



**Science
Societies**

When chemicals go to the dark side

The unintended consequences of emerging contaminants

By Kristen Coyne

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Opposite page: Sampling for per- and polyfluoroalkyl substances (PFAS) in a stream that wastewater discharges into. Photo by Tom Campbell, Purdue.

Half a century ago, in response to burning rivers and other high-profile environmental disasters, the U.S. Congress passed the Clean Water Act (CWA) as a means to protect waterways from sea to shining sea.

Commemorating that landmark legislation, the *Journal of Environmental Quality* this year has **published a collection of papers** celebrating the CWA. *CSA News* magazine is highlighting some of that work through a three-part series.

In September, we looked at research (<https://doi.org/10.1002/csan.20828>) on how constructed wetlands can decrease nutrient runoff on tile-drained agricultural fields. In October, we examined what scientists have learned about the benefits and challenges of using biosolids to fertilize crops, rehabilitate contaminated landscapes, and boost soil health (<https://doi.org/10.1002/csan.20853>).

This final story in the series discusses recent research on emerging contaminants—chemicals suspected of harming people and the environment. From “forever chemicals” to disinfection by-products, and from pharmaceuticals to the lithium batteries that we too often toss in the trash, these pollutants are resulting in unintended consequences that scientists are working hard to understand.

Chemicals can be convenient, useful, even lifesaving. We love them when they keep food from sticking to stuff or help us apply lipstick with ease. We love them when they power our cars, computers, and cell phones. We love them when they protect us from diseases. We love them when they make our drinking water safe.

But once we're done with them—once we have thrown them in the trash, washed them down the sink, or flushed them down the loo—they can become a lot less loveable. Some benign compounds transform into harmful ones. Some toxic molecules defy degradation. One-time helpmates can even turn deadly when they end up where we never intended—in our soil, food, tap water, and air.

Welcome to the ominous world of emerging contaminants, a vast group encompassing hormones, novel pesticides, nanoparticles, microplastics, disinfection by-products (DBPs), pharmaceuticals and personal care products (PPCPs), and per- and polyfluoroalkyl substances (PFAS). Although “emerging” suggests something novel, some of these pollutants have been around for decades. But building the scientific case for regulating these contaminants is a time-consuming, costly, and often controversial process.



*Alex Chow collects water samples
at the University of*

Alex Chow, a professor in the Department of Forestry and Environmental Conservation at Clemson University, believes it is high time we learned from our mistakes. In a recent article (<https://doi.org/10.1002/jeq2.20405>)

published in the *Journal of Environmental*

Quality (JEQ), Chow argues that society must be more proactive about preventing contamination from chemicals whose effects may not yet be understood. Over the decades, he has watched the same story unfold over and over as if stuck on repeat: A new compound with promising applications is synthesized; it is embraced by the public and hailed by scientists, perhaps even winning a Nobel Prize (as did **DDT** and **plastics**). Eventually, the compound reveals its dark side, leaving scientists and policymakers with a costly environmental and public health mess. He now sees the same story playing out with lithium.

“Our Society does not recognize it, does not learn from it,” says Chow, an SSSA and ASA member. He advocates taking a more proactive approach to managing the lithium widely used in batteries before it becomes the next **Nobel Prize-winning** environmental menace.



Soil coring for transport studies of per- and polyfluoroalkyl substances

California–Berkeley’s Sagehen Field Creek Station for a study on nutrients and pyrogenic dissolved organic carbon in surface water runoff. Photo courtesy of Alex Chow.

(PFAS). Photo courtesy of Linda Lee.

Below we introduce you to a trio of scientists who have dedicated their careers to mitigating the fallout from three classes of emerging contaminants: DBPs, PFAS, and PPCPs. Motivated by a love of the environment, they study these compounds from multiple angles—formation and transformation, fate and transport, remediation and prevention. Between the shifting regulatory landscape, the need to detect pollutants at ever more minute concentrations, and how intricately these compounds are enmeshed in our lives, the field keeps researchers on their toes.

“I feel like we’re working in an ever-changing landscape,” says Purdue University researcher [Linda Lee](#), an SSSA and ASA member who has been in the field for decades, “a rapidly changing landscape.”

When Drugs Go Down the Drain

As a girl, fish net in tow, [Heather Preisendanz](#) would hunt for newts, salamanders, and—her favorite—frogs in the wetlands, vernal pools, and lakes of northern New Jersey. In support of her zeal for amphibians, her family even built a pond in the backyard.

“I remember hatching tadpoles as a kid and just being so amazed that this creature could start as an egg, hatch into a tadpole, and then metamorphose into a frog,” recalls Preisendanz, an SSSA member. “These were creatures that I cared about protecting. And once I realized how sensitive they can be to all the pollutants in the environment, then that turned into, I guess, what it is now.”

What it is now is a career devoted to keeping bad stuff out of water. As an associate professor of agricultural and biological engineering at Penn State University,

Preisendanz studies emerging contaminants like PPCPs. The COVID-19 pandemic presented her team with a unique opportunity to study what happened to our wastewater while millions of people were taking drugs to treat the virus at home and in hospitals.

For a study recently published in JEQ (<https://doi.org/10.1002/jeq2.20398>), Preisendanz and her colleagues spent a year mid-pandemic collecting samples of wastewater as it entered (influent) and then left (effluent) two treatment facilities in Pennsylvania. One is the facility that treats Penn State's wastewater to the state's "class B" standard before repurposing it for irrigation on a tract of university land called the **Living Filter**. The other is the facility that serves the surrounding area, including a hospital, which treats wastewater to the state's "class A+" standard before using some for irrigation and discharging the rest into a nearby stream.

Preisendanz's team tested the samples for SARS-CoV-2, the virus that causes COVID-19, as well as for prescription and over-the-counter drugs used to treat the virus. They then looked for correlations between what they found in the wastewater, COVID infection and hospitalization rates, and the number of students on campus.

"We started at the most basic," Preisendanz says. "Do we see any trends with the COVID case numbers? And then: Do we see any trends with hospitalizations?"



They observed some correlations they expected: For the university samples, for example, antibiotics showed up when students were on campus but not when they weren't. However, when COVID infection rates rose in the community, they did *not* see a corresponding bump in over-the-counter drugs in wastewater. Rather, variations in those levels appeared to be seasonal.

Similarly, when COVID hospitalizations increased, they saw in their samples no rise in the prescription drugs used to treat the disease.

At first, this left the scientists scratching their heads. Then they drilled down to more specific data on the number of COVID patients on ventilators, who typically receive dexamethasone. That's when the correlations began to emerge from the data.

"You really had to look specifically for what the medicine was being used to treat, and then the numbers made sense," Preisendanz says.



Kristin Cochran, a Ph.D. student in the lab of University of South Carolina chemist Susan Richardson,

Treated wastewater effluent is sprayed at Penn State's beneficial reuse site, called the "Living Filter." This diverts the wastewater from Spring Creek and allows the soil to act as a natural filter for any chemical residuals that remain in the wastewater. Penn State's Heather Preisendanz has studied the effluent for emerging contaminants. Photo by Heather Preisendanz.

conducts a liquid-liquid extraction of drinking water to analyze disinfection by-products (DBPs). Photo courtesy of Susan Richardson.

More head scratching ensued when the team detected traces of remdesivir in campus wastewater: There were no hospitalized COVID patients on campus. After a bit of sleuthing, however, they learned that a lab

was running experiments using the drug around the time they detected it in the wastewater.

When comparing treated wastewater, the team found that the community facility, which treated the wastewater to a higher standard, did a better job at removing some pharmaceuticals than the campus facility. They also found that, in the effluent at both facilities, levels of some pharmaceuticals remained high enough to threaten aquatic organisms. To Preisendanz, the finding highlighted how important it was to filter the effluent through soil before it would eventually reach those organisms, as both facilities do, or to release it into streams that can immediately dilute it with fresh water. Unfortunately, notes Preisendanz, not all areas of the country can offer those ecosystem services.

“In more arid portions of the U.S., that’s just not true,” she says. “There, effluent is a larger portion of the streamflow, and so there is less opportunity for the streams to dilute out contaminants. If what we’re seeing holds true to other wastewater treatment facilities where these chemicals are persisting and there is less dilution happening, then potentially the risk could be higher in those areas.”

Preisendanz's work had previously focused on, as she describes it, "what's at the end of the pipe and where it goes after it is released into the environment." But this new study also showcases the epidemiological applications of wastewater and what it can tell you about the health of the population that generated it. By monitoring wastewater for pathogens or pharmaceuticals, she says, treatment facilities can alert communities about potential public health issues—and help scientists get more bang for their research buck.



Demand for disinfectants surged during the COVID pandemic, adding to the wastewater stream more chemicals that, under the right circumstances, could transform into harmful disinfection by-products (DBPs).

"These are not cheap compounds to analyze for," Preisendanz says. The data could be leveraged through collaborations with public health experts, universities, prisons, and municipalities. "It opened the window for us to think about what we are doing differently, as having connections back to human health on the *upstream* side, and not just the implications after the fact."

PFAS vs. DBPs: Picking Your Poison

In addition to drugs and the virus itself, there's another class of compounds COVID helped boost in wastewater: disinfectants. **Demand for disinfectants surged** during the pandemic, adding to the wastewater stream more chemicals that, under the right circumstances, could transform into harmful DBPs.

Disinfectants such as chlorine, widely used in public water systems, react with naturally occurring organic matter, bromide, and iodide to create DBPs, some of which have been linked to cancer and other health problems. According to **Susan**

Richardson, a leading expert in DBPs and a professor of chemistry at the University of South Carolina (USC), more than 700 variations of the compounds have been discovered in drinking water to date. Many were first identified in her own lab, including the recent discovery of **an entirely new class of them**.

Richardson has water in her blood, she says. She grew up on St. Simons Island off the Georgia coast where she swam, crabbed, and explored the maritime forests. These days, she uses her off time to scuba dive in tidal rivers and hunt for fossils. Her discoveries include a six-inch-tall megalodon tooth: She was so excited to find it, she recalls, that she screamed into her regulator.

“You’re holding a piece of an animal in your hand that was alive millions of years ago,” Richardson says. “It’s like holding history.”

Her day job also involves hunting in water. But the specimens she looks for in drinking water are even harder to spot than dinosaur fossils—and a lot more dangerous. Richardson has spent more than three decades ferreting out DBPs using mass spectrometry, first at the USEPA, and more recently at her own lab at USC.

Richardson is also concerned about PFAS; she has developed a new method that screens for them by measuring the total organic fluorine in a sample. But she reserves the bulk of her scientific energy for DBPs, which she believes pose the much greater threat. Like PFAS, they are found in most waters but in far higher concentrations—micrograms per liter rather than nanograms. The epidemiologic data, she argues, indicate DBPs are much more toxic to people than PFAS.



Dr. Tamie Veith, a research scientist with the USDA-ARS who collaborates with Penn State's Heather Preisendanz, downloads hydrologic and water quality data from a monitoring station in Pennsylvania's Halfmoon Creek watershed. The monitoring station records data every 15 minutes for water level, temperature, dissolved oxygen, and rainfall. Photo by Heather Preisendanz.

"We've got bladder cancer, we've got a little bit of colorectal cancer," Richardson says. "And then there's some more recent studies that show miscarriage and birth defects."

Richardson worries DBPs are losing ground to PFAS in the competition for funding and public awareness. To understand this, it helps to know how the USEPA makes tough choices about which contaminants to regulate in drinking water. The process, managed through the Safe Drinking Water Act (or SDWA, which followed the CWA by two years), takes place in five-year cycles. **The National Primary Drinking Water Regulations** (NPDWR) currently cover dozens of contaminants, including 11 DBPs. The

agency periodically updates a **contaminant candidate list**, the first step for considering a compound for regulation. Some candidates end up on a much shorter **list of contaminants that public water systems are required to monitor**. Based in part on that data, the USEPA selects a few new compounds to regulate every cycle.

When, at the end of 2021, the USEPA published its **latest list of contaminants to monitor**, all but one of the 30 pollutants—lithium—were PFAS. The agency had to pick which poisons to target with its limited resources, and it picked PFAS. Many saw the move as long overdue: Currently, the USEPA doesn't regulate *any* PFAS in drinking water (although it recently issued **new health advisories**).

While disappointed by the USEPA's choices, Richardson continues to build her case against DBPs, like a prosecutor determined to nail a crime ring. One key challenge has been finding the worst of the bunch.

"There are definite human health effects, but we still don't exactly know which DBP's are the culprits," Richardson says. "That's what's been driving me."

Recently, Richardson narrowed in on those culprits. With a team that includes longtime collaborator **Michael Plewa**, now a professor emeritus of genetics at the University of Illinois Urbana-Champaign, she produced what the authors call the **most comprehensive investigation of drinking water toxicity to date**. They collected drinking water from across the U.S. that had been impacted by factors such as agricultural runoff, seawater, wastewater, and algal blooms. Then, using mass spectrometry, Richardson's team tested each sample for 72 DBPs, many of which had originally been discovered by her lab.

After characterizing the samples, she sent extracts to Plewa, who exposed them to mammalian cells. The team then correlated the data to see which caused the most damage.

Richardson had a pretty good idea which compound would prove the worst offender: iodoacetic acid, a DBP she had **discovered in 2004**. She recalls the thrill of spying the pointy peak that denoted the new chemical as it jutted up from the x axis of her mass spec results like a tooth from a dino's jaw.

"I had looked for them, hunted for them in the past, didn't see them," she remembers. "And all of a sudden, we're seeing them big as you please in drinking water."

As with other DBPs, she knew it was a disinfection by-product because the chemical shows up in treated drinking water but not in the source water. After discovering its unique chemical fingerprint and confirming its makeup, she sent a batch to Plewa for toxicology tests.

"Oh my God," he reported, as Richardson recalls. "Iodoacetic acid is the most genotoxic thing I've ever looked at. It was like an atomic bomb going off on my cell plates."

In the recent toxicity study, Plewa's team confirmed that iodoacetic acids, along with another group called haloacetonitriles, were important drivers of drinking water toxicity. Both correlated the most with the observed toxicity of the drinking waters sampled. Neither class is regulated by the USEPA. Ironically, one of the DBP classes the USEPA *does* regulate, trihalomethanes, shows no cytotoxicity, the scientists found.

In other words, the USEPA nailed the wrong guys, nabbing a few petty criminals while letting the DBP kingpins off the hook. On the plus side, Richardson notes, a subset of the highly toxic haloacetonitriles they found, di-haloacetonitriles, would be relatively easy for the USEPA to monitor with existing methods.



Penn State lab technician Bill Clees filters a wastewater effluent sample that will be analyzed for pharmaceuticals. Photo by Heather Preisendanz.

Increasingly, utilities are having to turn to poorer quality water supplies containing potential DBP precursors originating from algae or other factors, according to Richardson. Recently, she has been examining water from South Carolina lakes overrun by benthic algae. [In a paper published earlier this year](#), she and her coauthors found that, when water contained as little as 15 mg L⁻¹ of the stuff, the amount of DBPs formed—including some of the most toxic—more than doubled.

Agricultural runoff contributes to the algal blooms, Richardson notes. Unfortunately, reducing those inputs now might not help for many years due to benthic algae's deep-reaching roots.

"Even if all that stopped, that stupid algae might be able to continue because it's able to suck up the legacy phosphorus from the sediment," she says.

The frustration of dealing with a mess that might have been avoided rings true for other scientists studying emerging contaminants. For Purdue's Lee, a distinguished professor of environmental chemistry, that feeling comes through clearly as she talks about her research on PFAS, toxic compounds so persistent they're known widely as "forever chemicals."

Vampires of the Chemical World

Lee always loved math, science, and nature: As an Army brat, she toted her rock and bug collections from one base to the next. At the University of Florida (UF), she followed an undergrad degree in chemistry with a master's in environmental engineering while also working in a forest soils lab before earning a Ph.D. in soil chemistry and contaminant hydrology. Then it was off to Purdue to teach and study antibiotics and hormones in land-applied manure.

In the mid-2000s, after establishing herself as an expert in emerging contaminants, she got a call from DuPont. The chemical company, which at the time was under scrutiny for its decades-long production and disposal of PFAS, wanted to give her half a million dollars to study the compounds.

“To use as I see fit—with no strings attached,” Lee recalls of DuPont’s offer. “They realized that they needed universities to begin studying the environmental behavior of PFAS and how to analyze them. It might not have gone in the direction they had hoped, but they knew that they had to have data, outside of their own data.”

Indeed, things did not go particularly well for DuPont whose PFAS history had begun to catch up to the chemical giant. The company has been mired in legal battles, paid hundreds of millions in fines, and struggled to mitigate an ongoing PR nightmare. While largely unheard of at the beginning of this century, the once obscure class of chemicals they distributed worldwide through products like Teflon is now a household word. The compounds have made headlines, were the subject of a [Hollywood film](#), have been the target of state legislation and, increasingly, federal regulatory authorities. If there was a poster child for emerging contaminants, PFAS would be it.

With her DuPont money, Lee bought a new mass spectrometer, began studying PFAS, and never looked back. Over several decades, she has studied the compounds in wastewater, drinking water, biosolids, plants, and at the military bases she once called home where decades of spraying PFAS-containing aqueous firefighting foams (AFFFs) have resulted in the heaviest contamination. She partnered with Purdue ecotoxicologists and health scientists to examine their harmful effects on frogs and salamanders as well as *C. elegans* and zebrafish used as animal models to predict impacts on humans. In one recent paper, she and her UF coauthors documented its [transfer from tomatoes to caterpillars](#). She even invented and has been testing a

treatment based on **nickel-iron activated carbon nanoparticles** that destroys PFAS.



Examples of some products that could be sources of per- and polyfluoroalkyl substances (PFAS). They are virtually everywhere, thanks to their mobility and widespread use in consumer goods like cookware, carpets, makeup, and raingear where their repellent properties are prized. Illustration courtesy of Adobe Stock/Graphic&Illustration.

Her research seems as far-reaching as the compounds themselves: Today, PFAS are virtually everywhere, thanks to their mobility and widespread use in consumer goods like cookware, carpets, makeup, and raingear where their repellent properties are prized. There are 5,000 to 10,000 kinds of PFAS out there, Lee says, depending on how you count. They are the vampires of the chemical world, thanks to their unyielding carbon-fluorine bonds. They persist, bioaccumulate, transform, transfer, multiply.

"It gets really hard for manufacturing companies to take PFAS out of their products because they're probably in their facility somewhere from previous use or are still being used for some products," Lee says. She

should know: She has the same problem in her own lab. "Every stock of organic solvent we get, we have to check it for residual PFAS."

In the U.S., **the USEPA has been aggressively targeting PFAS** recently, including earmarking \$5 billion over the next few years to address PFAS and other emerging contaminants in drinking water. The agency released new **drinking water health advisories** for some PFAS, lowering them to the incredibly infinitesimal levels of 4 parts per quadrillion for the class called PFOA and 20 parts per quadrillion for the class

called PFOS. (Even 1 part per *trillion* is hard to conceive: It is **one drop in the amount of water it takes to fill 20 Olympic-size swimming pools**.) PFOS and PFOA are the most common types of PFAS and among the most toxic: In August, the **USEPA issued a proposal** to designate both as hazardous substances under the Superfund Act.

Although PFOA and PFOS still enter the U.S. in products from other countries, American companies have stopped making them. But they *are* still created in this the U.S. by a different means, as Lee has discovered.

One group of PFAS found in food packaging and other U.S. consumer products is di-polyfluoroalkyl phosphate esters (DiPAPS). Through processes not yet fully understood, these compounds end up in biosolids, the solid portion of what comes out of wastewater treatment plants. Biosolids can be used as fertilizer, benefitting crops while diverting the material from landfills or incinerators. But once applied, the PFAS in those biosolids can take on a life of their own as **Lee and her collaborators recently reported**. The research team examined what leached out of biosolids over a six-month period. Among other findings, they observed that the amount of PFAAs—the group that includes the Superfund candidates PFOA and PFOS—in the leachate far surpassed what had been measured in the biosolids initially. PFOA is considered the terminal degradation product of other PFAS like DiPAPS: The toxic buck stops with these extremely persistent compounds.

“That’s why we say PFAS multiply,” Lee says. “It’s PFAS multiplication due to transformation.”

The uncertainty surrounding the fate and transport of PFAS in biosolids has prompted some communities to restrict **or even ban its use**. Lee suggests taking a few steps back to see the bigger picture.



“What we need to do is figure out in what scenarios it’s safe to apply them, and are there ways that we can mitigate PFAS leaching from the biosolids,” Lee says. “But the idea that they should be landfilled or burned is the *opposite* of what we try to do for climate change. We’re supposed to be *sequestering* carbon.”

Lithium battery recycling remains extremely low, but education could help, according to Alex Chow, a professor in the Department of Forestry and Environmental Conservation at Clemson University. Better recycling programs and more participation are key to slowing lithium pollution, he says. Photo courtesy of Adobe Stock/PKZ.

The harmful effects of AFFFs, she points out, are orders of magnitude worse than those of biosolids.

“We need to focus on cleaning up the areas contaminated by historical use of AFFFs, direct discharges, and industry-impacted biosolids and not all the lower-contributing PFAS sources causing everybody to be fearful ... that you can’t drink your water,” Lee says. “We’ve created a lot of confusion in trying to be more proactive.”

Needed: More Funding and Education

Contaminants are scary and complex; science can be hard to understand; reasonable people can disagree on where to draw regulatory lines; and there are a lot of unknowns. No wonder there are varying views on emerging contaminants. One person’s “proactive” may be another’s “overcorrection.”

But on this the scientists agree: More funding for this expensive research, and outreach efforts aimed at keeping pollutants out of the environment to begin with, will help. The uptick in PFAS funding across federal agencies is heating up the field fast, Lee says. “There’s a lot and it’s not going away anytime soon. What it means is that we’ll be able to do a lot more science in all areas.”

Penn State’s Preisendanz, for example, has begun to transfer her emerging contaminant expertise to PFAS. She and Lee (who was on Preisendanz’s Ph.D. committee at Purdue) are collaborating on an USEPA-funded study on PFAS in well water, the source of drinking water for **15% of Americans**.

Preisendanz also led a **recent study assessing the PFAS impacts** of decades of wastewater-fed irrigation at Penn State’s Living Filter site. Her team detected PFAS across its 600 acres with concentrations highest on irrigated areas. While levels were below current federal thresholds, they exceeded drinking water levels being proposed by the state for PFOS and PFOA, as well as the USEPA’s new health advisories, raising questions about the future of irrigating with treated wastewater.

Education is key to mobilizing the public and decision-makers, Lee says. “What I want to see is municipalities being empowered to deal with the sources coming in—industry-specific sources and landfills that have money behind them,” she says. “Secondly, to get every entity, including the public, empowered to realize that their choices can make differences, even at the cash register.” (Preisendanz’s group has created a **free, online tool for people who want to buy products with fewer endocrine-disrupting compounds**.)

Lee convinced Purdue officials to switch to a PFAS-free floor wax, for example. On the legislative side, influential California has banned, or is in the process of banning, PFAS in

food packaging, clothing, textiles, carpets, and cosmetics; other states are following suit.

Education could also boost lithium battery recycling, says Clemson's Chow, which remains extremely low (he recommends the USEPA's [website on recycling lithium batteries](#) as a resource). Better recycling programs and more participation are key to slowing lithium pollution, he says, which is already concerning: Roughly one-third to one-half of people in the U.S. have [potentially harmful levels of the metal in their water supplies](#), according to the U.S. Geological Survey.

"People usually think lithium is relatively mobile and non-toxic because it's at relatively low levels," he says. "But if we leave them there, they will get at higher and higher concentrations. Then I will expect maybe a different story."

Dig deeper

Elijah O. Openiyi, Linda S. Lee, Caroline R. Alukkal, Evaluating sorbents for reducing per- and polyfluoroalkyl substance mobility in biosolids-amended soil columns, *Journal of Environmental Quality*, 10.1002/jeq2.20658, **54**, 1, (118–131), (2024).

Check out these ***Journal of Environmental Quality*** articles mentioned in this story:

- "Proactive Approach to Minimize Lithium Pollution":
<https://doi.org/10.1002/jeq2.20405>
- "Spatiotemporal Patterns of PFAS in Water and Crop Tissue at a Beneficial Wastewater Reuse Site in Central Pennsylvania":
<https://doi.org/10.1002/jeq2.20408>

- “Impacts of the COVID-19 Pandemic on Pharmaceuticals in Wastewater Treated for Beneficial Reuse: Two Case Studies in Central Pennsylvania”:

<https://doi.org/10.1002/jeq2.20398>

In addition, our podcast, **Field, Lab, Earth**, is celebrating the Clean Water Act’s 50th anniversary with two new episodes: In the first episode, Dr. Alex Chow discusses how we can take a proactive approach to lithium pollution. In the second episode, Dr. Jim Ippolito discusses 45 years of biosolids research in Colorado. Find us at <https://fieldlabearth.libsyn.com> or through your favorite podcast provider. Subscribe for free to never miss an episode. CEUs available.

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