CHAPTER V

CONCLUSIONS

The present study aimed at acid rain formation over Delhi was divided into following groups of studies for Delhi:

1. Study on ambient air quality which includes:
   a. Measurement of the concentration of trace acidic gases (SO$_2$, NO$_x$) and
   b. Quantitative and qualitative analysis of existing aerosol.
2. Rainwater chemistry
3. Air pollution meteorology.

The above studies revealed the following facts:

Analysis of TSPM and gases has revealed the following facts:

a. Spatial and seasonal variations were observed in the concentration of TSPM, SO$_2$ and NO$_x$.

b. Dariaganj was the most polluted area followed by Okhla and Karolbagh. JNU was the least polluted area. Although on rare occasions the concentration of these gaseous pollutants exceeded their standard limit, their concentration was high. At Dariaganj the 24 hour averaged concentration of NO$_x$ ranged between 22.0 µg/m$^3$ to 98.8 µg/m$^3$.

c. The concentration level of NO$_x$ was higher than that of SO$_2$ at all the sampling sites.

d. On the basis of annual arithmetic mean value it was
concluded that the concentration of gaseous pollutants at Dariaganj, Karolbagh and Okhla was 3.5, 2.7 and 2.94 times higher than JNU.

e. The concentration level of TSPM at Delhi was very high. In comparison to gaseous pollutants, the urban/rural ratio for TSPM concentration was lower. The annual mean concentration of TSPM (495 µg/m³) was highest at Dariaganj. This annual average value is above the Indian Standard of 360 µg/m³ for an industrial area and much above 140 µg/m³ for a residential area as per Central Pollution Control Board recommendations.

f. Contribution to TSPM from anthropogenic sources has increased manifold resulting in increased aerosol acidity.

g. Seasonal variation in TSPM concentration was more pronounced than its spatial variation. During the summer periods, when the occurrence of dust storms is more frequent, the average TSPM value at all the sampling sites was very high, with an extreme reaching 1563 µg/m³ at Dariaganj. In general, the concentration of TSPM, NOₓ and SO₂ was also higher in winter and post monsoon period. Higher concentration of sulphate and nitrate was also observed during winter months which is due to maximum calm periods, lower mixing heights and ventilation coefficients in these periods. Minimum concentration of these pollutants was obtained in monsoon period.

h. There were significant differences in the constituents of TSPM (both water and acid soluble fraction) collected from different sites and in different season.
SO₄²⁻ concentration was always higher than NO₃⁻ at all the sampling sites, though the concentration of NOx was higher than SO₂. The annual mean concentration of SO₄²⁻ and NO₃⁻ at Dariaganj, Karolbagh and Okhla was nearly 1.4 and 1.3 times higher than at JNU. The seasonal variation in the concentration of anions and cations were higher than spatial.

High concentration of Cl⁻ in winter and summer was observed which suggests its non sea-salt origin. In comparison to other places, its concentration was higher in an industrial area (Okhla). It confirms its anthropogenic origin.

Except potassium and nickel all the ions displayed some tendency for higher concentrations in urban areas. K and Ni concentration tended to be higher in rural areas, which is consistent with its expected soil and vegetation sources.

Sources of NO₃⁻ is mainly local whereas SO₄²⁻ has its marine source of origin also.

A strong correlation of ammonium with sulphate, nitrate and chloride indicates that most of acid are effectively neutralised by ammonia.

A strong correlation of sulphate, nitrate and chloride with calcium, magnesium and potassium indicates that soil is also a source of origin for these acidic pollutants.

At all the sampling stations, the balance between the sum of basic and acidic constituents of TSPM is positive (\(\Sigma_{base} - \Sigma_{acid}\)), it suggests the alkaline nature of aerosols. So, it may be predicted that the pH of the rain water in Delhi would be in basic range. But in comparison to earlier studies, this
balance was found to be very low. It is attributed to the heavy increase in the emission of acidic pollutants into the atmosphere of Delhi. This is also substantiated from the decreasing pH data of rain water collected during the study periods.

p. Correlation between heavy metals was different at different places. Therefore, it was difficult to draw any definite conclusion.

Wet precipitation samples were also collected in Delhi at JNU, Dariaganj, Karolbagh, Okhla, Nazafgarh and NOIDA for each rain event. At JNU, rainwater sampling was done for two years (in 1992 and 1993). At rest of the places, it was done only for the year 1993. These samples were analysed for major cations (NH$_4^+$, Na$, K^+$, Ca$^{2+}$, Mg$^{2+}$) and anions (NO$_3^-$, Cl$^-$ and SO$_4^{2-}$) in addition to the pH and conductivity measurements. The concentration of these components has been expressed in μeq/l. The majority of samples showed an alkaline character as a result of neutralization, caused primarily by alkaline soil dust and secondly by atmospheric ammonia. In all rain samples, SO$_4^{2-}$ concentration exceeded NO$_3^-$ concentration. The contribution of maritime sources to the total SO$_4^{2-}$ concentration was also observed. Following conclusions have been drawn from the precipitation sample analysis:

a. The overall pH during the sampling period varied from 4.8 (mild acidic) at JNU in 1992 to 7.6 (alkaline) at JNU itself in 1993. But most of the collected samples showed an alkaline pH.

b. The dissolved mineral concentration differed from
shower to shower depending upon the weather conditions and the amount of rain. It was found that the precipitation amount was negatively correlated to the concentration of all the rain water chemistry parameters except H'. H' was positively correlated to the amount of rainfall.

c. The concentration of Nitrate and sulphate was higher at Dariaganj in comparison to other places which reflects the influences of local emission on precipitation chemistry. But in comparison to seasonal variation, this spatial variation was small. The concentration of major ions peaked in summer and was lowest in the monsoon months. These patterns are due to differences in summer and monsoon atmospheric chemistry and sources of air mass.

d. A non-significant correlation of sulphate, nitrate and chloride with H' but a significant correlation with Na, K, Mg, and Ca (upto 99% of confidence level) was observed. It indicates that these ions originate from the ionization of their salts and not from their acids.

e. The contribution of Sulphate in rainwater acidity was the highest in comparison to other anions.

f. Scavenging ratio suggests high wet removal of water soluble constituents (Ca, Mg, SO\textsubscript{4}\textsuperscript{2-} and NO\textsubscript{3}⁻).

**Air Pollution Meteorology:**

Following facts were revealed from the observations of meteorological parameters:

a. Spatial variation in temperature on annual basis was
about ±0.5° C. In the winter months, Dariaganj and Okhla were warmer (upto 2°C) than Karolbagh and JNU. This indicates that these areas are more polluted compared to other areas. The pollutants in these areas being more active in the radiation processes are keeping the temperature comparatively higher than the rest of the regions.

b. Wind pattern at Karolbagh and Dariaganj shows that these areas may receive pollutants released from the industrial areas like Zakhira, Shahzadabagh, Motinagar and Naraina causing higher concentration of pollutants in these regions.

c. Frequency of calm condition was minimum at JNU and maximum at Dariaganj.

d. On the basis of wind study, it can be said that Dariaganj will face maximum and JNU will face the minimum air pollution problem.

e. Out of the twelve months, maximum calm period was observed in October (58%). Calm conditions recorded in March, May, June, July and August were between 25-38%. The predominant winds were from N-W sector except monsoon period. In May, June and July winds were highly divergent whereas in September, winds were from the SE-NE sector.

f. Unstable condition in night time and stable condition in daytime was absent. During April-June, in the daytime high frequency of extremely unstable conditions and in nighttime high frequency of moderately stable conditions were noticed. In July-September, in daytime, neutral conditions and in nighttime extremely and moderately stable conditions dominated. From October-December in nighttime
g. Mixing heights and Ventilation coefficients were highest in April followed by May and March and minimum in December followed by January and February. The highest minimum mixing heights were obtained in September followed by August and July.

So, it may be concluded from the present study that the meteorological parameters for premonsoon season are the most and for the winter are the least favourable for dispersion of pollutants with respect to other months.

From the available data base, it is very difficult to arrive at any definite conclusion because the source emissions differs from season to season according to the need of the society. However, the present study points out that the possibility of acid rain formation over Delhi exists despite of alkaline dusts in the atmosphere from the natural sources.

The present study suggests following works in the future:

1. Work on wet and dry deposition of trace elements is required for better asessement of their impact on the receiving systems.

2. The study on variability and relationship between concentrations and
   a. meteorological conditions, and
   b. local and regional sources should be made.

3. If rural-urban differences are under investigation the number of rural sites should be adequate to allow valid statistical testing of differences.

4. Measurements of organic acids should also be done in TSPM and rainwater in order to assess their contribution to the acidity.