Dust, Health and Climate: Roles of Surface Chemistry and Heterogeneous Processes in Environmental Processes

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Atmospheric mineral dust continue to serve as an important component in climate, ecological balance, and human health. In addition to their environmental relevance, mineral dust also serve as inspiration for the understanding of heterogeneous processes, owing to their complex and chemically rich molecular frameworks. While numerous studies have focused on single component Fe bearing minerals such as hematite, goethite or clay minerals, the impact of non-Fe bearing minerals on Fe dissolution is largely remain unknown. Our studies disclose surface reaction mechanisms that governs the atmospheric processing of Fe-containing mineral dust in the presence of a common semi-conductor oxide, titania (TiO_2) – "Fe-Ti hypothesis". This work further reveals vital mechanistic insights on mineralogical controls in dust iron dissolution by molecular oxygen, acid anions, and solar flux to understand global iron mobilization. On the other hand, airborne mineral dust containing heavy metals can impact on human health. However, the surface chemistry of metal-containing-dust dissolution in lung fluids and the role of mineralogy are poorly understood. More recently, we focused on the dissolution of respirable-sized uranium-containing-dust in simulated lung fluids. We observe that the inhalable dust includes uranium minerals that yield the uranyl cation, UO_2^{2+}, as the primary dissolved species. Further, the extent of uranium dissolution greatly depends on the mineralogy; the types of uranium minerals as well as non-uranium-minerals in the inhaled dust. Thus, our findings emphasize the importance of site-specific toxicological assessments across mining districts with a specific focus on their mineralogical differences. Given that airborne mineral dust are capable of further transformation and interaction with atmospheric gases, our work also highlights the importance of detailed studies on the surface chemistry of these systems.