WICHITA STATE UNIVERSITY

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WSU researchers win $1.4 million NSF grant to mitigate environmental impact of road salt

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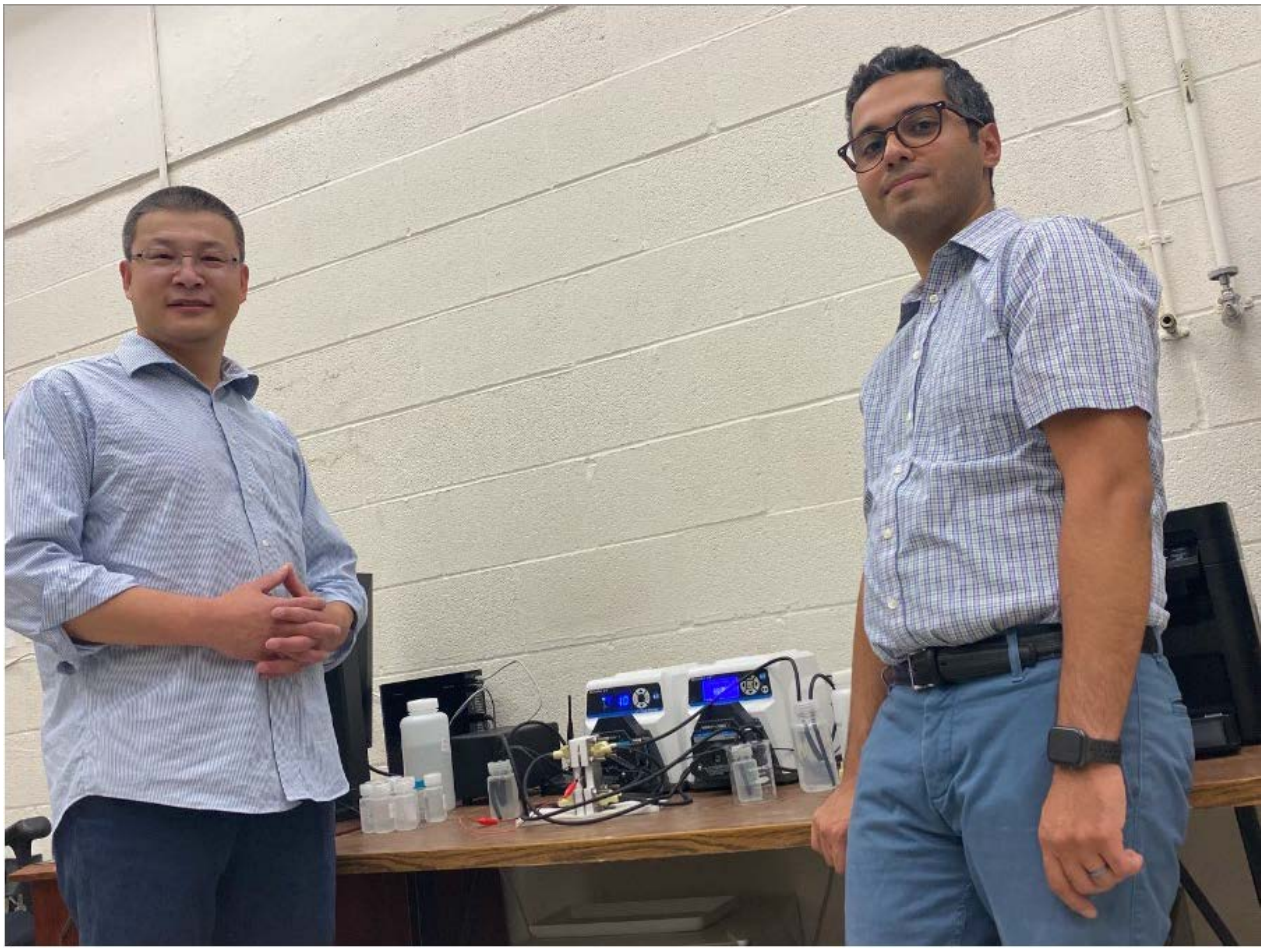

Dr. Shuang Gu, associate professor of mechanical engineering, stands with Pouya Ammari-Azar, a Wichita State Ph.D. student in mechanical engineering, in front of an electrodialysis system, which they are using to research and lessen the environmental impact of road salt.

Since the early 20th century, road salt has been saving lives on highways across the nation, but its liberal use also presents significant consequences for wildlife and human health.

An interdisciplinary team of Wichita State University researchers is working to curb pollution and damage caused by road salt. The project — ECO-CBET: Convergent Electrolysis-Electrodialysis System (CEES) to Curb Urban Chloride Pollution by Eco-friendly Road Deicing and Waste Salt Upcycling — was recently awarded $1.4 million from the National Science Foundation (NSF).

Wichita State and Iowa State are collaborating on the project with each university receiving $700,000 of the project's overall funding.

Dr. Shuang Gu, associate professor of mechanical engineering, is the principal investigator of the Wichita State award, while Dr. Wenzhen Li, professor of chemical and biological engineering, leads the efforts at Iowa State.

"We noticed in the past 50 years that the United States has exponentially increased the application of road salt," said Dr. Gu. "We can buy road salt anywhere in 20- or 50-pound bags to unfreeze roads for safe travel, and there's nothing wrong with that. It saves people's lives. But we never pay attention to the implications of the road salt."

Once the salt is washed off the roads, it seeps into groundwater and other fresh water sources, harming nearby ecosystems and humans. In 2019, the United States applied 24.5 million tons of road salt — or 43% of total national salt consumption — which translates to about 160 pounds of road salt per person.

"The sad part of the road salt is that most of the salt ends up in ditches, streams, lakes, or reservoirs, which gives rise to a series of ecological and health problems," Gu said.

As the salt leaches into fresh water sources, it changes the water chemistry and leads to decreased health for wildlife, particularly amphibians.

"A 2015 study by the U.S. Geological Survey found that 84% of urban streams studied have seen a steady increase in the salt concentration, and 29% exceeded the federal safety guideline for at least part of the year" Gu said. "This has affected amphibians' growth and reproduction."

For humans, the negative consequences of increased salt intake have been studied for decades. The Federal Drug Administration recommends no more than 2.3 grams of salt per day, but Americans consume on average about 3.4 grams per day. The additional salt that oozes into groundwater is cause for concern, Gu said.

"We are already eating too much salt, and we don't want drinking water to add to that," he said. "The salt accumulated in the nearby waterbodies finds its way into the drinking water system."

This is especially true for people who have well water or private water systems, which account for roughly 15% of the U.S. population. Public water systems, Gu said, have a bit more control to filter salt out of the drinking water supply.

Additionally, road salt's corrosive nature incurs significant property losses in automobiles, bridges, roads, and other traffic infrastructure every year. Annual cost from vehicle corrosion caused by road salt was estimated to be $11.7 billion nationwide.

An alternative deicing agent: Sodium formate

"We cannot stop people from using the road salt because we need it for safe traffic," Gu said. "But why not replace polluting road salt? Sodium formate is an alternative, eco-friendly deicing agent."

The CEES team's NSF abstract proposes that it will "initiate and establish a Convergent Electrolysis-Electrodialysis System as a viable engineering solution that can effectively mitigate the complex environmental-ecological-economic issues associated with the ever-growing chloride pollution in urban waterbodies, while reducing the emission of carbon dioxide."

In simple terms, "We can replace this concerning road salt with an ecofriendly deicing agent," Gu said. In addition to replacing harmful salt from the roads, the CEES team will be working to upcycle waste salt at the same time, when making the ecofriendly deicing agent.

According to the abstract, "The system is designed to directly cut down the chloride discharge by upcycling waste salt in the regeneration stream of urban water softeners, and to stop the continuous chloride pollution by switching the deicing agent from polluting road salt to the eco-friendly sodium formate."

Therefore, the CEES has a double effect on chloride mitigation: cutting down one source of salt pollution and avoiding another source of salt release.

"Sodium formate can be decomposed by mother nature and bacteria," Gu said. "It doesn't give us any major complications. It's a benign, safe and effective deicing agent."
With all the health and environmental benefits of sodium formate, it begs the question: Why would we use anything else to deice roads?

Understanding the problem

Despite all the advantages of sodium formate, it comes with its share of challenges.

First, sodium formate is currently made from fossil fuel — which, in and of itself, presents its own set of ecological issues.

"If we use the fossil fuel-derived deicing agent to replace the salt, then we are shuffling the problem from one pocket to the other," Gu said. "Sure, we solve this salt pollution issue, but we will create a bigger issue for our environment."

Secondly, there simply isn't enough sodium formate on the market.

“Currently, there are only about 1 million tons of the market,” Gu said. “Sodium formate has a price roughly 10 times as much as the road salt. We need cutting-edge research to create inexpensive and green sodium formate. That will be the true solution. We are proposing to use carbon dioxide to create sodium formate.”

The benefits of using sodium formate for deicing have been well-known for years, and it’s commonly used in airport runways and military facilities.

“Sodium formate is being used in some places; but the wider application is too costly, and we don’t have enough,” Gu said.

An interdisciplinary solution

Gu’s education and experience in mechanical and chemical engineering have given him valuable insight into the issues caused by road salt, but creating a sustainable solution will require a multifaceted, nuanced approach.

The team’s approach is an engineering system: CEES integrates the product-selective electrolysis and energy-efficient electrodialysis. Electrolysis converts carbon dioxide and salt into formate and chlorine products; while electrodialysis concentrates salt from waste streams and separates products as well.

“Our recent breakthroughs from electrolysis and electrodialysis essentially enable us to come up with the idea of CEES,” Gu said. “Powered by renewable electricity, the manufacturing of CO_2-based sodium formate from waste salt is sustainable and potentially inexpensive, compared with the fossil fuel-based counterpart.”

“This is not about a single device or a single process alone,” he said. “Curbing urban chloride pollution is a convergent effort that involves materials advancement, mass-transport understanding, process engineering, social science, and environmental science. It’s a whole bundle.”

One issue the CEES team wants to avoid is solving one ecological problem and creating another.

“What happens when we apply the sodium formate? According to existing literature, it’s fine. But we still want to see with our own eyes,” Gu said. “We will conduct an assessment on the fate of the sodium formate as well as the salt pollution.”

Wichita State’s Dr. Janet Twomey, professor of engineering and associate dean for graduate studies and faculty success, will be conducting a lifecycle analysis to understand the implications of replacing road salt with sodium formate.

“Just by saying this work will be reducing environmental impacts is not enough,” said Twomey. “You have to compare it to the predominant systems.”
For this project, Twomey said, Gu and the Iowa State team will be researching new technology to reduce chloride pollution in urban waterbodies. For her part on the CEES team, Twomey said, “We need to be

sure that this new technology will not have a greater environmental impact than the current system that is very polluting."

Dr. Ruowen Shen, assistant professor at WSU's Hugo Wall School of Public Affairs, is also part of the team, and she will conduct research on policy learning and behavior change, aiming to promote societal outcomes of the CEES. The acquired insight into policy process will help effectively achieve the needed policy change for deicing practices.

Dr. Jeremy Patterson, dean of Wichita State's College of Innovation and Design and executive director of Innovation and New Ventures, provided a strong support letter that unquestionably strengthened the CEES project.

"Dr. Gu and his team have a collaborative approach that includes an innovation and entrepreneurial mindset," Patterson said. "This award is addressing a sustainability and environmental issue that has been overlooked for years and is a good example of how deep scientific understanding can lead to technological solutions, then economic viability, and ultimately positive societal outcomes. This award emphasizes and advances WSU's commitment to translational research and innovation that may result in a direct benefit to our community.

Pouya Ammari-Azar, a Wichita State Ph.D. student in mechanical engineering, was integral in helping Gu develop and advance the electrodialysis, "which is the key to returning the waste salt into the eco-friendly deicing agent," Gu said.
CEES fits into Ammari-Azar's long-time interest in renewable energy and sustainability.

"I want to do what I can do to help our environment to be clean for ourselves and the next generations," he said. "When we can clean and recycle our waste, why shouldn't we?"

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>
> *— Dr. Shuang Gu*
> *associate professor of engineering at Wichita State*

Gu knows that urban water pollution caused by road salt is an enormous problem, but it's not insurmountable. The NSF grant is a good start toward a solution.

"I don't think $1.4 million is enough to solve the problem, but we can curb it. We can also bring awareness to the issue," he says. "We are working on an underappreciated problem, and the NSF recognizes our idea and vision by forming a team to look at this overlooked national problem. It's not a

simple matter; rather, there are many things to do. We have to start somewhere, and this is the first step."

The CEES team is committed to addressing and helping to mitigate the pollution.

"As a researcher, we want to focus on something great," Gu said. "When we developed the proposal, I told my team members that it doesn't matter if our proposal was selected. We're onto something important. This problem must be addressed one way or another, so we're doing the right thing in the right direction. That gave us the strong motivation and dedication."