Individual aerosol particles from the brown hazes in northern China: a study of transmission electron microscopy

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Abstract

The aerosol particles can impose impacts on the climates directly by absorbing and scattering light, as well as indirectly by acting as CCN to change the cloud-nucleating capacity. Different types of particle components, such as soot, fly ash, and mineral dust, sulfate, nitrate, organic carbon, sea salt and water, etc., may have different optical properties and thus different impacts on climates. The particles which travel in the atmosphere can mix with liquid, gases, as well as other types of particles, and this mixing would change the optical properties of the particles and further influence regional and global climate. With expansion of Beijing and its surrounding area in the past 30 years, severe brown haze episodes have become more frequent. Although the Beijing government has carried out many control measures to reduce local emissions and alleviate urban air pollution, the regional haze episodes with typically high concentrations of particulate matter still frequently occur in northern China and these aerosol particles can be transported long distance and influence Beijing air quality.

In this study, airborne aerosol collections were performed in urban areas of Beijing that were affected by regional brown haze episodes over northern China from 31 May to 12 June 2007. Morphologies, elemental compositions, and mixing states of 810 individual aerosol particles of different sizes were obtained by transmission electron microscopy coupled with energy-dispersive X-ray spectrometry. The phases of some particles were verified using selected-area electron diffraction. Aerosol particle types less than 10 μm in diameter include mineral, complex secondary (Ca-S, K-, and S-rich), organic, soot, fly ash, and metal (Fe-rich and Zn-bearing). Most soot, fly ash, and organic particles are less than 2 μm in diameter. Approximately 84% of the analyzed mineral particles have diameters between 2 and 10 μm, while 81% of the analyzed complex secondary and metal particles are much smaller, from 0.1 to 2 μm. Trajectory analysis with fire maps show that southerly air masses arriving at Beijing have been transported through many agricultural biomass burning sites and heavy industrial areas. Spherical fly ash and Fe-rich particles were from industrial emissions, and abundant K-rich and organic particles likely originated from field burning of crop residues. Abundant Zn-bearing particles are associated with industrial activities and local waste incinerators. On the basis of the detailed analysis of 443 analyzed aerosol particles, about 70% of these particles are in ternally mixed with two or more aerosol components from different sources. Most mineral particles are covered with visible coatings that contain N, O, Ca (or Mg), minor S, and Cl. K- and S-rich particles tend to be coagulated with fly ash, soot, metal, and fine-grained mineral particles. Organic materials internally mixed with K- and S-rich particles can be their inclusions and coatings.

From these TEM analyses, it can be further seen that most hydrophobic particles (i.e., mineral, certain organic, fly ash, soot, Fe-rich particles) in the brown haze episodes can be coated or coagulated with hygroscopic materials (i.e., nitrates, potassium salts, and...
ammonium sulfate). Once coated by hygroscopic materials, these internally mixed particles should easily grow larger through the absorption of more water and acidic gases along with increase of relative humidity. These grown particles may explain why the brown haze layer over northern China with high humidity has been associated with strong cooling in the region. Furthermore, the great amount of fine particles (e.g., metal, nitrates, ammonium sulfate, and potassium salts) transported from the anthropogenic sources and formed in the brown haze air could enhance adverse health impacts of aerosol particles in Beijing air.

**Keywords:** brown haze, individual aerosol particles, transmission electron microscopy, agricultural biomass burning, northern China