From Source to Sink, Geochemical and Mineralogical Dynamics of Sediment-Associated Metal(loid)s in an Acid Mine Drainage-Affected River

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Acid mine drainage (AMD) remains a major environmental concern, with long-term contamination of river systems requiring costly remediation efforts. While there is significant research on aqueous contamination from AMD, there is limited information on the spatial variation of AMD-generated metal(loid)s in the particulate phase in the affected rivers and their associated mineralogical phases. Specifically, the significance of Fe oxides to the sediment load of AMD-affected rivers and their role in particle size and mineralogy in contaminant source, transport and deposition in these rivers. This study addresses these gaps by examining the distribution of arsenic (As), copper (Cu), zinc (Zn), and iron (Fe) in sediments from a river catchment affected by AMD, into the estuary. Through a comprehensive analysis of particle size fractions, high concentrations of As, Cu, Zn, and Fe were recorded downstream of the AMD discharge, with fine sediments (<0.063 mm) hosting these contaminants. These metal(loid)s were predominantly associated with secondary Fe oxides. The study revealed that detrital and secondary mineral phases play a crucial role in contaminant transport and remobilisation, with sulfide and sulfate minerals hosting Zn, and Fe oxides being the primary hosts for As and Cu. This work fills a key knowledge gap by providing new insights into the complex interactions between metal(loid)s, particle size, and secondary mineralogy in AMD-affected riverine environments. The findings underscore the importance of considering these factors in future remediation efforts, particularly in the face of challenges such as climate change, which may further influence sediment stability and the mobilisation of contaminants.