Preventing dead zones in Lake Erie with nanomaterials

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By David Templeton / Pittsburgh Post-Gazette

Each summer, a dead zone expands in Lake Erie to an estimated 3,800 square miles, creating an oxygen-depleted area lethal to most fish and other aquatic organisms.

It might seem odd that aquatic life takes the biggest hit when fertilizer goes unused in cornfields and other croplands.

Corn, as it turns out, uses only half the nitrogen and even fewer of the phosphorus compounds in crop fertilizers, with the remainder free to leach into lakes, rivers and oceans and foster algae blooms that generate dead zones.

Researchers now are developing nanotechnologies — special microscopic compounds — to improve plant uptake of nitrogen and phosphorous. As with the fertilizers, such developments also beg the question of safety over the long term.

That’s why Leanne M. Gilbertson and her University of Pittsburgh research team advocate a “systems approach” to evaluate the health and environmental impacts of new technologies, from production to disposal.

Their recent report, published in the journal Sustainable Chemistry & Engineering, says “nanotechnology could be used to increase the amount of nutrients that reaches the crop, simultaneously decreasing the adverse impacts on the environment.”

Examples abound of fossil fuels, nuclear energy, chemicals, plastics, pesticides and herbicides producing adverse health and environmental impacts. Despite bolstering food production worldwide, fertilizers are responsible for ever-expanding oxygen-depleted dead zones in the Gulf of Mexico, Chesapeake Bay and Lake Erie, among other bodies of water.

The Gilbertson team’s other recent report, this one published in Environmental Science: Nano, discusses the “trade-offs between potential benefits realized by nano-enabling processes and potential impacts.”
“There are many examples of new technologies that aren’t so ‘green’ when you consider the entire product life cycle such as compact fluorescent lights that rely on toxic mercury for energy-efficiency gains, solar panels made with finite and rare metals, or electric cars charged by electricity from coal,” said Ms. Gilbertson, an assistant professor of civil and environmental engineering at Pitt’s Swanson School of Engineering.

“In sustainable engineering, our goal is to consider lasting effects when designing new technologies rather than narrowly focusing on the intended benefit,” she said. “In agriculture, the potential exposure to new materials will almost always be high, so focusing design on reducing the inherent hazard, for example, would have a big impact.”

**Fertilizing the wrong organisms**

Nitrogen and phosphorous are important plant nutrients. So it’s no surprise when they migrate off croplands, they can cause algae blooms whose proliferation exhausts oxygen levels in rivers, lakes and oceans. Sewage, vehicular and industrial emissions and some natural factors also can produce dead zones, a Scientific American article explains.

Most notable is “an 8,500-square-mile swath (about the size of New Jersey) of the Gulf of Mexico, not far from where the nutrient-laden Mississippi River, which drains farms up and down the Midwest, lets out,” the article states.

A 2015 report of the Ohio Department of Natural Resources says Lake Erie’s dead zone can expand to 3,800 square miles from July to October. That’s nearly the size of Pennsylvania’s southwestern corner — Allegheny, Westmoreland, Washington, Fayette and Greene counties (4,000 square miles). “Fish are forced to leave the cooler, deeper waters to inhabit new areas with more oxygen but potentially with different prey and warmer temperatures,” it says.

The United Nations Food and Agriculture Organization predicts a 34 percent human population increase worldwide, which will require a 70 percent increase in food production by 2050. Fertilizer is necessary to meet that goal, raising the demand for methods to prevent its migration from farmlands.

History offers multiple examples of technological failures, including the fact that 10 percent of plastics end up in oceans, where they biodegrade into toxic chemicals (bisphenol A or BPA, among others) that kill marine life.

DDT certainly killed mosquitoes that spread malaria and typhoid fever. “If the sole intent is to kill mosquitoes to control disease, DDT would be a ‘miracle chemical,’ ” Ms. Gilbertson said. “That designation quickly disappears when considering the entire life cycle of DDT. Even though it was banned in 1972 — 46 years ago — because of its toxicological effects on the environment, many adults still have traces of the chemical in their blood, research shows.
No crystal ball

Gregory V. Lowry, the Walter J. Blenko Sr. professor of civil and environmental engineering at Carnegie Mellon University, isn't part of the Gilbertson team. His research also focuses on engineering nanomaterials to enhance the resilience and productivity of cereal and specialty crops, including materials proposed for use in fertilizers and pesticides.

“Agriculture is notoriously inefficient,” he said, given the availability of inexpensive fertilizers and other materials. As a result, the full environmental costs, including environmental damage and promotion of climate change, “are not fully factored into the price of fertilizers,” he said.

Various nanotechnologies could be used to enhance plant uptake of fertilizers. Some opt to have nutrients target the most beneficial part of the plant. Others work to change or coat seeds before plantation to improve germination rates and improve water and nutrient uptake.

But with each method, and without a crystal ball, researchers must focus on weighing risks and benefits, he said.

“Life-cycle assessment is one established tool that can be applied to make broad assessments about the sustainability of a technology with respect to such examples as energy and water use and resulting environmental impacts relative to other alternatives,” he said. “In this regard, I fully agree with Leanne’s approaches.”

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