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TELLUS

SHORT CONTRIBUTION

Deposition fluxes of chemical components of fog water at a rural site in north-east India

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ABSTRACT

The north-eastern part of India has not been investigated for atmospheric deposition studies so far. In this study, deposition fluxes on an artificial surface of chemical components due to fog have been calculated during winter from December 2002 to January 2003 at Jorhat, a rural site in north-east India. As the land in this area is covered with vegetation, the site is representative of rural characteristics in this region. The average pH of fog water is 5.6. Among chemical components, NH_4^+ was observed to be dominating ion. Soil pH in this region is acidic (4.9). Unlike other parts of the country, chemical analysis of soil in this region revealed that influence of suspended soil dust on fog deposition was insignificant. A comparison of fluxes of fog with rain water during December–January months showed that deposition fluxes due to rain water were higher by almost one order of magnitude on an artificial surface but on natural surfaces, the fluxes may be comparable.

1. Introduction

Wet and dry depositions are two important pathways of atmospheric deposition. In India, dry deposition is an important removal mechanism during summer (March–April). During monsoon (May–October), rain is the most effective scavenger of pollutants from the atmosphere when around 81% of rainfall occurs (Statistical HandBook Assam, 1997). During winter, fog may be a significant wet deposition process in northern parts of India. Fog and cloud water chemistry plays a very important role as they may strongly influence atmospheric chemistry and air quality (Waldman et al., 1982; Fuzzi et al., 1996; Thalmann et al., 2002). Fog formation can significantly increase the removal rates of atmospheric particles, accelerate gas to particle conversion and lead to reactions in the aqueous phase and at the gas–liquid interface (Blando and Turpin, 2000; Kidron, 2000). In addition, since the deposition of fog water can be important source of water, nutrients and pollutants, fog can also play crucial roles in the maintenance and decline of ecosystems (Weathers, 1999).

In warm regions like India, fog occurs in the early morning due to radiation cooling at night under clear skies and calm conditions. It gets dissipated 2 or 3 hr after sunrise. But during past few years, it remains up to noon time hampering the road, rail and air transport systems (http://in.rediff.com/news/2005/jan/07cold.htm). On an average around 25 fog events occur during winter including less and severe foggy days. Understanding the effects of fog deposition on ecology requires detailed information on its chemical composition. Unfortunately, very few studies have been reported in India on fog water chemistry (Ali et al., 2004). This study is a first attempt to report chemical characteristics of fog water at a rural site in north-eastern India.

2. Experiment

2.1. Sampling site

Figure 1 shows the location of the sampling site. The sampling site is around 6-km away from the city centre of Jorhat (26.46° N, 94.16° E). Land use in the Jorhat district has 2.5% urban and

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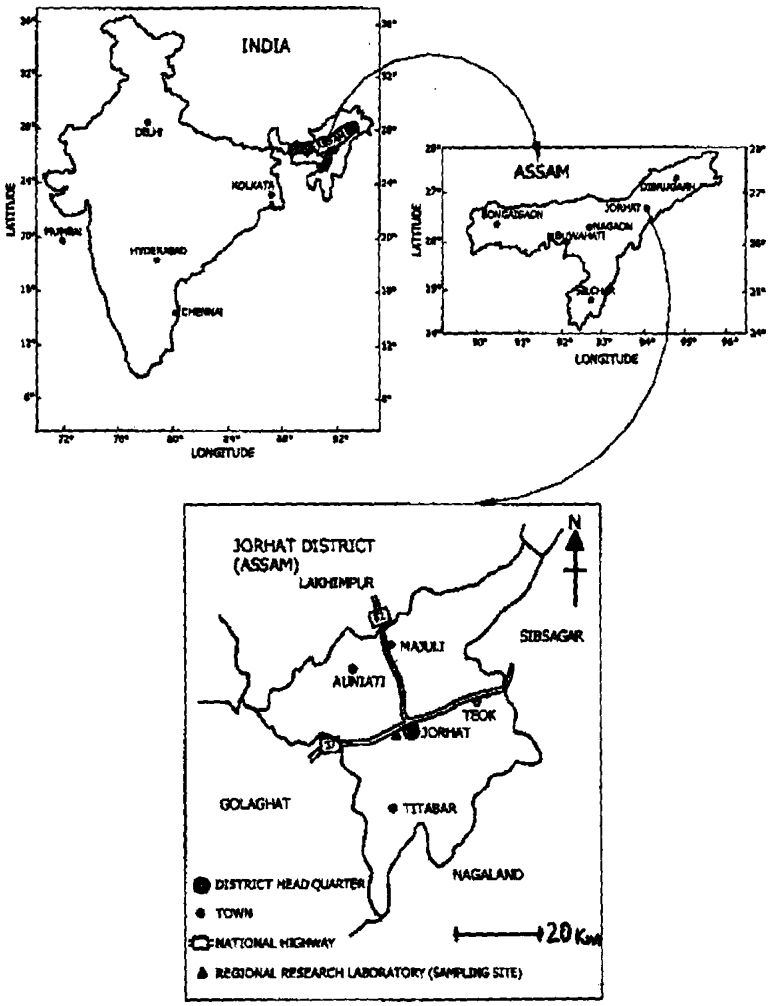

Fig. 1. Map showing the location of the sampling site in the Jorhat district.

97.5% rural characteristics. Jorhat is an area with very few industries for the manufacturing of food products, coat, textiles, wood products and furniture, etc. There is one national highway at around a distance of 1 km from the sampling site with a traffic density of around 10^3–10^4 vehicles per day. Most of the area of Jorhat district is occupied by tea gardens.

2.2. Sample collection

The samples were collected at the terrace of a residential building in the campus of Regional Research Laboratory (RRL), Jorhat at a height of around 10 m above ground through December 2002 to January 2003. The collection of samples was done using a polypropylene tray (28 × 23 × 16 cm) having solid walls. The tray was weaved with 1-mm thick nylon strings to make a net of 1 × 1 cm to increase the collection efficiency. The samples were collected on foggy days by exposing collector between 2200 and 0600 hr. The collected fog water was transferred to polypropylene bottles.

2.3. Analysis

Ten samples having sufficient volume (>5 ml) were checked for pH at IICT (Indian Institute of Chemical Technology), Hyderabad. Major anions and cations were determined by using high performance capillary electrophoresis (Prince, Model 460) at IICT. Anions Cl^-, SO_4^{2-} and NO_3^- were determined by chromate buffer, while cations Na^+, K^+, Ca^{2+}, Mg^{2+} and NH_4^+ by crown ether buffer.

3. Results and discussion

3.1. Ionic composition

During the fog episodes, among cations, NH_4^+ had the highest concentration, followed by Ca^{2+}, Na^+, K^+ and Mg^{2+}, and among anions, SO_4^{2-} had the highest concentration followed by Cl^- and NO_3^-. The high NH_4^+ may be attributed to vegetation, biomass burning, animal population, etc., which are strong sources of NH_3 (Parashar et al., 1998). The high SO_4^{2-} may be due to

Table 1. Average concentration of chemical components in soil (μeq g^{-1}) ($N = 6$)

Chemical components	Average	SD
NH_4^+	3.5	1.4
K^+	0.7	0.7
Ca^{2+}	1.0	0.8
Na^+	2.1	1.1
Mg^{2+}	1.4	0.3
Cl^-	2.5	1.3
SO_4^{2-}	2.0	1.5
NO_3^-	4.5	2.9

Table 2. Deposition fluxes by fog and rain water during December and January

Chemical components	Fog	Rain
NH_4^+	0.66	3.7
K^+	0.10	0.3
Ca^{2+}	0.24	1.3
Na^+	0.16	0.4
Mg^{2+}	0.06	0.2
Cl^-	0.31	1.2
SO_4^{2-}	0.41	4.9
NO_3^-	0.10	3.0

contribution from anthropogenic sources. SO_4^{2-}/Ca^{2+} and NO_3^-/Ca^{2+} ratios in rain water were higher (3.7 and 2.3) than respective ratios in fog water (1.7 and 0.4). These higher ratios in rain water can be attributed to higher concentrations of SO_4^{2-} and NO_3^- with respect to Ca as compared to other sites (Kulshrestha et al., 2003a,b,c).

The average pH value of 10 samples, which were analysed for pH, was observed to be 5.6. Out of 10 samples, three samples had pH values below 5.6. During this period, one rain water sample of an amount of 25 mm was also collected. Interestingly, the pH of rain water was observed to be acidic, i.e. 5.2. The reason for acidic pH of rain water is the high concentration of SO_4^{2-}, followed by NH_4^+ and NO_3^-. The average concentration of soluble components present in the soil is given in Table 1. The low concentration of calcium, unlike in other parts of the country shows that suspended soil dust is not sufficient to neutralize the acidity of atmospheric depositions. Concentrations of SO_4^{2-}, NO_3^- and NH_4^+ are very high as compared to Haflong site which is situated southerly in the same state (Kulshrestha et al., 2003a). But the Ca concentration at Jorhat in rain water is very low as compared to Haflong. This feature may be explained on the basis of soil and land use pattern. The Haflong is a high-altitude site (~1500 m a.s.l.) having shifting cultivation where soil is alkaline. In addition, trans-boundary emissions for acidic species may have influence on the atmospheric deposition in this region (Norman et al., 2001). This is more reflected at northern site like Jorhat.

The site is almost covered with vegetation and hence soil suspension does not play very important role in controlling the fog chemical characteristics. This is supported by the fact that ratios of different components to Ca^{2+} in fog water do not match those in the soil. The same is observed for rain water.

3.2. *Deposition fluxes due to fog and rain during foggy months*

In Jorhat, fog occurs mainly in the months of December and January. Generally, the fog deposition occurs in the early hours during mid-December to mid-January. We have made an attempt to compare the deposition fluxes of various chemical components of rain and fog during December–January months (Table 2). During these two months, the fog deposition fluxes due to rain have been calculated taking 40-mm rain (Statistical HandBook Assam, 1997). Table 2 indicates that, during these months, depositions due to rain are higher than the fog deposition by almost one order of magnitude. In fog, NH_4^+ had highest fluxes whereas in rain water SO_4^{2-} showed highest fluxes followed by NH_4^+. These interesting preliminary findings require more elaborated studies at this site to further investigate the chemistry, sources and transport of pollutants in this region.

Fluxes of fog deposition were calculated as follows:

$$\frac{C \times V}{A \times 1000}\ \text{meq m}^{-2},$$

where C is the concentration measured in μeq/l, V is the volume of fog water collected in ml, A is the area of collector (0.0644 m^2). Assuming 25 events in the season, using above formula, total fluxes were calculated which are given in Table 1. These fog deposition fluxes may be lower when compared to deposition on natural vegetation surfaces. The reason is that the leaves of vegetation provide more surface area for deposition and these leaves collect more drops. While the artificial collector used in this study collects fog due to strings where fog droplets attach and fall into the tray. Most likely, this underestimates the amount of fog deposited on natural surfaces.

4. Conclusion

A comparison of fluxes of fog and rain water during December–January months showed that deposition fluxes due to rain water were higher by almost one order of magnitude on an artificial surface but on natural surfaces, the fluxes may be comparable which requires further investigation. Among chemical components, NH_4^+ was observed to be dominating species which may most likely be due to biomass burning and animals. The soil of this region is acidic with average pH of 4.9. The result showed

that soil dust influence is less as this area in north-east region is covered with vegetation.

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