Optimizing phosphorous removal and struvite recovery from wastewater streams

Latest-generation technology for total phosphorus removal in municipal and industrial wastewater treatment plants eliminates chemical-P costs, minimizes plant struvite scaling, reduces aeration demand and power requirements for nitrification, and recovers 90 percent of struvite for recycling. Journalist Jim McMahon reports.

Municipal and industrial water resource recovery facilities use varied treatment processes to provide safe effluent levels before discharging into waterways. These systems are selected based on a number of important criteria, including the makeup of influent entering the treatment plant, the quality of finished water required to comply with federal and state requirements for decanting, capital investment requirements, ongoing maintenance and operational costs, and system flexibility. To assess these requirements effectively, treatment plant operators must stay informed of improvements in treatment facility systems technology and methods for minimizing operational costs.

One of these treatment plant processes is the removal of phosphorous from wastewater streams, which is of major interest to regulatory agencies and has come under progressively tighter United States Environmental Protection Agency (EPA) and state regulatory agency water quality regulations to lower total phosphorus discharge limits.

Phosphorus removal is an environmentally important process because nutrient pollution is one of the most widespread, costly, and challenging environmental problems in the United States (US). Phosphates contribute to the phenomenon of eutrophication, arising from the oversupply of nutrients, which induces an explosive growth of algae faster than ecosystems can handle. Significant increases in algae harm water quality in streams, rivers, lakes, bays, and coastal waters. Additionally, the algae harms food resources and habitats by decreasing the oxygen that fish and other aquatic life need to survive, creating the state of hypoxia.

Conventional phosphorus removal

Conventional treatment technology for phosphorus removal in water resource recovery facilities involves both biological and chemical removal processes to achieve the current 0.1 milligrams per liter (mg/l) standard. Biological processes remove a large percentage of the phosphorus load, with the remaining amount removed by the chemical addition of ferric chloride or other polymers to meet the discharge permit total maximum daily load (TMDL).

The mass balance of wastewater treatment plants indicates that up to 30 percent of the phosphorus load into the plant can come from the dewatering pressate or centrate stream return line. This result is visible in the phosphorus concentrations of liquors produced in the dewatering of digested biosolids, which can exceed 500 mg/l. However, these phosphorus-laden liquors, which are returned to the headworks of the plant, typically contribute less than 1 percent of the total wastewater influent into the plant.

Although this process is conventional, the highly concentrated returned phosphorous puts an unnecessarily high load back into the plant for treatment, increasing plant energy and chemical and maintenance requirements.

Removing phosphorus from side streams

Removing phosphorus from the side stream before it reaches the headworks can have significant efficiency advantages for the operation of the treatment plant, with tremendous economic impact.

In Japan, a process called Phosnix® has been successfully implemented in wastewater treatment plants for the total removal of phosphorus from dewatering filtrate or digested sludge streams. It is a highly cost-effective technology, removing 90 percent of the phosphorus before returning the water to the headworks. The process was developed and patented more than 25 years ago by Hitachi Zosen Inova, a global leader in environmental technologies in the water and waste segments. Phosnix, having evolved into a proven technology in Japan, has only

The Phosnix system allows resource recovery facilities flexibility in the design and operation of the process. Photo by HZI recently been introduced to the North American market by Hitachi Zosen Inova U.S.A.

Phosnix uses magnesium hydroxide, $Mg(OH)_2$, to form a chemical compound with phosphate and ammonium. The result is struvite (magnesium ammonium phosphate), a phosphate mineral, $NH_4MgPO_4 \cdot 6H_2O$, which is subsequently harvested.

The process is not intended to treat raw wastewater but rather nutrient-rich side streams in the wastewater treatment plant. It is often due to these side streams (sludge dewatering liquors) that it is impossible to achieve extremely low levels of nitrogen and phosphorus in the plant effluent. This is particularly the case for plants with enhanced biological phosphorus removal because phosphorus is released in anaerobic digesters and then not removed in the sludge. With the Phosnix process, a biological nutrient removal wastewater treatment plant can be upgraded to significantly improve its phosphorus removal performance.

The Phosnix process starts with both sewage sludge liquor and digested sludge being fed into a draft tube-type reactor as a continuous flow. Reaction is at atmospheric temperature and pressure, with pH 8.5. After a week of reaction, the struvite is extracted and put through a separator for further drying.

Phosnix plays an important role in plant-wide efforts toward achieving energy efficiency and reduced maintenance and costs for wastewater treatment plants. Compared to conventional processes for phosphorus removal, the Phosnix process is characterized by several conditions:

a) Decrease of energy usage – Reduced aeration demand and power for nitrification because Phosnix uses ammonium.

b) Elimination of chemical P – No need for chemical phosphorus (chemical P). No ferric chloride or polymers required, which saves chemical costs.

c) Reduction in sludge production – Sludge treatment depends on the volume of solids generated. Elimination of chemical P reduces sludge loads, and the corresponding disposal costs are minimized.

d) Minimized struvite scaling – Struvite scaling is a continual problem in wastewater treatment, particularly after anaerobic digesters release ammonium and phosphate from waste material. Struvite forms a scale on lines and belts, in centrifuges and pumps, and clogs system pipes and other equipment including the anaerobic digester itself. With Phosnix, struvite is pulled out in the process. Diagnosing and removing struvite from clogged pipes is no longer an issue, reducing maintenance labor and costs, and avoiding process shutdowns.

Struvite nutrient recovery

Unlike many other wastewater treatment processes, Phosnix produces no harmful by-products. The technology recovers struvite from both digesters and the dewatering filtrate or centrate stream for reuse as an eco-friendly fertilizer.

The Phosnix process removes nitrogen phosphorus from nutrient-rich wastewater by binding these two compounds together in the form of crystallized struvite. The struvite's composition on a weight basis is 9.9 percent magnesium, 5.7 percent nitrogen, 12.6 percent phosphorus, with the remainder being crystalline water. It satisfies a need for mineral slow-release fertilizers, which have widespread uses in horticulture and nursery applications.

The recovered struvite is therefore a highly marketable byproduct for wastewater treatment plants, currently market-valued at approximately US$350 per ton.

Performance and flexibility

For treatment facilities using the Phosnix process, total cost savings are approximately $400,000 annually. These savings come from the combined cost reductions related to decreased energy usage for aeration, elimination of chemicals for phosphorous removal, reduced need for sludge removal, reduction in plant maintenance for anti-scaling, and market returns from struvite sales.

The Hitachi Zosen Inova Phosnix system allows water resource recovery facilities flexibility in the design and operation of the process, providing full turnkey installations encompassing design, financing, construction and operation, or providing specific functions of the Phosnix system. This flexibility also extends to the disposal of struvite since Phosnix allows the facility full flexibility to market or broker its struvite as it deems appropriate.

Phosnix is designed to be technically simple and robust, and while the investment costs are in the range of traditional and alternative methods, it has a fraction of the operational costs of traditional systems. It is likely that with these cost and operational efficiencies, North American municipal wastewater treatment plants and industrial plants handling high-phosphorous-content wastewater will gravitate toward adopting this new-generation process for phosphorous removal and struvite recovery.

Author's Note

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About Hitachi Zosen Inova

Hitachi Zosen Inova (HZI) is a global leader in energy from waste (EfW), operating as part of the Hitachi Zosen Corporation Group. Formed from the former Von Roll Inova, HZI acts as engineering, procurement, and construction (EPC) contractor delivering complete turnkey plants and system solutions for thermal and biological EfW recovery. HZI has delivered an estimated 570 reference projects since 1933.

Above: The composition of the struvite produced from the Phosnix® process is 9.9 percent magnesium, 5.7 percent nitrogen, and 12.6 percent phosphorus, with the remainder being crystalline water. Photo by HZI

WEF, ABC to accelerate resource recovery

The Water Environment Federation (WEF) and the American Biogas Council (ABC) are partnering to expand the conversion of organic waste into renewable energy and valuable soil products at facilities across the United States (US).

More than 2,200 biogas facilities are operating in the US. About 1,300 of them are at water resource recovery facilities, but there are nearly 4,000 water facilities where new biogas systems could be installed.

There is a long history of using biogas as a reliable, renewable fuel source for electricity generation, heat, combined heat and power, and vehicle fuel. WEF's recent publication *Accelerating Resource Recovery: Biosolids Innovations and Opportunities* provides a thorough review of biogas systems in the water sector. ABC launched the new Digestate Certification Program that creates a standard method for describing the qualities of digestate, the product generated by anaerobic digestion of organic materials.

The ABC is a US trade association with more than 200 company members that specialize in maximizing the production and use of biogas from organic waste.

The organizations will continue to work together to promote resource recovery, specifically the use of energy and products produced from biogas systems at water facilities. WEF and ABC reaffirmed these goals by signing a new memorandum of understanding (MOU) in June 2017.

"Energy derived from wastewater and biosolids moves our nation toward a more resilient and sustainable future, and there is tremendous potential for growth in the generation of these renewable resources" said WEF Executive Director Eileen O'Neill.

"A significant opportunity exists to utilize existing wastewater digester capacity to recycle organic materials, like the billions of pounds of food that Americans waste each year," said ABC Executive Director Patrick Serfass. "In the US, we could build more than 13,000 new biogas systems. One-third of them can be built at water resource recovery facilities. These biogas projects will create jobs, investment and choices for generating energy, soil products and waste management."

Specifically, WEF and ABC support:

- Beneficial use of biogas, digested materials and biosolids for communities
- Use of proven technologies that facilitate energy and nutrient recovery
- Encouraging federal and state legislation that promotes the use of biogas as a renewable energy source; communications and public outreach to build a base of community support
- Continued research and sound science in regards to biosolids management; and the development of state and federal regulations.

WEF and ABC believe that wastewater treatment plants are water resource recovery facilities that produce clean water and, through the use of biogas systems, yield renewable energy, recover nutrients and produce nutrient-rich soil amendments that reduce the need for synthetic fertilizers.