SUMMARY

Environmental pollution is generally referred to man made pollution introduced directly or indirectly into the atmosphere, hydrosphere, lithosphere and biosphere through man's activities. The ultimate goal of man's activities is the economic development for comforts of life. In a country like India, both poverty and economic growth pose serious environmental challenges. In desperate attempt to survive today, people are forced to forsake their tomorrow and overuse their environment. Really, we are unconsciously inviting perilous calamities. The disasters or the events occurring are portents of the future and as such environmental protection cannot be looked upon as an after thought. It should be linked to planning and costing of industries.

As the present work is based on the sorption studies on the removal of heavy metals from industrial waste waters, a brief discussion on treatment technology of heavy metals needs attention. Interest has arisen recently in the investigation of some unconventional methods and materials for scavenging heavy metal ions from industrial waste waters. The most common method for the removal of heavy metals involves the precipitation of metals as their hydroxides. Other methods include evaporation, ion-exchange, electrolytic extraction reverse osmosis and adsorption
techniques. Because of their low cost and ease in application, non conventional adsorbents are currently enjoying popularity in pollution control.

In developing countries like India, there is an immense need of simple and inexpensive methods for pollution monitoring and control. The use of various sorbents make it possible to work out sensitive and selective methods of separation as well as determination of a large number of heavy metals. In waste water treatment, the process of adsorption has an edge over other methods due to its clean sludge free operation. In quest of an inexpensive methodology for the removal of toxic metal pollutants, the possible utility of an adsorbent i.e. Mangifera Indica(Mango) seed or seed shell has been considered. Moreover a survey of present literature shows that the said adsorbent which is easily available and also cheaper has not yet been used by the workers in this field.

The work summarized in this thesis contributes substantially to the development of two major aspects (adsorption and separation) of analytical and physical chemistry. The contents are summarized in five chapters.

Chapter-I, an introductory part, provides a general idea about the environmental pollution, elements of pollution, its classification, characteristics of chemical pollutants and the role of heavy metals as pollutants and
their sources. Besides, a brief discussion on thin layer chromatography (TLC) along with a complete literature survey (1973-1995) has been provided in this chapter. Moreover, a brief outline of various treatment techniques and complete literature survey (1984-1995) on the removal of heavy metals from water and waste water using different adsorbents are given.

Chapter-II deals with the chromatographic behaviour of cations and anions on mixed sorbent layers prepared from binary mixtures containing alumina, silica gel and/or cellulose in different ratios and developed with aqueous methanol containing tri-n-butyl phosphate and formic acid. All metal ions were clearly detected. Most of the metal ions migrates with the solvent (R_F ~ 1.0) on silica gel or cellulose layers. Some binary and ternary separations, not possible on single-component layers, were realized on mixed beds. The results obtained on plain silica gel, alumina and cellulose have been compared with those obtained on mixed sorbent layers. MO^{6+} has been separated from VO^{2+}, Th^{4+} and W^{6+} at different pH values. The effect of the amount of MO^{6+} on its separation has also been investigated. In addition to metal ions, common anions were also chromatographed on mixed beds with the aim of exploring the analytical potentialities of mixed bed for the separation of anions and studying the effect of anions on the separation of cations and vice-versa.
Chapter-III summarizes the chromatographic behaviour of cations and anions on layers prepared from mixtures of synthetic inorganic ion exchangers (tin molybdochilicate or stannic arsenate) and silica gel, alumina and cellulose in 1:9 ratio with tri-n-butylphosphate-formic acid as solvent systems. Several binary separations of analytical interest have been achieved on mixed sorbent phases. Moreover, the ion exchangers were synthesized under different experimental conditions. None of the mixed layers containing tinmolybdochilicate was found suitable for the separation of metal ions. However, stannic arsenate containing mixed layers were found useful for a selective separations of cations. The layers prepared from mixtures of stannic arsenate and alumina were the best yielding highly compact and well formed spots of cations. These layers can be used for the selective separation of Hg$^{2+}$ from multicomponent mixtures of cations. Similarly, stannic arsenate - cellulose layers can be used for the selective separation of Ag$^+$. 

The effect of pH on the separation of IO$_3^-$ from NO$_2^-$ and BrO$_5^-$ in presence of cations was examined and the quantitative determination of IO$_3^-$ on mixed bed of stannic arsenate and alumina (1:9) was also examined.

As evident from the results (Table 1) the proposed method is quite accurate for the recovery and quantification of IO$_3^-$. Moreover it has been found that stannic arsenate is one of the best synthetic inorganic ion exchanger with
Table 1: Quantitative determination of KIO$_3$ on stannic arsentate-alumina (1:9).

<table>
<thead>
<tr>
<th>Amount of KIO$_3$ loaded (mg.)</th>
<th>Amount of KIO$_3$ found (mg.)*</th>
<th>% Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.2</td>
<td>3.3</td>
<td>+ 3.03%</td>
</tr>
<tr>
<td>5.0</td>
<td>4.9</td>
<td>- 2.0%</td>
</tr>
<tr>
<td>6.8</td>
<td>6.5</td>
<td>- 4.4%</td>
</tr>
<tr>
<td>7.6</td>
<td>7.2</td>
<td>- 5.2%</td>
</tr>
</tbody>
</table>

* Average value of triplicate results.
tremendous analytical potentialities. Besides, its blending with conventional sorbent materials is an attractive alternative for its analytical applications. The mixed layers combining the favourable features of individual sorbents lead to the altered selectively for inorganic ions and as a consequence better separation possibilities.

Chapter-IV describes a comparative study of the behaviour of chemically treated and untreated Mangifera Indica seed and seed shell for the uptake of copper(II) ion from aqueous solution. Batch sorption studies were carried out at different temperatures. Moreover different chemical reagents were used to study the effect of copper(II) removal. It was observed that treatment with Na₂HPO₄ enhanced the sorption capacity of the adsorbent. The sorption of Cu(II) increased (80-91%) with the increase in pH value of the Cu(II) solution and a contact time of 90 min was found to be optimum for complete adsorption. Effect of concentration shows that most of the Cu(II) can be removed from water. Sorption of Cu(II) was found to proceed in accordance with the Freundlich adsorption isotherm (Fig.1). Further the free energy of the process at all temperatures was negative and smaller which indicates that the process was spontaneous in nature with almost similar value of G. Moreover, it was found that treated Mangifera Indica seed shell were having more sorption capacity than Mangifera Indica seed.
Fig. 1 Freundlich plots for the adsorption of Cu(II) by Mangifera Indica Seed Sheel (a) Untreated (b) treated.
Light metal ions ($\text{Ca}^{2+}$, $\text{Mg}^{2+}$, $\text{Na}^{+}$ and $\text{K}^{+}$) interfere in the removal of Cu(II). The proposed method is suitable for the removal of copper from sea water as well as waste water.

Chapter-V deals with the adsorption behaviour of cadmium, zinc, nickel and lead from aqueous solutions by Mangifera Indica seed shell. The treated Mangifera Indica seed shell had a good sorption capacity towards metal ions. As such, the said adsorbent was used for the uptake of metal ions viz, cadmium, nickel, zinc and lead.

The present studies indicates that the sorption of cadmium, nickel, zinc and lead increases with the increase in pH value. For cadmium, the maximum adsorption (72%) was attained at around pH 5. However, after pH 5, there was a decrease in the adsorption efficiency. It may be due to the formation of soluble hydroxy complexes. In case of zinc, nickel and lead, the maximum adsorption (91%) was attained around pH 6. A contact time of 90 min was found to be optimum. The effect of concentration shows that the adsorbent is capable to remove most of the cadmium, zinc, nickel and lead from water and the sorption conformed to the Freundlich adsorption isotherm (Fig. 2-3) as it is evident from the values of regression coefficient. This Freundlich type behaviour is indicative of surface heterogenity of the adsorbent i.e. the adsorptive sites.
(surface of the Mangifera Indica seed shell) is made up of small heterogeneous adsorption patches which are homogeneous in themselves. Moreover, total adsorption decreased with the increase in temperature at low concentration leading to a reversal in the adsorption capacity at high concentration, whereas total adsorption increased with the temperature. The overall system seems to be endothermic in case of zinc, nickel and lead. But in case of cadmium, it is probably exothermic.

Further, the free energy change at all temperatures was negative and it increases with the increase in temperature. The presence of sodium chloride influences the adsorption of cadmium, zinc, nickel and lead.

The present study thus reveals that the treated Mangifera Indica seed shell is an excellent adsorbent for the removal of toxic heavy metals from various types of metal plating industries and also from the aqueous solutions. This adsorbent may also be used in water quality control. Besides, the adsorbent is a suitable, promising, cheaper and easily available and as such may offer an inexpensive alternative to the advanced treatment plants.
Fig. 2   Freundlich plots for the adsorption of (a) Cadmium and (b) Zinc on Mangifera Indica Seed Shell.
Fig. 3 Freundlich Plots for the adsorption of (a) Nickel and (b) Lead on Mangifera Indica Seed Shell.