SUMMARY

The work described in this thesis deals with monitoring of rivers Ganges, Yamuna, Hindon and Kali for their physico-chemical characteristics, heavy metals and organic pollutants (organochlorines, polycyclic aromatic hydrocarbons, phenols, etc.). Apart from monitoring studies, the disposal of refinery wastes (oily sludge) on land (landfarming) has also been studied.

Chapter 1 is a review of the literature on monitoring of rivers for their physico-chemical characteristics, heavy metals and organic pollutants and land disposal of wastes. It has been found from the survey of literature that little or no work has been done so far along the stretch of the rivers under study. The studies on the disposal of the refinery wastes on land have also not been carried out in this country. In view of this, it was, therefore, felt that there is a necessity for the monitoring of rivers and oily sludge disposal on land.

Chapter 2 describes the experimental part of the work and is mainly devoted to sampling, analytical procedures and techniques used. A detailed description of the procedures involved during the analysis has been given.

Chapter 3 deals with the physico-chemical characteristics and heavy metals in sediments and submerged plants of river Ganges. The stretch (about 236 km) under study was from Narora to Kannauj.
The concentrations of Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb and Zn in the sediments ranged between 2.70-4.50, 10.59-32.40, 27.44-130.00, 3.69-81.29, 4870.0-87440.0, 80.20-332.20, 12.06-38.15, 20.27-547.80 and 4.10-147.30 ug/g, dry weight, respectively. The levels of Cd and Pb at all the sampling sites were found higher than the world's mean sea sediment concentrations. The metals were detected in high concentrations at the sites having alkaline pH, maximum % CaCO₃ and high organic matter content. Sedimentation of the metals may have occurred through precipitation with CaCO₃ and interaction with organic matter. There was high metal content during the postmonsoon due to surface runoff followed by summer because of concentration factor.

In the submerged plants, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb and Zn level ranged between 0.48-4.42, 2.42-40.83, 12.72-269.00, 6.8-1344.0, 430.00-10522.00, 142.08-9498.00, 5.11-49.62, 9.40-7450.0 and 4.30-1124.00 ug/g, dry weight, respectively. All the three plants studied showed high metal enrichments whereby Vallisneria spiralis is tolerant towards Cd, Co, Ni, Pb, Fe, Mn and Zn. Hydrilla verticillata towards Cr, Ni, Cd, Co, Cu, Fe, Mn and Zn and Nechamandra alternifolia towards Cr, Pb, Cu and Zn accumulation. The high metal accumulation in the plants may be due to their uptake from the sediments as well as from the water.

The sources of these metals may have been probably the domestic sewage, land surface runoff and to a lesser extent
industrial effluents coming from upstream as the river does not receive any major industrial effluents in this stretch. The Ganges river at Kannauj was found to be the most polluted among the sampling sites chosen. The results showed that sediments and submerged plants can be used as a good indicator of heavy metal pollution in aquatic environment.

Chapter 4 deals with the physico-chemical characteristics and heavy metals in water and sediments of three Indian rivers (Yamuna, Hindon and Kali). The data have been compared with those of rivers Maume, Cuyahog, St. Mary's, Ganges, Msimbazi, Lagan and Chao Phraya.

The physico-chemical characteristics of the rivers indicate that the rivers are being grossly polluted in terms of dissolved oxygen (DO), COD and BOD. Considerable variations of heavy metals in the surface water of the rivers were observed. The concentrations of Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb and Zn ranged between 1.6-17.0, 8.6-65.2, 3.9-152.0, 5.8-26.4, 338.4-2896.0, 9.5-4180.0, 30.6-132.3, 6.1-169.0 and 27.9-258.0 ug/l, respectively. The levels of Cu, Pb and Zn of all the rivers exceeded the world's mean stream concentration of 7, 3 and 20 ug/l, respectively, whereas Cr exceeded the stream standard for tropical countries of 50 ug/l.

The importance of the water quality from the health point of view is very significant because about 30% of the population lives on untreated water as far as the drinking and the other
domestic uses are concerned. The levels of Cr (summer), Fe, Cd (Okhla, Mathura D/S and Ghaziabad), Mn (Okhla and Aligarh) and Pb (Mathura D/S and Ghaziabad) exceeded the prescribed limits for drinking water. Therefore, the water is not suitable at all for the drinking purposes without proper treatment. The river water, however, was found suitable for the irrigation of the agricultural land.

The sediments in a river body play a very important role in determining the extent of pollution as all insoluble pollutants settle down. These insoluble pollutants always pose a danger when get dissolved in water. The levels of heavy metals in sediments detected ranged between Cd 0.96-1.82, Co 11.20-20.50, Cr 33.36-181.96, Cu 4.00-22.00, Fe 2080.0-50320.0, Mn 107.00-776.00, Ni 85.40-406.00, Pb 19.50-80.18 and Zn 57.40-492.00 μg/g, dry weight. It has been observed that high concentration of metals were present at sites having alkaline pH, high percentage of CaCO₃ and organic matter, indicating that sedimentation of heavy metals occurred through these parameters. The sediments may be used as a good indicator of heavy metal pollution in rivers.

The water quality at Wazirabad (Delhi) was comparatively better than the other stations downstream of river Yamuna. As the river passes through Delhi and Mathura, the water quality at downstream deteriorated due to input of sewage and industrial wastes from these cities apart from the land surface runoff during the monsoon. Therefore, the rivers Yamuna (Delhi to
Mathura), Hindon (Ghaziabad) and Kali (Aligarh) are grossly polluted and is comparable to the polluted rivers of the globe.

The studies on gas chromatography- mass spectrometric (GC-MS) analysis of four polluted river waters for phenolic and organic compounds have been given in Chapter 5. Some selected sites of four north India's major rivers (Ganges, Yamuna, Hindon and Kali) were monitored for phenolic pollution during the four seasons (spring, summer, winter and postmonsoon) in 1968-89. GC-MS was the technique chosen for the survey due to its sensitivity and ability to identify even unknown compounds encountered during analysis. Recovery studies carried out showed recovery of trichlorophenol above 53%, however, pentachlorophenol showed a higher recovery due to interference.

Phenols and monobromo derivatives of phenol were not detected at any of the sampling spots of the rivers. There were no phenolic compounds detected in rivers Hindon and Kali. Trichlorophenols and pentachlorophenols, suspected of causing cancer, were frequently detected and at times above the permissible limits for drinking water standards (WHO). The chlorophenols detected were within the raw water standards and some exceeded the odour and taste threshold (WHO). The absence of phenolic compounds at most of the sampling sites may probably be due to their incorporation with the sediments.

The Ganges river was found to be polluted most by phenolic compounds at Kannauj, followed by Narora, Kachhla and Fatehgarh.
The maximum concentration were found at Mathura downstream followed by Mathura upstream, Okhla, ITO and none at Wazirabad. The presence of organic compounds other than phenols in the Ganges river during this survey shows that the river is organically polluted especially with cyclohexanes. The sources of the phenolic compounds in the Ganges river seem to be domestic sewage and agricultural runoff in the absence of industrial sources of phenols. In addition to these sources, the refinery effluent discharged into the Yamuna river is most probably seems to be responsible for the frequent occurrence of phenolics at Mathura downstream. The municipal sewage and industrial effluents seem to be the source of these substances in Yamuna at Delhi.

Chapter 6 describes the studies on monitoring of organochlorine (OC) pesticides and polycyclic aromatic hydrocarbons (PAHs) in the sediments of river Ganges at some selected sites. The stretch undertaken is from Naroora to Kannauj covering about 236 km of the river.

Fourteen OC pesticides and two PAHs were selected to monitor the pollution in the sediments of river Ganges by GC-MS technique. The frequently detected OCs were \( \delta \)-BHC, aldrin, dieldrin, heptachlor and heptachlor epoxide being identified in 56.25 (0.002-0.014 µg/g), 56.25 (0.0012-0.012 µg/g), 50.0 (0.002-0.014 µg/g), 43.75 (0.0014-0.008 µg/g) and 53.25% (0.002-0.018 µg/g), respectively, of the samples analyzed. The frequently detected PAH was phenanthrene, 56.25% (0.0002-0.0176 µg/g). Only
a few OCs were detected at Fatehgarh and Kannauj whereas no PAHs were detected at Kannauj. Benzo(a) pyrene was only detected at Narora in March. Generally, low levels of the OCs and PAHs were detected. Although high organic matter contents (0.045-0.482%) were found at some of the sites, no correlation could be established with the organic contaminants.

The Ganga water at Kachha was found to be the most polluted, followed by Narora and least polluted at Fatehgarh and Kannauj. The major source of these organic contaminants is possibly the municipal wastewaters originating from residential areas as these pesticides are mostly used for vector control. The contribution due to agricultural runoff is negligible because their consumption for agriculture is very low.

Chapter 7 deals with studies on oily sludge disposal on land. The oily sludge generated from storage tank of Gujarat Refinery was used for land application. A field study was conducted on sludge having 80% oil with the aim of studying the disposal of oily sludge in alongwith the cultivation of crops (millet). Two application rates of oily sludge, 50 and 100 l/m².year were investigated. The study carried over to two crop cycles over a period of two years. It was found that only 0.0025 kg oil/kg soil per month was degraded. This would amount to an oily sludge application rate of 9.4 l/m².year when the sludge contains 80% oil. The higher application rates result in accumulation of oil in soil. For example, for steam pit treated
sludge containing only 20% oil, the application rate could be 37.6 l/m².year. Samples of soil taken at various depths showed that leaching of oil was minimal even at high application rates used in the study. Leaching would still be further reduced for the above recommended application. Cultivation of hardy crop such as millet along with sludge application is recommended even though this may not result in any increase in oily sludge decomposition. The agricultural productivity of the land receiving the recommended application rate is not expected to decrease.

The sludge could also be applied to the green belt area around the refinery at above rates. It is recommended that regular monitoring programme be instituted if this alternative is adopted.

The oily sludge contains a number of heavy metals. However, the recommended application rate may not pose any environmental hazards.