

Metals vs Minerals: comparison of trace elements in particulate and sub-micron aerosols deposited on snow from an open-pit bitumen mining and upgrading region

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Anthropogenic dust from wind erosion of disturbed lands accounts for approximately 30 to 70% of the total global dust flux. Significant portions of these dusts are from open pit mining of coal, iron and base metal mining and smelting, aggregate extraction, and road dust. The chemical composition of these dusts plays a critical role given that they may contain contaminants such as trace elements (TEs).

Snow is an excellent archive of wintertime atmospheric deposition of TEs. In the northern hemisphere, up to one-third of the land is covered with snow. During snowmelt, the concentrations and bioaccessibility of TEs in rivers and lakes can fluctuate markedly.

As a case study, we collected dusty snow in 2016 from the Athabasca River (AR) banks which bisects the Athabasca Bituminous Sands (ABS) region in Canada. Size-resolved analyses of selected TEs were undertaken in a clean lab. Our aim was to determine how much of these elements are (i) present as “metals” i.e. ionic species and single molecules (< 300 Da) or (ii) present in particulate form (> 0.45 µm) as “minerals” and amorphous materials. Concentrations and size distributions of TEs were determined using ICP-MS and AF4-ICPMS respectively. Conservative, lithophile elements (Al, Th, Y), elements enriched in bitumen (Mo, Ni, V) as well as potentially toxic chalcophile elements (As, Cd, Pb, Sb, Tl) were overwhelmingly found in the particulate fraction, with an increasing trend toward the centre of the ABS region. The mineralogical composition of this fraction was similar to natural and anthropogenic dust sources found in the area. With the exception of V, TE concentrations in the “filterable” snow (< 0.45 µm) were below AR waters and in global average uncontaminated rivers. Filterable Al, Mo, and V in snow increased toward industry. The “truly dissolved” (< 300 Da) fraction which represents the potentially bioavailable form, dominated the filterable fraction. However, the “truly dissolved” concentrations of TEs were extremely low: Cd and Pb, for example, were similar to ancient arctic ice. Consequently, during snowmelt, TEs in this fraction would have a limited impact on aquatic organisms.