Geochemistry and mineralogy of antimony in enriched riverine water and mineral phases

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Antimony (Sb) is a critical material and one of the top ten mined elements worldwide. Centuries of Sb extraction generated tons of mining waste enriched in Sb and dispersed in riverine and coastal ecosystems. Geochemical and physical weathering of mining waste mobilises Sb and other metals, posing an environmental risk. Antimony is a non-essential element with the European guideline threshold value of 5 µg/L for drinking water, and still critical to sustainable technologies. Understanding Sb geochemistry and mineralogy is fundamental to implementing remediation, Sb recovery, and mining, limiting the risk it can pose to the environment and human health.

Historical Sb mining in southeast Sardinia (Italy) offers a case study where Sb can be found in outcropping rocks, mine wastes, foundry slags, and the impacted riverine system. Mineralogical investigations (XRPD and SEMEDS) highlighted the presence of various Sb-bearing phases such as Sb_2O_3 (valentinite/sénarmontite), stibnite (Sb_2S_3), metallic Sb, and the rare mopungite ($NaSb(OH)_6$). The weathering of these Sb-bearing phases released Sb into the water, with the water samples showing a median of 323 µg/L (range 48 - 4,020 µg/L). The most common $Sb_{(aq)}$ phase found in the waters was $Sb(OH)_6^-$ with Sb(V) species. Reaction with high concentrations of carbonate and Na-phases are suspected to react with the $Sb_{(aq)}$ and precipitate as mopungite (NaSb(OH)6). The presence of these phases contributes to the attenuation of Sb in the riverine systems limiting its mobility. This process is of high relevance since the river system draining the mine system feeds the Flumendosa River, an important water source for the downstream valley characterised by agricultural and urbanised land use. These findings highlight the geochemical process driving Sb mobility in impacted river systems and natural attenuation processes. Further research is required to implement such an understanding to monitoring, remediation, and land use of Sb-enriched areas.