

Arsenic Is Ubiquitous but Not Elevated in Abandoned Coal-Mine Discharges in Pennsylvania

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Despite elevated concentrations in coal beds, dissolved As rarely is elevated in abandoned coal-mine discharges in Pennsylvania. For 140 samples collected in 1999, concentrations of As ranged from <0.03 to 15 µg/L in 41 anthracite mine discharges and from 0.10 to 64 µg/L in 99 bituminous coal-mine discharges (table 1). The pH of these discharges ranged from 2.7 to 7.3, with dominant modes at pH 3-4 and 6-7; concentrations of Fe ranged from 46 to 512,000 µg/L. The As was positively correlated with pH, alkalinity, Fe, SO₄, Cl, Br, and I and was inversely correlated with redox potential. Aqueous speciation computations indicated arsenate species (H₂AsO₄⁻ and HAsO₄²⁻) predominated.

Concentrations of As in Fe-rich precipitate (ochre) samples from 20 of the anthracite discharge sites ranged from <0.07 to 270 mg/kg. Generally, the concentration of As in the solids was positively correlated with the concentration of As and pH of the source water; the ratio of As concentrations in solution to As in solids (K_d) did not vary with pH. This trend could indicate increased capacity for attenuation of As by Fe compounds at higher pH. Poorly crystalline Fe(III) oxyhydroxides, such as ferrihydrite, tend to form under near-neutral conditions whereas Fe(III) oxyhydroxysulfates, such as schwertmannite, and crystalline Fe(III) oxyhydroxides, such as goethite, are predominant Fe(III) phases formed at low pH. Ferrihydrite could have greater sorption capacity for arsenate than goethite or schwertmannite. Nevertheless, the As that is associated with metastable Fe(III) compounds, such as ferrihydrite and schwertmannite, can be remobilized (1) upon conversion of metastable compounds to more stable phases such as goethite or (2) from reductive dissolution or acidic digestion.

Table 1: Composition of discharges from abandoned coal mines in Pennsylvania, 1999
[median(minimum-maximum)]

| Coalfield & number of samples | pH | Eh (mV) | Oxygen | Sulfate | Iron | Manganese | Arsenic |
|-------------------------------|------------------|------------------|-------------------|-------------------|-------------------|-------------------|--------------------|
| | | | (mg/L) | | | | (µg/L) |
| Anthracite N=41 | 5.1 (3.0-6.3) | 390 (170-770) | 1.9 (0.3-11.1) | 260 (36-1300) | 15 (0.046-312) | 2.9 (0.019-19) | 0.62 (<0.03-15) |
| Bituminous N=99 | 5.2 (2.7-7.3) | 340 (140-800) | 0.6 (0.2-11.5) | 580 (120-2000) | 43 (0.16-512) | 2.3 (0.12-74) | 2.0 (0.1-64) |

<http://wwwbrr.cr.usgs.gov/Arsenic/FinalAbsPDF/cravotta.pdf>