

Aerosol Scavenging Experiments

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1. Introduction

The term 'scavenging' summarizes all processes that lead to the incorporation of aerosol particles or gaseous compounds into the liquid phase (i.e. either into cloud, fog or rain droplets). Scavenging processes can take place either in-cloud or below-cloud.

Nucleation scavenging is the most important process of aerosol scavenging, as droplet formation itself is closely linked to the presence of aerosol particles in the atmosphere - '*without the dust particles in the atmosphere there will be no haze, no fog, no clouds and therefore probably no rain*' (John Aitken, as cited by Pruppacher and Klett 1998). At water vapour supersaturation ranging from less than 0.1% up to approximately 1% the condensation of water vapor occurs on aerosol particles, the so-called cloud condensation nuclei (CCN). The ability of an aerosol particle to act as a cloud condensation nucleus strongly depends on its size and its chemistry. Furthermore collision and coalescence contribute to aerosol scavenging processes.

The incorporation of trace gases into droplets is called gas-phase scavenging. Eventually chemical reactions and transformations in the liquid phase follow this process (i.e. reactive gas phase scavenging). Most of the droplets evaporate again and release processed aerosol particles, which are aerosol particles modified in size and chemistry.

2. Scavenging experiments

Investigations of the phase partitioning of trace gases in fog and clouds by Austrian groups started during the GCE (Ground based Cloud Experiment) project (Facchini et al. 1992, Winiwarter et al. 1994).

Scavenging experiments at high elevation sites were carried out at Sonnblick (3106 m a.s.l.) and Rax (1640 m a.s.l.). These investigations were initiated already in 1991 within the EUROTRAC project ALPTRAC (Alpine Transport of Air Constituents), which comprised in-cloud scavenging experiments as well as an alpine wide snow sampling program and thus allowed to link the process oriented scavenging studies to the ongoing deposition monitoring (Winiwarter et al. 1998). Starting with inorganic species organic aerosols were included in the program reflecting the growing interest on the ability of these aerosol compounds to act as cloud condensation nuclei (Novakov and Penner 1993).



Figure 1: Cloud Water Sampling at the Sonnblick Observatory during the ALPTRAC campaigns showing the Cloud Water Sampler (Kruisz et al. 1993) and an actual sample of subcooled droplets.

Cloud water sampling and analysis

Early results within ALPTRAC included the development of a sampling method to conduct measurements in a cold cloud, i.e. to sample subcooled cloud water droplets as seen in Figure 1 (Kruisz et al. 1993), the determinations and calculations of the phase distribution of pollutants between the gas phase and the liquid droplets (Brantner et al. 1994, Winiwarter et al. 1992) and investigations on the degree of riming (Kalina and Puxbaum 1994). The investigations on cloud water chemistry and physical properties were later extended to organic material (Hitzenberger et al. 2002, Kasper-Giebl 2002, Löflund et al. 2002).

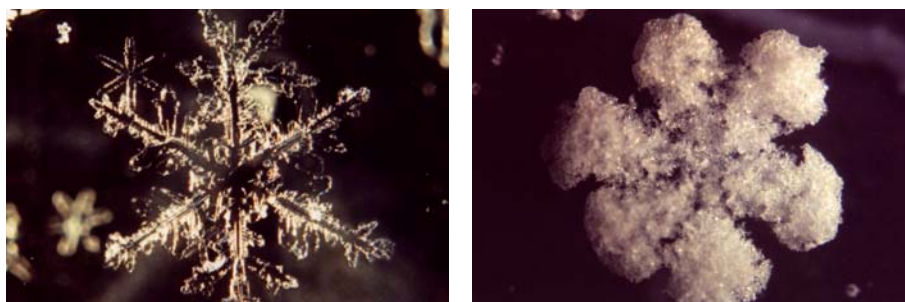


Figure 2: Ice crystal replicas prepared during the field campaigns at Sonnblick (Kalina and Puxbaum 1994).

Scavenging ratios

The scavenging ratio is the simplest approach to account for the overall scavenging process by relating air to liquid concentrations. At the Sonnblick Observatory scavenging ratios could be determined based on measurements performed at cloud level and thus were not influenced by different vertical profiles of aerosol concentrations and concentrations in wet deposition, respectively.

The simultaneous determination of aerosol species and trace gases (Kasper and Puxbaum 1998) furthermore allowed to determine the relative contribution of aerosol and trace gas species to total nitrate, sulfate and ammonium in precipitation (Kasper-Giebl et al. 1999). More recent results are given in Effenberger (2008) and Cerqueira et al. (2010) covering also scavenging ratios on organic compounds.

Scavenging efficiencies

The scavenging efficiency quantifies the fraction of a pollutant incorporated into cloud water droplets and thus quantifies in-cloud scavenging processes only. Based on the approach of Daum et al. (1984) and Dutkiewitz et al. (1995) the scavenging efficiencies for sulfate and lead were quantified and showed a strong dependency of the efficiencies on the liquid water content (LWC) of the cloud, but not on the total concentration values (Kasper et al. 1998).

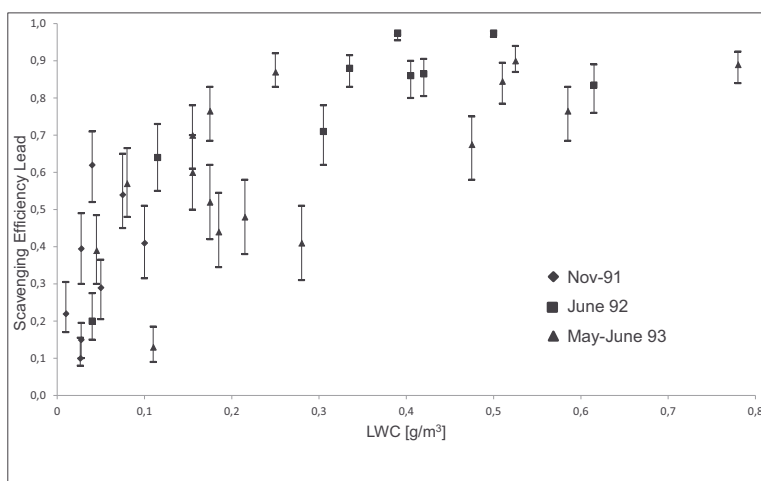


Figure 3: Scavenging Efficiency of lead determined at Sonnblick Observatory (Kasper et al. 1998).

Reflecting the growing interest on organic aerosols scavenging efficiencies were also determined for aerosol carbon (Kasper-Giebl et al. 2000), black carbon (Hitzenberger et al. 1999, Hitzenberger et al. 2001), total carbon (Hitzenberger et al. 2000) or for single organic compounds (Gröllert and Puxbaum 2000, Limbeck and Puxbaum 2000). The surface tension of cloud water was found to depend on its organic carbon content (Hitzenberger et al. 2002). Although being scavenged less efficiently than sulphate, black carbon is scavenged substantially and other more hydrophilic compound classes or compounds showed higher values up to nearly quantitative scavenging. This again emphasizes the importance of organic material in cloud processes. The dependency

on the LWC was observed for all studies. These investigations also led to the development of a gas and aerosol monitoring system (Löflund et al. 2001).

Bioaerosols

The concentration levels of organics determined in cloud water droplets led to research about the presence and viability of microorganisms in cloud droplets (Sattler et al. 2001) showing that cloud droplets form a habitat for bacteria to survive and grow. Further research on bioaerosols in respect to scavenging behaviour comprises the distribution of bacteria and fungal spores in cloud water, precipitation and aerosols (Bauer et al. 2002) and the ability of bacteria to act as cloud condensation nuclei (Bauer et al. 2003). More information about bioaerosols is given in this compendium, pp. 47 ff.

Determination of cloud condensation nuclei

Other investigations on the behaviour of single compounds as cloud condensation nuclei using a cloud condensation counter developed at the University of Vienna comprised lab experiments on selected organic acids (Giebl et al. 2002) and pure and coated carbon black particles (Dusek et al. 2006) as well as properties of jet engine combustion particles (Hitzenberger et al. 2003, Gysel et al. 2003).

3. References

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