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Arsenic in the Yellowstone hydrothermal system

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The Yellowstone Plateau Volcanic Field (YPVF) contains more than 10,000 thermal features including hot springs, pools, geysers, mud pots, and fumaroles that have diverse chemical compositions. Arsenic concentrations in YPVF thermal waters typically range from 5 µg/L to 4 mg/L but have been reported as high as 17 mg/L. Arsenic data from hydrothermal features, thermal drainages, rivers, volcanic rocks, and silica sinter were used to identify arsenic sources, fate, and fluvial transport. Arsenic in YPVF thermal waters is mainly derived from high-temperature leaching of rhyolites. Arsenic concentrations in thermal waters primarily depend on water type, which is controlled by water-rock interactions, phase distribution (liquid or vapor) and microbial activity. The distribution of arsenic concentrations for 330 individual thermal springs located in 30 different thermal areas across YPVF was determined and springs with low arsenic concentrations include acid-sulfate (0.1 ± 0.1 mg/L); ammonium-sulfate rich (0.003 ± 0.007 mg/L); and dilute thermal waters (0.1 ± 0.1 mg/L); travertine-forming waters have moderate arsenic concentrations (0.4 ± 0.2 mg/L); and neutral-chloride waters (1.9 ± 1.2 mg/L) have elevated arsenic concentrations. Additional processes affecting arsenic concentrations include mixing different types of thermal waters, boiling and evaporation, and mineral precipitation and dissolution. Reduced arsenic species (arsenite (As^{3+}) and thiolated arsenic species) are most prevalent in hydrothermal features near the main vent, but during discharge arsenic rapidly oxidizes to arsenate (As^{5+}). Most of the water discharged from thermal springs and geysers mixes with a nearby river and downstream arsenic is fully oxidized, remains soluble and exhibits little attenuation. Arsenic transport in rivers and creeks in the YPVF is conservative because arsenate does not sorb to silica-coated sediments, sorption sites are likely saturated, the pH is high (7-9), and there is very little iron entering the rivers to coprecipitate arsenic. For water years 2010-2020, 183 ± 10 metric tons/year of arsenic were transported from Yellowstone National Park via rivers. The arsenic geochemical cycle in Yellowstone National Park from source rock to fluvial transport at the Park boundaries is quantified much better from this investigation.