Circle Back
Research Update

CIRCLE BACK

Research Update: New Insights Into Curbing Plant Uptake of PFAS from Biosolids

| **By** Tess Joosse

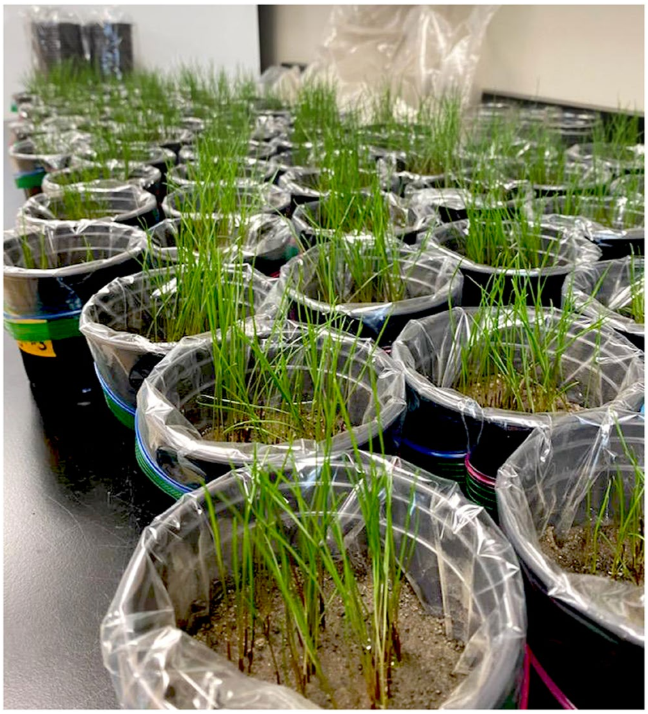
Back in September 2022, we told you about how researchers use biosolids (https://doi.org/10.1002/csan.20853)—nutrient-packed sewage separated from waste streams and treated to remove pathogens—to regenerate depleted landscapes. These biosolids prove particularly potent (https://doi.org/10.1002/jeq2.20376) at fertilizing soil, soaking up chemicals, and spurring ecological restoration at former mines or other contaminated sites.

But biosolids specifically, and human waste generally, contain per- and polyfluoroalkyl substances (PFAS), the uber-stable "forever chemicals" linked to health issues we explored in an October 2022 article (https://doi.org/10.1002/csan.20894). Applying biosolids to the land risks introducing PFAS into growing plants and up the food chain to organisms in higher trophic levels. While PFAS molecules are notoriously tough to get rid of by breaking them down, some studies show that materials containing aluminum (Al), iron (Fe), and calcium (Ca) can sorb PFAS chemicals, slowing their mobility through soil.

Recently, a research team from the University of Florida and Purdue University turned to a different waste product, drinking water treatment residuals (DWTRs), to address the biosolids-PFAS problem. Drinking water treatment residuals are rich in Al, Fe, and Ca, so the researchers tested if applying DWTRs to soil treated with biosolids could reduce PFAS uptake in plants.

To make the stuff from aquifers, lakes, and rivers potable, water treatment plants apply coagulants to influent water to remove its dirt and particles. Drinking water treatment residuals are the sludgy by-products of this clarification process. The United States produces more than two million tons of DWTRs each day, and like biosolids, researchers are interested in recycling and reusing them in other applications.

A previous benchtop study showed that DWTRs containing aluminum, or Al-DWTRs, grabbed on to some PFAS molecules and stopped their movement through water. So lead author Emma Broadbent, then a graduate student at the University of Florida, and colleagues took this idea to soil, setting up two experimental conditions mimicking land treated with the proper doses of biosolids for agricultural fertilization and for mine reclamation, respectively. Before adding the biosolids to the soil, they quantified their PFAS concentrations and mixed them with one of three different DWTRs: one containing iron (Fe-DWTR), one containing calcium (Ca-DWTR), and Al-DWTR.



Perennial ryegrass planted to evaluate the effects of DWTRs on uptake of PFAS in soils amended with the relevant rate of biosolids for mine reclamation. Photo by Emma Broadbent.

The scientists planted tomatoes (*Solanum lycopersicum*) for the agricultural scenario and perennial ryegrass (*Lolium perenne*) for the mine reclamation scenario and harvested the plants several weeks later, analyzing their tissues for PFAS content.

The DWTRs had a spotty effect on the plants' uptake of PFAS, the researchers reported recently in *Journal of Environmental Quality*

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SOCIETY SCIENCE

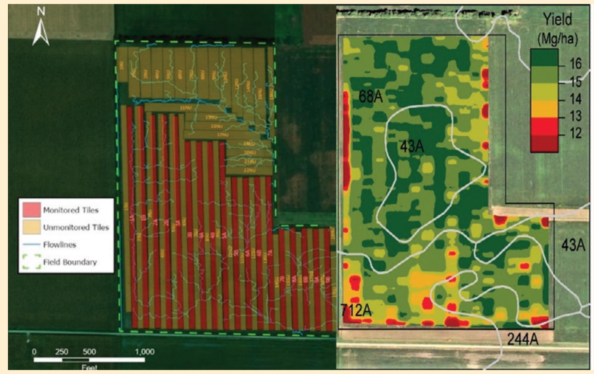
SOIL SCIENCE SOCIETY OF AMERICA JOURNAL

Relationship of Soil Health Indicators to Yield and Nitrate-N Loss

Although soil health is of growing interest to scientists, the relationship of soil health indicators (SHI) to yield and water quality is not well understood. Farmers in the United States Corn Belt use relatively high amounts of nitrogen (N) fertilizer. But it is difficult to predict how much N crops need, and excess can be lost to surface waters through subsurface tile drainage and other pathways.

Researchers in central Illinois evaluated the relationships of maize yield and tile drain nitrate-N losses to SHI. The team evaluated SHI proposed by USDA-NRCS as well as nematode-based indicators with the potential to serve as biological SHI. They applied a range of N rates and gathered data over the growing season.

They found that SHI varied more by sampling time than by location or N rate, underscoring the importance of reporting and standardizing the timing of soil sampling for SHI evaluation. The study also revealed the potential role of nematode indices as biological SHI. Nitrogen application rate did not relate to tile nitrate-N loads. Different SHI were related to variation in maize yield versus nitrate-N loads, providing potential directions for future investigation.



Tile system (left) and maize yield (right) of the researchers' Illinois study field. Image courtesy of Andrew Margenot.

Adapted from Li, N., Bullock, D., Butts-Wilmsmeyer, C., Gentry, L., Goodwin, G., Han, J., . . . & Margenot, A.J. 2023. Distinct soil health indicators are associated with variation in maize yield and tile drain nitrate losses. *Soil Science Society of America Journal*. https://doi.org/10.1002/saj2.20586

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(https://doi.org/10.1002/jeq2.20511). Of the at least 30 PFAS the researchers counted in the biosolids, only three (all short-chain, which have been previously reported to be more phytoavailable than long-chain PFAS) were detected in all of the plant samples. Ca-DWTR was able to reduce uptake of one PFAS in tomatoes and one in ryegrass. Treatment with Fe-DWTR also reduced uptake in ryegrass but didn't seem to affect uptake in tomatoes, and no plants treated with Al-DWTR saw reduced PFAS concentrations.

These differences could boil down to the contents of the biosolids–soil mixture itself, the researchers say. The soils used in the experiments had relatively high Al and Fe content, indicating an already-high capacity for PFAS retention. Adding DWTRs wouldn't have as impactful an effect in this situation, especially if the biosolid used had a low PFAS concentration.

The researchers continue to probe how DWTRs can be applied to mitigate PFAS contamination says study corresponding author Jonathan Judy, a soil and water chemist at the University of Florida and a member of ASA, CSSA, and SSSA. They're now testing how using a larger amount of DWTRs might create a stronger response. "The most important next step, however, is to do field trials examining effects in a more realistic setting, using the information collected to date to guide amendment rates and what DWTRs to use," Judy says.

Concerns about PFAS have crescendoed in recent years, and in 2022, the state of Maine banned biosolids outright in an effort to curb contamination on the state's farmland and in its groundwater. But if PFAS risks can be mitigated, the benefits of biosolids could be huge. "Nutrients, such as phosphorus and nitrogen, can be less prone to leaching or loss when applied in biosolids versus being applied via inorganic fertilizers," Judy explains. "Any domestic waste that can be safely and beneficially reused, as opposed to being incinerated or landfilled, is a net benefit to society."

DIG DEEPER

Read the original *CSA News* articles "From Sewage Sludge to Biosolids: Building the Case for Waste" here: https://doi.org/10.1002/csan.20853

and "When Chemicals Go to the Dark Side: The Unintended Consequences of Emerging Contaminants" here: https://doi.org/10.1002/csan.20894

Read the recent (September 2023) article on the effects of DWTRs from *Journal of Environmental Quality* (JEQ), "Effects of Drinking Water Treatment Residual Amendments to Biosolids on Plant Uptake of Per- and Polyfluoroalkyl Substances," here: https://doi.org/10.1002/jeq2.20511

Read the 2022 JEQ article on the history of biosolid use in Colorado here: https://doi.org/10.1002/jeq2.20376