Wash-out and Rain-out Contribution of Aerosol Species over a Tropical Rural Atmosphere in India

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Introduction

Global aerosol distribution is largely controlled by the rate of removal of aerosols by wet scavenging processes. Two major processes called “below-cloud” scavenging or “washout” and “in-cloud” scavenging or “rain-out” are usually described for the scavenging of aerosol chemical species. The rain-out chemical species significantly contribute to the later stage of the precipitation event after washing-out of the chemical species below the cloud at the earlier stage of the precipitation. Thus one can expect the variation in concentrations of chemical species within the event itself. In this study, several rain samples were collected in each rain event in monsoon during 2006 - 2007 over Gadanki (13.5^{0}N, 79.2^{0}E), a rural region in southern peninsular India. Thus the present study on the temporal variation of chemical species within rain events significantly contributes to the limited knowledge on wash-out and rain-out precipitation chemistry. The primary focus of this study is to estimate the relative contribution of wash-out and rain-out process in the total deposition of major water soluble ionic species.

Methodology

Rainwater samples were collected within several rain events in monsoon during 2006 - 2008 using a standard rain gadget. Collected samples were stored in polythene bottles and enough care was taken for preventing any biological degradation within the sample. All samples were refrigerated at 40C in the laboratory till the analysis was over. The concentrations of major water soluble ions; Na^+, $NH_4{}^+$, $Ca_2{}^+$, $Mg_2{}^+$, $NO_3{}^-$ and SO_4^{2-} in rainwater samples were determined by ion chromatograph (Metrohm 861 Advance Compact IC). pH of the rainwater samples were measured using a digital pH meter (Sartorious Professional Meter, PP 20 with PY- P11 probe). The rainfall information was obtained from a co-located optical rain gauge

(ORG-815), which provides 1-min integrated rainfall rate.

Results and discussion

We found a gradual decrease in concentrations of Na^+, Ca^{2+}, Mg^{2+}, Cl^-, NO_3^- and sea-SO_4^{2-} in rainwater with time. Na^+, Ca^{2+}, Mg^{2+}, Cl^-, NO_3^- and sea-SO_4^{2-} were found to mainly form coarse mode (aerodynamic diameter larger than 2.5 μm) sea-salt and soil dust aerosols. The effective below-cloud scavenging or washing-out of those coarse mode aerosol components resulted in the gradual decrease of their concentrations with time. In contrast, NH_4^+ and non-sea-SO_4^{2-} show a sharp fall in their concentrations at the earlier stage of the precipitation and then concentrations fall slowly with time and significant concentrations were observed even at the later stage of the precipitation. The effective below-cloud scavenging of the coarse mode non-sea-SO_4^{2-} (associated with Ca^{2+}) resulted the sharp fall in its concentrations with time at the beginning of the precipitation. The other part of non-sea-SO_4^{2-} probably formed fine mode aerosol (aerodynamic diameter smaller than 2.5 μm) associated with mmonium as $(NH_4)_2SO_4$ and/or NH_4HSO_4. The slow decrease in concentrations at the later stage of the precipitation indicates the incloud scavenging (rain-out) of non-sea-SO_4^{2-}.

An attempt was made to find out the contribution of rain-out (in-cloud scavenging) and wash-out (below-cloud scavenging) in the total deposition flux of ionic species. To do this, we separated the samples in each rain event into below-cloud events (BCE) and incloud events (ICE) for NH_4^+ and non-sea-SO_4^{2-} as they show both in-cloud (rain-out) and below-cloud (wash-out) scavenging. It was estimated that the rain-out (in cloud scavenging) contribution of NH_4^+ was 26.7 % and that of non-sea-SO_4^{2-} was 25.6 % over the entire study period. The deposition fluxes for non-sea-SO_4^{2-} was maximum followed by Ca_{2+} and NO_3^- whereas the deposition fluxes of Na^+, Mg^{2+} and sea-SO_4^{2-} were much lower.

Conclusion

1. Na^+, Ca^{2+}, Mg^{2+}, Cl^-, NO_3^- and sea-SO_4^{2-} were found to be scavenged below the

cloud whereas NH_4^+ and non-sea-SO_4^{2-} showed in-cloud scavenging.

2. The acidity was found to increase at the later stage of the precipitation due to the incomplete neutralization of non-sea-SO_4^{2-}
3. The removal of NH_4^+ and non-sea-SO_4^{2-} from “below the cloud” was about 3 times higher than the removal from “within the cloud”.