CHAPTER 5
CONCLUSION

5.1 General Conclusions

From the results of the investigation, given above, the following general conclusions can be made:

- The texture of the roadside soil almost resembles that of the control soil [sand: 95.5%, clay: 4.5%, silt: 0.01%]. All the samples were found to be sandy in nature.

- In case of bulk density, most of the values corresponding to the 20 locations are higher than the value 0.87 g cm\(^{-3}\) of the control sample. This indicates entry of foreign matter to the roadside soil altering the density.

- The roadside soil samples had lower water holding capacity than the control soil (75.2%), indicating accumulation of hydrophobic matter.

- The hydraulic conductivity of the roadside soil samples was also lower than that of the control soil (0.63 %). Thus the presence of some oily substances in the roadside soil can be inferred.

- Organic matter content of the roadside soil was found to be higher than the control soil (1.73 %) except in a few locations. It is generally seen that the organic matter content was considerably high in the vicinity of the road in comparison to the control soil.
- The pH of all the roadside soil samples was found to be higher than that of the control soil (5.8), indicating significant input of alkaline components from vehicular emissions and the related activities.

- Electrical conductivity of the roadside soil was higher than that of the control soil (0.03 mS cm⁻¹) at all the locations indicating some soluble electrolyte input into the roadside soil.

- Nitrogen content showed wide variations among the locations but the values were much lower than that of the control soil (0.14%) at almost all the locations.

- The phosphorous content of the roadside soil was found to be rich in comparison to the control soil (26 mg/kg).

- In case of major and minor oxides, the control sample had higher SiO₂ (59.21 %), MnO (0.136 %) contents than all the locations. Al₂O₃ content of the roadside soil was found to be lower at all the locations except 13 than that of the control sample (13.42 %). In case of Fe₂O₃, all the locations excepting the locations, 2 and 19, had lower content than that of the control sample (6.69 %). The control sample had lower MgO (1.99 %), CaO (0.53 %), K₂O (2.06 %), P₂O₅ (0.19 %) than those of all the sampling locations. The TiO₂ content of the roadside soil was lower than that of the control sample (1.32 %) excepting two locations.

- Na and K content of the roadside soil were higher than those of the control soil [Na⁺: 6.1 meq/kg; K⁺: 5.0 meq/kg] excepting a few locations.
• Ca content showed that it was significantly higher than that of the control soil (23.6 meq/kg), but Mg content was substantially lower than that of the control soil (9.6 meq/kg) in most of the locations. Ca content was also reasonably higher than that of the Mg content, which resembles with the control soil.

• Chloride content was considerably higher than that of the control soil (119.0 mg/kg) excepting a few locations.

• Sulphate content of roadside soil was higher than that of the control soil (111.0 mg/kg) excepting a few locations.

• Sulphide content was higher than that of the control soil (108.0 mg/kg) with a few exceptions.

• Iron content of the roadside soil showed that almost all the samples have higher iron content than the control sample (92.2 meq/kg) with a few exceptions.

• Mn content at all the locations was found to be higher than that of control sample (87.2 mg/kg).

• All the locations have higher lead content than that of the control sample (4.8 mg/kg).

• Similar is the case for Zn content. Zn content of the roadside soil was much higher than that of control sample (48.3 mg/kg).

• Considerable amount of Cd was measured at most of the locations, although the same could not be detected for the control sample.

• The presence of nickel was also significant at all the locations and was higher than that of the control sample (4.6 mg/kg).
• In case of chromium, 90 % of the locations showed higher Cr content than that of the control sample (9.6 mg/kg).

• Cu content was also high at all the locations in comparison to the control soil (1.4 mg/kg).

• In case of mercury, 90 % of the locations exhibited higher mercury content than that of control soil (71.7 μg/kg).

• Higher values for the contents of the common metals (Na, K, Ca, Mg) were recorded in the leaves of the roadside trees than those of the control location. Much more calcium could be found in the tree leaves of the roadside locations than those of the control location (47.2 mg/kg). 90 % of the locations showed higher Mg content than the control (8.5 mg/kg). Na concentration in the tree leaves of all the locations was higher than that in the control (2.9 mg/kg) with one exception. Potassium was plentifully present in the tree leaves of all the locations at a level higher than that in the control (74.4 mg/kg) location.

• Similar results were also observed for the metal contents of the tree barks. Ca, Mg, Na and K contents in the barks of trees at all the roadside locations were higher than those of the control location with a few exceptions. The values of the contents for the tree barks of the control location are Ca: 79.3 mg/kg, Mg: 5.2 mg/kg, Na: 2.8 mg/kg, K: 92.2 mg/kg.

• Trace metals present in the leaves of the roadside trees generally demonstrated higher values than those at the control location. Thus, lead content of the tree leaves of the roadside locations was higher than that of the control location (14.0 mg/kg)
with just one exception. Cadmium, Nickel, and Copper and mercury were present in most of the roadside tree leaf samples, while these metals could not be detected in the tree leaves of the control location. The tree leaves of the control location contained Cr: 5.6 mg/kg, Zn: 14.8 mg/kg, Fe: 31.4 mg/kg, Mn: 41.8 mg/kg which were less than the corresponding values for the roadside tree leaves.

- Trace metal content in the barks of the roadside trees exhibited higher values than those of the control location. For example, the tree barks from the control location contained 8.5 mg Pb per kg, which was much less than the Pb content of the tree barks of the roadside locations. Ni and Cr contents of the tree barks for all the roadside locations were higher than those of the control sample (Ni: 0.8 mg/kg; Cr: 1.4 mg/kg) with one or two exceptions. Cd, Cu and Hg were detected in the roadside tree barks of most of the locations, but they could not be detected in the control location. Zn, Fe and Mn were plentifully present in the roadside tree barks at values, which were much higher than the values for the control location (Zn: 32.1 mg/kg; Fe: 31.4 mg/kg; Mn: 18.7 mg/kg).

- The polycyclic aromatic hydrocarbons (PAHs) had their significant presence in most of the locations. Only one PAH, phenanthrene could be detected in the control sample (0.23 ng/g) and it was much lower than that of the other sampling locations.

5.2 Overall conclusion

This investigative study with the basic objective of physicochemical characterization of the roadside soil at Guwahati shows that the properties of the soil have significant variation both with distance and depth from the paved surface at major traffic activity locations.
Most of the characteristics, having some relation to running of vehicles and other activities on the road, have shown a tendency to accumulate close to the paved surface. The results obtained can be summarized as follows:

(i) The parameters which showed a decline away from the road are: (a) Organic matter, (b) pH, (c) Electrical conductivity, (d) N-content, (e) P-content, (f) Na, K, Ca – contents, (g) Fe and Mn – contents, (h) Chloride, sulphate and sulphide, (i) Pb, Cd, Ni, Cr, Zn contents.

(ii) The parameters, which showed an increase away from the road, are: (a) Bulk density, (b) Hydraulic conductivity, (c) Mg – content.

(iii) The parameters, which did not show a clear trend, were: (a) Water holding capacity, (b) soil texture.

Similarly, the general trends between the surface soil and the subsurface soil are:

(i) The parameters, which demonstrated a decrease in value with depth from the road surface are: (a) Bulk Density, (b) pH, (c) Electrical conductivity, (d) N and P – contents, (e) K, (f) Ca, (g) Chloride, sulphate and sulphide.

(ii) The parameters, which demonstrated an increase in value with depth from the road surface are: (a) Water holding capacity, (b) Hydraulic conductivity, (c) Organic matter content, (d) Na, Fe, and Mn – contents, (h) Pb, Cd, Ni, Cr, Zn, Cu and Hg – contents.
The parameters, which did not demonstrate any significant change in value with depth from the road surface, are: (a) soil texture, and (b) Mg – content.

One other observation from the present work is that the surface soil at all the roadside locations had significant presence of eight polyaromatic hydrocarbons with various distribution patterns.

Significant results were also obtained for the trace metal contents of the leaves and barks of the roadside trees. The common metals, Ca, Mg, Na and K were present in higher amounts in the barks than in the leaves, while the Ca and K contents were higher than those of Mg and Na in both. Of the trace metals, Pb, Cr and Cu had higher contents in the tree leaves while Cd, Ni, Zn, Hg, Fe and Mn had higher concentration in the tree barks. The study could not find any significant correlation between (a) the surface and the subsurface contents of various parameters, (b) the contents at 1 m and 5 m distances from the paved surface, (c) the contents for the roadside tree leaves and barks. Inter-parameter correlation analyses also did not yield significant results. This may be an indication of the fact that the contamination is the result of a large number of mutually independent complex processes involving multiple sources.

From the study, the overall conclusion is that traffic-related activities on the city's roads have led to a substantial degradation of the roadside soil quality.
5.3 Suggestions for further work

The present investigation being highly exploratory in nature, it could not go into the details of various aspects, for example,

(a) Identification of the specific sources responsible for contamination of the roadside soil,
(b) Segregation of the vehicle-related components from the possible other sources, such as atmospheric deposition,
(c) Speciation of the metals present in the soil to draw more clear cut conclusions about their horizontal as well as downward mobility,
(d) Estimation of the contamination loads from various sources contributing to the degradation of the roadside soil quality, and
(e) Analysis of the possible impact of the contaminated roadside soil on the nearby water bodies or on the quality of soil of the parks and gardens in individual as well as public domains.

Any further study should aim to address all or some of the points raised above.