Proper phosphorus fertilizer management is no longer just an issue for agriculture. On the heels of record-breaking blooms of algae in places like Lake Erie, the public has taken a keen interest in how farmers and their CCAs keep phosphorus, or P, on their fields. And conservation tillage practices like no-till may be at the heart of the pollution problem.
Public attention on P fertilizer management reached a new high in 2011 when record rainfall in Ohio washed phosphorus from farmers’ fields into Lake Erie, feeding a toxic algal bloom that covered 1,930 square miles—the largest in the lake’s recorded history and more than twice the size as the previous largest bloom in 2008.

The following year, when farmers struggled with epic drought conditions, the size of the algal blooms shrank to 10% the size of the previous year. With phosphorus runoff from farm fields on the agenda, farming practices immediately became the topic of discussion.

The massive algal bloom that covered a fifth of Lake Erie in 2011 wasn’t the first episode of phosphorus feeding algae growth. Farmers faced a similar challenge in the 1970s when massive algal blooms raised the ire of the recreational and fishing industries, sparking an international movement to curb phosphorus fertilizer pollution.

The result was a resounding success of farmers, government, universities, and industry working together to solve the problem. Thanks to the widespread adoption of conservation tillage and no-till practices, the amount of sediment-bound phosphorus that left farmers’ fields and spilled into Lake Erie via soil erosion dropped off significantly, and the algae that fed on the phosphorus nearly disappeared.

But by the mid-1990s, a strange new phenomenon occurred. The algal blooms that were once thought of as a thing of the past began reappearing. And, they were becoming more frequent and toxic.

The blue-green algae blooms made of potentially toxic cyanobacteria began returning in the western basin of Lake Erie at an increased frequency through the 1990s and into the 2000s. But all the while, farmers were becoming more efficient with fertilizer use and were applying at significantly lower rates than they were in the 1970s.

The conundrum, says Gail Hesse, executive director of the Ohio Lake Erie Commission, was that less phosphorus fertilizer was going into the system while algal blooms were becoming bigger and more frequent.

“We don’t see this as an overapplication problem just based upon the phosphorus being supplied and what’s being removed,” explains CCA Robert Mullen, director of agronomy at Potash Corp. in Wooster, OH. “I would guess that the issue is the general rule of 80–20—that 80% of the problem comes from 20% of the production system. There are times when applications are made in less-than-ideal conditions that can result in a fairly large amount of phosphorus being transported. But, it doesn’t look as if all

Left: In 2011, Lake Erie experienced its largest algal bloom in recorded history, covering 1,930 square miles. Photo courtesy of NOAA.
farmers are the bad players, according to the data.”

Rising fertilizer prices, Mullen adds, have limited farmers’ ability to buy large quantities of phosphorus. Thanks to soil testing, precision technology, and improved information through CCAs and extension, farmers largely are applying fertilizer at only required rates. That’s in stark contrast to previous decades.

“When you look back historically during the 1960s and 1970s, we were probably oversupplying fertilizer phosphorus during that era,” Mullen says. “But in the last five years, at least in Ohio, we’ve actually been supplying less P than farmers are using with crop production.”

That’s often resulted in P deficiency on many farms today, he adds. Still, the algal blooms are back, and public attention is growing as other industries and the public bear the cost of algae-filled waters.

CCA Greg LaBarge, field specialist in agronomic systems at Ohio State University Extension, says tourism on Lake Erie is a $10 billion industry, while sports fishing alone generates $1 billion. The algal blooms, which can significantly reduce oxygen levels and threaten fish and other aquatic life, have caused tourists to cancel outings or not rebook for upcoming seasons. The toxic blue-green algae called microcystis (top middle) has become more common in Lake Erie and has caused numerous problems with pets. Photos by (clockwise): Ohio Department of Natural Resources, D. Schloesser (USGS Great Lakes Science Center), Tom Archer, and Susan Winsor/Corn & Soybean Digest.

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And, at the right levels, toxins released by the algae can cause illness and even death in animals and occasionally in humans, according to the National Center for Water Quality Research (NCWQR), located at Heidelberg University in Tiffin, OH.

“It’s a different kind of algae than what was dominant back in the 1970s,” Hesse notes. “What we’re seeing now is what we call harmful algal blooms. We refer to them as cyanobacteria, and they have the potential to create toxins. Obviously, that’s a concern—in addition to the nuisance aspects from an aesthetic and recreational standpoint.”

One toxic blue-green algae called microcystis, which produces the toxin microcystin, has become more common in Lake Erie and has a safety recommendation by the World Health Organization at 1 part per billion for drinking water and 20 parts per billion for recreational contact. In Lake Erie, this toxic algae has caused numerous problems with pets.

“We’ve had reported illnesses in pets in Ohio because dogs will swim in the water and drink the water, but they just don’t have the body mass to process the toxins out of their system,” Hesse says.

The Ohio Department of Natural Resources also has a monitoring system in place to warn the public of levels of exposure during algal blooms. Beaches at Lake Erie have even closed during severe algal blooms.

The social cost of algal blooms isn’t just borne by beach goers and the tourism industry, though. Local
public water supplies are also affected via higher treatment costs.

“The good news is that the treatment of the public water supplies is effective at removing the toxin,” Hesse says. “The city of Toledo has spent $3,000–$4,000 a day for additional treatment costs when there’s an algal bloom. So, in addition to the public health concern, there’s a broader public policy concern from our infrastructure cost. The costs get passed onto all of us as rate payers to our public water supplies.”

Dissolved P on the rise

Stumped by both the return of the algal blooms and their toxicity, government and industry leaders created the Ohio Lake Erie Phosphorus Management Task Force in 2007 to determine what had changed. The cause of toxic algal blooms, Hesse says, isn’t so simple. The return of the algae is a culmination of factors that have coalesced with time. Understanding the problem begins by distinguishing two different forms of phosphorus and their unique contribution to algae growth.

Phosphorus entering Lake Erie comes in two basic forms, according to the task force’s final report released in 2012: (1) dissolved phosphorus, which is P with sediment filtered from the water, and (2) particulate phosphorus that is bound to sediment particles. Together, these two forms comprise total phosphorus.

However, the difference between dissolved and particulate phosphorus is significant. While particulate phosphorus is chemically bound to sediment and is only about 30% bioavailable for algae growth, dissolved phosphorus is about 95% bioavailable. And, while particulate phosphorus that’s bound to sediment settles to the bottom of the lake, dissolved P remains suspended in the water column and supports the development of algal blooms, according to NCWQR.

Meanwhile, NCWQR researchers found that while the amount of particulate phosphorus bound to soil particles had been decreasing over the years, there was a dramatic increase in the concentration and load of dissolved phosphorus, starting in the mid-1990s. In recent years, dissolved phosphorus comprised of 26% of the total P but 52% of the bioavailable P moving into the western basin of Lake Erie from the Maumee River.

Why the increase in the more-potent dissolved P and a decrease in particulate P?

NCWQR data revealed that only about 7% of the total P—comprising both dissolved and particulate P—entering the western basin of Lake Erie from the Maumee River can be attributed to municipal and industrial sources. That isn’t enough to account for the total increase, says Harold Watters, CCA and crops specialist at Ohio State University Extension.

“The task force knew that there were wastewater overflows out of Detroit, Toledo, and a number of other places mostly affecting the western basin of Lake Erie, but that still didn’t come up with enough phosphorus to indicate that’s the problem,” Watters explains. “They looked at homeowner lawns, storm sewers, on down the list and finally came to agriculture and determined from some information from the [NCWQR] that, yes, there was phosphorus going down those streams and rivers and into Lake Erie, and there’s probably phosphorus coming off the fields.”

With agriculture comprising the majority of land use in the Maumee River Basin, fertilizer for agricultural use is the largest contributor, Hesse adds. But something in the agricultural production system had changed.

Conservation tillage, tile drainage, and climate change

An increase in the amount of dissolved phosphorus coming from farms was invariably linked to the return of the algal blooms, the task force concluded. What wasn’t so
certain, though, was exactly how dissolved phosphorus was increasing and making it into the lake. Changing production practices in agriculture most likely accounted for the shift in less particulate P and more dissolved P moving through the system.

The answer may be hard for some farmers to swallow: The widespread adoption of reduced tillage and no-till may be at the center of the increase in dissolved P moving into Lake Erie.

By not incorporating fertilizer with tillage, fertilizer sits on top of the soil and remains vulnerable to rain or snowmelt, the task force concluded. And, by applying fertilizer in the fall and leaving it on top of hard, frozen soil through the spring, the phosphorus is allowed a long enough window to be washed into a river or stream.

“Typically, what farmers do is apply fertilizer to our soybean stubble in the fall ahead of corn,” Watters explains. “Unfortunately, we don’t necessarily incorporate it until the next spring shortly ahead of corn planting. It lays exposed out there from the first of November after soybean harvest until around April 1. And because it’s not incorporated, it’s subject to movement.”

More than 80% of Ohio’s soybeans are no-tilled, he says, while only about 20% of the corn is no-tilled. Even fields that are tilled, he notes, are in some form of reduced tillage.

Worm channels that develop in the soil may also be contributing to nutrient movement, Watters adds. In reduced-till or no-till systems, worm holes are allowed to develop in the soil, which create passageways for phosphorus to travel through the soil profile to drainage tile and then exit the field as dissolved P.

“When we plant corn, we don’t till it until we harvest the soybeans. So we’ve got a year-and-a-half to two years of opportunity for worms to start creating their little channels again,” Watters says. “And, it is believed that some of this phosphorus is going with water down these worm channels through the tile and then moving from the tile into the streams and on out into the lake. Again, this is all dissolved reactive phosphorus.”

Phosphorus exiting fields through drainage tile is no small issue in Ohio, which is comprised of heavy clay, poorly drained soils and where fields are commonly tiled. All northwest Ohio and Indiana counties that are included in the Lake Erie watershed have between 60.1 and 100% of harvested land drained by subsurface tile, according to the last survey done by the USDA Natural Resources Conservation Service. That’s the most of all Midwestern states.

Major precipitation events are also deemed a concerning factor for P removal from farm fields, according to a recent article on the Lake Erie algal blooms published in Proceedings of the National Academy of Sciences of the United States of America (PNAS). In addition to conservation tillage and fall P application, extreme meteorological events associated with climate change—particularly regarding precipitation and temperature—are making conditions ripe for large and toxic algal blooms to form, the authors assert.

“Severe spring precipitation events, coupled with long-term trends in agricultural land use and practices, produced a pulse of remarkably high loading of highly bioavailable dissolved reactive phosphorus to the western basin of Lake Erie,” according to the academic
team in reference to the remarkable algal bloom that resulted in 2011. In addition, uncommonly warm and calm conditions in late spring and summer provided ideal incubation, seeding, and growth conditions for bloom development in the lake, the team concluded. And if current trends in climate continue, the authors warn, the remarkable events of 2011 will occur with increasing frequency if no action is taken to change the system.

Back to the basics with 4R nutrient management

The challenge to modify long-established farming practices isn’t small, Watters acknowledges. Making the necessary changes in agriculture must start by changing the way CCAs and their farmers think about P management and how to bring tillage back into systems where it was removed.

The hurdle, he warns, is that there is often times little economic incentive for the farmer to change practices when the loss of P costs the farmer less than a dollar per acre or if an investment in a new implement is required. Educating farmers of the larger consequences of phosphorus loss, he stresses, is where solving the problem of P loss begins.

“We’re starting with educating farmers and making them think about some incorporation with tillage or doing some banding with a planter,” Watters says. “And, it would help if we changed our tillage practices to incorporate fertilizer immediately after application rather than waiting for several months to go by.”

The critical discussion that CCAs must have with their farmer clients, adds LaBarge, ultimately comes down to the 4Rs of nutrient management: The right time, right rate, right source, right placement of fertilizer on the field. (Read more about the 4Rs of nutrient management in the September–October 2012 issue of Crops & Soils magazine.)

“We’re really looking at the adaptation of the 4R nutrient stewardship program,” LaBarge says. “In addition to that, we’re looking at a 4R certification program—a third party type of certification of practices that ag retailers can put in place as far as nutrient management. It’s a conscience effort on their part to bring better advice to their growers about what happens to that nutrient.”

Greater use of soil testing to limit overfertilization, the use of streamside buffers, and placing filters on drainage tiles have also been recommended as solutions that farmers implement to reduce the amount of P that makes its way into rivers and streams.

While more is still being learned about the problem, Mullen says action must be taken now at the farm level. Otherwise, he warns, it may become a government issue down the road if the problem persists.

“If no action is taken, there’s a greater likelihood of regulation from the state and federal level,” says Mullen. “Will they have the information to stop the problem? I’m not convinced.”
This summer, agronomists, crop and soil scientists, growers, extension agents, economists, and other agricultural experts will gather at an interactive conference in Kansas City, MO to discuss nutrient use efficiency (NUE) and the barriers and opportunities for improving it. The question at the root of the discussions will be: What are the economic and social impediments to adopting farming and livestock management practices that we know will improve NUE? Are there success stories for voluntary programs, regulatory approaches, and economic incentives?

Decades of research have yielded a wealth of knowledge to effectively manage nitrogen and other nutrients in agriculture. Small-scale studies have demonstrated that inadvertent nitrogen losses to the environment can be minimized without jeopardizing profitable crop yields. Despite great strides made in improving crop and livestock breeding, fertilizer products, feed management, and other technologies, nitrogen losses to the atmosphere, surface water, and groundwater are increasing at levels that pose serious environmental and human health concerns in many regions of the world.

This will be an interactive gathering, so that participants will have ample opportunities to discuss barriers and solutions and share ideas during poster sessions and beer and coffee breaks.

The workshop is sponsored by the Woods Hole Research Center, International Plant Nutrition Institute, and The Fertilizer Institute. Co-sponsors include the Soil Science Society of America, American Geophysical Union, and International Nitrogen Initiative.

For more information:
www.soils.org/meetings/specialized/nitrogen-use-efficiency