

Contrasting Pollution Sources in Acidic versus Alkaline Coal Mine Waters: Hydrochemical and Boron Isotopic Evidence

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Coal mining activities pose a significant risk of groundwater contamination. Toxic substances in coal mine drainage are critical threats to water quality safety, with severe implications for human health and ecosystem integrity. While extensive research has focused on the acid mine drainage, the identification of typical pollutants and their sources in alkaline mine water remains poorly understood. To address this knowledge gap, this study conducted a comprehensive geochemical investigation on mine water, coal, and gangue samples collected from multiple coal mines in northern China, aiming to compare hydrochemical characteristics between acidic and alkaline mine water.

Significant differences in water chemistry were found between acidic high-TDS and alkaline high-TDS mine water ($\text{TDS} > 3 \text{ g/L}$). The acidic water contains high levels of SO_4^{2-} , F, B, Pb, As, Cd, Cr, Zn, Fe, and Mn, whereas the alkaline water is characterized by elevated concentrations of SO_4^{2-} , F, and B. Alkaline water displays heavier $\delta^{11}\text{B}$ values (+25.53‰ to +34.49‰) compared to its acidic counterpart (+4.18‰ to +20.94‰), suggesting distinct B sources in these two systems. Combined with the correlated relationships between SO_4^{2-} and major cations (e.g., Ca, Na, Mg, Al, Fe, and Mn), we suggest that evaporites might be an important pollution source for alkaline water, while oxidation of sulfides enrich SO_4^{2-} and other metal elements in acidic water. This is consistent with the results of coal and gangue leaching experiments, which show that leachates from gangue collected near acidic waters have a pH of 3.41 and are enriched in heavy metals, while leachates from coal and gangue collected near alkaline waters have a pH > 7 and are typically characterized by the enrichment of SO_4^{2-} and B. Our findings reveal that pollutants in acidic and alkaline mine waters originate from distinct sources, and highlight that the integration of hydrochemical signatures with boron isotope tracers can provide valuable insights into the pollution sources of coal mine waters in contrasting pH environments.