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Climate-driven increases in stream metal concentrations in mineralized headwater catchments throughout the Colorado Rocky Mountains, USA

ANDREW MANNING[1], TANYA N PETACH[2], ROBERT L RUNKEL[1] AND DIANE M MCKNIGHT[3]

[1]U.S. Geological Survey

[2]University of Colorado Boulder

[3]Institute of Arctic and Alpine Research, University of Colorado Boulder

Presenting Author: amanning@usgs.gov

Increasing stream metal concentrations potentially caused by climate warming have been previously reported for a small number of mineralized watersheds, containing hydrothermally altered bedrock with abundant sulfide minerals. Such increases have significant implications for future stream ecosystem health, mine-site remediation efforts, and downstream water resource management. However, the ubiquity and magnitude of this phenomenon have not been systematically explored on a regional scale. We collated and analyzed available time-series water chemistry data from the past 40 years for 22 headwater streams with elevated metal concentrations draining mineralized watersheds throughout the Colorado Rocky Mountains. Data are from the late-summer and fall low-flow period. We focused on Zn and Cu, being primary metals of concern in the region, as well as SO_4 and pH, reflecting overall sulfide weathering rates. Sites were grouped into 17 low-pH sites (median <5.5) and five neutral-pH sites (median 7-8) based on initial data inspection suggesting strong differences in trend behavior. Temporal trend analysis was performed for site groups using the Regional Kendall Test ($p < 0.05$ considered significant), with trend magnitude equaling the Sens slope (percent of observation-period median per year). For low-pH sites, SO_4, Zn, and Cu all display significant upward trends of 1.9 to 2.5%/yr, equivalent to a concentration doubling time of 25-35 years. For neutral-pH sites, SO_4 displays the same upward trend as above, but Zn and Cu have borderline-significant downward trends of ~4%/yr ($p = 0.04$ and 0.06, respectively). No significant pH trends were found. Streamflow data from eight reference gauges located near the 22 stream chemistry sites display significant downward trends in August-October mean monthly flows. However, these are substantially smaller in magnitude than observed concentration increases (0.6 to 1.1%/yr), suggesting that stream metal loads are also increasing regionally. Furthermore, “index loads” computed using reference gauge data to estimate temporal changes in load, display significant upward trends for SO_4 and Cu for the 12 low-pH sites with mean elevations >3450 masl. Work is ongoing to correlate trend significance/magnitude with watershed characteristics to better understand specific climate-linked controlling mechanisms driving these concerning observed increases in concentration and possibly load.