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Natural Resources Research Institute

# NRRI Now

A monthly newsletter from the Natural Resources Research Institute
**April 2023 | Volume 08 | Issue 4**

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## Meeting at the Crossroad

NRRI's charter, 40 years old this summer, has tension built into it.

Fostering the economic development of Minnesota's natural resources in an environmentally sound manner to promote private sector employment.

It puts us at the intersection of environment and economy, meeting the needs of today without hindering the prosperity of future generations. No small feat!

As we celebrate Earth Day on April 22, join me in pledging to change a wasteful habit. I am trying to reduce the amount of plastic in our house by eliminating liquid laundry detergents, shampoos and dish soaps, reusing all plastic bags and -- my final hurtle -- eliminating plastic wrap.

Get inspired at earthday.org.

**June Breneman**
Editor, Marketing & Communications Manager
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# State support prepares MN for future success

Rolf Weberg gestures to research staff while talking to UMN Associate VP of Research Amy Kircher (right) and VP of Research Shashank Priya during a 2022 visit to NRRI Coleraine.

June Breneman
Apr 5, 2023

## Legislation will bolster NRRI research capacity and delivery

Minnesota's future opportunities require investment today. The state's transformative investment in research by E.W. Davis at the University of Minnesota during the 1950's saved the Iron Range with taconite pellets. The industry was able to transition from lean ores to pellets to keep providing domestic ore resources to the nation's steel plants.

Today's challenges and opportunities are just as disruptive and complex but offer exciting possibilities for Minnesota's future economy. But we need to be ready to support the technologies of the future with research.

And, like eggs and automobiles, salary and equipment costs have risen which means the cost to do research has increased. NRRI's stagnant base funding hasn't kept pace with 35 years of inflation despite the growth of the Institute and the expanding state and federal expectations.

"We just stretched our base funding to hire three new metallurgists," said NRRI Executive Director Rolf Weberg. "Now, we're poised with the expertise we need to move the Iron Range forward, which will move Minnesota forward."

## What's Next?

"What are the new disruptive technologies in the minerals, wood and biomass, forest products, water treatment and ecosystem monitoring sectors?" Weberg asks. "There's a lot of innovation happening there. Will we be ready? Will we have the key players and support staff?"

NRRI's goal is to have the core team ready to engage, partner and execute with new opportunities. That means hiring and retaining top talent, providing the necessary technical and research support in the form of equipment, instrumentation and infrastructure. Inquiries to assist in these innovations has increased, and NRRI wants to have the people-power to onboard these projects at the speed of business.

## Funding MN's Future

The omnibus bill in both houses of the legislature has included a one-time increase to NRRI's base funding for FY24 and FY25 to help bridge the base funding gap with $2M/year via the Higher Education Committee. This is of critical importance to have this support right when state agencies, the federal government and industry partners are engaging NRRI for assistance.

The Governor's budget includes an MPCA-sponsored change item, Innovative Solutions for Managing Pollutants, provides $3M in critical funding for NRRI demonstration projects:

$2.1M to support demonstration projects in water treatment/remediation targeting sulfate, phosphate and PFAS contaminants.

$900K to support NRRI's long-term Iron of the Future program to characterize Minnesota's varied iron resources and create new technologies to process them, while reducing energy and water consumption and capturing industrial effluents.

These two efforts have bipartisan legislative support. Senators Grant Hauschild and Jennifer McEwen and Representative Dave Lislegard have "carried the water" to ensure these provisions progress during the session, according to Weberg.

So how can you help? Please encourage your legislators to continue to support NRRI's requests. A quick note or email makes a big impact. (Here's how.) The passing of this legislation will allow NRRI to be ready to partner effectively to accelerate disruptive technologies and opportunities already peeking over Minnesota's horizon.

# Delivering on sulfate remediation

Chan Lan Chun works in the pilot scale biological sulfate remediation trailer.

June Breneman
Apr 5, 2023

NRRI sulfate remediation technologies ready for industry, agency collaborations.

Minnesota has a globally unique challenge to reduce sulfate levels in wild rice water bodies to 10 parts per million (ppm). It's a regulatory standard set so low that no other states or countries have even tried to develop a way to achieve that. For comparison, the drinking water standard for sulfate levels is 250 ppm.

Sulfate concentrations at high levels also cause scaling and corrosion in industrial infrastructure during water reuse processes. The need to manage sulfur-rich dissolved solids is a challenge for mining, power generation, paper production and other industries.

NRRI has taken on these challenges by developing multiple processes that can reduce sulfate concentrations in a variety of wastewaters and for varying sulfate levels. Three of these technologies have achieved success in lab tests, and two of them have been piloted and demonstrated in real-world applications.

## Ready for the Next Step

In March, NRRI's lead researchers presented the state of the technologies in a webinar to a variety of stakeholders – from industry representatives to state and tribal resource managers. The 78 registrants got an overview of three approaches, each having specific benefits and challenges to be addressed.

"NRRI is really pushing the envelope to make a positive impact for Minnesota," said Jill Crawford-Nichols, NRRI's Technology Development Manager. "These technologies are ready for the next milestone and we will need the right partnerships to get them there."

# A Challenge for Minnesota and Beyond

In April 2022, the Minnesota Pollution Control Agency identified three new water bodies impaired by sulfate levels that could harm wild rice growth. The Agency's bi-annual accounting is required by the federal Clean Water Act to list, and make publicly available, impaired waters that fail to meet water quality standards.

NRRI is developing treatments that target three different levels of sulfate in Minnesota waters:

1. 50 – 250 ppm (typical range in municipal water treatment facilities) treated to 10ppm and lower.
2. 250 – 2,000 ppm (range associated with mine pit lakes and agricultural runoff) treated to below 250 ppm.
3. Greater than 2,000 ppm (associated with power generation and industry effluent) treated to greater than 250ppm.

"Each of these challenges may require a portfolio of two or more technologies in combination," explained NRRI Director of Research, Lucinda Johnson. "There are technologies out there now – reverse osmosis and nanofiltration – but the cost and infrastructure are expensive."

# Treatment Technology 1: Low Sulfate Levels (Targeting Level 1)

Sulfate dissolves in water, which makes it challenging to remove. But when barium chloride is added, the sulfate reacts rapidly to form small particles of insoluble barium sulfate, or barite. A second flocculant chemical is then added which clumps the particles together so the barite sinks and can be removed. A final filter is added at the end of the process.

"This process has been used to remove sulfate at high concentrations, so it's not new," said Mei Cai, lead researcher and NRRI environmental engineer. "But it hadn't been accomplished at such low sulfate levels."

*Photo left: Mei Cai in the chemical treatment trailer.*

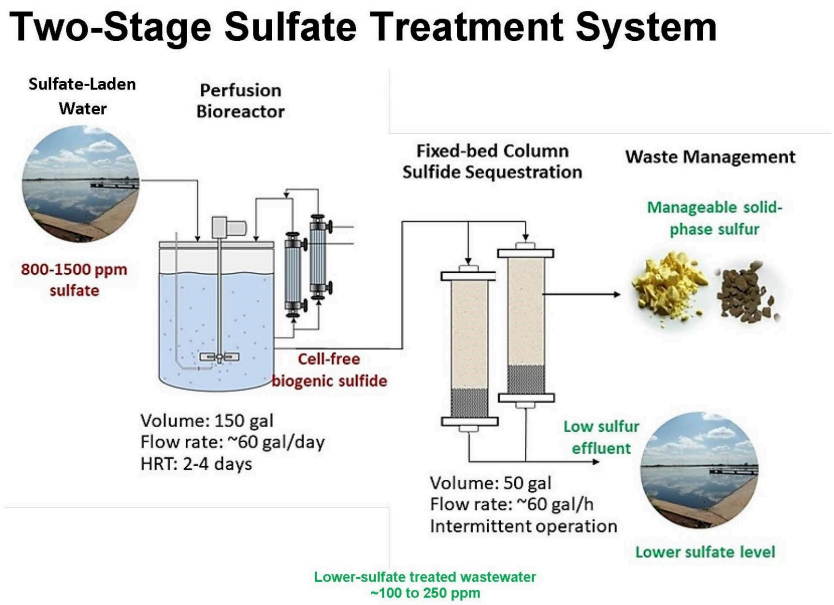
The effort started five years ago in the lab and successful results led to a scaled-up pilot system deployed in a trailer to three water treatment facilities in northern Minnesota. The system successfully reduced sulfate levels to below 10 ppm and a lot was learned. This technology currently operates at a small scale of 1 to 2 gallons per minute and is being developed for full-scale application.

"It's a very simple system and uses existing equipment at the treatment plants," said Cai. "But we'd like to figure out how to manage the chloride that is left in the water and develop a strategy for repurposing the resulting sludge. We also need to develop a plan for commercial application of the technology."

# Treatment Technology 2: Mid-Range Sulfate Levels (Targeting Levels 2 & 3)

Certain bacteria have evolved to metabolize sulfate, similar to how we metabolize food. These bacteria are widely present in the environment and are being applied in an active sulfate reduction process. In this case, the bacteria are collected from the environment and grown in a controlled bioreactor. Sulfate-containing water is passed through the bioreactor.

The bacteria consume sulfate and convert it to sulfide which reacts with iron, resulting in a stable iron sulfide that can be safely stored. The iron used in the process is Minnesota taconite byproducts. A pilot-scale system was recently deployed at an energy production plant and successfully reduced sulfate from 2,000 to 3,000 ppm to less than 500 ppm.




Nate Johnson

“Now, with our grasp of the underlying process, we think we can begin to test and implement this approach on a larger scale using commercially available equipment,” said Nate Johnson, environmental engineer at UMD. “I think we can have this active biological sulfate remediation process ready in the next 3 to 5 years, or sooner if we can get the right partners to help us move to the next phase of development.”

## Technology 3: Wide-Range and Elevated Sulfate Levels (Targeting Levels 2 & 3)

A passive, electrochemically-enhanced bioremediation method is being developed in the lab to address a wide range of sulfate levels (from 400 to >2,000 ppm). It uses the same sulfate-consuming bacteria in a landscape-scale treatment system, like an engineered wetland.

“We use electrodes to ‘tickle’ the bacteria which makes them more active,” explained Chan Lan Chun, NRRI environmental engineer. “Pit lake water can be passively fed into the landscape to reduce sulfate levels with electricity generated by solar panels.”

Currently, this process is being tested in a lab-scale bioreactor with sulfate-impacted soil. The researchers are working to control the sulfate reduction rate while limiting mercury methylation reactions during the process. Chun and her team are also working on a conceptual design for a scaled-up demonstration process using mathematical simulation.

## Partners Wanted

Moving these technologies forward for real impact around the state requires key partnerships and creative thinking. The hope is that the broader teams built around the sulfate challenge will lead to commercialization.

“This program really showcases NRRI’s mission to deliver integrated research solutions for Minnesota,” said Rolf Weberg, NRRI Executive Director. “We took on this challenge with key partnerships and state legislative support, but it’s time to push this beyond our walls with a bigger team effort.”

For more information, contact Tim White, NRRI director of Partnership Development, at twwhite@d.umn.edu.

# Expanding biochar's potential

June Breneman
Apr 5, 2023

Bridget Ulrich pours biochar into a beaker in 2020.

## Promising lab results raises biochar's potential to filter pollutants in stormwater runoff.

Back in 2008, scientists started calling biochar “black gold” for its ability to improve poor agricultural soils. But in this era of climate change concern, biochar’s bigger value may be as a significant carbon sink opportunity. It has earned a respected place in the $1 billion carbon offset credit market, offering companies a way to mitigate their carbon impact by removing carbon elsewhere.

Meanwhile, this “black gold” can do another important job – filtering contaminants from stormwater runoff. But not all biochars are created equal. And the function depends on both the type of contaminant and the type of biochar.

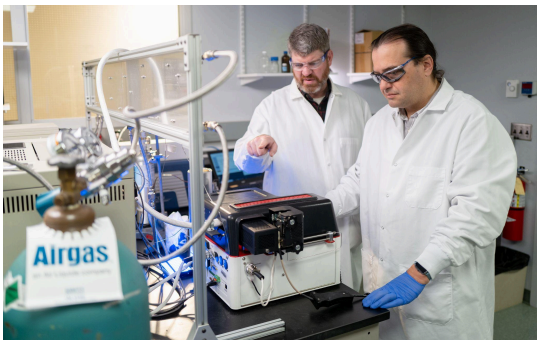
A team of NRRI researchers are working to sort it all out. Environmental Chemist Bridget Ulrich leads one team in collaboration with the Chemistry and Materials Science team. Together, they have made significant headway in understanding what it takes to use biochar effectively to filter stormwater pollutants, conducting a series of experiments from lab scale to demonstration scale.

And what they’ve learned is…. it’s complicated.

“Biochar is not the silver bullet; it has limitations and challenges,” said Ulrich. “But it can be very useful if used correctly.”

# Understanding Biochar

Biochar is (not so simply) charred biomass, like charcoal but with key differences. The beauty of biochar is in its pores, especially biochars with micropores – tiny channels within the biochar material – called “intraparticle” porosity.




These micropores can provide some biochars with up to 5,000 square feet of surface area per gram. But not all biochars contain surface areas of this magnitude. Biochars with low porosity can house surface areas of less than a hundred square feet per gram. To the naked eye, most biochars appear the same, a black powdery substance. But at the microscale, it’s like the difference between a mansion and a shed.

Biochar is commonly produced by pyrolysis, heating in a low-oxygen kiln, in ranges of 500 degrees F to nearly 2,000 degrees F (250 Celsius to 1,000 Celsius). In contrast to combustion, which converts carbon in biomass to carbon dioxide, pyrolysis instead concentrates the carbon to a form that can remain stable for hundreds of years. This is what makes biochar a potential “carbon sink.”

Kiln temperatures and different biomass feedstocks – from wood waste to agricultural waste – affect the properties of the end biochar product. For example, biochars produced from woody feedstocks at higher temperatures tend to contain higher porosities and higher fixed carbon content. In contrast, biochars produced from the same feedstock but at lower temperatures have lower microporosities and less charred surfaces. The variety of equipment being used also changes the outcomes.

Biochar applied as an agricultural soil amendment or to capture carbon is largely dependent on the amount of stable carbon in the final product. But capturing finicky contaminants requires a variety of process considerations to ensure the selected biochar has the right properties for the job.

“There are a lot of studies out there about how the contaminants are removed with biochar at the lab scale,” said Ulrich. “But that knowledge isn’t being translated consistently into the biochar production industry. Our work to fill in the gap at intermediate scales will help with that translation.”

# In the Lab

Ulrich’s team is testing and documenting which contaminants are best filtered with which biochars. They are also working with the Chemistry and Materials team to understand what material properties make biochars effective for filtering contaminants. Ultimately, NRRI researchers hope to be able to provide a biochar guide with specifications for the type of biochar needed to remove specific contaminants.

They’ve identified key properties including the intraparticle porosity – the space available to house contaminants – surface chemistry. And while “the bigger the better” may be true for contaminants that are drawn to higher fixed carbon surfaces (such as organic contaminants like pesticides), this is not

necessarily true for all contaminants. For example, contaminants like dissolved metals, which are positively charged, tend to be more attracted to less charred surfaces, which contain more negatively charged sites.

*Photo right: Bridget Ulrich*

“It’s important for stormwater treatment facilities to first know what their primary target is for contaminant removal,” Ulrich explained. “Then they can acquire a biochar that has the properties with the best chance for success and test it to make sure it works under environmentally relevant conditions.”

## Real World Trials

Ulrich’s team is working with several partners to help translate success from the laboratory to the field. Over the last two years, they have been working with the Mississippi Watershed Management Organization to install biochar in a demonstration-scale stormwater filtration system. This mobile unit will evaluate its effectiveness for treating parking lot runoff before it drains into the Mississippi River.

They also recently partnered with the Lake County Soil and Water Conservation District to assess the performance of a new biochar filter. It will be installed this summer to treat runoff draining into Agate Bay.

## Addressing Challenges

One of the challenges is understanding how biochar performance differs in the lab where conditions are clean and controlled, versus in the environment where conditions can be dirty and unpredictable. The researchers are addressing this problem by conducting experiments that simulate realistic conditions and using natural waters, but in filter vessels that can fit in a greenhouse.

And there are more challenges. Biochars that are produced under controlled conditions in the lab are not available at scales large enough to install in treatment systems in the field. Most biochar products on the market today are meant for soil amendment, and their potential effectiveness for stormwater treatment is unclear.

NRRI is working to span this scale-up gap between bench and demonstration scale production. A mid-sized kiln will be acquired allowing them to produce kilogram quantities of custom, experimental biochar at a time. The researchers will evaluate the performance of the biochar materials under realistic conditions to influence production procedures adopted by large scale producers.

“I think, as we work more on these intermediate scales to evaluate performance there might be more of a market ahead for biochars specialized for water treatment,” Ulrich said. “I see a niche emerging for biochars produced under more controlled processes.

“If it’s certified for specific uses, it could be a value-add material. But we need to make sure we don’t over engineer ourselves out of the market,” she added.

# Tiff's Tip #14 - Earth Day 2023

## Tiff pens a poem in an Ode to Mother Earth

Tiffany Sprague
Apr 5, 2023

*Tiffany Sprague is NRRI's Sustainability Coordinator (among other roles), helping us all live out our best, sustainable lives at work and at home. This month's blog is an Ode to Mother Earth.*

I got a lot of flack from my fans for not writing an April article last year to honor Earth Day (thanks, mom and dad). To avoid the familial humiliation this year, I'm going to push through this head cold, throat lozenge and tea at the ready, and hopefully offer Mother Nature some of the justice she deserves.

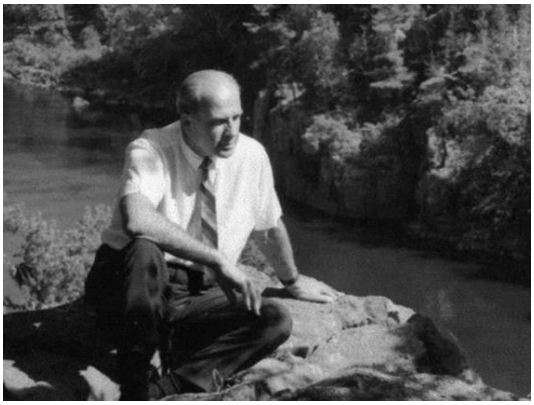
## An Ode to the Earth

April 22, 1970:
Earth Day is born from creativity
By Senator Gaylord Nelson,
Hoping to get national attention.

Following in his legacy
The U.S. creates the Environmental Protection Agency.
Based on science, research and facts,
We get busy passing many acts.
Safe Drinking Water, Endangered Species, Clear Air -
And many more in our pursuit of being fair.

Reflecting in 1980,
Senator Nelson passed along this malady:
Our very survival will depend
Upon our ability to preserve, protect and defend.

We are not free to decide about whether
Or not our environment matters.



What are you choosing to do on this day,
So Mother Nature and her creatures no longer pay,
For propping up the human race,
Attempting to keep up with our pace?

Big or small,
You cannot do it all.
Identify a task,
A friend to join you, you might ask,
The more the merrier,
And bring along the neighbor's terrier!

Doing good deeds for the Earth,
Will add to your sense of worth.
I look forward to hearing what you choose to do
For Earth Day 2023, woo hoo!

See y'all in a jiff,

Tiff

*Photo left: Gaylord Nelson*

# Meet the Researcher – Malachi Granmo

Malachi Granmo at work at the Ballast Water Treatment System Testing Facility in Superior, WI.

June Breneman
Apr 5, 2023

## A winding path leads aquatic scientist to study water's tiniest inhabitants

You've heard the phrase "When one door closes, another opens." For Malachi Granmo, the closing of the company he worked for back in 2011 opened a door to graduate school and, eventually, to NRRI.

Granmo is a protistologist, an expert in the tiny critters at the bottom of the aquatic food chain – phytoplankton, diatoms and tiny invasive species -- so he spends a lot of time looking through a microscope. But as the seasons change, so do his tasks.

"The work I do is varied and sometimes fast-paced," he said. "Winter is data entry, lab work and writing papers. But late spring to early fall I'm at a facility in Superior, Wisc., testing ship ballast treatment systems, validating the facility's results, and helping with other projects. I also go on trips throughout the Great Lakes to test water in ship ballasts."

On the long trips, Granmo sets up a temporary lab in a hotel and waits for colleagues to bring ballast water samples to him from a ship that is moored at a nearby port. There, he uses a microscope to identify what's travelling in the ballasts. The samples come in sporadically – it could be 3 p.m. or 3 a.m. – but Granmo is always ready. This year, a week-long trip covered six states – from Minnesota to Ohio and back again.

"I am also working on a project to analyze sediment cores from the St. Louis River Estuary for metals which will teach us about industrial legacy pollution," said Granmo. "Knowing the historic levels of certain contaminants can help Minnesota set reasonable standards for remediation."

## Circuitous Route

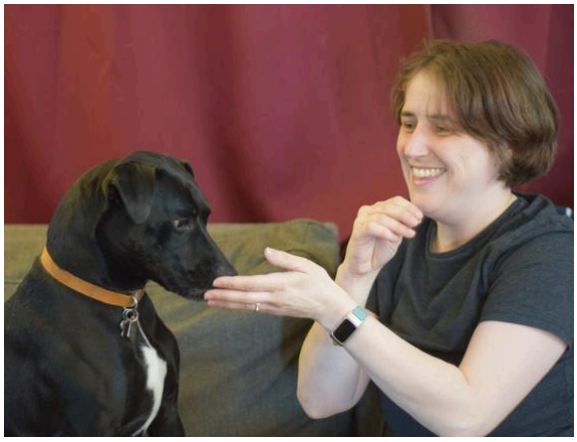


*Photo left: Malachi and rescue pup, Tahani.*

Malachi started his college career at Bowling Green University in Ohio with a nine-week geology field program, travelling across the U.S. in vans and sleeping in tents. He also considered careers in social work and creative writing. But it was a Biology 101 class that introduced him to diatoms and algae. He had found his focus.

“So then I switched majors again in my junior year and started taking biology classes,” he said. “But I still managed to graduate on time.”

In 2015, Granmo graduated with a master’s degree in the Water Resources Science program at the University of Minnesota Duluth, and then joined NRRI as a full-time aquatic research scientist. The Institute is also giving Granmo a chance to stretch – both personally and professionally – with a role as a founding member of NRRI’s Diversity-Equity-Inclusion (DEI) Committee, in which staff volunteers recommend policy and opportunities to NRRI leadership.

“That's a position I wouldn't have seen myself in 10 years ago,” said Granmo, “but with the murder of George Floyd in 2020, I felt like I needed to get involved in some way.”

## Collaborative Effort

Granmo takes good advantage of the broad expertise throughout NRRI – especially for geochemistry projects, where he needs geology and mineralogy data.

“I published two substantial papers in the journal PeerJ with help from our Minerals Research Group,” he said. “And I plan to bring them in to help me with minerals characterization for the St. Louis River Estuary project.”

He also collaborates regularly with professors in UMD’s Swenson College of Science and Engineering on the Great Waters Research Collaborative ballast water treatment system research.

## Central Support

It takes a lot of lab supplies and unique equipment to pull off the work Granmo does. He relies heavily on the purchasing support of Tammy Thomasson-Ehrhart to get what he needs. Given recent supply chain issues this is often quite challenging. He also gets assistance from shop professional Scott Johnson to construct specialized sediment sampling devices.

# Off Hours

Granmo enjoys getting together with friends to play the fantasy Dungeons & Dragons tabletop game.  He is also training his dog, Tahani, a rescued mix-breed, with a goal to compete in agility courses.

“She’s a really smart and energetic dog and these activities help her work out her physical and mental energy,” Granmo added.

*Edited to reflect name change from Meagan Aliff.*

# About NRRI

The Natural Resources Research Institute was established by the Minnesota legislature in 1983 as an applied science and engineering research organization to inform state citizens and decision-makers while leveraging the power of the University of Minnesota. **The forward-looking charter provided by the Legislature is to *foster the economic development of Minnesota's natural resources in an environmentally sound manner to promote private sector employment.*** We are a mission-driven, project-focused team working to create opportunities for natural resource stewardship.

As part of the University of Minnesota system research enterprise, the Natural Resources Research Institute (NRRI) employs over 140 scientists, engineers, technicians, staff and students in two industrial research facilities.

### Two Industrial Research Facilities



NRRI has extensive laboratory capabilities to discover and deliver at the bench-to-pilot scales, reducing risk inherent in commercializing innovations. NRRI Duluth has 19 labs to meet the needs of land, wildlife, water and minerals research. There's also an additive manufacturing lab and several technology development labs. NRRI Coleraine is a 27-acre site focused on minerals and bio-based energy research.

## NRRI Mission

Deliver integrated research solutions that value our resources, environment and economy for a sustainable and resilient future.

## NRRI Vision

Discover the economy of the future.

**Find out more:** NRRI website / Facebook / Twitter / Instagram / YouTube / LinkedIn