6. SUMMARY

The present study on "Heavy Metal Pollution in the Faridabad Industrial Area in Haryana" was undertaken to understand the nature and extent of the metal related pollution of soils in Faridabad industrial area. The Faridabad city, located adjacent to the national capital region of Delhi, houses many industries like electroplating, metal coating, tyre, tractor, power plant etc ranging from small, medium to large type. A large number of them are being run in an organized manner and located in the residential parts. Recently after the Ho'ble supreme court of India order, many small and medium scale industries have found this adjacent region as soft target and started operations. The soils in this region have not been investigated for the heavy metal pollution. The main feature of the area is that it very densely populated and host for mixed type of industries. In general, there is lack of information on soil metal pollution in such area having multiple type and different scale industries. The soil samples were collected at two different depth i.e. 0-10 cm and 10-20 cm form nearly 20 location in two seasons i.e. pre monsoon and winter from Faridabad industrial area. The surface dust, taken as surrogate marker for metal pollution of soils underneath and have larger health implications to the children, old age person and persons suffering from disease, was also sampled from again nearly 20 locations but in three seasons, pre and post monsoon and winter from the Faridabad industrial area. All types of samples were digested and metal data was generated using standard protocols as discussed in previous chapters. The metal data is interpreted to understand the metal distribution, spatial and temporal variation in the collected urban soil samples and to correlate it with environmental and health effects in this region.
6.1 Surface Dust Pollution

The surface soil in the Faridabad industrial township show variable contamination levels of metal ranging from least polluted to extremely polluted. These changes are metal, space and time specific. The variations in the metals present in higher concentrations namely Al, Fe, Mn, Ti and alkaline earth metals Ca and Mg show limited variations and lower abundances compared to UCC probably due to silica dilution effect; only Fe content in samples shows enrichment over UCC and seasonal changes. The other group of metals Cd, V, Co, Ba, Ti, Ni, Cu, Cr and Zn show significant variation with space and time in the study area. They also show higher values than UCC indicating the anthropogenic sources, industrial emissions in present case. The seasonal variability could be due to 1) differential nature of industry in and around sampling point, 2) variations in the emission factor of particular industry on a yearly time scale, 3) Change in the land use pattern, 4) shifting of the industries particular of small scale nature very frequently with in the region. In addition to these factors, the rain wash out, metal complexation chemistry, metal dissolution and precipitation process play a vital role in the seasonal patterns of metals in surface dust in a given region.

The sampling sites are least polluted for Ca, Mg, Al and Ti except Ti in winter; 2) least to moderately polluted for Ba, Co and V but season specific; 3) follows a range from moderately to extremely polluted for other trace heavy metals. The sampling sites located residential area housing small to medium scale unorganized industry are more polluted for different metals compared to sites around large industries. Sites carry consistently high overall pollution load (Average PLI = 2.67 – 2.87) as throughout the year.
There are three dominants source components 1) mixed anthropogenic industrial sources; 2) crustal components; 3) vehicular emission, oil and battery related burning. The third component is related to Ba and Pb, Cd, Zn and Cr, but the components frequency and intensity is such that it further gets bifurcated into the component three and four as observed in the pre monsoon and winter samples. The crustal component has only Al as common element in all the three seasons; the other elements are V, Pb and Ti. Such change in metal association in the crustal component are indicative of dumping and mixing of industrial waste in the open soil as well as the deposition of industrial emission as the nature of crustal material, which is largely a mixture of fluvial and Aeolian processes, cannot change frequently over a seasonal scale. Industrial emissions are the dominant source of metal pollution in the area. The variable nature and scale of industries in the area, in particular the small scale industries, are responsible for the seasonal changes in metal associations. Correlation of V with Ti and Co in winter and pre monsoon samples indicate the mixed sources of V as Ti is primarily of crustal origin and Co come from industrial pollution. Dissolution and re precipitation of Ca and Mg carbonate do incorporate some metal like Zn, Cr, Pb and V. Another important feature of correlation matrix is that total organic carbon content does not show any correlation with the metals identified rather is negatively correlated. This strengthens the inorganic nature of anthropogenic emissions in the study area. Overall this region is significantly polluted and the surface dust is enriched in toxic heavy metals. The small scale unorganized metal related industries located in small residential pockets are the main contributor compared to the large scale industries. The observed levels of metal pollution in the surface dust are likely to serious health hazards in the residents of the area. There is a need to make shift from unorganized sector to formally organized industrial set up in
this region to reduce the metal pollution and safeguard the human health and environmental quality as a whole.

6.2 Surface and Sub Surface Soils Pollution

All the metals except Al, Fe, Mn, Ba, V and Co are enriched in soil samples compared to UCC. Al content is affected by silica dilution effect and do not have anthropogenic addition. Among trace metal Ba, V, Co and Cd show very limited enrichment whereas Cu, Ni and Pb, Zn and Cr show marginal to significant enrichment respectively compared to UCC. The metal enrichment indicates their anthropogenic sources, in particular, industrial emission in the present study. Ba too have emission source irrespective of marginal enrichment as the soil of this region are inherently depleted in Ba content by their geological origin. The higher enrichment ratios indicate anthropogenic emissions for metals in the area. The pollution load of metal, in both surface and sub surface samples, is also very significant and consistent throughout the year.

Geo accumulation data revealed that among all the metal studied Al, Fe, V, Mn and Ba and Co except for two sites that are moderately polluted for Ba, Co and Mn are showing least levels of pollution. Al and V have shown more symmetrical distribution in both seasons. Fe and Co are moderately accumulated in post monsoon samples. All other metals Zn, Cr, Cu, Pb, Ni and Cd corresponds to the moderately polluted to heavily polluted class. Some of the sites are extremely polluted for Zn, Cr and Cd. Sites around the small scale metal related industries show very high geo accumulation of metals like Zn, Cr, Pb, Mn, Ni, Co, Cd and Ba compared to those near the heavy industries suggesting that they are main contributors. Further these heavy metal may get dissolved with changing pH conditions in the soil system and become bioavailable. Most of the studied metal at the existing and reported
concentration levels will have toxic effects on living organisms (MacFarlane at al., 2000).

Overall there are four and three dominant sources of studied metal in the of Pre and post monsoon surface soils collected from Faridabad industrial area. The crustal source with loadings of Al and V remains common in both seasons whereas the industrial sources PC1 and PC 2 recorded before rains merge into one after rains suggesting that the rain water interaction with soils play vital role in developing new metal associations in surface soils. The third dominant source of metals includes fossil fuel and battery burnings along with vehicle related wear and tear. In sub surface samples of post monsoon season show four components against the three in surface soil; a situation just opposite to that observed in pre-monsoon surface and samples. This is possibly due to the interaction of soil and rain water during monsoon season which resulted in the new metal associations linked to four factors instead of three in surface explaining the cumulative variance equal to 92.84 %.

The sub surface soils are also polluted compared to UCC for all metals except Al. Zn, Cr, Cd, Cu, Ni and Pb show very high values of ERs clearly pointing out the anthropogenic addition i.e. industry in the present case. All metal are enriched more in post monsoon samples compared to pre monsoon except Ni and Cd. Again the metal Al, Fe, Mn, Ba, V and Co show almost negligible changes between surface and sub surface in both seasons. The differences in ER of Zn and Cr, Pb, Cu and Ni to some extent are very distinctive in post monsoon samples; the surface samples are heavily enriched. This could be due to the insoluble complex formation of metal in the surface soils. The pre monsoon season samples show noticeable changes only for Zn and Cr.

The average PLI in sub surface soil samples of all sites is 2.77±0.01 for both seasons, an observation very similar to surface soil samples. This indicates persistent
pollution load in both types of samples irrespective of season in the study area. It is understood that the leaching for metal from surface to sub surface is a site specific feature as also observed by Muller et al., (2005) in urban soils.

Cr, Zn, Pb, Cd, Cu and Ni show moderate to extreme level of pollution in the sub surface soil samples in both seasons. Almost all metal show more pollution in post monsoon season. The site specificivity is too observed for geo accumulation of metals, in particular, the sites around the small scale industry are more affected. Overall it is suggested that the sub surface soils follow nearly same nature but to lower extent of pollution as the surface soils. In both types of samples of both seasons, metal are not associated with the organic part of soils. Still the inorganic processes are guiding the metal accumulation and leaching on the soils of the region. The leaching of metals is seen in progress. The rain water and soil interaction during the monsoonal season are the main deriving force for leaching.

Based on the above it is evident the residents children, old age persons and those already suffering from some disease are at high risk due to metal related surface dust and soils pollution prevalent around the small scale industries. It is suggested that the local administration should take an initiative of shifting the small and medium scale industries that are run in an unorganized manner to the earmarked industrial zones. The workers, particularly in the metal plating industry, should be made aware about the adverse effects of occupational hazards due to pollution. The higher geo accumulations and high pollution load is also expected to have impact on the plant species as these metal could be subjected to leaching depending on pH conditions in the environment.