

New Issue: Orbital Catastrophe Ahead? Read Now

SCI
AM

[September Issue](#)

[Newsletters](#)

[Podcasts](#)

[Games](#)

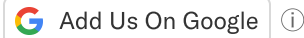
[Explore](#) 

[Subscribe](#)

[Sign In](#)



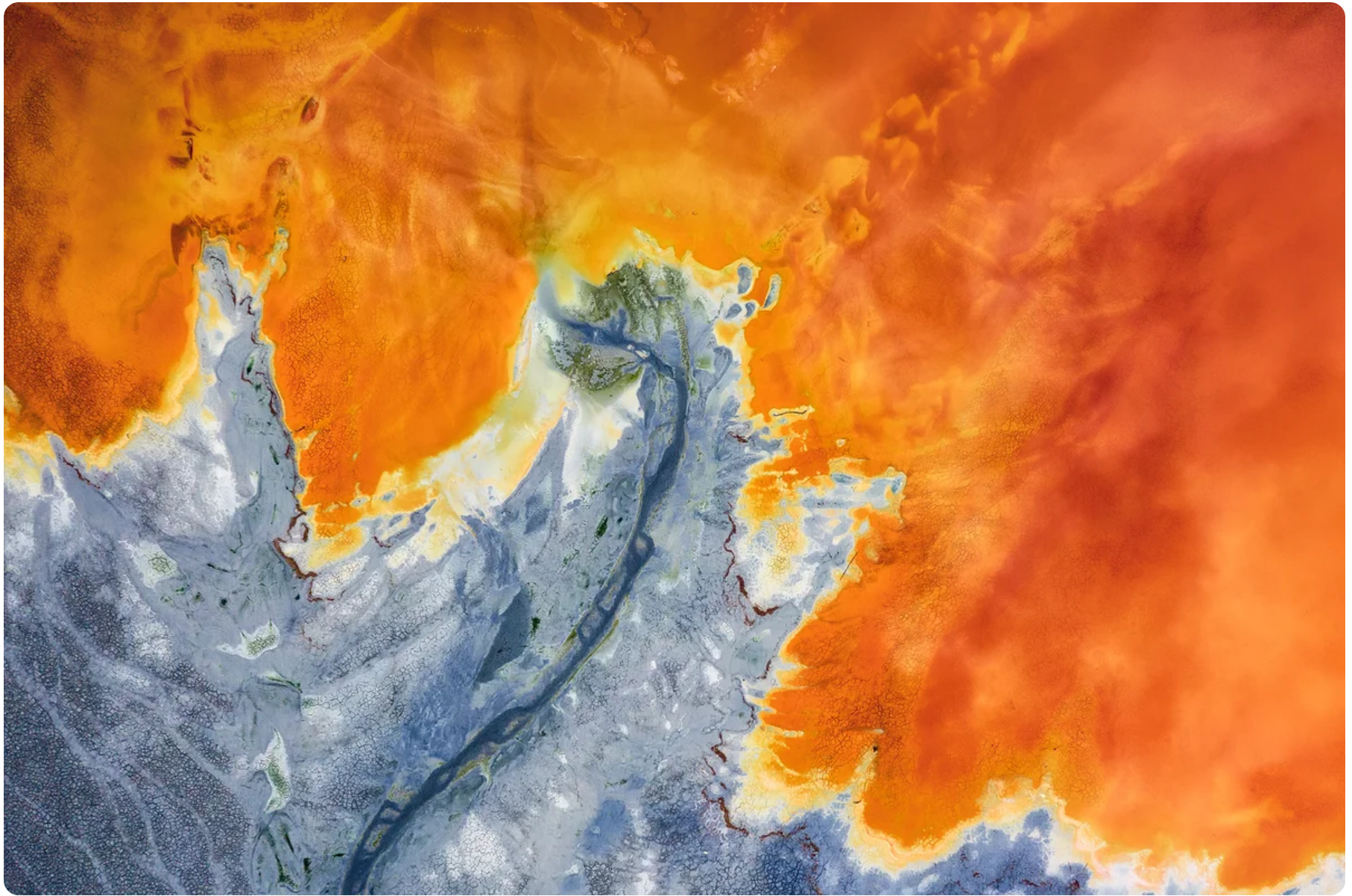
November 4, 2021 | 7 min read



Climate Change Is Acidifying and Contaminating Drinking Water and Alpine Ecosystems

Hotter, drier mountains leach more metal into streams from abandoned mines and natural deposits

BY [ELIZABETH MILLER](#) EDITED BY [ROBIN LLOYD](#)



Geamana village flooded with waste water from mining, Romania, taken in May 2019. [Lukas Bischoff Getty Images](#)

Garrett Rue grew up fly fishing in central Colorado, often surrounded by mountains stained amber and maroon, and hiking along streams that seemed to borrow those colors. Sometimes he would cast for native trout and come back with nothing—because there was nothing to catch. Then he started hearing stories about people in nearby mountain communities who couldn't drink their own water. He began to wonder: "These streams have problems supporting ecosystems, and they're not usable for drinking. What's going on here?"

Nowadays, Rue, a postdoctoral scientist studying waterways at the University of Colorado's Institute for Arctic and Alpine Research, knows how to read the color code of stream ecology: rusty red or orange for iron oxide, chalky white for aluminum, and yellow for manganese. Such colors reveal the presence of minerals that wash down mountainsides; the results can be hostile to local aquatic life and dangerous for drinking water systems. Some mineralization and acidification occur naturally. But decades of research show some is also a result of historic excavations and waste disposal practices at regional gold,

silver and other mines, often found in mountainous regions. Now, climate change seems to be speeding up the process.

The chemistry starts in high mountain valleys, many of which have long served as the world's natural water towers. Climate change is raising temperatures and increasing the frequency and intensity of droughts in those high-elevation alpine environments, where mines typically are located. A growing body of research links these hotter, drier conditions to increasingly acidic water, which causes rocks to shed more minerals into waterways. And the list of what's entering those waters continues to grow. These trends could potentially compromise water quality in watersheds anywhere in the world where mountains contain high concentrations of minerals, from the Rocky Mountains to the Himalayas to the Andes.

Research co-authored by Rue is among the latest entries on this front, and one of the first to link rising temperatures with increasing concentrations of dissolved rare earth elements in mountain streams. These metallic elements are used to polish and color glass—and to make the batteries and magnets that run our ubiquitous cell phones, televisions and motor vehicles. Rue says his findings, published in August in *Environmental Science and Technology*, could hold still more ramifications for the safety of surface water used for drinking, and for the long-term health of ecosystems fed by these streams.



Mine drainage exiting Natalie-Occidental mine entrance, a major source of acidity and metals to the South Fork of Cement Creek in a historic mining district near Silverton, Colo. Credit: Garrett Rue

The rare earth elements identified by Rue are relative newcomers to research around water quality concerns. Little is known about the human health effects of these elements, and the U.S. Environmental Protection Agency's [drinking water regulations](#) do not specify thresholds for them. Typically, they are found in water in parts per trillion—often undetectably low—Rue says. In samples collected between 2012 and 2019 in Colorado's Snake River Basin for Rue's recent research, the team found tens of parts per billion of dissolved rare earth metals lanthanum, cerium, neodymium, samarium, gadolinium, dysprosium, erbium, ytterbium and yttrium. "They may not have been a toxicant at low levels," Rue says, but "we could be crossing a threshold." Rue also reported finding rare earth elements in the bodies of stream-dwelling insects, suggesting these metals are entering the food web.

Even in parts of the Snake River Basin without a history of mining, Rue found that concentrations of rare earth elements in waterways are rising. This suggests that mountain mineral deposits, which have shed these elements at a relatively steady rate for decades, will also leach more extensively as temperatures rise and drought conditions worsen, says study co-author and civil and environmental engineer Diane McKnight of the University of Colorado Boulder. There are no water quality standards related to rare earth elements. So, McKnight and Rue looked to U.S. water quality standards for

lead and cadmium to estimate the potential risk this leaching could pose. The researchers found concentrations of rare earth elements above the level at which lead and cadmium are considered safe for aquatic life and human health. Climate aside, links between mines and downstream water quality concerns—often related to the release of various metals beyond those meant to be extracted—are widespread, and in some cases enduring. Elsewhere in the Rockies, including Idaho's [Coeur d'Alene River Basin](#), a 1998 study tracked metals from old mines entering waterways. Researchers found metals in sediment and river rocks 50 miles downstream from historic mining. Residents of Italy's island of [Sardinia](#) have dealt in recent decades with groundwater contamination caused by acidified floodwaters laden with zinc, cadmium and lead draining from mines, including millennia-old Phoenician ones. And in [Germany](#), highly acidic water flowing from silver, lead, copper and zinc mines dug over the last 800 years reportedly continued to contaminate groundwater as recently as 20 years ago.

There has been little, if any, formal investigation of climate change's role in the above examples. But if climate-related droughts are affecting downstream water quality elsewhere, there could be a lot of sites to investigate in the United States alone. More than 100,000 abandoned [mines](#) remain in this country, according to federal tallies. Rue estimates that [over 40 percent](#) of

major U.S. rivers have montane headwaters potentially contaminated by either mine-related heavy metals or natural sources of them. In Australia, where mining also boomed in the 1800s, a public policy think tank reports some 60,000 abandoned mines.

Conventional mining practices contribute to the potential water contamination. For every ounce of gold, silver, copper and lead extracted, miners hired to chase those veins produce tons of waste rock. Until the 1970s, U.S. mining law allowed private companies, individual prospectors and mill operators to leave behind piles of such waste. Veins of minerals are often intertwined, meaning these rock piles include a variety of metals that emerged from the ground along with the targeted ore. Rue's research adds rare earth elements to the list of potential constituents washing out of the rocks.

Piles of waste rock might look innocuous, but mined metals are often found in rocks that also contain sulfides. When weathered over time by air and precipitation, sulfides degrade and create sulfuric acid, which can slough off remaining traces of aluminum, cadmium, iron, lead, zinc and other metals—including rare earths at the Snake River Basin sites of Rue and McKnight's study. Snowmelt or rain then carries these metals downstream.

Sufficient amounts of rain and meltwater can dilute metals' impact on downhill waterways, and wetlands can serve as water filters. But a warmer, drier

climate, with its accompanying droughts of increasing duration, cuts into these mitigating factors.

For a detailed look at how these climate impacts affect stream health, researchers have reviewed stream chemistry samples collected over the past 40 years in the Snake River Basin in central Colorado. A 2012 study analyzing these data linked the area's rising summer temperatures to a five-fold jump in concentrations of zinc and other metals of ecological concern in the basin's waterways. Andrew Manning, a research geologist at the U.S. Geological Survey, was a co-author on that study, and followed it in 2013 with a study demonstrating that as climate change extends the summer season in the basin, those warmer and drier months lower the water table—potentially exposing deeper layers of rock to weathering that yields the corrosive sulfuric acid. Declining snowpack caused by global warming can also lead to higher concentrations of dissolved minerals in shrinking bodies of water, Rue adds.

“It’s amazing how, when you start messing with the climate, all of these unforeseen consequences are tied together,” Manning says. “And these ecosystems, especially in places like the Arctic and the mountains, were delicately weaved together based on a fairly stable climate.”

McKnight has studied the Snake River Basin for decades, recording increasingly acidic water that will release more heavy metals (likely including

rare earths) from rocks. The first time a student tested stream pH at a site there and reported it at an extremely acidic 2.7, she recalls, “I said, ‘That can’t be right.’ And it was.” Acid rain typically ranks closer to neutral, around 4 on the pH scale—which is also the level at which enough metals dissolve into the water that the basin’s rainbow trout die, a 2007 study concluded.

Downstream, dissolved metals can compromise human communities’ water supplies. For example, the Snake River basin drains into Dillon Reservoir, which provides drinking water to Denver. Dilution and settling address much of the concern, says Denver Water spokesperson Todd Hartman, but the utility company closely watches the issue of mine water draining into drinking water. If nearby ski areas have to rely on more intensely mineralized and acidified water to make artificial snow, that could compound the problem, McKnight adds. Spring melting could wash metals that collect in the prior winter’s artificial snow into nearby streams in a concentrated pulse.

Rue’s findings are less a cause for alarm than a cue for additional research, Manning says.

“There are so few watersheds where we have long-term water quality data that we’re left with the bigger question of ‘How widespread is this?’” says Manning, who recently sampled watersheds across Colorado to try to answer that

question. “This is very much a concern, but one of the big things we’re trying to figure out right now is how concerned we should be. We just don’t know.” Rue’s work has seen him splashing around waterways in New Zealand—some of them thick enough with iron oxide to stain his tennis shoes orange. In his travels there nearly four years ago, Rue visited an abandoned coal mine where tanks of oyster shells, which are naturally alkaline, are being used to neutralize acidic runoff from old mine shafts and reduce the load of metals coming from them. He hopes to see similar innovations in the U.S. to address contaminated runoff from abandoned mines. With demand for rare earth elements outpacing the global supply chain, harvesting minerals from the polluted water in these mountain streams could both address a manufacturing need and ease environmental concerns—if technological and legal hurdles can be overcome.

“But this is not about finding the next boom,” Rue says. “This is about finding sustainable solutions to environmental problems... We’re already in this mess, so we kind of have to science our way out of it.”

RIGHTS & PERMISSIONS

ELIZABETH MILLER is an environmental journalist who covers the West. [Follow her on Twitter](#)
[@WroteElizabeth](#).

[More by Elizabeth Miller](#)

It's Time to Stand Up for Science

If you enjoyed this article, I'd like to ask for your support. *Scientific American* has served as an advocate for science and industry for 180 years, and right now may be the most critical moment in that two-century history.

SciAm always educates and delights me, and inspires a sense of awe for our vast, beautiful universe. I hope it does that for you, too.

If you [subscribe to *Scientific American*](#), you help ensure that our coverage is centered on meaningful research and discovery; that we have the resources to report on the decisions that threaten labs across the U.S.; and that we support both budding and working scientists at a time when the value of science itself too often goes unrecognized.

In return, you get essential news, [captivating podcasts](#), brilliant infographics, [can't-miss newsletters](#), must-watch videos, [challenging games](#), and the science world's best writing and reporting. You can even [gift someone a subscription](#).

There has never been a more important time for us to stand up and show why science matters. I hope you'll support us in that mission.

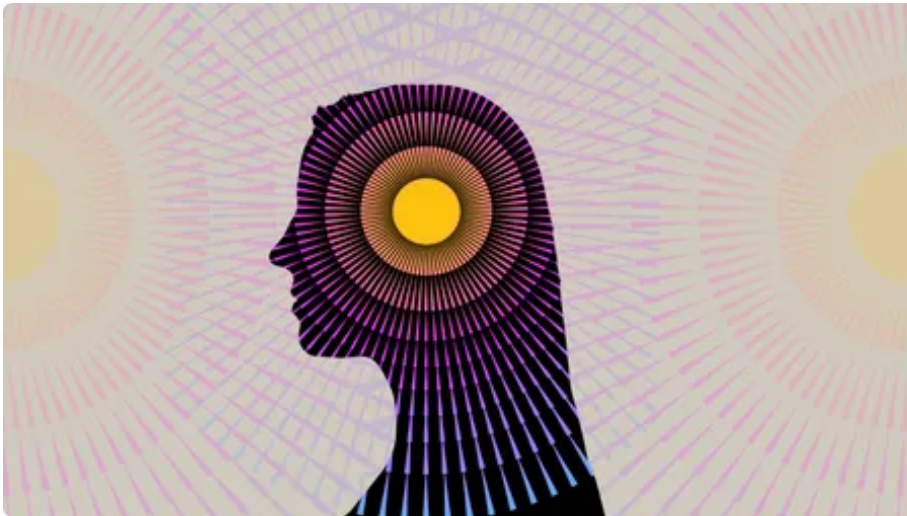
Thank you,

Jeanna Bryner, Editor in Chief, *Scientific American*

Subscribe

Popular Stories

.....



PSYCHEDELICS | AUGUST 19, 2026

How psilocybin alters consciousness to create a sense of 'oneness'

Psychedelics can create a new “hidden order” in brain activity that could explain how these drugs alter our sense of self

ALLISON PARSHALL

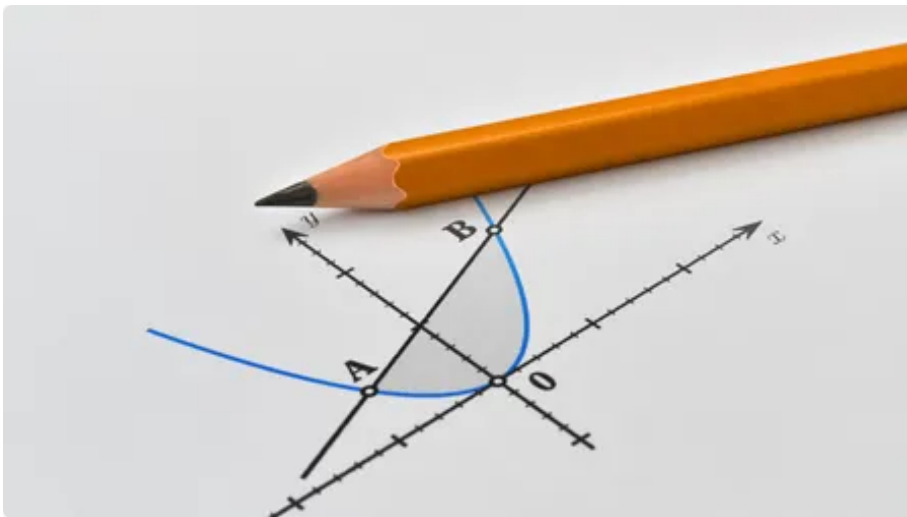


ARCHAEOLOGY | AUGUST 18, 2026

What really happened on Easter Island?

For decades, an influential theory blamed the Rapanui for their own downfall—a story made famous by Jared Diamond's book *Collapse*. New evidence tells a different tale

MICHAEL MARSHALL

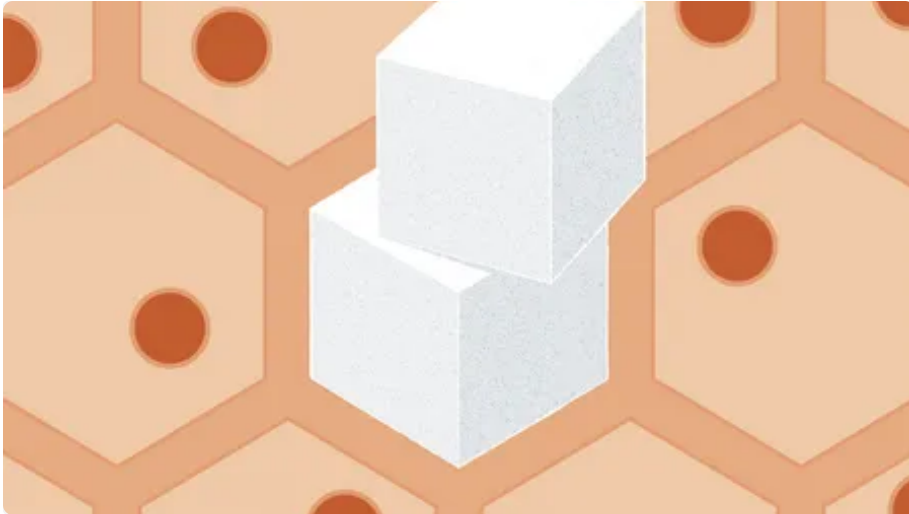


MATH | AUGUST 18, 2026

Why parabolas are crucial to cryptography

Cryptographers use points along a curve to build tough codes

MANON BISCHOFF



DIABETES | AUGUST 13, 2026

Popular drug metformin transforms your gut into a sugar sink

Researchers are finally learning the mechanism behind one of the most prescribed medicines in the U.S., primarily used to treat or prevent type 2 diabetes

VIVIANE CALLIER

AGING | AUGUST 19, 2026

Super agers have an immune system superpower

Could this secret cellular weapon be the key to longevity?

MARY RANDOLPH



ENERGY | AUGUST 18, 2026

Solid-state batteries have reached a make-or-break moment

Two American companies are pursuing rival manufacturing strategies for these long-promised cells in an industry China dominates

ALEX PASTERNAK

Subscribe to *Scientific American* to learn and share the most exciting discoveries, innovations and ideas shaping our world today.

[Subscription Plans](#)

[Give a Gift Subscription](#)