An Experimental Investigation of the Effects of Environmental and Fog Condensation Nuclei Parameters on Fog Visibility

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1. Abstract

The effects of relative humidity (RH), temperature (T), and number concentration, size distribution and chemical nature of fog condensation nuclei (FCN) on the nature of fog generated and visibility through it in a newly developed Fog Chamber Facility is investigated using a He-Ne monochromatic laser. The IIT Kanpur Fog Chamber Facility has been conceptualized and built indigenously to study the fog formation and dissipation (fog life cycle) at various environmental conditions. The chamber is designed such that all the governing parameters can be controlled and optimized. Some results pertaining to effects of temperature, RH and FCN (NaCl, graphite and coated graphite) parameters on the nature of the fog generated and visibility through it are presented.

2. Introduction

Atmospheric fog is a weather phenomenon wherein tiny water droplets suspend in the vicinity of the Earth's surface and cause reduction in horizontal visibility. The poor visibility leads to severe disruptions and delays in rail and air traffic, which amounts to great economic loss. It is therefore necessary to have detailed information about the optical nature of fog particulate system (water droplet +FCN +vapors), which, in turn, governs the visibility.

Keeping this goal in mind, we have developed a state-of-art fog chamber facility for characterizing fog's physical, chemical and optical properties as a function of T, RH, and FCN number, size and chemical parameters. Experiments were performed in Fog Chamber Facility using different types of FCN e.g. NaCl, graphite and coated graphite etc. for a range of temperatures and RH. Experiments were carried out to determine the individual effects of RH, temperature, number, distribution and chemical nature of FCN on the nature of fog generated and visibility through fog because these are the most crucial parameters for the formation of fog.

3. FCN size distribution

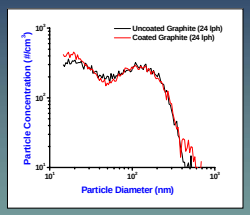

Fig 1(a) Average size distribution for coated and uncoated graphite particle at 24 lph flow rate measured by SMPS.

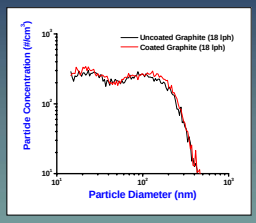

Fig 1(b) Average size distribution for coated and uncoated graphite particle at 18 lph flow rate measure by SMPS

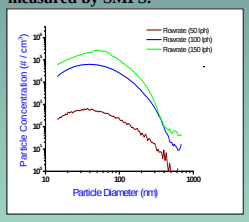

Fig 1(c) Average size distribution for NaCl particle for different flow rate measured by SMPS.

FCN	Flow rate (lph)	Number of particles entering into the chamber during experiment
NaCl	50	6.54×10^{8}
NaCl	100	1.40×10^{11}
NaCl	150	7.59×10^{11}
Uncoated Graphite	18	1.14×10^{10}
Coated Graphite	18	1.23×10^{10}
Uncoated Graphite	24	1.26×10^{10}
Coated Graphite	24	1.30×10^{10}

Table 1 Number of FCN entering into the chamber during experiment

A large number of experiments were carried out in fog chamber facility using different types of FCN e.g. NaCl, coated and uncoated graphite for different range of temperature and RH. For a particular temperature range, such as 8.2-8.8 ^{0}C, we performed experiments at different FCN flow rates of 50, 100, and 150 lph.

4. Results and Discussion

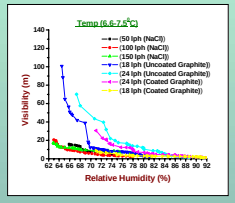

Fig 2 (a)

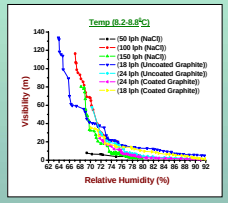

Fig 2 (b)

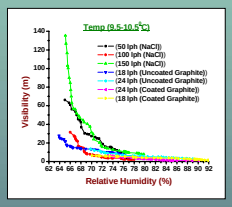

Fig 2 (c)

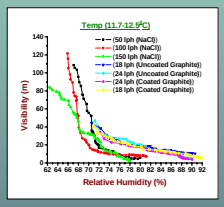

Fig 2 (d)

Fig 2. Visibility of chamber generated fog as a function of RH at different temperatures.

- For a specific temperature range , the visibility decreases as the RH increases as expected. The same trend is followed for all the four temperature ranges when NaCl was used as a FCN.
- The trend in the visibility for NaCl FCN for all temperature ranges at flow rate 50 lph and 100 lph shows that visibility in later case is generally lower except at temperature range of 8.2-8.8 ^{0}C. Based on the size distribution data measured from SMPS (Table 1), it is concluded that this is due to large number of small fog droplets formed for 100 lph flow rate that causes more scattering and reduce the visibility to a large extent .
- On the other hand visibility at 150 lph is found to be greater than 100 lph for the same type of FCN. This happens because of the particle number concentration exceeding a critical value leading to reduced activation of fog droplets due to lack of availability of water vapor.
- The visibility for the coated graphite particles is lower as compared to uncoated graphite in general for all temperature ranges due to enhanced affinity of coated graphite particles for water [Fuzzi et al., 2002].
- The lower visibility for NaCl FCN (hygroscopic) compared to other FCN shows that the activation of NaCl particle is much greater because for soluble nuclei condensation occurs even at lower RH.
- Except for temperature range 6.6-7.5 ^{0}C, the visibility through the coated and uncoated particles at flow rate 24 lph is lower than visibility at flow rate 18 lph.

References

1. Fuzzi, S., Facchini, M.C., Decesari, S., Matta, E., Mircea, M., 2002. Soluble organic compounds in fog and cloud droplets: What we have learned from the past over the few years? Atmospheric Research, 64, 89-98.

Acknowledgements

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