The Imagination to Innovate; The Stamina to Succeed

Ernest C. Manning Awards Foundation

MEDIA BACKGROUNDER: The Why and How of Phosphorus Recovery

The P in Wastewater

It's in our DNA, our cells, our teeth and our bones. Every living thing needs phosphorus, and unlike oil and gas, there is no alternative to this essential element. We get phosphorus — P, for short — in the chemical form of phosphate from our food and water. Plants get it from the soil.

"I don't worry so much about oil, because you have alternate sources of energy," says Manning Innovation Award winner, Dr. Donald S. Mavinic. "I worry about water and I worry about phosphorus. Without 'em, nothing can live."

Mavinic's research team invented a cost-effective system that allows wastewater treatment plants to recover pipe-clogging phosphate — which is both a dwindling global resource and a pollutant — and reuse it as the environmentally-friendly fertilizer, Crystal Green®. The process was commercialized by Vancouver's Ostara Nutrient Recovery Technologies Inc.

Centuries ago, early chemists concentrated phosphorus from urine. They were searching for a way to make gold, but perhaps recovering phosphorus from wastewater is just as valuable. To keep up with demands for fertilizer, over 150 million tonnes of phosphate rock are mined every year. Mining and processing scars the landscape and can produce mine tailings laced with toxic, even radioactive metals. Conventional phosphate production is also energy intensive and generates greenhouse gases.

Furthermore, global phosphate reserves are limited. It is difficult to know how much is left, but what is accessible and free of heavy metals could run out in decades.

Too Much of a Good Thing

The looming phosphorus shortage goes hand in hand with another serious environmental challenge: phosphate pollution of water.

Satellite images reveal a trail of travesty that runs from the foothills of the Rocky Mountains through to Lake Winnipeg, relates Mavinic. The nutrient-enrichment of water — a condition known as eutrophication — sparks algal blooms, which soon die off and decompose, removing oxygen from the water in the process. "Starved" of oxygen, fish and other aquatic life die.

Similar dead zones in the Great Lakes and oceans can be traced back to run-off from urban centres and agricultural land across North America. Says Mavinic, "too much of a nutrient is not a good thing…everything is about balance."

The bloom and bust ecology of phosphate-rich waters is the reasoning behind phosphate-free detergents, a connection convincingly demonstrated by another Canadian, David Schindler, in the 1960s. But using eco-friendly detergents solves only part of the problem.

The Pearl® Nutrient Recovery Facility at Edmonton, Alberta's Gold Bar Wastewater Treatment Plant is a demonstration facility that can produce about a half tonne of Crystal Green® per day. The reactor can remove over 80 percent of the phosphate from sewage sludge liquors as well as up to 15 percent of the ammonia, another nutrient used in fertilizers. Not only is a pure, saleable fertilizer made on site, the process keeps the nutrients out of natural waters.

William McDonough, a champion of sustainable design and co-author of *Cradle to Cradle: Remaking the Way We Make Things*, lauds Ostara's approach. "Cradle to Cradle Design is fundamentally different from other approaches to sustainability. Instead of pushing a guilt-ridden agenda of minimizing damage to the environment, we celebrate abundance. Crystal Green® is created in this spirit of abundance by recovering phosphorus and other nutrients from wastewater into a premium, renewable commercial fertilizer."

An even richer source of phosphates than sewage is agricultural waste, in part because of fertilizer that washes off the land into natural waters. Crystal Green®, however, is a high quality, slow-release fertilizer that, unlike other fertilizer products, virtually eliminates nutrient run-off. As Ostara board member and environmental advocate Robert F. Kennedy, Jr. explains, "you just sprinkle it on the ground and it just stays there until the plants absorb exactly what they need."

Livestock waste also adds to nutrient run-off. Cows, for example produce 15 to 20 times as much phosphorus in their waste as we do. Mavinic's research team at the University of British Columbia is presently looking at ways to recover phosphorus from agricultural waste. So far they have tested a reactor that removes nutrients and produces methane from pig and dairy waste. Through ongoing research collaborations between UBC and Ostara, the team hopes to turn another stinking problem into a marketable product.

Not Just a Fish Story

It was the drive to rejuvenate the lifeless water reservoirs of British Columbia that led BC Hydro to put out an appeal for a Canadian source of phosphorus in 1999.

At the time, Mavinic was working on a solution to the phosphorus-compound buildup plaguing biological wastewater treatment plants. Years earlier he had recognized that the same mineralized crud that cost plants $100K or more each year to remove was, in fact, rich in phosphorus. The challenge was how to get it out.

BC Fisheries researcher, Ken Ashley — Mavinic's former grad student — saw another reason to recover the phosphorus. Phosphorus is not only an essential nutrient for plants. Without it, natural ecosystems cannot support life. Before dams blocked BC's rivers, salmon would swim upstream to spawn, live and die, their rotting carcasses feeding phosphate and other nutrients back into the water. Algae used the nutrients to grow, shrimp ate the algae, and salmon ate the shrimp. But without the dead salmon to act as nutrient pumps, the waters were oligotrophic (nutrient-deficient) and therefore lifeless.

Encouraged by Ashley and BC Hydro's Ed Hill, Mavinic and his Research Associate Fred Koch wrote a proposal for BC Hydro's Strategic Environment Initiatives Program. Their proposal to recover phosphorus from wastewater and turn it into fertilizer for BC's water reservoirs was enthusiastically accepted. With the grant award, the development of a new approach to phosphorus recovery was underway.

The plan was to recover the phosphorus in the form of struvite, the mineral with the chemical name magnesium ammonium phosphate. "I started a research program right from scratch," recounts Mavinic. "We literally went back to basic chemistry in the lab."

Innovative Engineering

Reverse-engineering the process to make struvite pellets took patience, not only on the part of Mavinic's research team, he notes, but also from BC Hydro.

In hindsight, Mavinic's gift for innovation is not hard to trace. Growing up in Windsor, Ontario, he used his free time to build igloos, tunnels, tree forts, super-powered go-carts, and, with the help of some friends and neighbours, a backyard garage or two that got the attention of the city inspector. "We used wood, steel, concrete blocks, asphalt shingles, wire, rope — basically anything that would keep our structures standing, especially under heavy Windsor storms," Mavinic recalls.

Summer jobs in environmental engineering while at the University of Windsor piqued his interest in the environment, and, with a nudge from mentor Dr. J.K. Bewtra — someone Mavinic still goes to for advice — he entered grad school, obtaining a PhD in 1972.

A professor with UBC since 1973 and a consultant to over 50 government agencies and engineering firms worldwide, Mavinic has long been a leading force in environmental engineering.

Even so, the struvite recovery problem was tricky, and Mavinic credits Koch — "nuts and bolts man, tinkerer…pilot plant manager and Jack of all trades" — for convincing him to stick with the project. After going so far as to correct some errors about struvite chemistry in the published literature, Mavinic and his team worked out an elegant design for a practical phosphorus recovery system.

An NSERC Collaborative Research and Development grant allowed the team to test small-scale reactors at the Advanced Wastewater Treatment Plant in Penticton, BC. Stantec Consulting Ltd, an engineering firm from Edmonton, Alberta, also lent their support. With the background work complete, Mavinic and Koch, along with fellow UBC instructor Noboru Yonemitsu and grad student Ahren Britton, applied for a patent on the reactor design in 2004.

The system, a fluidized bed reactor, looks like a stack of giant, enclosed kitchen funnels. Wastewater pumped in at the bottom of the cones flows upward, and as it splashes around, struvite crystals form. A pinch of sodium hydroxide to control the pH helps optimize the process. Small pearl-like struvite pellets suitable for agricultural applications float, while larger pellets, sought after by BC Fisheries, sink to the bottom.

Ostara: Goddess of Spring

In 2003, additional funding from the Greater Vancouver Regional District (now known as Metro Vancouver) provided for the first of a series of scaled-up reactors at Lulu Island. These and newer reactors at the Penticton site proved the technology's success.

UBC's University-Industry Liaison Office searched out the right entrepreneurs to commercialize the technology, and in May 2005, a team led by business executive Phillip Abrary founded Ostara Nutrient Recovery Technologies Inc. Like their namesake, Ostara, Scandinavian goddess of spring, the company looked forward to a bountiful future.

A year later, Ostara shipped a pilot unit to the City of Edmonton. The success of the pilot study led to the construction of Ostara's first full-scale demonstration facility, commissioned in Edmonton in 2007.

"I've always believed in putting research into practice," says Mavinic, one of Ostara's original board members.

In 2009 Mavinic stepped aside so that VantagePoint Venture partners Robert F. Kennedy and Dr. Rafael Simon could join Ostara's distinguished Board of Directors. Thanks to $10.5 million from the US-based green tech investors, and Frog Capital (UK), Ostara's capacity is expanding quickly.

"It's been a team effort," says Mavinic, adding that the researchers and Ostara are thrilled with the Manning Innovation Award win. "They're sky high," he reports.

Trialed across North America, China, Israel and Europe, Ostara's first commercial nutrient recovery facility opened at Clean Water Services Durham Advanced Wastewater Treatment Plant in Tigard, Oregon in 2009. Additional commercial nutrient recovery facilities have since begun operations in Suffolk, Virginia and soon in York, Pennsylvania.
