

Letter to a Young Scientist

Always stay curious!

By DR. NATALIE KRUSE DANIELS

Dr. Natalie Kruse is an Associate Professor and Director of the Environmental Studies Program, Voinovich School of Leadership and Public Affairs, Ohio University, Athens, Ohio. An alumna of State Science Day and other Academy programs, she currently directs the Academy's District 12 Science Day at Ohio University. Early, pre-college research efforts helped draw Dr. Kruse toward a BS, magna cum laude, in civil engineering and a minor in geological sciences from Ohio University. She received both a Barry M. Goldwater Scholarship and a Morris K. Udall Scholarship. Her British Marshall Scholarship led to a 5-year stint in England where she received a PhD in civil engineering and geosciences from Newcastle University, United Kingdom.

ALWAYS STAY CURIOUS! The most exciting scientific problems of today need curious minds to solve. I grew up curious about the world around me. When I was eleven, my mentor, Dr. Mary Stoertz, a geology professor from Ohio University, took me to a water education day. On the way, we collected water quality samples from a few abandoned underground mines. I was beyond curious!

Deep-red or cloudy-white water flowed from the mine openings into creeks, a legacy of a century of coal mining without regulation. We looked downstream where no fish could live and even the plants and trees growing near the stream were impacted by the drainage. We tested the water and found that it was as acidic as vinegar. I had so many questions: What caused this acidic water to flow from the mines? What were the impacts? What could we do about it?

What I saw on that field trip was acid mine drainage caused when pyrite, or fool's gold, is exposed during mining. It reacts with water and oxygen and releases iron and sulfuric acid. The acid then dissolves other metals into the water. This leads to rusty-red water rich in iron or a cloudy-white water rich in aluminum. Acid mine drainage impacts not only water quality, but also aquatic organisms. Streams impacted by acid mine drainage tend to have few fish or bugs and don't function like a healthy stream. Acid mine drainage is

usually treated by adding a basic chemical, like lime or limestone, to the water to neutralize the acid. At a neutral pH, metals tend to precipitate and deposit on the streambed or in specially created sediment ponds. This treatment is expensive and must be done forever if the streams are going to recover.

My curiosity drove me to experiment, so I designed science fair projects through middle and high school to start answering my questions. First, I studied how the vegetation on the banks of streams varied with water quality. Not only was the community of plants and trees different at the mine site when compared to an unimpaired site, but those at the mine site were also smaller despite their age. This led to the next question—how would plants respond to being watered with acid mine drainage when compared to tap and distilled water. The plants watered with acid mine drainage did not grow. It was clear that acid mine drainage impacted plant communities, so I moved on. What could be done to treat it?

After reading scientific papers and books about the subject, I planned my next experiment. I would compare treatment systems for acid mine drainage and report on their effectiveness. With the help of the shop teacher, I built three plexiglass tanks to set up bench-scale treatment systems in my bedroom (sorry Mom!). I gathered buckets and buckets of acid mine drainage from an abandoned mine in the nearby Wayne National Forest and set up my tanks. One system represented a shallow wetland with plants, one represented a limestone leach bed, and one represented a deeper wetland with less oxygen than the shallow one. Daily, I dutifully added acid mine drainage to the tanks and took samples from locations I had drilled into the tanks. I tested how water quality changed from the influent to the effluent and started to understand how the treatment systems worked. I had the great honor of presenting my research at the District 12 Science Day in Athens, Ohio, the Buckeye Science and Engineering Fair (BSEF), the State Science Day, and the International Science and Engineering Fair (ISEF). It was a whole new world

of curiosity—in both high school and beyond I had opportunities to talk to experts and scientists and to ask new and exciting questions.

As a senior in high school, I wrote a computer program to determine the best type of acid mine drainage treatment system to use at a site based on the water chemistry and information about the location. It was an idea I gained by collaborating with other scientists and mentors, and I spent lots of all-nighters (sorry Dad!) writing code and testing the program. I incorporated the best science to date and tested my program on numerous abandoned mine sites across southern Ohio. Again I got to present my research at District, BSEF, State Science Day, ISEF, and even at two national and international conferences thanks to supportive mentors.

With these experiences behind me, and a renewed curiosity about the world, I began my full-time studies at Ohio University seeking a degree in civil engineering with a minor in geological sciences. As an undergraduate I stayed involved in acid mine drainage research, but was able to expand my skill set—and my flexibility as a scientist—by getting involved in other research. I learned how to make and test asphalt, experimented with biodiesel production from waste grease produced from the dining halls, developed a low-cost system to remove arsenic from drinking water, designed a system to treat water from a produce-wash facility, and designed water treatment for a tanker-truck wash-out facility. I gained new research skills that helped me realize my passion about the natural water environment and addressing the pollution caused by mining. With that self-assurance, I began to seek opportunities for graduate study.

My research and academic mentors supported me in my application to be a Marshall Scholar and study in Newcastle upon Tyne in North East England, an ancient home of coal mining and current home of eminent scholars on water impacts from mining. To my great surprise, not only did I get an interview, I was offered one of 40 scholarships in the nation. I have to admit that I was scared and nervous to take this next step and move overseas, but I was also excited and still curious. I studied with some of the best scientists in my field at Newcastle University and collaborated to create a computer model that tracked the sources and sinks of pollution in abandoned underground mines, playfully called POSSUM (Pollutant Sources and Sinks in Underground Mines). I sampled water in two abandoned underground mines regularly, one

that had been mined for coal and one that had been mined for lead and zinc. Beyond my dissertation topic, I also contributed to research on the effectiveness of acid mine drainage treatment systems in Northern England. After earning my PhD and staying on at Newcastle University for an additional two years to do further research, I got an offer to return to the United States as a faculty member.

In 2009, five years after moving to England, I relocated back to Athens, Ohio, to become a faculty member in the Environmental Studies Program at Ohio University. At Ohio University, I have had the honor of working with an interdisciplinary group—the Appalachian Watershed Research Group—from across campus to ask and answer interesting questions about what is affecting the watersheds in southern Ohio and how to recover good biological communities. We tackle questions from different perspectives (biology, plant biology, geochemistry, engineering, and hydrogeology) and develop answers that are deeper and more interesting than any single aspect. We bring students from many disciplines together to study stream systems, building an understanding of the importance of interdisciplinary research. I've become the Director of the District 12 Science Day; now my students, colleagues, and I get to support the next generation of young scientists in our district as they develop into STEM professionals in an increasingly complex world.

We live in a changing world that requires answers to complex problems; we need curious people to continue to seek these answers even though the road may be long and difficult. At Ohio University we are investigating the important question: Why don't fish and bugs always return to a stream after the chemistry is returned to normal? Streams are complex systems and acid mine drainage impairs their most basic functions in addition to creating a water environment that struggles to support life. This problem cannot be answered by only one discipline. Now we ask: How do changing energy systems affect our water environment? How will climate change affect these same streams?

From early curiosity and science fair exploration, I have been able to develop a career based on what I love and what I'm still curious about. I have been supported by mentors who saw potential in me and, now, I get to mentor young scientists. It is most important to find what you're excited about, what you're curious about, and never stop asking questions. Then get to work to find the answers.