. The maximum value of other physico-chemical parameters i.e., turbidity, pH, alkalinity, hardness, TS, TSS, TDS, BOD, and COD were observed 34.6 NTU, 8.0, 198.6 mg/l, 229.0 mg/l, 1740.0 mg/l, 421.0 mg/l, 1310.0 mg/l, 8.5 mg/l and 14.2 mg/l respectively. The maximum DO was observed 12.2 mg/l, organic carbon and ammonical nitrogen 102.0 mg/l and 29.4 mg/l respectively. The minimum values of different above parameters except DO, were found 24.0 NTU, 6.4, 140.5 mg/l, 209.0 mg/l, 1325.0 mg/l, 295.8 mg/l, 1014.0 mg/l, 4.0 mg/l and 4.5 mg/l respectively. The minimum organic carbon and ammonical nitrogen were observed 59.5 mg/l and 15.9 mg/l. Minimum value for DO was observed 5.7 mg/l in 2007-08.
Monthly variation in Turbidity of Yamuna water samples (Site-Kailash).

Months of study 2007-08

Monthly variation in pH of Yamuna water samples (Site-Kailash).

Months of study 2007-08
Monthly variation in alkalinity of Yamuna water samples (Site-Kailash).

Months of study 2007-08

Monthly variation in hardness of Yamuna water samples (Site-Kailash).

Months of study 2007-08
Monthly variation in TS of Yamuna water samples (Site-Kailash).

Monthly variation in TSS of Yamuna water samples (Site-Kailash).
Monthly variation in TDS of Yamuna water samples (Site-Kailash).

Monthly variation in DO of Yamuna water samples (Site-Kailash).
Monthly variation in BOD of Yamuna water samples (Site-Kailash).

Months of study 2007-08

Monthly variation in COD of Yamuna water samples (Site-Kailash).

Months of study 2007-08
Table 6.3:
Monthly variation in physico-chemical parameters of Yamuna water samples
(Site-Poilya Ghat)

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LG-Light green; DG -Dark green; SM - Slightly muddy; M - Muddy

The colour of Yamuna water was observed light green and the maximum value of other physico-chemical parameters i.e., turbidity, pH, alkalinity, hardness, TS, TSS, TDS, BOD, and COD were observed 35.2 NTU, 8.4, 215 mg/l, 239.5 mg/l, 1810.0 mg/l, 426.6 mg/l, 1355.0 mg/l, 8.8 mg/l and 15.8 mg/l respectively. The maximum DO was observed 13.0 mg/l. Organic Carbon and ammonical Nitrogen 121.0 mg/l and 22.4 mg/l respectively in 2007. The minimum values of different above parameters except DO, were found 23.8 NTU, 6.6, 157.0 mg/l, 216.0 mg/l, 1358.0 mg/l, 303.5 mg/l, 1029.2 mg/l, 4.3 mg/l, 5.0 mg/l the minimum organic carbon and ammonical nitrogen was observed 76.8 mg/l and 10.6 mg/l in 2008 respectively. DO was minimum 5.4 mg/l in 2007.
Monthly variation in turbidity of Yamuna water samples (Site-Poiyaghat).

Month of study 2007-08

Monthly variation in pH of Yamuna water samples (Site-Poiyaghat).

Month of study 2007-08
Monthly variation in alkalinity of Yamuna water samples (Site-Poiyaghat).

Months of study 2007-08

Monthly variation in hardness of Yamuna water samples (Site-Poiyaghat).

Months of study 2007-08
Monthly variation in TS of Yamuna water samples (Site-Poiyaghat).

Months of study 2007-08

Monthly variation in TSS of Yamuna water samples (Site-Poiyaghat).

Months of study 2007-08
Monthly variation in TDS of Yamuna water samples (Site-Poiyaghat).

Month of study 2007-08

Monthly variation in DO of Yamuna water samples (Site-Poiyaghat).

Month of study 2007-08
Monthly variation in BOD of Yamuna water samples (Site-Poiyaghat).

Months of study 2007-08

Monthly variation in COD of Yamuna water samples (Site-Poiyaghat).

Months of study 2007-08
Table 6.4:
Monthly variation in physico-chemical parameters of Yamuna water samples
(Site-Kacchpura)

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LG-Light green; DG-Dark green; SM-Slightly muddy; M-Muddy

The colour of Yamuna water was observed light green and the maximum value of other physico-chemical parameters i.e., turbidity, pH, alkalinity, hardness, TS, TSS, TDS, BOD, and COD were observed 36.9 NTU, 8.5, 202.0 mg/l, 257.2 mg/l, 1983.0 mg/l, 435.2 mg/l, 1370.2 mg/l, 9.0 mg/l and 16.5 mg/l respectively. The maximum DO was observed 14.6 mg/l. Organic Carbon and Ammonial Nitrogen 135.0 mg/l and 31.5 mg/l respectively. The minimum values of different above parameters except DO, were found 23.0 NTU, 6.5, 56.2 mg/l, 224.2 mg/l, 1509.0 mg/l, 268.5 mg/l 1370.2 mg/l, 5.0 mg/l and 7.0 mg/l respectively. The minimum of organic carbon and ammonial nitrogen was recorded as 84.5 mg/l and 15.3 mg/l and DO was recorded minimum as 5.2 mg/l in 2007-08.
Monthly variation in turbidity of Yamuna water samples (Site-Kachpura).

Monthly variation in pH of Yamuna water samples (Site-Kachpura).
Monthly variation in alkalinity of Yamuna water samples (Site-Kachpura).

Monthly variation in hardness of Yamuna water samples (Site-Kachpura).
Monthly variation in TS of Yamuna water samples (Site-Kachpura).

Monthly variation in TSS of Yamuna water samples (Site-Kachpura).
Monthly variation in TDS of Yamuna water samples (Site-Kachpura).

Monthly variation in DO of Yamuna water samples (Site-Kachpura).
Monthly variation in BOD of Yamuna water samples (Site-Kachpura).

Months of study 2007-08

Monthly variation in COD of Yamuna water samples (Site-Kachpura).

Months of study 2007-08
Table - 6.5
Monthly variation in physico-chemical parameters of Yamuna water samples
(Site-Chhaalesar)

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LG-Light green; DG -Dark green; SM - Slightly muddy; M - Muddy

The colour of Yamuna water was observed light green. The maximum value of other physico-chemical parameters i.e., turbidity, pH, alkalinity, hardness, TS, TSS, TDS, BOD, and COD were observed 28.8 NTU, 7.8, 181.0 mg/l, 202.0 mg/l, 1630.0 mg/l, 396.0 mg/l, 1273.0 mg/l, 6.0 mg/l and 12.0 mg/l respectively. The maximum DO was observed 15.0 mg/l, organic carbon and ammonical nitrogen 82.0 mg/l and 21.8 mg/l. The minimum values of different above parameters except DO, were found 19.6 NTU, 6.6, 122.0 mg/l, 120.0 mg/l, 1265.0 mg/l, 231.0 mg/l, 1029.0 mg/l, 2.8 mg/l and 2.6 mg/l and minimum DO was observed as 6.4 mg/l in 2007-08 (Table-5).
Monthly variation in turbidity of Yamuna water samples (Site-Chalesar).

Monthly variation in pH of Yamuna water samples (Site-Chalesar).
Monthly variation in alkalinity of Yamuna water samples (Site-Chalesar).

Monthly variation in hardness of Yamuna water samples (Site-Chalesar).
Monthly variation in TS of Yamuna water samples (Site-Chalesar).

Months of study 2007-08

Monthly variation in TSS of Yamuna water samples (Site-Chalesar).

Months of study 2007-08
Monthly variation in TDS of Yamuna water samples (Site-Chalesar).

Monthly variation in DO of Yamuna water samples (Site-Chalesar).
Monthly variation in BOD of Yamuna water samples (Site-Chalesar).

Monthly variation in COD of Yamuna water samples (Site-Chalesar).
Discussion:
The present study has been undertaken to ascertain the problem of pollution of the Yamuna River at Agra by analysing the various physico-chemical characters of river water. River Yamuna has been getting the pollution load in huge amounts in terms of domestic wastes, fertilizers, sewage etc. The sewage, sullage, septic-effluents, hospital wastes, burning of dead bodies, are the potential sources of river pollution at Agra. During monsoon season the city garbage and street run off are the major sources of river pollution. Five sites on the right bank of river Yamuna have been selected along the city, as described in Chapter I, for Physico-chemical analysis. The present study includes thirteen (13) parameters, of which two (colour, turbidity, Total suspended solids and pH) are physical parameters and rest are chemical parameters. pH was determined on the spot. The samples were brought in the laboratory for the detailed analysis, which were estimated following the procedures as given by R.P. Mathur in Water and Waste water Testing by, Nem Chand & Bros, Roorkee, 1993. The results obtained from physical and chemical investigations are given below.

In the present study relating to pollution, pollutants are being added continuously in the river Yamuna have been investigated by analyzing the different physic chemical parameters of Yamuna river water in different months. These parameters revealed the net pollution load carried by river water which is effective and act as health hazards.

Colour:
The colour of the Yamuna water has been observed at all studies sites light green from October to May which turned dark green due to retarded supply of upstream river in the month of June to September. During monsoon and flood the colour of river water turned slightly muddy to muddy due to suspended clay particles.

Turbidity:
Minimum turbidity was 22 NTU in the month of February and March at Kitham where the river Yamuna enters Agra city maximum value of turbidity 36 NTU.
was noted at site Kachhpura in the month of June. The values of turbidity vanish with the flow and translucency of the river water. The value of turbidity is due to high concentration of algal forms especially blue green stagnation or poor flow of water at Kachhpura. The sewage influx the settleable solids had a tremendous affect on the water quality by increasing the turbidity which affect productivity and photosynthesis adversely. According to Torzwell (1967) (Ganga Pollution and health azard) these sediments are the result of large scale soil erosion and these solid particles and turbidity prevent light penetration and decrease photosynthesis.

**Hydrogen ion concentration:**

The volume of pH of Yamuna river water did not show any clear trend in different months. Maximum value of pH (8.5) was observed in the month of November, 2007 at Kachhpura (Site IV); where as the minimum value of pH (6.4) was recorded in the month of October at Kailash (Site - II). The reaction taking place in water is largely factor of hydrogen ion concentration which controls the mobilization of a number of elements in aqueous solution.

**Alkalinity:**

The alkalinity of water is acid neutralizing capacity and gives information to decide mode of treatment of water. Alkalinity is almost entirely due to the bicarbonate, carbonate and hydroxide ions in the water usually associated with calcium, magnesium, sodium, potassium. Alkalinity can exist in water below the neutral point of pH 7.0 because of the relationshiop between alkanity, carbon di oxide and pH value. The alkalinity is in equilibrium with carbon di oxide in the water between pH value 4.6 and 8.3. Above pH 8.3 free CO₂ ceases to exist and combined to give both carbonate bicarbonate alkalinity between ph values 9.4 and 10. 0 the alkalinity is all due to caustic or hydroxide alkalinity.

**Hardness:**

Hardness of water is caused due to the presence of sulphates and chlorides of calcium and magnesium. The value of hardness show a gradual increase from moderately hard (150) to hard (210) site-1 i.e. Kitham upstream to downstream site i.e. Chhalesar. Hardness is not regarded as pollution
because it does not harm the health but it cause a number of economic hardships.

**Total solids (TS):**
Total solids include both the suspended and dissolved solids. Water with high solid content is inferior and polluted. Suspended solid give the water a muddy or dirty appearance and is unfit for drinking. Themaximum value of TS was 1684 mg/l (June’2007) and 1280mg/l in (February’ 2008) at site I, 1740 mg/l (June’ 2007), and 1.325mg/l (February’2008)at site II, 1810 mg/l (June 2007) and 1.358 mg/l, (February’2008) at site III, 1983mg/l (June’2007) and 1.409mg/l (February’2008) at site IV, 1.630mg/l (June’2007) and 1265 mg/l (January’2008) at site- V. The minimum value of the TS was observed during January-February’ 2008 and maximum during June at all sites. The maximum values of TS during June was due to high temperature 45 °C — 46.8 °C and high rate of evaporation.

**Total Suspended Particles (TSS):**
TSS is that portion of solids present in water which are not dissolved and can be gel up on a filter paper. It also includes the settleable solids which settle down to the bottom if the sample is kept on an undisturbed surface for certain period. TSS may be on accounts on clay, humus and others fine debris or particulate matter discharged in the river. TSS may be harmful for aquatic animals and retard light penetration. They make the water unfit for drinking and other purpose and reduce the water quality and usefulness. The maximum value of TSS was observed during summer season 398 mg/l (June’2007) and minimum during winter 254 mg/l (February’ 2008) at site I, 221 mg/l (June’2007) and 295.8mg/l (February’2008) at site II, 426.6 mg/l (May’2007) and 303.5mg/l (February’2008) at site III, 435.2mg/l (June’2007) and 268.5mg/l (February’2008) at site IV, 396mg/l(June’2007) and minimum 231mg/l in (February’2008) at site V. The maximum value of TSS was observed at site IV 435.2mg/l at Kachhpura in (June’ 2007) and minimum value of Chhalesar site V 231mg/l (February’2008).
Total Dissolved solids (TDS):
TDS are mainly the inorganic minerals and some organic matter. There are a large variety of salts. Such as chlorides, carbonates, biocarbonates, nitrates, phosphate and sulphates of calcium, magnesium, sodium, potassium, iron etc, which impart taste to water. If any one of these becomes increase it becomes pollutive in nature. The maximum TDS was observed 1370.2mg/l at Kachhpura (Site IV) during June 2007 and minimum 1014.0 mg/l during February, 2008 at site-II

Disolved Oxygen (DO):
All aerobic organisms require free oxygen for respiration. In water, free oxygen is available in dissolved form from 8-10ppm/l. The saturation level of the dissolve oxygen is 14-15 ppm at 0°C in clean water with the increasing temperature it is reduce at reaches optimal level at 100 °C. Rivers except during active photosynthesis period in day time, DO is a critical factor and may result in the death of aquatic organism. The national standard for DO level should be higher than 5mg/l for a river to be considered fit for bathing and drinking.

In the winter season and during flood maximum DO in river water is observed 13.4 during July'2007 at Kitham site I and minimum 5.2 during June 2007 at Kachhpura site IV due to increasing biological activity DO in the river water is regulated by –

a. Flood
b. Atmospheric interface
c. Photosynthetic activities
d. Consumption of oxygen by plant, animals and decomposer animals.
e. The presence of organic matter or sewage also lower the DO level

Biological Oxygen Demand (BOD):
The BOD is used as a degree of pollution and also as an approximate measure of the amount of biochemically degradable organic matter present in the water. After receiving the cities treated, untreated and partially treated waste, the BOD increases. The value for BOD in river Yamuna at Agra ranges
in between 9.0 mg/l to 2.8 mg/l. The minimum value for BOD (2.8 mg/l) was recorded at Site V i.e., Chhalasar during July, 2007 and maximum BOD was observed (9.0 mg/l) during June, 2007 at site IV that is Kacchpura. Minimum values of BOD were generally observed during the months of monsoon from all the study sites whereas maximum values of BOD were recorded during summer months.

The national standard for BOD is 3 mg/l for a river to be considered fit for drinking and is considered unpolluted. According to Moss (1988) river water in which BOD exceed 5.0 mg/l is polluted. Yamuna at most stretches are highly polluted during the low water period between April to June and show higher value for BOD due to lack of dilution and highly contaminated effluents.

Chemical Oxygen Demand (COD):
COD is an immediate or rapid method for characterizing cities sewage, industrial wasteland treatment of plant effluents. The catalyst in COD, reacts and the process of oxidation include all organic compounds. It is a measurement of oxygen equivalent of organic matter susceptible to oxidation by a chemical oxidant. The value for COD in river Yamuna at Agra ranges in between 16.5 mg/l to 2.3 mg/l. The minimum value for COD (2.3mg/l) was recorded at Site I i.e., Kitham during October, 2007 and maximum COD was observed (16.5 mg/l) during June, 2007 at Kachpura i.e., Site IV. Minimum values of COD were generally observed during the months of May and June, 2007.

Organic Carbon
After receiving the cities treated, untreated and partially treated waste, the Organic carbon increases. The value for OG in river Yamuna at Agra ranges in between 135.0 mg/l to 54.4 mg/l. The minimum value for OG (54.4 mg/l) was recorded at Site V i.e., Chhalesar during February, 2008 and maximum OG was observed (135.0 mg/l) during May, 2007. Minimum values of OG were generally observed during the months of winter season from all the study sites whereas maximum values of OG were recorded during summer months.
Ammonical Nitrogen

After receiving the cities treated, untreated and partially treated waste, the Ammonical nitrogen increases in water of river Yamuna. The value for Ammonical nitrogen in river Yamuna at Agra ranges in between 9.5 mg/l to 29.4 mg/l. The minimum value for Ammonical nitrogen (9.5 mg/l) was recorded at Site V i.e., Chhalesar during January, 2008 and maximum Ammonical nitrogen was observed (30.7 mg/l) during May, 2007. Minimum values of Ammonical nitrogen were generally observed during the months of January and February from all the study sites whereas maximum values of OG were recorded during the month of May.

River water at Agra however remains unfit for any use despite the Supreem Court ruling to clean it up. Studies relating to pollution load which is being added continuously in the river Yamuna have revealed that the problem of pollution has attained a magnitude.