Chapter-VIII
GENERAL DISCUSSION

The advent of the industrial revolution has irreversibly impacted on the way people across the globe live their daily lives. The process of industrialisation has left none untouched, in some way or the other, though in varying measure. While it as influenced both, family and society, its impact on humankind's struggle against its environmental after-effects has been most profound. The larger environmental repercussions of our industrial age have to do with the pollution that accompanies it. Pollution accompanies every outshoot of industrialisation, be it industrial production, generation of electric power or vehicular transport. It has also become a market feature of the lifestyles that have come to mark the end of the twentieth century. The varied sources and forms of pollution are only matched by the various technologies developed to control pollution, be it pollution generated from industries, vehicles, use of fuel in generation of power steam, liquid and solid wastes generated from municipal/residential areas. Indeed, the scientific community all over the world has been giving an extra thrust to researching and designing pollution control mechanisms.

Present investigation deals with the study of physico-chemical properties and heavy metal content in river Varuna water at four selected sites. The study also covers analysis of the water sediments of the respected sites in addition to the study of monthly variation in macrophytic composition at the selected sites for complete one year. The study also covers the laboratory experiments conducted to control the pollution load. Chemical and biological treatments for the river water was performed. The obtained results are discussed herewith.

WATER POLLUTION

Industries generate a significant quantity of wastewatert which ultimately finds its way to stream or rivers. Industrial discharges containing toxic and
hazardous substances contribute to the severe kind of pollution in the aquatic systems. Industrial development is largely because of the production of chemicals resulting in the generation of toxic and hazardous substances which have been continuously on the increase during the last three decades. The number of pesticide production had reached to 56.20 thousand tonnes during 1986-87 which was only 1.46 thousand tonnes during 1960. Similarly, fertilizer production had reached 7000 thousand tonnes during 1986-87 which was only 153 thousand tonnes in 1960. All this contribute to the pollution of water ultimately, either their production or their utilization.

THE STUDY SITES

For the study of chemistry of river Varuna, four study sites were located. Site 1 was selected at Rameshwar in Jansa area. This site was free from any prominent source of pollution, thus it was treated as the control site. The other three sites consisted of one of the prominent small scale industrial groups. Site 2 was selected in the Nadesar area, the prominent industrial source was battery industries. Site 3, the site near Chaukaghat consisted of mushrooming of automobile servicing stations. Site 4 which was in Kazzakpura area consisted of small scale washing and dyeing industries. The above small scale industries were selected for study because in most of the investigations generally the small scale industries are overlooked, which though low in magnitude individually but collectively they affect on large scale.

METEOROLOGY

Study of meteorological variables are essential because they directly or indirectly affect the concentration of pollutants. During summer season the temperature was recorded much higher, precipitation was also recorded to be low, which ultimately causes high rate of evaporation from the surface of water bodies, due to which the water bodies become concentrated.
In rainy season the average temperature was lower, the amount of precipitation increases many fold, also the rate of evaporation decreases. Rate of evaporation from surface of water bodies is inversely proportional to the relative humidity also. This results in flow of large amount of water through the rivers, as a result the water body becomes diluted and pollutant concentration lowers. Due to large water content in river in rainy season the rate of flow of river increases many fold as compared to the other seasons, which lowers the pollutants content also by continuous washing.

**PROPERTIES OF RIVER VARUNA WATER**

Physico-chemical properties of river Varuna was studied throughout the year in reference to the following parameters:

**Temperature**

Temperature was found highest at site 4 and lowest at site 1. The other two sites were intermediate. The contribution for temperature may be attributed to the pollution load of the different sites. Increase in temperature may be due to the chemical reactions taking place among the pollutants. Site 1 which was poor in pollutant did not undergo such reaction, therefore, the temperature of this site was recorded to be least throughout the study. Most of the chemical reactions are exothermic. As we move the downstream the amount of pollutants increases, thus, the rate of increase of temperature follows a positive trend.

**pH, Acidity and Alkalinity**

pH and alkalinity of site 1 was higher as compared to the other sites. As we move down to site 2, 3 and 4 the value of pH and alkalinity gradually falls. Value of acidity shows inverse relationship to alkalinity and pH. The reason for higher pH and alkalinity at the control site may be due to the addition of fertilizers and other organic components from the agricultural runoff. Most of the agrochemicals
including the fertilizers are basic in nature due to the presence of phosphatic and nitrogenous compounds. During rainy season pH of the river water increases at all the sites this is attributed towards the various street runoff, nitrogenous waste washing from open fields at the bank of the river etc. Comparatively lower pH of site 4, 3 and 2 through out the study may be due to the reaction of acidic components with pollutants at these sites which lowers the pH; and also during the flow the level of alkaline compounds continuously decreases.

**Nitrate and Phosphate**

Lowest concentration of phosphate and nitrate was found at site 1; but comparatively higher concentration was recorded during the initial part of rainy season. This was attributed to the run off water reaching to the river in concentrated form by the initial shower of rain. Nitrate and phosphate concentration was found gradually increasing from site 2 to site 4. This nitrate and phosphate would have been due to the city sewage, which gradually increases as the river moves down stream. Largest amount of phosphate at site 4 was also due to addition of the effluents from the small scale washing and dyeing industries of Banarasi sarees. In addition, at most of the sites lower concentration of phosphate and nitrate was recorded during rainy season due to dilution of the river in this season.

**Chloride**

Chloride content of an aquatic habitat gives an idea of the organic matter and nitrate present in it. Chloride content in the river gradually decreases from summer to rainy season and increases again in winter at all the sites. This may be due to dilution of the river water in rainy season. Gonzalves and Joshi (1946), Ganpati (1962) and Prakash (1994) findings also confirming the above observation. Comparatively increasing trend in concentration of chloride were recorded from site 1 to site 4 because chloride is one of the most common anion
present in industrial discharges; while moving down the stream accumulation of chloride occurs.

**DO, BOD and COD**

DO shows inverse relationship with BOD and COD, while BOD and COD parallel with each other at all the sites. DO, BOD and COD is an important indicator of the oxidisable organic pollutants present in the sample. Value of DO at site 1 was higher throughout the study as compared to the other sites, this shows that the other sites are rich in organic compounds. The highest value of BOD and COD were obtained at site 3 which was followed by site 4 and site 2, throughout the study. The above observations may be contributed to the high amount of organic matter present in the water of site 3, which was due to the large number of automobile servicing stations present in the area. Seasonally increase in DO and reduction in BOD and COD was found due to dilution and addition of water in the river during rainy season. Similar findings were reported by Kemp and Murray (1986) and Chen et al. (1999) also.

**Total Solids**

Higher value of total solids were obtained at site 4 followed by site 3 and site 2. The lowest value of total solids at site 1 shows it to be comparatively pollution free because the pollutants ultimately accumulate and produce colloidal particles which contribute for the total solids. Highest value of total solids at site 4 indicates this site to be the most polluted site. During summer months the value of total solids was higher followed by winter and least during rainy season at all the sites, this value corresponds to the contribution of rain and dilution of the river during rainy season.

**Total Hardness and Electrical Conductance**

Hardness of water is due to presence of the calcium and magnesium salts in water. Electrical conductance is the conductivity of charges in a solution and this
is also directly proportional to the charged molecules present in the solution. As water moves downstream in the river from site 1 to site 4 it shows gradual accumulation of the charged molecules released from battery industries at site 2, from automobile servicing stations at site 3 and from the dyeing industries at site 4. That's why site 4 shows maximum level of total hardness and electrical conductance.

**Oil & grease**

Oil & grease was found in highest proportion at site 3, followed by site 4, and site 2. Site 1 shows least amount of oil & grease throughout the study. The little amount of oil & grease at site 1 may be due to the oil discharged at various levels in agricultural practices e.g. by tractors and various mechanical acts. The reason for extremely high concentration of oil & grease at site 3 was washing activity and servicing of the automobiles. Large amount of oil & grease are discharged in this act. Any prominent source of oil & grease was not present at site 4, but presence of still higher concentration of the same was due to its high persistence owing to which the oil & grease was carried by water till site 4 with nominal change in concentration.

**Heavy Metals**

Heavy metal analysis in water shows that the highest concentration of Cd was recorded at site 4 followed by site 2 throughout the study. Cd is a prominent heavy metal required by battery industry; higher concentration was found at site 2, which may be due to its presence in the effluent of such industries. The reason for its higher concentration at site 4 may be due to the fact that Cd is an important component of dye.

Lowest concentration of Cu was recorded at site 1 with gradual increase from site 1 to 4. Similar trend was recorded in the case of Cr and Ni also. Their
performance was attributed to the three important industrial sources at the specific sites. The river gradually collects the pollutants and shows its high concentration at site 4. Another similar observation common to the above three heavy metals was reduction in their concentration during rainy season with highest in summer; this was due to the fact that during summer the rivers become concentrated as also reported by Sivasubramani (1999).

Lead distribution also follows pattern similar to Cd i.e. highest concentration at site 2 followed by site 4, 3 and site 1. This variation was also because of lead being used prominently in battery industry and in the dyes. Painting and polishing activities are also performed in the automobile servicing centres to some extents that's why lead was present in considerable amount at site 3 also.

Zinc content was also found to be highest at site 2 because of its discharge from the battery industries. Gradual decreasing trend was also recorded at the following sites. Heavy metal analysis shows lower concentration at generally all the sites during rainy season. Heavy metals content in the river water was contributed directly to the industrial units.

**Properties of Water sediments**

Study of physical and mechanical properties of the water sediments at the research sites shows that the colour of water sediment of site 1 was light as compared to the other sites throughout the year. As we move down stream colour of the water sediments gradually darkens and the colour of the water sediment of site 4 was darkest. Similar observation was reported in the case of dry as well as wet sediment. Darkness of the sediment is directly controlled by the level of pollution. Due to very low DO at the polluted sites the condition becomes anaerobic in which the population of anaerobic bacteria (sulphur bacteria) increases. This bacteria converts most of the sulphur into sulphide which is black.
due to deposition of the sulphides at polluted sites colour of the water sediments becomes dark. During rainy season the colour of sediment turns slightly light, it is due to deposition of fresh colluvial soil in the water sediments.

Texture of the water sediment remains more or less same throughout the study, showing slight change in composition of the sediment components. During rainy season the loam component of sediment increases and this increase was recorded initially at site 1, it was due to soil erosion from the banks during rain.

Physico-chemical Properties

pH

Variation in the value of pH of the water sediments was recorded during summer and winter season among the sites. The variation among sites was least during rainy season, this may be due to the fact that during rainy season the variation among different variables of rain water becomes nearly constant due to dilution. Throughout the study pH was alkaline which indicates nature of the water flowing throughout the year.

Potassium

Potassium in water sediments was found to be highest at site 2 followed by site 1, 3 and 4. The reason for high potassium content in water sediments at site 1 was due to accumulation of agricultural runoff rich in chemical fertilizers, as potassium is an important component of NPK fertilizers. Water sediment sample at site 2 was rich in K because of accumulation of K in largest amount. K is used in battery industries as KCl and KMnO₄, thus its amount must be discharged in the effluents in excess. Further, accumulation of K in water sediments at the following sites was recorded gradually lesser amount, this may be due to consistency of potassium in the flowing water throughout the following sites.
Sodium

Highest Na was recorded in the water sediments of site 2 but lowest in that at site 3. Reason for high Na content at site 1 and site 2 was similar as that for potassium i.e. from agricultural runoff and discharged from battery industries. Na was released during washing process of the batteries and also from site 4 during washing and dyeing of the Banarasi sarees. Low Na content in water sediments was recorded at site 3 because of low precipitation reaction at this site due to the presence of high amount of oil and grease in water.

Calcium and Phosphorus

Lowest Ca was recorded in the water sediments of site 1, with continuous increasing trend till site 4. Agricultural washing and decay of plants and their parts are prominent source of Ca at site 1. Therefore, Ca gradually increases as the water flows forward, because Ca is an important component of sewage discharge also which are introduced into the river intermittently. Therefore, Ca increases in the water sediments down stream the river. Ca is also an important component of dye, thus its accumulation in water sediments at site 4 is more pronounced as compared to the other sites.

More or less similar trend was observed in the case of phosphorus accumulation in the water sediments. Considerably higher proportion of phosphorus at site 1 was recorded as compared to Ca because P was an important component of chemical fertilizer and agricultural runoff. P is also used in detergents, so it is discharges in high proportion from site 3 during automobile washing. Similarly, at site 4 also it was released during washing of the Banarasi sarees. Seasonally slight fluctuation in Ca and P was recorded because water sediment is comparatively stable component.
Total Nitrogen

Total nitrogen was found to be highest in the water sediments at site 1 with least at site 3. Very high total nitrogen at site 1 was due to nitrogenous component released by urea and other chemical fertilizers. Decomposition of plants in water also adds nitrogen to the water sediments. From site 1 to site 3 gradual reduction in total nitrogen in water sediments was recorded due to regular precipitation down the stream. Slightly higher concentration of total nitrogen was recorded at site 4 because of sewage discharge. Seasonally, slightly lower concentration of nitrogen in water sediments was recorded during rainy season at all the sites because of dissolution of little amount of nitrogenous components due to dilution.

Organic Carbon

Highest organic carbon was recorded in water sediments at site 3 because of accumulation of organic compounds oil & grease etc. During washing and servicing process of automobiles, large amount of oil are discharged because washing of motor parts is performed in oil. Oil during its flow reacts with other components and precipitate, it is for this reason accumulation of organic carbon is highest in the water sediments at site 3. Due to consistency, high proportion of organic carbon was recorded at site 4 also. Comparatively lower organic carbon was recorded at site 1 and 2 because of the absence of any prominent source of carbon except the plant decomposition. Similar results were observed by Kaul (1981) and Janssen and Walker (1999).

Macrophytic Study of River Varuna

Macrophytic composition

Macrophytic composition of an area depends upon the prevailing environmental conditions. Six plants at site 1 and site 2 each were recorded during the study. At site 3 five and at site 4, four plants were recorded. Reduction in
biodiversity was recorded from site 1 to site 4, this may be contributed to the increasing pollution load from site 1 to site 4, as biodiversity is inversely proportional to pollution load as also reported by Mathew (1969) and Ault et al. (2000). The plants were also found to be present only during summer and winter season, during rainy season they were washed by the running water.

Similarly and Dissimilarity Index

This was a comparative study conducted to establish similarity and dissimilarity between different sites on the basis of macrophytes present at the sites. Maximum similarity index was found between site 1 and 2 and between site 3 and 4. This was because of similarity among the above pair of study sites. Site 1 was non polluted while site 2 was less polluted. Similarly site 3 was more polluted but site 4 was most polluted. Dissimilarity index between site 1 and 4 was recorded to be highest because site 1 was the control site i.e. the least polluted site and site 4 which was the most polluted site.

Phytosociological Study

Density

Least density of plants was found during rainy season because all the plants were washed by rain water. At all the sites highest density of plants were recorded during winter season followed by summer season. During summer decrease in their density started because by increase in temperature the rate of physiological reactions increases specially, respiration, therefore, decline in their population was recorded, as also recorded by Jude et al. (1986) and Gauf (1974).

Frequency

Frequency was also found to higher during winter season because the river was nearly calm and the plants got proper time for growth and development.
Salvenia molesta showed higher frequency during June 2001 at sites 2, 3 and 4 where the plant was found. Salvenia molesta is a pollution loving plant, so its frequency was found in summer, when pollutants were in highest concentration in the river water.

The macrophytic composition of more polluted sites differ from the less polluted sites. For example Eichhornia crassipes, Lemna minor and Salvenia molesta were found only at the polluted sites, while Potamogeton pectinatus, Pistia stratiotes etc. were not found at the polluted sites because they were sensitive to pollutants. The plants preferring polluted area are pollution resistant, thus, they absorb the pollutants from the medium.

Treatment of the river water

During the study from April 2001 to March 2002, it revealed that April was the most polluted month, because due to high temperature and scanty of rain the water flowing through river decreased. On the other hand the amount of pollutants flowing into the river remained the same, thus the river turned concentrated in April. Therefore, April 2002 was the month selected for the laboratory experiments for treatment. The samples were subjected to chemical and biological treatments.

Chemical Treatment

Depending on the nature of pollutants, activated charcoal and ozone treatment was supposed to be the most suitable chemical treatment practice. Reduction in all the pollution parameters were recorded in the case of samples of all the sites. Charcoal treatment showed marked reduction in heavy metal, nitrate, phosphate, total hardness etc. in the water sample. But due to highly absorptive and porous nature reduction in DO was also recorded by charcoal treatment. Reduction in DO resulted in increase in BOD and COD. These three are very
sensitive parameters for the water quality, thus, this recorded as a prominent drawback of this treatment.

Marvelous response was recorded in the case of ozone treatment where 100% removal of chromium from polluted water was surprising. Most of the heavy metals were nearly washed along with reduction in acidity, nitrate, phosphate, BOD, COD and total hardness. Similar results were obtained in the treatment of water samples of all the three sites. Ozone treatment also showed increase in the value of DO and total solids. Enormous increase in DO was recorded because ozone gas dissolves in the water and many fold increase in DO was recorded. The reason for increase in total solids may be due to precipitation of all the pollutants in the form of oxides as a result the amount of total solids by this treatment would have increased. Except only one drawback i.e. increase in the total solids, the ozone treatment was most convincing treatment process.

Biological Treatment

On the basis of nature of pollutants, resistance and sensitivity of plants two plants were selected for the water treatment experiments. The two plants were *Eichornia crassipes* and *Hydrilla verticillata*. *Eichornia crassipes* is a floating macrophyte while *Hydrilla verticillata* is a submerged plant. In monoculture of *Eichornia* considerable reduction in pollutants was recorded released specially in the case of nitrate, phosphate and some heavy metals like Cr, Ni, Pb and Zn in case of treatment of samples of all the sites. Slight increase in DO was recorded by this treatment.

Monoculture of *Hydrilla* also showed marked reduction in pollution load specially in case of BOD, COD, total hardness, phosphate, nitrate, oil & grease, Ni, Pb and Zn. High increase in DO was also recorded in this treatment. This may be due to the fact that since *Hydrilla* is a submerged plant, during photosynthesis it releases high amount of oxygen directly in the water due to which pollutants were
oxidised and DO also increased. The value of total solids does not increase as in the case of ozone treatment because the rate of oxygen production was slowly and steadily in this case.

Mixed culture of *Eichhornia* and *Hydrilla* showed brilliant response. In this treatment extensive reduction in nearly all the parameters were recorded. Reduction in pollutant was recorded because the pollutants are absorbed by the growing resistant plants and they are taken as fertilizers of the plants. DO also increased many folds in this treatment. In this treatment no drawbacks were recorded.

Comparatively, mixed culture experiment was also found to be the most feasible and practicable in the rivers as it required least input. Similar results were also recorded by Gaudet (1977), Miner (1971), Shulze (1996) etc.

During study it was also recorded that the aquatic macrophytes can be harvested and can be used for production of paper (Nolan and Kirmse, 1974). The plants used in waste water treatment can also be used for energy production (Verma, 1979; Wolverton and McDonald, 1981).