UNIVERSITY OF WISCONSIN–MADISON
COLLEGE OF ENGINEERING

FALL 2021 NEWSLETTER

CIVIL & ENVIRONMENTAL ENGINEERING

ENVIRONMENTAL EXCELLENCE

New undergrad major amplifies environmental impact

Greetings from beautiful Madison!

I'm writing from Engineering Hall, surrounded by the exciting and hopeful energy of a new semester with students back on campus. It's wonderful to see our hallways and classrooms filled again as we cautiously start a new chapter after 18 remarkable and uncertain months. Students are thrilled to be back on campus, and I think the future looks bright from here.

This newsletter highlights exciting new directions for the department, including our new bachelor of science in environmental engineering degree, which after many months of tireless effort led by Professor Greg Harrington, will see its first cohort of students this fall. The BSEnvE degree is the third undergraduate degree offered by our department, joining the long-established civil engineering and geological engineering degrees. You will also learn about fascinating research in herbicides, sustainable cement production, and PFAS, in addition to the many activities and accomplishments of our students and faculty.

Thanks to all of you for your support and engagement with the department. Our alumni are a dedicated group, and many had a blast at our 24th annual golf outing held in early September. We had 200 golfers join us on what may have been the nicest day of the year and we raised significant funds to support student activities including the concrete canoe and steel bridge teams. It's never too late to help, and if you would like to support the program, please contact Rob Herrick (Rob.Herrick@supportuw.org) or me directly (likos@wisc.edu).

I hope you enjoy reading about our outstanding department.

On, Wisconsin!

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Engineering students' engaging educational game gaining momentum

The educational board game that Joel Baraka developed emerged in large part from his experiences as a child in Africa.

Now he's starting to receive national and international attention and funding to further develop the game.

Fifth-year senior Baraka and fellow civil engineering student Anson Liow created the 5 STA-Z educational board game for use in Ugandan refugee camps. It incorporates core curriculum subjects taught in Uganda—math, science, social studies and English—and breaks them down into easy-to-understand parts for a unique blend of learning and fun. The result is that students in the large camp classes stay more engaged in the classroom.

Baraka knows the refugee experience himself; he was born in the Democratic Republic of Congo, but his family fled to Uganda's Kyangwali Refugee Settlement to escape civil war in his home country. He attended high school at the African Leadership Academy in South Africa and came to UW-Madison through the university's King-Morgridge Scholars Program.

Baraka and his team have won a $5,000 Wisconsin Ideas fellowship and $4,000 in prizes from the 2021 Transcend Madison competition. And they have, with the support of collaborator Emily Chan, raised approximately $16,000 through a give.asia campaign focused on overseas donations. All of that is in addition to a GoFundMe campaign that's generated more than $12,500 in donations to support 5 STA-Z.

Thanks to the awards and support from donors around the world, Baraka and his team can expand the reach of his education game faster than even he anticipated. The more than $40,000 they've raised so far will allow 5 STA-Z to fully support the Kyangwali Refugee Settlement, the first partner camp for the project. Now, Baraka is working to expand to the nearby Kyaka II Refugee Settlement by August 2021 and hopes to reach a third refugee camp by the end of the year.

"Anson and I have some exciting plans this year and this money will be able to take us far if we can sustain the focus," Baraka says. "A few years ago when I started working on this, it was just going to be for one class, then I started thinking about multiple classes, and now we are working with schools and communities. When we raised the money on GoFundMe, the idea of going to other refugee camps came to mind, but I never imagined it would be this quick."

New environmental engineering major is a natural fit for undergrads

A new engineering bachelor's degree at UW-Madison will prepare students for a lifetime of work as leaders in environmental engineering through exposure to multidisciplinary work and building communication and team skills.

The BS in environmental engineering degree, or BSEnvE, is now available to first- and second-year CEE students. Professor Greg Harrington, who oversaw the program's creation, says it builds upon previously existing environmental engineering offerings and provides students deeper specialization that was not previously available through the environmental engineering option in the civil engineering major.

Ultimately, the major will include approximately 150 students at any given time; in addition to a strong foundation for careers in environmental engineering practice, it will also prepare students who want to advance into graduate school for environmental engineering or pursue other graduate majors, including the environmental chemistry and technology and environmental science programs at UW-Madison.

Students in the program will learn about the design, construction and operation of systems or facilities that treat and distribute water; manage solid waste; protect natural water resources such as streams, lakes, wetlands or groundwater; manage stormwater to minimize flood risks; and treat and minimize industrial and agriculture waste and air pollution.

Due to the urgent threat climate change poses to communities around the world, the environmental engineering program will also include a focus on sustainability—emphasizing meeting today's needs while allowing future generations to achieve their needs for environmental health, public/societal health, and economic health. As such, the program will empower students to design solutions that prepare society to face the impacts of climate change, and allow students to explore ways to slow down or reverse climate change by implementing sustainable energy sources and recovering greenhouse gasses from industrial air emissions.

Harrington says these experiences will allow students to contribute immediately in the workplace when they graduate. "For example, they'd work with engineering firms to design and implement the sustainable and resilient strategies needed to manage the environmental problems that are here now and on the horizon," he says.

Drying out

Prabhakar receives NSF CAREER Award to study moisture's impact on polymer composites

Fiber-reinforced polymer composites are used in countless facets of everyday life, from the vehicles we travel in to the infrastructure in the world around us.

Charles G. Salmon Assistant Professor Pavana is seeking ways to better design these commonplace materials to deal with another ubiquitous substance: water. Whether used in aircraft fuselages, automobile chassis, pipes and even marine structures, polymer composites inevitably come into contact with moisture.

"In all of these applications, these composites are exposed to moisture to different extents," Prabhakar says. "For example, in marine decking, there's constant contact, while for aircraft fuselages, it's just moisture in the air. Whatever the amount, moisture is detrimental to these structures; we've seen weight gain, swelling and premature structural failure when they are exposed to moisture."

Prabhakar received a prestigious CAREER Award from the National Science Foundation to tackle this issue. The $536,00 grant will fund a five-year research project in which she will use novel experimental and computational research approaches to better understand how moisture can infiltrate the composites.

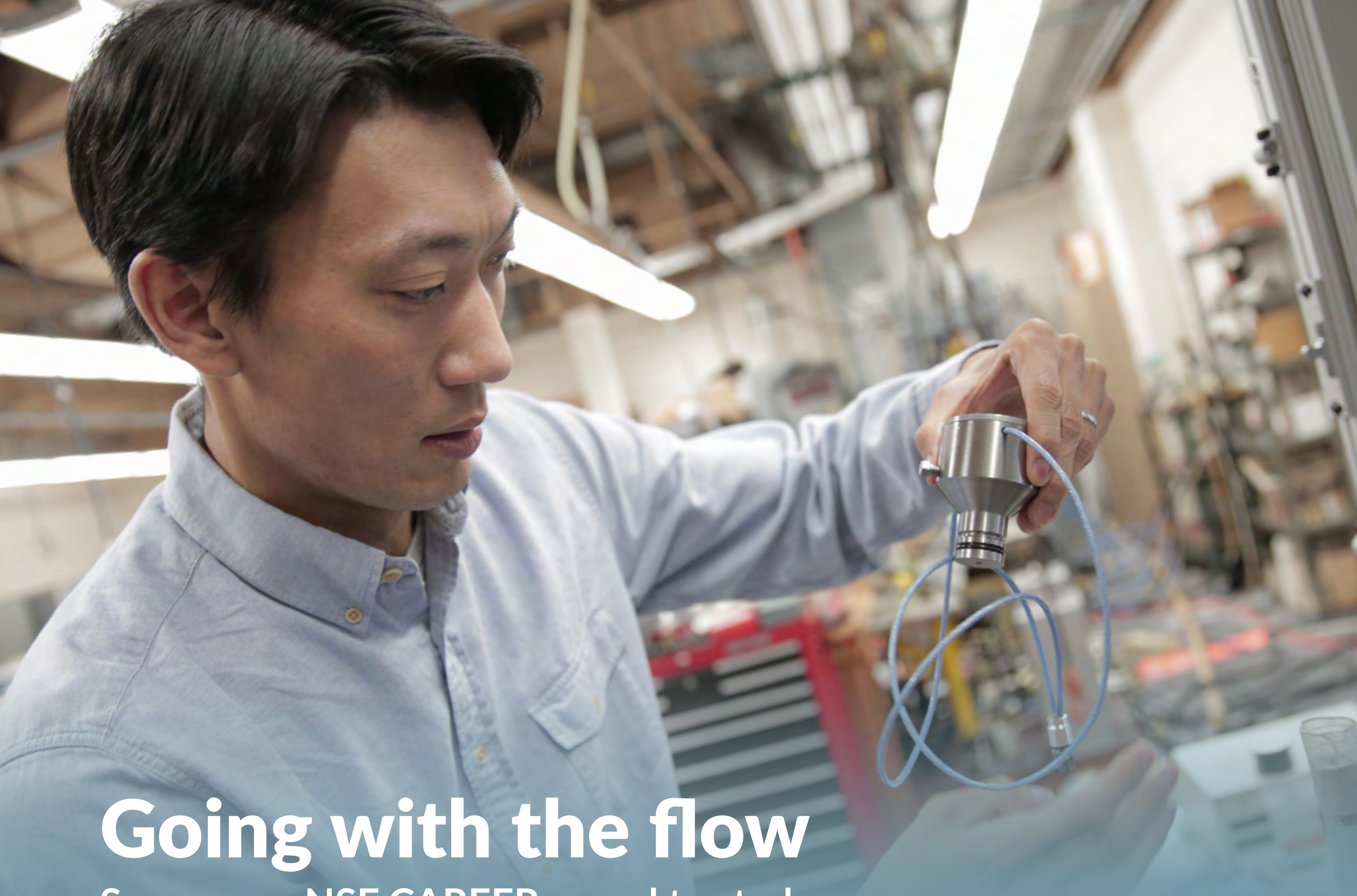
Fiber-reinforced polymers are strong, yet lightweight, and that has led to their widespread use in structural applications. To create them, manufacturers combine fibers into bundles and place them in resin, which hardens, binds the fibers in place, and forms the composite. However, the same fibers that give composites strength may also control moisture infiltration. These fibers, which are usually about 10 micrometers in diameter, can be laid in complex patterns. Those patterns can, in turn, lead to complicated moisture diffusion pathways through the composite material.

While the issue of moisture degradation in these materials is known, Prabhakar says there's not yet been much research into the connection between fiber architecture within the composites and moisture diffusion pathways. With better understanding of these relationships, Prabhakar hopes to both fill a scientific knowledge gap and strengthen the foundation for designing future generations of stronger, more damage-tolerant composites.

> "These pathways can affect the extent of material degradation, and further introduce failure mechanisms that are different from what we've observed without moisture diffusion happening," Prabhakar says. "It's rare that fibers have been studied from this perspective, to see what their role is with these diffusion pathways."

Prabhakar hopes to use her award as an opportunity to help create a talented, diverse workforce for the field. Industries in the field face a number of challenges, including an aging workforce, high worker demand and an insufficient pipeline to produce workers who can meet that demand. Women and minorities are also underrepresented in the workforce.

"We'll be offering a graduate-level blended online course on composite materials that will be designed with working professionals and adult learners in mind," she says. "We're partnering with the College of Engineering's Interdisciplinary Professional Programs team to deploy this course and hope that it can reach a wide audience to directly contribute to workforce development."



Going with the flow

Sone earns NSF CAREER award to study viscous fault rock properties

Think of rocks and hard, unyielding structures come to mind.

But Assistant Professor Hiroki Sone says the truth isn't so straightforward. In fact, rocks are elastic, in certain ways. Press on them with enough force over enough time, and they'll flow and bend permanently. These characteristics can play out over huge scales along fault lines, where pieces of the earth's crust grind against each other.

The idea that rocks can flow isn't new. Since the dawn of computer research, scientists have tried to incorporate the idea of rock elasticity into models to better understand what causes earthquakes as tectonic plates move past each other. However, Sone says rocks, which can be porous aggregates of different materials, may actually also act like a fluid over long periods of time, with changes that aren't due solely to pressure. Now a $528,000 National Science Foundation CAREER Award will fund a five-year research project to help him study those properties.

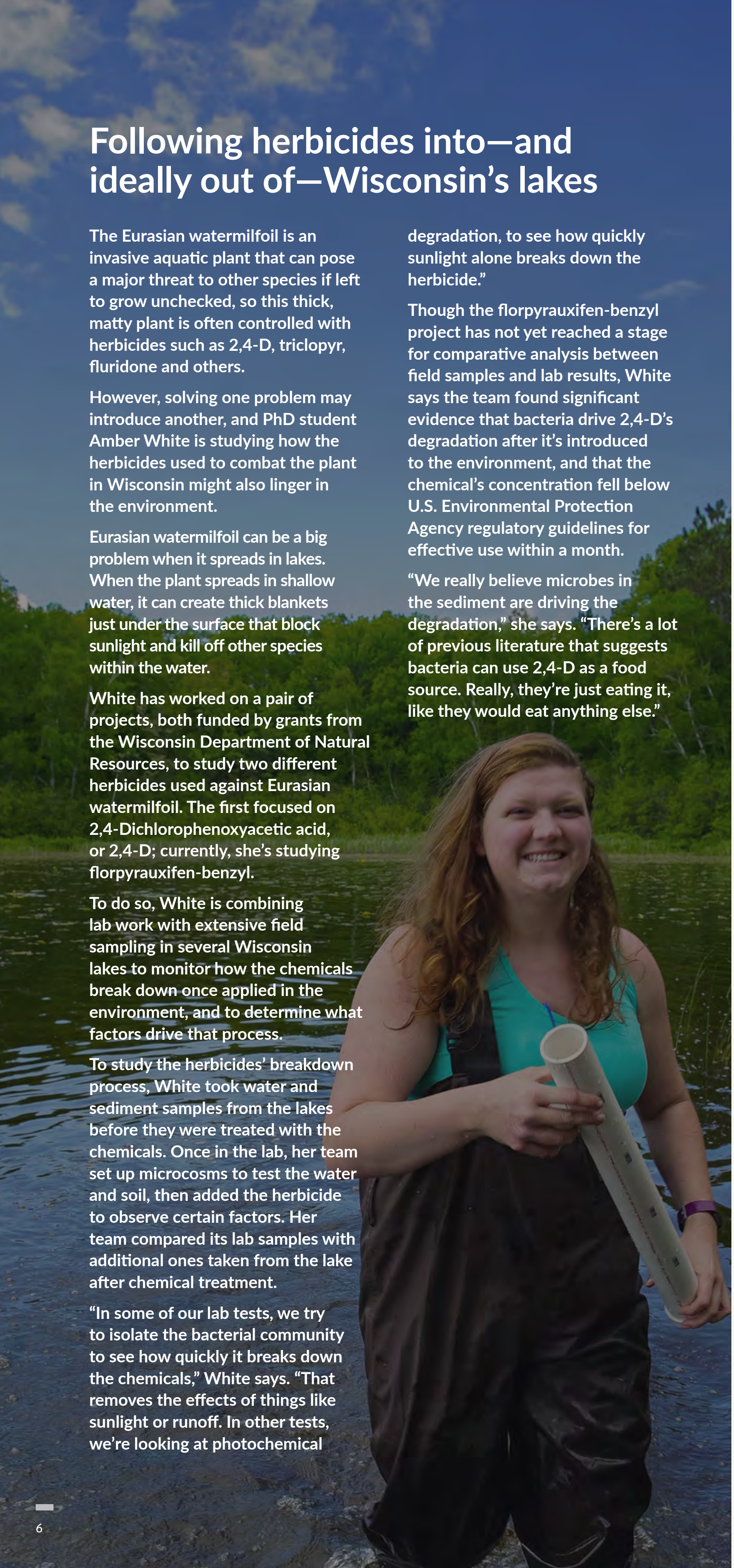
"Rocks are a poro-viscoplastic material," Sone says. "If you press on a rock, if it's linearly elastic, it shrinks, and then stays that way as long as you don't change the force you're applying to it. A viscous material will also deform due to elasticity, but there's also time-dependent, slow deformation that happens. Rocks are solid, but if you give them enough time, they can behave somewhat like a fluid."

For his project, Sone will investigate the damage zone around faults. Despite their common depictions as smooth lines, faults have rough, uneven edges. When faults slip, creating earthquakes, those edges tear at the surrounding material. That causes cracking and damage zones.

Sone will work to develop a formulation that describes these viscous properties after conducting field observations. He hopes such a formula could be implemented into numerical models that acknowledge a damage zone's effect on earthquakes, as current models do not account for it. Sone has recently begun working with Mechanical Engineering Assistant Professor Shiva Rudraraju to make this leap, taking advantage of their strengths in modelling multi-physics problems.

Sone hopes his work will bolster research on the interseismic periods, or the times between earthquakes, along faults. Acknowledging the damage zone, combined with rocks' poro-viscoplastic properties, can help us understand how stress accumulates along faults. Understanding how pressure builds and moves the rocks along faults can, ultimately, help us better understand how earthquakes happen.

"Studies to try to understand the interseismic period have been severely lacking," Sone says. "Part of that is because what governs this phenomenon is this really messy rock behavior that not many have dared to study. It's a very difficult challenge experimentally and theoretically. But we have to start somewhere."



Following herbicides into—and ideally out of—Wisconsin's lakes

The Eurasian watermilfoil is an invasive aquatic plant that can pose a major threat to other species if left to grow unchecked, so this thick, matty plant is often controlled with herbicides such as 2,4-D, triclopyr, fluridone and others.

However, solving one problem may introduce another, and PhD student Amber White is studying how the herbicides used to combat the plant in Wisconsin might also linger in the environment.

Eurasian watermilfoil can be a big problem when it spreads in lakes. When the plant spreads in shallow water, it can create thick blankets just under the surface that block sunlight and kill off other species within the water.

White has worked on a pair of projects, both funded by grants from the Wisconsin Department of Natural Resources, to study two different herbicides used against Eurasian watermilfoil. The first focused on 2,4-Dichlorophenoxyacetic acid, or 2,4-D; currently, she's studying florpyrauxifen-benzyl.

To do so, White is combining lab work with extensive field sampling in several Wisconsin lakes to monitor how the chemicals break down once applied in the environment, and to determine what factors drive that process.

To study the herbicides' breakdown process, White took water and sediment samples from the lakes before they were treated with the chemicals. Once in the lab, her team set up microcosms to test the water and soil, then added the herbicide to observe certain factors. Her team compared its lab samples with additional ones taken from the lake after chemical treatment.

"In some of our lab tests, we try to isolate the bacterial community to see how quickly it breaks down the chemicals," White says. "That removes the effects of things like sunlight or runoff. In other tests, we're looking at photochemical degradation, to see how quickly sunlight alone breaks down the herbicide."

Though the florpyrauxifen-benzyl project has not yet reached a stage for comparative analysis between field samples and lab results, White says the team found significant evidence that bacteria drive 2,4-D's degradation after it's introduced to the environment, and that the chemical's concentration fell below U.S. Environmental Protection Agency regulatory guidelines for effective use within a month.

"We really believe microbes in the sediment are driving the degradation," she says. "There's a lot of previous literature that suggests bacteria can use 2,4-D as a food source. Really, they're just eating it, like they would eat anything else."

Making sustainable cement is hard, but likely not impossible

Cement has a carbon footprint problem. A key ingredient in concrete—one of the most widely used manmade construction materials on the planet—it's the "paste" that binds together crushed rocks and other materials.

With more than 4.1 billion tons made globally in 2020, cement is also one of the most produced materials in the world. This production accounts for about 8% of the world's carbon emissions. About half of that comes from processes around production, like transportation. The rest comes from the needed chemical process to create cement.

"To make cement, you have to fire the ingredients up to about 1,500 degrees Celsius," says Assistant Professor Bu Wang, who's also a Grainger Institute for Engineering fellow. "You have to burn fuel to get to that high temperature, which of course creates emissions. During this heating process, the limestone used as an ingredient breaks down into lime and carbon dioxide, which creates further emissions. The challenge here is that the chemical reaction is a necessary part of making cement."

Wang is leading a multi-institution research team that aims to halt that looming trend. He received a $1.9 million grant from the National Science Foundation's Emerging Frontiers in Research and Innovation program to find sustainable ways to make cement.

Rather than attempt to reinvent the wheel, Wang's team is looking to take advantage of cement's ubiquity. Because so much of it is produced every year, there's plenty of alkaline in concrete that's no longer used. Now, the researchers hope to pull the necessary alkaline from old concrete. If their effort proves successful, it could open a new, sustainable way to make cement.

"Current cement uses calcium oxide as an alkaline," Wang says. "After it's made into concrete, that calcium is still in there. If we can extract the calcium from spent cement paste, we've solved the issue—as long as we can get an alkaline without generating additional CO^2, we're good."

Their ultimate hope is to provide an alternative to producing new cement. While there are ways to improve upon cement, Wang says if they're not easily accessible and affordable, they won't catch on.

"The big issue is that because this material is used so much, we need materials that are widely available and cheap," Wang says. "We hope that this process, because concrete is everywhere, can provide an alternative to help solve this problem."

Near-miss crash data propels alumni team to the top in transportation competition

A team of engineering alumni won the Institute of Transportation Engineers Vision Zero Sandbox Competition for innovative solutions that make intersections safer.

The competition drew professional and student teams from across the United States and tasked them with analyzing traffic data from six intersections in Bellevue, Washington, a suburb of Seattle.

ITE separated students and professionals into their own categories and announced the winners in July 2021. Two UW-Madison teams made it to the finals: the Proactive Badgers, a team of alums who work across Wisconsin, and a student team. The Proactive Badgers took first place, while the student team finished second in its competition. ITE will include the Proactive Badgers' work in an upcoming edition of its publication, the ITE *Journal*.

John Campbell, left, a member of the Proactive Badgers who earned his master's degree in civil engineering in 2005, says the teams analyzed post-encroachment time—a measure of how close vehicles come to a collision if they maintain their trajectory while moving through an intersection. The team used that data as a surrogate for actual collisions, and developed a methodology that's modular enough to suit the needs of different cities or states.

Kentin Brummett, a first-year CEE master's student and member of the student team, says her team also focused on extrapolating near-miss data into potential collision events, and suggested targeted solutions like improving signal coordination at intersections, using protected left-turn lanes, or adding countdown timers for pedestrian crossings.

Campbell says there are often low-cost, high-impact solutions that can help mitigate issues between cars and pedestrians, such as using high-visibility crosswalk paint or restricting right turns during red lights. The Proactive Badgers focused on that with their model, giving decision-maskers the flexibility to conduct cost-benefit analyses to determine what might work best for them.

"One of the things we wanted to highlight is fixing these issues can be like fixing a scratch on a car," Campbell says. "If you have a scratch, you don't rebuild or repaint your whole car. You bring in a targeted solution. This is about fixing what you can using solutions with high benefit-to-cost-ratios."

The Proactive Badgers team also included Christian Sternke (BSCEE '13), Kevin Scopoline (BSCEE '12, MSCEE '14), and Ahnaray Bizjak, (BSCEE '99).

With research fellowship, sophomore Porter Garst splits rocks to follow the fluid

If you want to engineer better underground systems, it's important to understand how fractured rocks deep underground allow fluid to move through them.

That's exactly what sophomore Porter Garst is studying under assistant professor Hiroki Sone. Garst is one of 28 students who earned support for their work from UW-Madison as 2021 sophomore research fellows.

Garst's project will build upon foundational research that's already been conducted on various factors at play for fluid permeability in underground sites. He says that, while reviewing previous research papers on the topic, he and Sone noticed that some researchers studied the permeability of fractured rocks, while others cracked rocks under stress or studied the roughness profiles related when rocks break.

Now, Garst and Sone will fracture rock samples, flow water through them while they're under the same types of pressure that would be expected in the field, and shear the rock samples again. By doing all of these steps under conditions that are as realistic as possible, they hope to better understand how rock permeability behaves in conditions that could be expected in geothermal or other underground systems.

"We realized there's research that touches on all of these foundations—how the fractures form, how roughness forms, and so on," Garst says. "We're going to build on all of that."

Garst's research will focus on shale gas and enhanced geothermal systems—the two primary industries that rely on rock permeability. He and Sone will crack shale with similar characteristics to that found in shale gas fields, and they'll use granite to study rock permeability for enhanced geothermal systems.

Sone says this research is valuable for engineers who design systems for shale gas extraction or enhanced geothermal systems or want to model how fluid flows through rocks in underground reservoirs. To do that, they have to also take into account how rock moves along fractures over time and the effect that has on overall rock permeability. Ultimately, he and Garst hope the project will lay the groundwork for further research.

"This is very fundamental-level research, but we are trying to overcome the shortcomings of past datasets so we can improve the knowledge of how permeability changes," Sone says. "That can then be implemented into models and improve the overall engineering approach to these systems in the field."

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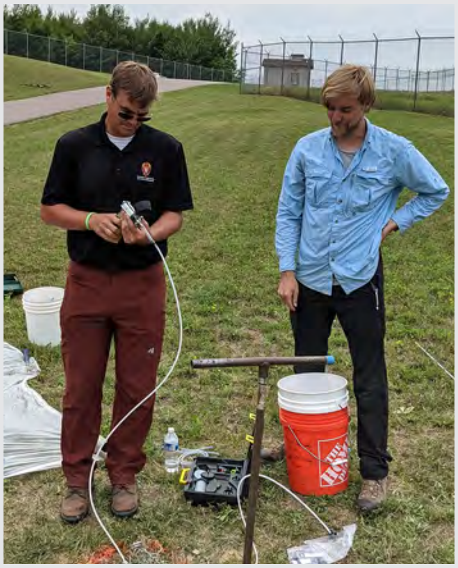
Tracking PFAS to preserve a community's water supply



The city of Rhinelander in northern Wisconsin has dangerous "forever chemicals" in its water. In fact, in 2019, the city shut down two of its water wells after it found per- and polyfluoroalkyl substances (PFAS) levels well above state regulations for safe drinking water.

Associate Professor Jim Tinjum is helping the city understand where those chemicals originated and what to do about them.

PFAS chemicals may interfere with the human body's natural hormones, increase cholesterol, adversely affect the immune system and increase the risk of some cancers. PFAS have been found in water in cities across the United States. The chemicals are specifically designed not to break down under harsh conditions—but that also means that when they get into the environment, they linger.

"You can imagine if they tend not to degrade, they're going to last a very long time," Tinjum says. "The problems we're seeing in Rhinelander and other places may have been there for decades."

Soon after shutting down the two wells, Rhinelander Mayor Christopher Frederickson contacted Tinjum to enlist his aid. Tinjum led a research team that visited Rhinelander in July to conduct field testing using a variety of tools, including ground-penetrating radar—which works like weather radar pointed at the ground to observe soil conditions, locate the water table, and search for changes in the area's general geological profile.

It's important to understand the underground features, because they may tell the story of how PFAS-contaminated water moves from its source—whether that's from the airport, landfill or somewhere else—to mix with water that feeds city wells. Tinjum's team can use that information to offer remediation suggestions to city leaders.

The work is an example of the Wisconsin Idea—the idea that research and knowledge developed at UW-Madison should be shared for the benefit of the state and the world—in action. In this case, Rhinelander is just one beneficiary among many other communities such as Eau Claire and La Crosse that also are facing their own PFAS challenges.

"Without question, we're taking the Wisconsin Idea and putting it into play," Tinjum says. "We're taking our expertise on campus and using it for the public good. This is starting with Rhinelander, but other municipal leaders may be able to use similar technologies while they work through their issues."