Rare earth elements and old mines spell trouble for Western U.S. water supplies

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Nate Rock, accompanied by his dog Nita, collects aquatic insects from the Snake River during a 2015 field trip for a CU Boulder course on stream ecology taught by Diane McKnight. These samples are considered "bioassessments," which use insect diversity and abundance to characterize habitat quality, pollution tolerance, and are also later analyzed by a lab to measure metals present in their biomass. Credit: Stephen Cardinale

Rare earth elements are finding their way into Colorado water supplies, driven by changes in climate, finds a new study published in the journal *Environmental Science & Technology*.

Rare earth elements are necessary components of many computing and other high-tech devices, like cell phones and hard drives. But there is growing recognition that they can be hazardous in the environment even at low levels of concentration.

"This is of concern because their concentrations are not monitored and there are no water quality standards set for them," says study author Diane McKnight, who is an INSTAAR Fellow and engineering professor at the University of Colorado Boulder.

The study is the first to look at how rare earth elements move within a watershed that is rich in minerals. It is also the first to investigate how climate change, by altering stream flow and natural weathering processes, is releasing more rare earth elements into streams.

Diane McKnight has led her students in investigations of water quality in the Snake River watershed of Colorado since the 1990s. Their main focus has been measuring and observing acid rock drainage. In this process, rocks that include sulfide-based minerals, such as pyrite, oxidize when exposed to air and water. The resulting chemical reaction produces sulfuric acid and dissolved metals like iron, which drain into streams. More acidic water can further dissolve heavy metals, like lead, cadmium, and zinc, and as it turns out can carry rare earth elements as well.

"What really controls the mobility of rare earth elements is pH. Acid literally leaches it out of the rocks," says first author Garrett Rue, who earned a masters degree studying limnology with McKnight and a subsequent Ph.D. from CU Boulder.

Acid rock drainage happens naturally throughout the western United States, with its pyrite-rich geology. But historic mines that disturb large amounts of rocks and soil amp up the process dramatically and cause downstream water pollution.

Within the Snake River watershed, towns impacted by acid mine drainage have been forced to adapt to poor water quality. Some former mining boomtowns, like Silverton, import water from distant sources. Others rely on expensive water treatment plants. All fish in the Snake River are stocked, since the water is too high in zinc for any native fish species to survive. The problem is endemic to the western United States, says Rue: "Upwards of forty percent of the headwaters to major rivers in the West are contaminated by some form of acid mine or rock drainage."

The Snake River has made a good natural laboratory for investigating both, since the Peru Creek part of the watershed was heavily mined, while the Upper Snake River was not. But Rue and McKnight found that both parts of the watershed are now contributing significant amounts of metals downstream, as climate change has brought longer summers and less snow in the winters. Longer, lower stream flows make it easier for metals to leach into the watershed, and concentrate the metals that would otherwise be diluted by snowmelt.

The same processes that mean more heavy metals are finding their way into streams are also acting on rare earth elements. The researchers found rare earth elements throughout the Snake River. "We documented a concentration range of one to hundreds of micrograms per liter—several orders of magnitude higher than typical for surface waters—with the highest concentrations nearest the headwaters and areas receiving drainage from abandoned mine workings," says Rue.

They also documented that increases in rare earth elements in the Snake

River corresponded to warming summer air temperatures, and that rare earth elements are accumulating in insects living in streams at concentrations comparable to other metals such as lead and cadmium shown to be toxic.

"We're starting to understand that once rare earth elements get in the water, they tend to stay there," says Rue. "They aren't removed by traditional treatment processes either, which has implications for reuse and has led some European cities to designate REEs as an emerging contaminant to drinking water supplies. And considering that the Snake River flows directly into Dillion Reservoir, which is Denver's largest source of stored water, this could be a concern for the future."

The researchers suggest that investigating and investing in technologies to recover rare earth elements from natural waters could yield valuable commodities and help address the problems associated with acid rock and mine drainage, which are poised to worsen as the climate shifts.

"Rare earth elements are used to make a lot of products. But most of the supply comes from China. So our government has been looking for sources, but at the same time mining has left an indelible mark on the waters of the West," says Rue. "If we can harvest some of these materials that are already coming into our environment, it might be worthwhile to treat that water and recover these materials at the same time."

"This problem is getting worse and we need to deal with it," adds McKnight. "If we can solve the problem holistically, we can have a valuable resource and also think about climate adaptation."

More information: Garrett P. Rue et al, Enhanced Rare Earth Element Mobilization in a Mountain Watershed of the Colorado Mineral Belt with Concomitant Detection in Aquatic Biota: Increasing Climate

Change-Driven Degradation to Water Quality, *Environmental Science & Technology* (2021). DOI: 10.1021/acs.est.1c02958

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