Divining Rod

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Arsenic-Sulfide Precipitation Analyzed in Groundwater Environments

by Steve Carr, UNM

Water. It's the lifeblood of any civilization, and in the Western United States, its scarcity has researchers looking for ways to preserve the precious commodity. Contamination of groundwater is one of the reasons preservation efforts are important. For example, the contamination of drinking water with arsenic is a significant hazard to human health not only in the West, but worldwide. Long-term exposure to arsenic in drinking water may cause a wide range of cancers, including skin, lung, bladder, and kidney cancer.

Matthew Kirk takes a sample in the laboratory. He plans to complete his Ph.D. in geology in May of this year.

A study by University of New Mexico graduate student Matthew Kirk is designed to identify ways that may help reduce arsenic levels in groundwater. Matthew thought sulfate reduction might be a simple, yet effective way for removing arsenic from contaminated groundwater. Matthew says it isn't clear, however, how sulfide minerals remove arsenic from water or how effective they are, so before trying to use this approach, he needed to find out more. Matthew's results didn't turn out as he thought, but there's more information out there.

"My results weren't as expected," Matthew said. "But that just means we have much more to learn about arsenic and groundwater. Arsenic is linked to a number of adverse health effects. Its occurrence is widespread in drinking water. In naturally contaminated groundwater, it often comes from the dissolution of minerals in the aquifer."

Diving Rod

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WRRI is starting off the new year with a new design. Many thanks to Jud Wright with Del Valle Printing. We hope you enjoy our new look!

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As part of his research, which he started in January 2007, Matthew performed four semi-continuous flow bioreactor experiments to test arsenic behavior in different systems containing iron and sulfate reducing microbial activity, sulfate reducing activity, iron reducing activity, and no microbial activity.

"In the lab we designed the experiment to simulate the flow of water in an aquifer," Matthew said. "We made artificial aquifers and introduced natural microbial communities. We simulated the conditions of real aquifers. The idea was to use a simplified setting to isolate the chemical and biological processes that control arsenic's behavior. By learning about arsenic, we hope to find simple ways to help remediate arsenic contamination."

He periodically collected and analyzed headspace gases and solid phase samples. Every week he removed one-third of the volume and replaced it with one-third new water and analyzed the solution that came out of it. His results are being used to help create a reactive-transport model of arsenic biogeochemistry.

Unexpectedly, Matthew's findings suggest that neither mackinawite, which is an iron sulfide mineral, nor orpiment, an arsenic sulfide mineral, had much of an effect removing arsenic. He also found out that the rest of the research went as expected.

"It appears that neither of the minerals we expected to form and remove arsenic were effective in our experiments," Matthew said. "It's not that simple. Mackinawite doesn't appear to be that effective, but it may help provide a long-term solution. In nature, mackinawite slowly turns into the mineral pyrite. Many studies have shown that pyrite can absorb arsenic. So if we can make mackinawite in the aquifer, eventually the arsenic levels should drop as pyrite forms. It would be much more useful, though, if we could make this happen more rapidly."

"The rest of the chemistry and reactors from the research evolved as expected, so that's reassuring," he said. "I have some details to work out to determine if this can be a way to remove arsenic from groundwater. I don't plan to give up on this strategy just yet, even though there's still a lot we don't know."

Matthew, a fourth-year graduate student who earned his bachelor's of science at Bradley University and his master's from Illinois, both in geology, received a WRRI student research grant to conduct this research. He still needs to complete a numerical model, which he says can be very helpful in interpreting what's going on in aquifers containing arsenic both biologically and chemically.

NMHU Student Examines Arsenic Adsorption and Desorption in Storrie Lake Sediments

by Sara Ash, WRRI

Inorganic arsenic has been shown to be carcinogenic, increasing the risk for respiratory, skin, liver, and GI tract cancers. The primary source of inorganic arsenic in soil and water near Las Vegas, New Mexico, is the underlying bedrock. Storrie Lake, one of three reservoirs used as a drinking water supply, is located in an area that contains arsenic concentrations up to 10 ppm.

Celestine prepares to take a sample from Storrie Lake, his study site located near Las Vegas, New Mexico.

Celestine Ngam, a master's student in natural resources management at New Mexico Highlands University from Cameroon, Central Africa, has begun research to quantify arsenic adsorption/desorption between the sediment and water in Storrie Lake to identify a possible source of arsenic contamination.

He has conducted preliminary water quality tests on four samples from the lake, testing for dissolved oxygen, heavy metal content, sodium and magnesium concentration, and turbidity at 0, 3, 15, and 30 feet deep.

"The water is considered hard because the hardness (141 mg/l) and alkalinity (154 mg/l) values are high, but the concentration of dissolved oxygen (8 mg/L) is good enough to support aquatic life," Celestine said. "The water arsenic concentration is below 1.2 ug/L, which meets the EPA water quality standard for arsenic, but the arsenic content in the sediment is still to be determined."

"The most important issue is to determine the effect of pH and changes in water arsenic level on sediment arsenic desorption and adsorption, which will help predict arsenic levels in the lake should it experience a significant change in pH and arsenic concentration," he said.

The lake is slightly basic, with an average pH of 8. Currently, the water is channeled to the Las Vegas water treatment plant, where the pH and turbidity are decreased to 7 and 0.3 NTU, respectively.

"I predict that a decrease in pH of the lake will result in an increase in arsenic concentration in the water because of decreased arsenic adsorption by the soil," Celestine said.

He will conduct two studies to determine the adsorption/desorption capacity of the soil. The first study will use arsenic contaminated water with a pH of 8. In the second study, the pH will be decreased to 6. Four grams of sediment will be mixed with 40 mL of arsenate solution and left for 0.25, 0.5,

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1, and 2 days. The samples will then be analyzed to determine the amount of arsenic adsorbed into the sediments. The Freundlich and Langmuir adsorption isotherms will be used to determine the adsorptive capability of the sediment and the maximum amount of arsenic the sediment can adsorb at different reaction times.

Along with the batch experiments, Celestine will use GIS to design a map of the study area that includes vegetation, streams, lake area, and GPS coordinates of the collected samples.

Celestine received a 2007-2008 WRRI student water research grant that helped fund this research.

Celestine gathers equipment to take water samples.

NMHU Student Investigates Heavy Metal Contamination in the Santa Fe River on the Cochiti Reservation

by Sara Ash, WRRI

Carlos Herrera, from the Cochiti Reservation in northern New Mexico and a graduate student at New Mexico Highlands University, is working to quantify the concentration of heavy metals in macroinvertebrates, sediment, and water along the Santa Fe River to determine if heavy metal accumulation has occurred due to past mining activities in the La Bajada mine located near the Cochiti Reservation.

Carlos stands in a pool habitat collecting stream substrate samples.

"Water quality tests only test for physical and chemical properties," Carlos said. "Sampling the macroinvertebrates will incorporate the biological aspect of this complex system, so we will get a better understanding of it by comparing physical, chemical, and biological properties."

So far, Carlos has sampled the water at three sites along the Santa Fe River: above the Cochiti Reservation and mine, at a USGS gauging station, and below the Cochiti dam. He tested for depth, flow, and water quality and hopes to find a correlation between heavy metal concentrations and the location of the mine.

His preliminary water quality tests show that uranium is present in the water before reaching the mine, and the uranium concentration increases from 4 ug/L at the first sampling point to 8 ug/L below the dam.

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"The sediment and invertebrate analyses will have to be performed before the final results can be determined. The increase could be due to other factors," Carlos said. "But I expect to find elevated levels of heavy metals in sediment and macroinvertebrates that interact with the sediment due to the mine."

Carlos, who received a WRRI student research grant to conduct this research, has collected some of the invertebrate and sediment samples. "We used nets to capture the invertebrates," he said. "You have to use the right kind of net and be careful, because you have to collect enough invertebrates to weigh 0.5 grams dried. That's a lot of organisms, because they are made of mostly water and can be very small."

The invertebrate samples will be categorized by family and feeding guild, fixed using ethyl alcohol, oven dried, and analyzed using ICP-MS to determine the concentration of metals accumulated by the different macroinvertebrate families and feeding guilds.

"This study will show if organisms can be used as a tool for measuring water quality and accumulation of metals," Carlos said. "Macroinvertebrates reflect their environment, so if there is contamination in the sediment and water, the macroinvertebrates will reflect that."

The water from the Santa Fe River in Cochiti Pueblo is used for a small scale fish hatchery, agriculture, rangelands, and drinking water for the Village of La Bajada. "We want to help Cochiti Pueblo with water quality and share this situation with the Pueblo and the state of New Mexico," he said. "We do this for the good of the Pueblo and of all people who depend on the river for water."

Tech Hydrology Professor Recognized by Soil Society

by Argen Duncan, El Defensor Chieftain Reporter

New Mexico Tech Professor Robert Bowman

A New Mexico Tech professor of hydrology has received high recognition from his peers in being named a fellow of the Soil Science Society of America. Robert Bowman, who has done much work on a porous rock with many uses called zeolite, was one of 14 individuals chosen to receive the honor for 2007 based on professional achievement and meritorious service.

Tech Professor of Hydrology Jan Hendrickx nominated Bowman. "Rob is a very effective mentor for his students, but this nomination is driven by his exceptional abilities to consistently conceive novel scientific research strategies for dealing with complex hydrological problems," Hendrickx said in his nomination form.

Bowman said he was happy about the award. "It's recognition by your peers that your work has been good quality and has had a positive impact on the science," he said.

The formal awards ceremony took place at the society's national meeting in October in New Orleans, but Bowman couldn't attend due to prior commitments. For selection, people in the society nominate colleagues and a committee ranks candidates for final selection, according to a news release from the society.

Hendrickx cited Bowman's work with chemical tracers, which allow researchers to track the movement of water. The tracers have clarified effects of differences within soil and rock formations on flow and transport processes and are used worldwide.

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52^{nd} Annual Water Conference Highlights

We know that it is time to be smart and to work hard and to work together to get the most out of what we actually have here, which is this wonderful place that we call the Land of Enchantment… It is my very strong belief that the century of water is really just beginning in New Mexico. -NM Lt. Governor Diane Denish

The fact is there really has been no organized national effort to look at our nation's water availability and water use nationwide consistently since 1978…We think that broad kind of overview of understanding our resources and how they are changing is a part of what is needed for proper stewardship of our nation's water resources. -Robert M. Hirsch, U.S. Geological Survey

The health of New Mexico's rural economy, its blend of cultures, and unique ecosystems are tightly hinged to water. We tend to take water for granted, but it is the backbone of everything that we do…With no water to spare, the Rio Grande is a highly vulnerable watershed, where virtually all water is consumed in some way or another. -Julie Coonrod, University of New Mexico

We are going to establish a Middle Rio Grande adjudication pilot project and adopt a statute general reform goal for the adjudication. We are going to create a Middle Rio Grande water court, effective July 1, 2009. We will endorse general fund appropriations adequate to support the pilot project and practical resources for the Office of the State Engineer. -NM Representative Andy Nuñez

"Beyond the Year of Water"

We have to remember that the anthropogenic factors, plus the decadal, ENSO, regional, and local variability, add up to one thing: surprise. There are surprises in the system that we have to try to account for, and that is the problem with trying to create a service that has this high degree of uncertainty. -Roger Pulwarty, National Oceanic and Atmospheric Administration

Is there a difference in water consumption between an old population and a young population? My staff, who are younger than me and have children, said, "Of course. If you have babies and a teenager, water consumption goes up. As you get older, water consumption levels off." …Culture and lifestyle also dictate what the water consumption is. -Adélamar Alcántara, University of New Mexico Bureau of Business and Economic Research

We can only affect what is local. As they say, all politics is local… If we are to meet the economic challenges and environmental concerns of this century, we must be able to utilize a different model that allows us to act locally and accrue benefits statewide and nationwide as well as globally. -NM State Engineer John D'Antonio

The Family Farm Alliance represents farmers. Anything that makes farmers do well, we're for. Our mission statement is very simple: Adequate supplies of affordable water. It is not much more complicated than that…We're running as fast as we can as farmers to be more competitive, more creative, and more efficient to conserve more water. -Pat O'Toole, Family Farm Alliance

Water Conference photos by Stephen Nowaczek

Effects of Human Disturbance Studied in Stream Ecosystems

by Steve Carr, UNM

Have you ever walked through a river and found it difficult to get a solid foothold on the streambed? You slip and slide on the rocks and think "Oh, it's algae." But that's simplistic and only part of the answer. In actuality, it's a biofilm containing microhabitats and communities, which efficiently recycle dissolved organic matter, transform and remove nutrients, and trap particulate matter. What exactly are the components of this biofilm, how does it affect the water we use everyday, and how do human disturbances impact its ability to function?

University of New Mexico biology graduate student David Van Horn is currently working on an experiment, sponsored in part by the New Mexico Water Resources Research Institute. The study will determine how eutrophication, the enrichment of water bodies with excess nutrients, affects stream biofilm communities. Generally, David is trying to discover how elevated nutrient levels in streams affect the diversity and function of stream biofilm communities.

David also hopes to find the answers to related but more specific questions, including what mechanisms drive eutrophication induced community change; whether or not the changes in community structure affect the ability of biofilm communities to process nutrients and organic carbon; and if enrichment thresholds exist and if crossed, what rapid changes in community structure and function will result?

David's experimental setup near Gila, New Mexico

Streams are particularly susceptible to eutrophication because they concentrate agricultural and aerial inputs dispersed over watersheds and are used for wastewater disposal. Microbial biofilms growing on stream substrates are a component of stream ecosystems that could be negatively affected by eutrophication; however, little research has been conducted in this area.

So far, finding a suitable site has been one of the biggest challenges for David. His latest site, in the Sandia Mountains, went dry after a drier than usual late summer and fall season. He's now scouting possible sites in the Gila Wilderness and the Jemez Mountains.

"I need to find a site where I can set the experiment up near a stream with high clarity, no travertine deposits, a power source, and some security from vandalism," said David. "The goal is to create 15 artificial experimental stream channels for growing the biofilm. The channels will be fed continuously by natural stream water pumped from the stream adjacent to the channels. The artificial channels are lined with ceramic tiles to provide a substrate for biofilm colonization." To determine how enriching the water with nutrients will affect the growth of the biofilm, David will continuously add a solution

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of nutrients including carbon, nitrate, and phosphate to the channels to create an eutrophication gradient ranging from low to high impact. After four weeks of growth, the colonized tiles will be collected to assess the impacts of the eutrophication disturbance.

"There will be lots of lab work and analysis," David said. "One set of samples will be analyzed using DNA extraction, polymerase chain reactions, and cloning to characterize the structure of the bacterial communities growing in the different stream channel treatments. Other samples will be incubated in two different bottle experiments to measure the functional capabilities of the communities from the different treatments. One bottle experiment will determine dissolved organic carbon utilization patterns, while the other will measure the ability of the various biofilm communities to process nitrate and ammonium."

Results from the community structure analysis and the functional capability experiments will be combined to determine whether or not eutrophication altered the biofilm community structure or its functional capacity. The enrichment gradient established in the 15 channels will help determine whether or not eutrophication thresholds exist for stream biofilm communities.

"Eutrophication in stream ecosystems is a widespread phenomenon. We currently don't know how this disturbance impacts stream biofilms, their diversity, and their ability to provide important ecosystem services. My goal is to provide answers to some of these questions," said David.

David at the Albuquerque Wastewater Treatment Plant

"Finding a site in New Mexico to do my research that has a running stream has been difficult. However, I think research aimed at keeping streams in working order is particularly important in this part of the country, where water is such a limited resource and where streams are intensively utilized, modified, and disturbed by humans."

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Bowman said his work brought the number of available tracers up from three or four to 16. "So it greatly expanded the opportunities and types of tests you can do in water tracing," he said. Bowman has also modified zeolites to filter various contaminants out of water. "We can sort of tune it to pick out certain contaminants from the water without removing other stuff," he said. In addition, Bowman developed an electrode system to remove pollutants from soils with very low fluid conductivity.

During Bowman's directorship of the Tech hydrology program from 1995-2005, the number of tenure-track faculty and research assistant professorships nearly doubled, Hendrickx wrote. Bowman has also written over 100 technical papers and holds one patent, with another in review.

Bowman has advised doctoral and master's students and supervised post-doctoral associates as well as being involved in middle and high school science classes or activities. "Dr. Bowman has had a lifelong commitment to encouraging young people to participate in science," Hendrickx wrote.

Bowman has held numerous leadership positions including his current chairmanship of Tech's Earth and Environmental Sciences Department and chair of the organizing committee for Zeolite 2006, the International Natural Zeolite Association quadrennial conference.

In addition to the Soil Science Society of America award, on January 25, 2008, the New Mexico Earth Science Achievement Awards will be presented

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to Dr. Bowman for outstanding contributions advancing the role of Earth science in areas of applied science and education in New Mexico. Maxine Goad will also be honored for her outstanding contributions advancing the role of Earth science in areas of public service and public policy in New Mexico. These annual awards are cosponsored by the New Mexico Bureau of Geology and Mineral Resources and the Energy, Minerals and Natural Resources Department in Santa Fe.

Dr. Bowman has participated in the WRRI's research program over the years including as a principal investigator back in the late 1980s. In 2003, he took part on a review committee assembled by the state's Commission on Higher Education to evaluate the institute. Dr. Bowman has also been an active member of WRRI's Technical Symposium Planning Committee. We congratulate him on his latest recognition.

WRRI Staff Changes

In August 2007, Kristine Kitchens retired from WRRI after four years on the staff. She had been with New Mexico State University for 25 years. Deborah Allen, who has been with WRRI since October 2004, was promoted into the vacated Projects Coordinator position. Deborah's duties include pre- and post-award research administration and supervising the institute's financial activities.

In December, the WRRI welcomed Annette McConnell who assumed the institute's Records Specialist position. Annette will assist Deborah in posting and reconciling accounts, maintain the institute's library and assist its patrons, assist with conferences and meetings, serve as the institute's receptionist, and work on special projects with other staff members.

Deborah Allen (left) and Annette McConnell

Annette moved to Las Cruces this past summer after living in Alaska for 30 years and is sure she will miss the beauty of Alaska's mountains and ocean. She worked in Sitka at the University of Alaska Southeast in the Business Department as a fiscal technician.

The college in Sitka was built in a World War II airplane hangar just a few feet away from the Pacific Ocean overlooking one of the harbors. There is a fish processing plant on the other side of the harbor where fishermen bring in their catch. Annette recalls daily sightings of eagles, sea lions, and seagulls enjoying the leftovers that the plant tossed into the sea. The WRRI staff feels it won't be long before Annette learns to love New Mexico's desert mountains and wildlife.

Annette is pursuing a degree in business administration and enjoys walking, swimming, cooking, reading, and sewing. She has two grown children who live in Alaska.

The WRRI wishes Kristine Kitchens well in her retirement and is pleased to have Annette on the institute's staff.

NMT Student Studies Upper Rio Grande Runoff Processes

by George Zamora, NMT

The south fork of Saguache Creek, looking west toward the headwaters and the drainage divide.

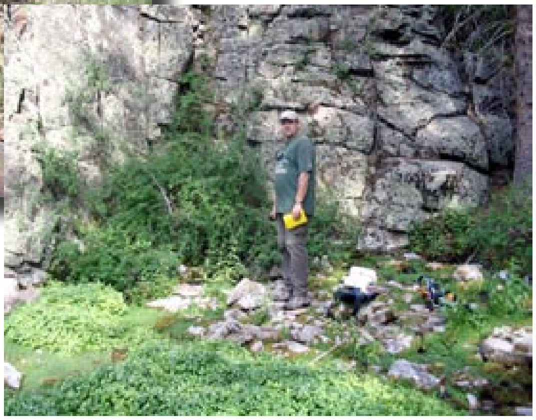
New Mexico Tech doctoral candidate Marty D. Frisbee can often be found hiking the high elevations of the northern San Luis Valley in south-central Colorado, not in hopes of taking in more of the beautiful scenery, but in trying to better understand the runoff and recharge processes of the Upper Rio Grande.

Marty's research study of a portion of the headwaters of the Rio Grande, titled *"Runoff Processes and the Evolution of Water Chemistry in the Saguache Creek Watershed of the Upper Rio Grande,"* is funded in large part by the New Mexico Water Resources Research Institute (WRRI).

"So far, during the first two years of this study, we're beginning to see some very interesting temporal and spatial trends in the stream, spring, and groundwater chemistry of our field samples," Marty says. "After analyzing water samples collected from 32 spring and stream sampling locations ranging from the headwaters to the lower reaches of this particular subcatchment, we're finding that stream chemistry appears to be heavily dependent upon groundwater contributions. Also, some interesting trends in chemistry emerge as the sampling scale changes within the watershed.

"Not a lot is known about the nature of deep groundwater flow within a mountain block, and, consequently, not much is known about deep groundwater contributions to streamflow in these settings, but what we're finding is that these contributions from the fractured bedrock may be significant," he adds.

Furthermore, Marty's initial findings about the water chemistry of streams in the high reaches of the San Luis Valley are likely directly applicable to watersheds found in geologically similar mountain ranges, such as the Cascades and Sierra Nevadas.



Marty prepares his instrumentation

"The results of this study will aid in understanding the partitioning of water and also will help develop better distributed models that simulate and predict mountain front recharge and flow and transport at high-elevation catchments," Frisbee says. "Also, the information we gain on water residence times, flow paths, and runoff mechanisms in headwater systems of the Rio Grande can be applied to larger-scale climate change models of the region."

Marty and his research colleagues, including his faculty and research advisor, hydrology professor Fred Phillips, at New Mexico Tech have used much of the WRRI funding made available for this particular study to purchase and install equipment to continuously monitor and data-log the chemistry at a long-term monitoring site located in the lower reach of the stream. Other lab equipment was purchased to measure the chemical composition of

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samples that are collected along a longitudinal transect of Saguache Creek.

A typical set of field measurements includes conductivity, pH, temperature, TDS, and various chemical components naturally present in the water, such as chloride, sodium, and calcium.

"It takes at least three or four days to retrieve the collected data from all the monitoring stations and gauge the flow at each site situated throughout this watershed during each sampling trip," Marty says. "And then after that, there's a good deal of lab work involved to identify and evaluate these deep groundwater contributions to streamflow. . .Nevertheless, my research at New Mexico Tech has introduced me to some beautiful places, which is a fringe benefit of studying hydrology."

Upcoming Meetings

February 21-22: 3rd Annual Water Conservation/ Xeriscape Conference, Albuquerque, NM (http://www.xeriscapenm.com)

March 7: Workshop on New Mexico Hydrologic Resources – Measurements, Modeling, and Online Tools, Socorro, NM (http://www.nmepscor.org/HydroWorkshop.html)

March 17-19: 2008 AWRA Spring Specialty Conference – GIS and Water Resources V, San Mateo, CA (http://www.awra.org/meetings/San_Mateo2008/)

August 12: New Mexico Water Research Symposium, Socorro, NM (http://wrri.nmsu.edu)

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