Fertilizers applied to farm fields, golf courses, and residential landscaping to benefit plants do not always stay in place. These added nutrients, including nitrogen (N) and phosphorus (P), can be washed away by rainfall into nearby waterways. An abundance of nutrients in aquatic ecosystems can result in algal blooms, which deplete oxygen as they decompose.

Low levels of dissolved oxygen, or hypoxic conditions, create what are known as “dead zones” because few organisms can survive under such conditions. One of the largest dead zones occurs where the Mississippi River meets the Gulf of Mexico. The Mississippi River drains roughly 40% of the lower 48 U.S. states, picking up nutrients from farms, lawns, and animal waste along the way. Given the negative impacts on the fishing industry, tourism, and marine ecology in the Gulf of Mexico and other dead zones worldwide, it is important to reduce nutrient runoff upstream.

During a symposium at last year’s ASA, CSSA, and SSSA International Annual Meeting in Phoenix, AZ, researchers gathered to explore new and creative solutions to not only remove N and P from agricultural waters, but to recover those nutrients for reuse.

“We’ve got an “abundance” of nitrogen and phosphorus in our waters at times,” says Gary Feyereisen, an agricultural engineer with the USDA-ARS and organizer of the symposium. “Wouldn’t it be great if we could capture that abundance and then make those nutrients ‘scarce’ in the waterways that are leaving agricultural land?”

From adapting existing water treatment techniques to emerging technology, four speakers shared ideas and initial results. Feyereisen, who chairs ASA’s Managing Denitrification in Agronomic Systems Community, which sponsored the symposium says, “Right now, those solutions may not look economical,” but all have potential to help solve the problem of nutrients polluting surface waters. Here, we share these thought-provoking ideas with those unable to attend this session in Phoenix.

Electrodialysis

Denitrification is one method for reducing the amount of nitrogen that enters waterways. But John Baker, Research Leader with the USDA-ARS, says, “It takes a lot of energy, with substantial emission of greenhouse gasses, to produce nitrogen fertilizer. It seems somewhat wasteful to encourage microbes to convert it back to atmospheric nitrogen.” As an alternative, Baker, a Fellow of the ASA and SSSA, has been experimenting with electrodialysis as a method for capturing nitrogen in runoff for reuse.

Electrodialysis is already used in desalination and wastewater treatment plants, and Baker’s work...
explores how the technology could be adapted for agricultural settings. Electrodiolysis systems use an electrical field to move ions from one solution (the diluent) across a semi-permeable membrane into a concentrated solution (or brine). Baker thinks the concentrated brine could be processed back into a nitrogen fertilizer, providing a way to reduce nitrate levels while also reducing the need for additional manufactured fertilizer.

There are multiple ways an electrodialysis system can be set up, with solutions recirculating or flowing as a continuous stream. A system where both solutions are recirculated may be most appropriate where there is a confined amount of water with very high nitrogen levels, for example, a drainage pond from a dairy, Baker says.

Baker has also tested a hybrid system where tile outflow from a farm field provides a continuous flow of diluent solution and the concentrate solution recirculates. However, variability in the outflow from a tile drain can be problematic.

“In situations where tremendous amounts of water come through in a very short time, it would be very challenging to apply electrodialysis,” he says. “It is more appropriate for situations where you might have a relatively steady base flow.”

A steady flow of water from agricultural sites is also more cost-effective. Due to the initial cost of an electrodialyzer, a system cannot extract and concentrate nitrate economically if it is only run for short periods of time. This challenge of determining the circumstances in which the technology works best, or would be more likely to provide a return on investment, was a common theme among the symposium speakers.

Ion Exchange Resin

Kari Wolf, a graduate student at the University of Minnesota who is advised by Dr. Satish Gupta, is also studying how existing water treatment technology can be adapted for agricultural settings. Wolf, a member of ASA, is investigating how ion exchange resins could be used to remove nitrogen from agricultural tile drainage.

Ion exchange resins are used for water purification, metal separation, and in the pharmaceutical industry. The technology is also used in most home water-softening systems, in which ion exchange resins remove calcium from hard water. And, just like the resin in a water softener can be recharged and reused, ion exchange resins for nitrate have the potential for repeated reuse.

The initial results are promising, with one type of resin retaining approximately 40% of the nitrogen in tile outflow. The system Wolf has been testing is passive, where tile outflow is diverted through resin columns, eliminating the need for a power source. However, maintaining the effectiveness of the resin columns is time-consuming and labor intensive. The resin columns needed to be replaced at least once a week during the field season.

Recharging the resin for reuse in a way that did not produce a waste product was an important part of this project.

“What we did was use potassium chloride [to recharge the column, thus] the waste product would be potassium nitrate, which is a fertilizer,” Wolf says. “We still have to develop a fool-proof way of cleaning the resin . . . it’s very hard to get it 100% clean in the way that I’ve been doing it.” Developing an automated system or making it easy to swap used and clean resin canisters will be necessary before there is widespread use of this method.

Wolf has thought of other adaptations and improvements from working with the test system. “We had to specifically use fields that didn’t have surface inlets where the soil could get in [because] soil would essentially just clog up the columns,” she says, adding that having a sediment trap or filtration step could expand where resin columns could be used. The system was also overwhelmed by high-flow events, but that could be overcome by using additional canisters or finding ways to control flow through this passive system.

**Below:** Resin column in place at the end of a tile outlet. **Insets:** Unused resin (top) and used resin after two growing seasons (bottom). Photos by Satish Gupta.

Ochre

In addition to the work presented on nitrogen removal, Philip Sibrell
presented research on phosphorus removal. Sibrell, General Engineer at the USGS Leetown Science Center, shared a successful method for using mining ochres to remove and recover P from agricultural runoff. He says ochre is an “inexpensive, yet very effective material for P sequestration and removal” that has the potential for use in agricultural settings.

Ochres are a by-product of mine drainage treatment and are composed of iron and aluminum oxides, which bind P. Currently, there is limited use for ochre, and it is generally considered a waste product that mining companies need to dispose of. Both active and abandoned mine sites produce ochres, making this by-product a potentially useful resource that is abundant and likely to continue to be available in the future.

For use in P removal, the ochres are processed through air-drying, crushing, and screening. This creates a granular porous sorption media that water can pass through. Initial testing with a fixed bed application showed ochres can be an economical treatment method for wastewater treatment plants, such as the demonstration system in operation at the Leetown Science Center. Sibrell is also interested in working with passive systems, which could be used at tile drain outlets or in combination with denitrifying bioreactors. However, a passive system can encounter “problems when you lose permeability,” Sibrell notes, due to an accumulation of sediment.

Similar to the ion exchange resin, the ochre media can be regenerated and re-used after it becomes saturated. The P recovered can be processed into a form that could be re-applied as fertilizer, providing “an opportunity to close the recycle loop” Sibrell says. Having the ability to capture and reuse P from runoff is of great interest because P is currently sourced from mines. If mining becomes less productive and more expensive, methods like this may become a more economical way to produce P fertilizer.

Microalgae

Len Smith suggests that while algae are part of the problem, they may also be part of the solution. “Microalgae have long played a role in the environment of being sort of a sponge, a filter,” says Smith, Chief Business Officer at Heliae Development LLC, a biotech startup investigating uses for microalgae, including use in agriculture.

Currently, Heliae grows microalgae at a facility in Arizona, which requires
nutrient inputs. When describing the role for microalgae in pollution reduction, Smith says, “The dream would be to capture NPK on farm sites or other sites where NPK waste is present . . . and to use that as an input to grow microalgae.” The microalgae could be used to make products like fertilizer, non-fertilizer soil amendments, and animal feed. “Or you could always use the algae to make other products like cosmetics, or plastics, or fuel,” he says.

Researchers are only beginning to understand the diversity and role of microalgae in the soil. Microalgae, Smith says, are “key components of the soil” and play a role in interactions among soil microorganisms and plants. And with thousands of species of microalgae in the world, researchers need to determine which microalgae are likely to have a high affinity for the nutrients farmers want to remove from runoff and can also be used to make a product.

Achieving these objectives could require using a mix of algal species, or polyculture. Working with polycultures makes the system more complex. Smith says polycultures are “very stable, very robust . . . but there will be some level of variation in what’s in that polyculture.” Variation in the microalgae cultures could impact the consistency of the products being made, so addressing these issues is an essential part of the research and development at Heliae.

“One of my takeaways from being at [the] session was it may be a combination of these things that are really what is necessary,” says Smith, “because none of them may be perfect.”

**Women in Science**

*Editor’s note: CSA News magazine is pleased to present a new series, Women in Science. Each month, summarized articles from women scientists will appear monthly in print with the full-length versions posted on the following websites: (1) www.agronomy.org/membership/women-in-science, (2) www.crops.org/membership/women-in-science, and (3) www.soils.org/membership/women-in-science. Also, watch for more details in CSA News magazine about the 2017 ASA, CSSA, and SSSA Women in Science Workshop at the Annual Meeting in Tampa, which will focus on “Maintaining a Work–Life Balance.”*

**Tips for Work–Life Balance**

My father was a world-renowned workaholic literature professor. My mother was a stay-at-home mom, despite being trained as a pharmacist. Their work–life balance consisted of doing his paid work and her doing everything else (the second shift). Obviously, this recipe was not going to work for my husband, a sole-practitioner personal injury attorney, and myself, a USDA-ARS research soil chemist (a career from which I retired in May 2016 after 33 years of service). We had to develop a new system, some of which I would like to share with you.

• **Organize:** This one is a no-brainer! I always had to-do lists with due dates at work. At home, we use Post-it notes on our cabinet, which sometimes looks like a Christmas tree.

• **Say no:** Young scientists feel compelled to accept all tasks and all invitations. Over the years, I have learned to ask myself: Do I want to do this? Do I need to do this? If the answer to both of these is no, then I say no to the invitation.

• **Evenings and weekends are personal time:** In my case, personal time means family time. Except for very unusual, extenuating, and rare circumstances, my husband and I leave our offices at 5:15 pm and do not work on weekends. That is not to say that we are not serious about our careers. It’s just that we have learned to concentrate fully on our work at the office and not bring it home.

• **Exercise:** Exercise is a vital part of my routine in the morning before work and during the morning coffee break and my lunch hour. These breaks enhance my productivity by allowing me to clear the cobwebs out of my brain and return to work refreshed and with new ideas.

These are just a few suggestions—more tips are available in the full article at the above-listed Women in Science websites.

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