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Microbial and Spectral Reflectance Techniques to Distinguish Neutral and Acidic Drainage

"Acid mine drainage from coal affects drinking water quality, property values, and stream habitat for fish and other organisms. Coal is an important resource that fuels our industrial economy. So new techniques are needed in conjunction with mining to stop acids and metals from leaking into streams. New remote sensing techniques can locate sites of leakage because they use diagnostic wavelengths of light to distinguish between acidic and neutral water. Bacteria are known to use a variety of strategies to precipitate toxic metals. Stopping the metals from moving downstream from the mining sites can protect our land and water and keep our industrial base functioning."

Eleanora Iberall Robbins

Author collecting a sample of iron flocculate produced by microbial activity in acidic water.

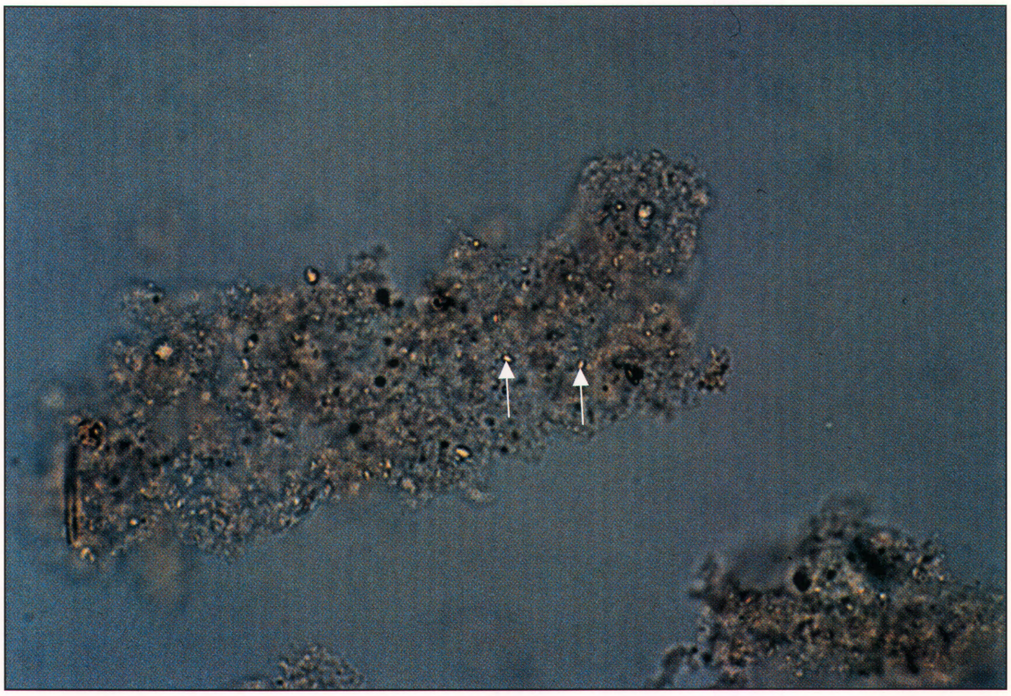
Acid mine drainage site in Virginia. Metal and coal mines within the Chesapeake Bay basin are being studied to learn the limitations of new remote sensing techniques. Contrary Creek in the Piedmont Pyrite Belt in southern Virginia is an ideal test site because it has neutral seeps entering a severely acidified stream. The stream bed is yellow orange from acidic flocculates and precipitates. Dried yellow flocculates extend over the creek banks. In contrast, a neutral tributary in the background (arrow) is red from iron precipitated by bacteria in neutral, iron-rich ground water.

Acid drainage from abandoned coal mines is affecting thousands of miles of rivers in the eastern United States.

Acidic drainage is common in places where high-sulfur coal and sulfide-bearing rocks have been mined, but not properly reclaimed. Although mining and reclamation methods that stop acidic drainage from forming or from leaving the site are currently used throughout the United States, numerous old abandoned mines continue to produce acid mine drainage (AMD) from underground tunnels and mine waste piles. As the tunnels fill with water and water percolates through the waste piles, the sulfide minerals oxidize producing acids, iron, and other metals that leak into streams. These produce yellow ferric oxy-hydroxide (FeOOH) and sulfate ("yellow boy") flocculates and precipitates that encrust rocks, logs, leaves, and streambeds. Acidified streams are considered to be dead systems because they have no fish.

U.S. Geological Survey (USGS) scientists are finding that neutral drainage is sometimes being mistaken for acidic drainage because both involve the formation of iron oxide-rich materials.

Iron-rich flocculates can form naturally in places where iron-bearing, anoxic ground water discharges into streams. In these near-neutral pH settings, flocculates have red and red- orange hues in the visible spectrum and are composed of ferric oxy-hydroxide minerals. These iron-bearing materials are natural and are even found in the oldest rocks on Earth.

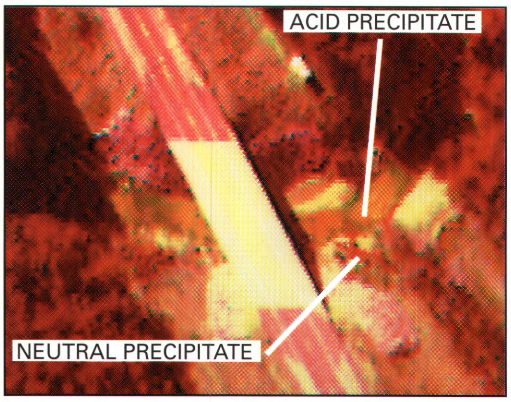


Yellow flocculates ("yellow boy") from an acidic site are colonized by numerous colorless bacteria (arrows), as seen using a light microscope.

Red flocculates from a neutral site are formed by iron-coated bacteria called Gallionella *that look like braids, as seen using a light microscope.*

USGS scientists are adapting microbial techniques to learn about the processes that form the acidic and neutral iron oxide-rich flocculates.

Different microbial communities can participate in the production of these acidic and neutral iron oxide flocculates. The acidophilic bacteria that create iron-rich flocculates in acidic water are often *Thiobacillus* species. These bacteria derive energy from oxidizing the iron or sulfide in pyrite, FeS_2, which is the most common sulfur-bearing mineral in coal. Oxidation of pyrite produces sulfuric acid and iron flocculates that appear yellow and yellow-orange in sunlight. In contrast, neutral pH water contains a different group of bacteria, as well as fish, frogs, and turtles. Where neutral water contains iron, the neutralophilic iron-depositing "iron bacteria" such as *Gallionella* derive energy from iron oxidation.

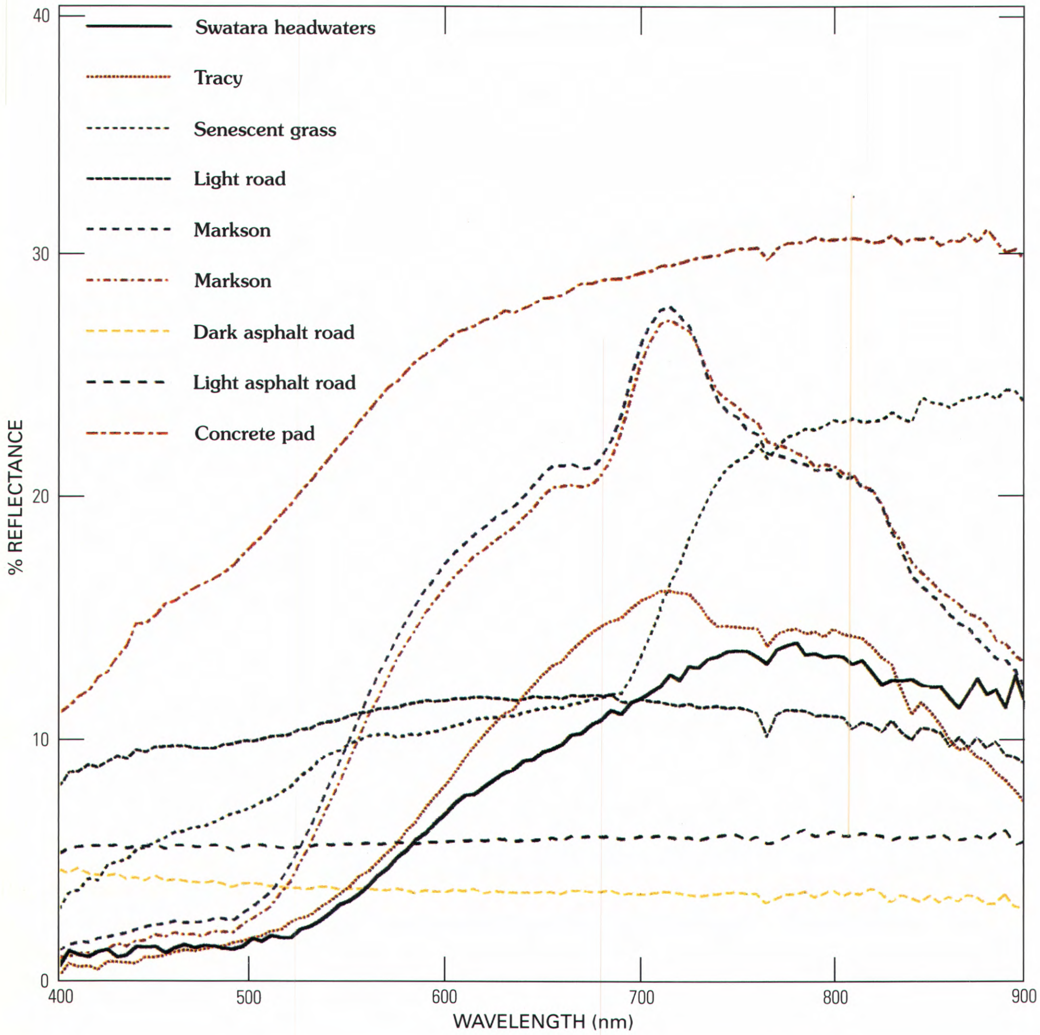


This false color composite image uses the digital multispectral video (DMSV) and selected filters to show acidic water as yellow and neutral water as red. The DMSV instrument was mounted in a fixed-wing aircraft and flown at an altitude of 1,650 m above the site. The filters that produced this image have central wavelengths of 450 nm (blue), 650 nm (red), and 750 nm (near-infrared). The straight line crossing the middle of the image is U.S. Route 522, and the central rectangle is the bridge across Contrary Creek. (Image supplied by John Anderson, Topographic Engineering Center, U.S. Army Corps of Engineers.)

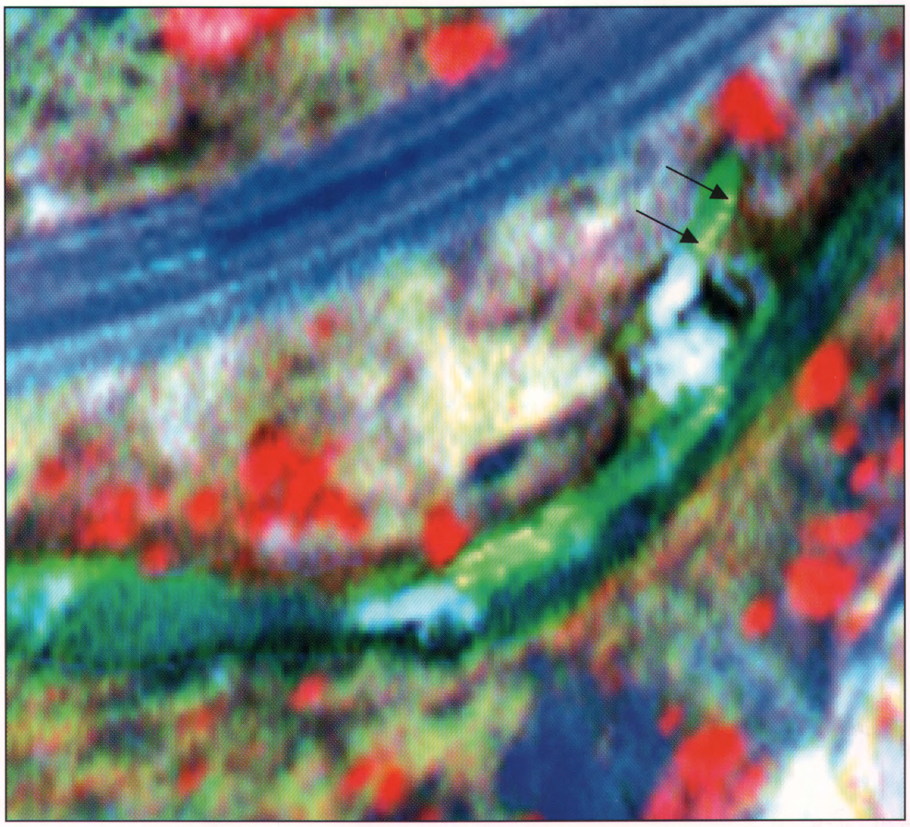
Scientists are developing spectral reflectance techniques that differentiate between acid and neutral materials.

New technology that allows above-ground measurements of reflected light is being tested to characterize mine drainage on the basis of the spectral properties of various iron minerals. Cooperative work between the USGS, the Army Corps of Engineers, and the Pennsylvania Department of Environmental Protection, demonstrates that certain remote sensing tools can be used to differentiate between acidic and neutral waters because the iron flocculates in acid water have distinctly different spectral signatures from those formed in neutral water. A hand-held, field spectroradiometer produces graphical displays showing that the yellow-hued flocculates in acidic water have higher spectral reflectances than the red-hued flocculates formed in neutral water. An aerial technique using a 4-channel, digital multispectral video system (DMSV) can create digital composite images of the flocculates using specific wavelength filters. The images show a uniformly bright yellow or yellow-green signal above acidic water having yellow flocculates when the filtered video channels are combined in certain ways.

COMPARATIVE SPECTRAL SIGNATURES FROM PENNSYLVANIA DISCHARGES AND ENVIRONS
APRIL 18, 1996



Spectral reflectance graphs show data from abandoned coal mine discharges in the Southern Anthracite coalfield of central Pennsylvania. The hand-held spectroradiometer produced distinctly different spectral reflectance graphs for acid (Markson discharge) and near-neutral (Tracy discharge) discharges. The yellow of the acidic flocculates has higher spectral reflectance than the red of neutral flocculates.



False color composite image of the area around the Markson discharge from an abandoned underground coal mine in Pennsylvania. Where anoxic water from the mine discharges to the surface and becomes aerated, the yellow acid-type flocculates form (arrows). Other yellow pixels in the image along the edge of Rausch Creek may be sites where pyrite-bearing mine waste was piled along the bank and where yellow flocculates are collecting in slack-water pools. In this image, trees are red, the road is blue, and Rausch Creek water, having no iron-rich flocculates, is blue and green.

Federal and State regulatory agencies are using these data to help make land-use decisions.

Is acid still leaking from sites and mines that are thought to have been reclaimed? Have all the places that leak acids and metals into streams been identified? Remote sensing from the air can help answer such questions. Aerial measurements allow the examination of places that are remote or cover large areas. Regulatory agencies could use an objective scientific tool such as remote sensing to monitor coal mining permits and to check the effectiveness of efforts to prevent pollution. Other agencies need to report on the health of all our Nations's streams, even the remote ones, to meet requirements of the Clean Water Act. Although more work is needed to refine the techniques at disparate localities and different hydrological or seasonal conditions, preliminary data suggest that multispectral imagery can be used as an objective tool for resource and regulatory agencies that manage water quality and mining reclamation in coal-mining regions.

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