Academic Filtration Innovations Aim To Solve What Ails A Perishable Resource: Water

University of Vermont (UVM)

Water quality is a growing global concern. Under stress from pollution, climate change and a surging population growth, the status of this important and perishable resource is propelling this planet toward a multifaceted crisis.

According to the United Nations Environment Programme's (UNEP) 2010 Clearing the Waters: A Focus on Water Quality Solutions, "Every day, millions of tons of inadequately treated sewage and industrial and agricultural wastes are poured into the world's waters. Every year, lakes, rivers, and deltas take in the equivalent of the weight of the entire human population — nearly 7 billion people — in the form of pollution. Every year, more people die from the consequences of unsafe water than from all forms of violence, including war. And, every year, water contamination of natural ecosystems affects humans directly by destroying fisheries or causing other impacts on biodiversity that affect food production. In the end, most polluted freshwater ends up in the oceans, causing serious damage to many coastal areas and fisheries and worsening our ocean and coastal resource management challenges."

Phosphorus and nitrogen loading from sewage and other agricultural, industrial and urban uncontrolled discharges is a major cause of eutrophication (excessive nutrients enrichment of water bodies) that triggers taste and odor problems in the public water supply and excess blue green algae that leads to deoxygenation and fish kills. The estimated cost of the excessive runoff into U.S. waterways of phosphorous, a valuable fertilizer used in farming, urban and industrial settings, is more than $2 billion a year, according to the Year Book 2011: Emerging Issues in Our Global Environment by UNEP, "indicating that globally and annually the damage may run into the tens of billions of dollars." Also, phosphorous reserves are nonrenewable, with projected shortages to develop in less than 100 years.

University of Vermont Academic Filtration Technologies Show Promise

Given the extent of this growing crisis and the need for environmentally and economically sustainable water-treatment options, numerous management strategies and technical innovations are starting to emerge, including a portfolio of filtration technologies for the removal of phosphorous from waste-water sources that were developed by Aleksandra Drizo, Ph.D., a research associate professor at the University of Vermont (UVM) and licensed by the college's Office of Technology Commercialization (OTC) to PhosphoReduc LLC, a UVM startup company located in Burlington, Vt.

Drizo has pioneered research in the use of various iron-, aluminum- and calcium-based materials — natural and industrial byproducts that can be used to remove phosphorous from waste waters as a lower-cost alternative to other traditional technologies. The suite of UVM sustainable filtration technologies — two with patents pending and a third in the application process — is based on a plentiful and recyclable byproduct of steel manufacturing industry, steel slag.

> *The sustainable filtration technology has been shown to reduce phosphorous, suspended solids and pathogens (E. coli) loads from sewage, agricultural and urban point and nonpoint pollution sources by 90 – 100 percent.*

Apart from providing treatment for a variety of waste-water streams, Drizo and her UVM research team have adapted their technologies to an array of climatic regions, from subtropical to temperate regions, where large storms or snowmelts are common, but large areas of land to handle the high volumes of water from these events are scarce. They also have shown that once the lifespan of the system is completed, the phosphorus and minerals retained by the filtration material can be re-used, instead of chemical fertilizer, to enhance soils used for agriculture, horticulture and forestry.

Specifically, she and her research team at UVM have developed technologies for a simple filtration system that uses unique, but abundant, metal compounds as the filtration medium:

- An integrated, multistage constructed wetlands and phosphorus removal filter system
- Phosphorus removal and sequestration filters for treatment of agricultural, municipal and residential waste waters (point pollution sources)
- Simple "torpedo" system for phosphorus reduction from agricultural tile drains and urban storm-water outflows or in agricultural and onsite waste-water disposal drain fields for capturing and treating pollution originating from nonpoint, diffuse pollution sources and residential waste waters

As a leading researcher in filter technologies for phosphorus removal from waste waters that can help solve the worldwide occurrence of algae blooms and eutrophication, Drizo has received grants and awards for her research from a variety of federal agencies and programs: the U.S. Department of Agriculture, the Natural Resources Conservation

Service, the National Research Initiative and the Environmental Protection Agency.

Steel slag, available in different types, including electric-arc furnace, blast furnace, basic oxygen furnace and iron smelter slag, for various applications, including mining and road building, "shows real promise as filtration material, not just for phosphorous and suspended solids but also for the bacteria E. coli in waste-water treatment plants in smaller, rural communities, as well as in storm-water applications found in urban areas," says Robert Slusser, a self-described champion of the UVM technology outside his official duties as a watershed field coordinator for the Virginia Department of Conservation and Recreation.

Slusser, who first learned of Drizo's research with steel slag as a filter medium via an email exchange with a New Zealander, says the pollution threat posed by waste-water discharge from farm and rural activities justifies a closer look at sustainable filtration technologies like those developed at UVM. Today, waste-water discharges from 30 percent of the population that depends on septic systems, since they live in areas where it is prohibitively expensive and impractical to extend sewer lines, pose two water pollution concerns: Most of the onsite systems are not properly managed for lack of management skills and/or neglect, and they were installed decades ago and have long since passed the recommended replacement dates. Examples of septic systems failures typically include holes in the pipes

or tanks, clogs that cause tanks to overflow and back up solid waste into buildings or leach fields and soils that either become saturated with nutrients or ill-suited for removing the pollutants.

"When I talk to state and municipal officials, planning consultants and farmers about waste-water issues, I always have the steel slag story in my back pocket," says Slusser, who has befriended and introduced Drizo to various public and private individuals who are interested in her filtration technologies.

UVM OTC Helps Innovator Launch a Startup

"These filtration innovations represent more of a platform technology where we see several application and market opportunities," says Todd Keiller, director of UVM Ventures and UVM OTC, which was instrumental in obtaining patent protection for the UVM intellectual property and establishing the startup company. "We could have taken the nonexclusive licensing approach with multiple entities, but it became clear that a better strategy was to license the technology to one entity that would have exclusive rights to target multiple applications and markets."

Keiller and his UVM OTC team decided it was worth helping Drizo and her partner, Hugo Picard, a Canadian entrepreneur with experience in small-company business development and operation management, start their own company based on the UVM-licensed technology.

So, in 2007, Drizo and Picard established PhosphoReduc, with seed funding assistance from UVM Ventures.

"In the early stages, we helped PhosphoReduc bridge the gap between early stage research and angel, early seed ventures,"says Keiller. "Our activities included conducting a thorough market assessment, as well as working with them to develop a prototype and a business plan."

In return, UVM Ventures holds an equity stake in the company with a royalty agreement.

"I certainly had envisioned owning a business because my partner has been a successful entrepreneur for about the past 10 years," Drizo says looking back on the decision. "I saw how well it was working so it gave me the strength to go into business."

Drizo credits the UVM OTC and the UVM College of Agriculture and Life Sciences (CALS) for playing a pivotal role in the

expansion of her academic innovations beyond university laboratory and field settings.

“In 2006, the UVM OTC funded our first patent application for System and Method for Removing Phosphorus from Non-Point Pollution. Then we received the necessary funding through the UVM OTC and CALS Dean’s Office Agricultural Innovations Fund to establish our small-business venture, PhosphoReduc LLC,” says Drizo. “Now we have broad applications in the United States, Canada and Taiwan.”

Persistence Coupled with Desire to Solve Water Issues

Since 2007, when Drizo, Picard and the UVM support team first established PhosphoReduc, the startup has had to overcome several hurdles in its drive to create pilot, demonstration or full-scale projects. The startup was confronted by various regulatory challenges, from state-to-state, within U.S. agencies and around the world, as well as expensive certification requirements that were made even more challenging during the global economic recession.

“Despite these challenges, the desire to help solve a crucial water-quality issue was what encouraged the PhosphoReduc team to persevere,” Drizo says.

Today, the PhosphoReduc custom-designed systems consist of one or more filter units filled with iron- and/or calcium-based filtration material derived from slag. Phosphorus and other pollutants are removed from waste water by capturing it within the filtration material at the specific hydraulic residence times. The filtration media is packed, arranged and integrated in specially designed modules that form a modular composite filter. This method developed by PhosphoReduc allows users to replace the modules as needed and also extend the overall lifespan of the system, ensuring the effluent meets water-quality targets.

“Our technologies are showing to be highly efficient, not only in removing phosphorus, but also other pollutants including suspended solids, pathogens and various metals and minerals,” Drizo says, citing to-date PhosphoReduc treatment performance data that shows on average: 95 percent phosphorus removal from point pollution sources (residential, municipal and agricultural effluents); 80 percent phosphorus removal from nonpoint pollution sources; 90 percent removal of suspended solids; 95 percent removal of E. coli bacteria; and 85 percent removal of manganese, iron, aluminum and zinc.

In addition to reducing phosphorus and diminishing blue green algae growth, Drizo says PhosphoReduc filters based on UVM technology require little to no energy, a small land footprint, and minimal operation and maintenance. And, since the filtration materials efficiently reduce phosphorus, they decrease the reliance on costly chemicals and the amount of sludge accumulation and disposal in municipal waste-water treatment facilities, are simple to install with negligible land disturbance and provide a significantly longer lifespan compared to other passive treatment systems.

These innovations developed by Drizo and her research team are backed by years of testing and research. They are found in Vermont, Virginia and Taiwan, where demonstration and full-scale systems are contributing to the environmental sustainability of waste-water management in agricultural, urban, residential and municipal settings. Vermont is even considering adopting the technology as a “best management practice” for agricultural tile drains, pending evaluation on a test site in that state.

Meanwhile, in Virginia, Slusser believes that Drizo’s steel-slag argument is going to get a much-needed boost when data becomes available from the residential waste-water treatment project that is being tested and considered in Taiwan.

“We need inexpensive, environmentally sustainable solutions, not only for waste-water treatment plants in smaller

communities, but for expensive storm-water detention applications as well. This is a huge problem that is starting to be discussed in Virginia, the rest of the country and the world," Slusser says. "If steel slag can come along as acceptable as we focus attention on water quality, then this filtration medium can be incorporated into more consistent regulations, and we can really achieve a significant reduction in pollution and bacteria in our planet's perishable resource."

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