

Minephos: Sustainable Solution for Phosphorus Recovery from Wastewater

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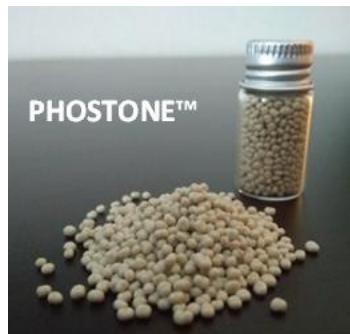
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Introduction

As the global population rapidly increases so does the demand for food and the resources required to produce it, such as energy, water, and nutrients. To ensure the sufficiency of these resources they should be utilized in a sustainable manner. One of the most important pathways to it is to recover valuable commodities from non-traditional and renewable sources, such as waste streams, which could otherwise create environmental pollution problems. Many sewage treatment plants around the world are currently facing tightening regulations on nutrient discharge into the environment, particularly phosphorus, which force them to adopt innovative nutrient removal and recovery technologies. Despite being considered a pollutant, phosphorus is an essential nutrient for all forms of life and one of the major nutrients used in the agriculture industry. However, it is very common that the nutrients are applied to the agricultural land in large excess, whether by means of synthetic commodity fertilisers or through manure land application. This creates significant environmental pollution problems since the excess nutrients leach into the ground water and result in eutrophication and algae blooms. At the same time, agricultural waste has been shown around the world to have a great potential for resource recovery. The concept of renewable resources recovered from waste enables to lower the burden on the traditional resource mining, to increase agriculture sustainability and lower the costs of food production, as well as to shift towards the circular economy.

Principles of MINEPHOS Technology

In order to address the aforementioned challenges, PHOSMAG Group has developed MINEPHOS technology that can selectively extract phosphorus from waste streams in the form of a concentrated valuable fertilizer, free of any contaminants. The technology is based on a process of phosphorus recovery in the form of struvite (tradename PHOSTONE™) which is a valuable slow-release fertilizer that contains 28% of phosphorus (as P_2O_5). Unlike traditional water-soluble fertilizers, struvite is a slow-release fertilizer that prevents the loss of nutrients in the soil and at the same time provides sufficient nutrition to the plants. The slow-release nature of struvite solves environmental problems such as eutrophication, thus relieving policy and economic pressure regarding environmental impact of agricultural activities and waste management.



Phostone™ granules

The MINEPHOS process is based on the principle of fluidized bed reactor where phosphorus containing wastewater is injected at the bottom of the reactor and is mixed with precipitating reagents to form struvite. *Unique chemical and hydrodynamic conditions in the reactor controlled by a smart process software allow struvite to form into granules which settle down below the reactor by means of elutriation and can be easily separated from the wastewater, while the treated effluent exits at the top.* The technology is capable of treating a wide variety of waste streams such as livestock and poultry manure, sewage sludge, and various industrial wastewater. It is currently patented in 7 countries and there are patents pending in 14 more jurisdictions around the world.

Many existing struvite technologies recover it in the form of powder or small crystals, which is more difficult to separate from the liquid. As a result, such products have low purity and contain various contaminants. This reduces the value of the recovered struvite and creates the need for additional processing before the product can be used as a fertilizer. One of the main advantages of PHOSMAG's innovative patented struvite crystallization reactor is that it is capable of extracting struvite in the form of a granular product. Large struvite granules are much easier to separate from the biosolids and other contaminants in sludge, as well as easy to dewater, dry, and transport. The granular struvite product meets the requirements of the fertilizer market and it can be easily blended with other fertilizers to provide products with different nutrient ratios. Our proprietary reactor produces a valuable product, ready for the market, which does not require any further processing or purification.



PHOSMAG pig manure treatment project, 2023

The process has successfully been piloted in China in 2019 for treatment of chicken manure. The pilot was able to treat 200 t/day of the liquid manure and produce up to 300 kg/day of struvite. The recovered struvite product has been successfully tested as a very efficient fertilizer and a source of phosphorus that does not contain any harmful contaminants. The second pilot project was successfully launched in 2023 to recover phosphorus from anaerobically digested pig manure. The treatment capacity was 50 t/day of digested manure slurry and the process produced 400 kg/day of struvite fertilizer. Phosphorus recovery efficiency from the phosphorus enriched liquid was over 95%. Soluble orthophosphorus concentration in the liquid was reduced from average 1000 ppm down to less than 30 ppm. The process also recovered up to 15% of ammonia nitrogen. Currently, PHOSMAG is working on a pilot project for phosphorus recovery from anaerobically digested sewage sludge at Bailonggang (白龙港) wastewater treatment plant in Shanghai, China, which is the largest sewage treatment plant in Asia. The project will treat over 100 t/day of anaerobically digested sewage sludge and produce 500 kg/day of struvite.

Competitor Technologies

There are several technology providers globally that developed struvite recovery technologies. However, only a small number of these technologies produce struvite in the form of granules that do not require additional processing. The key technologies that have significant global presence in wastewater industry are

Pearl and WASSTRIP by Ostara and MagPrex (formerly AirPrex) by Centrisys CNP. OSTARA Pearl technology is a fluidized-bed reactor where chemicals are added to a wastewater containing phosphate and ammonia and struvite crystallization takes place in a controlled environment, producing struvite granules. WASSTRIP is an optional add-on process that allows for additional biological phosphorus release from waste activated sludge before struvite recovery in the Pearl reactor. MagPrex process uses magnesium salt addition to sewage sludge in a mixed tank reactor before anaerobic digestion to prevent struvite scaling in digesters and improve dewaterability. The advantages of both processes are controlled struvite crystallization in a dedicated reactor, reduced maintenance costs by preventing pipe clogging, and established commercial applications. In addition, one of the main advantages of Ostara Pearl process is high product purity.

Company	Technology
Ostara Nutrient Recovery Technologies	Pearl; WASSTRIP
Centrisys-CNP	MagPrex (formerly AirPrex)
Royal Haskoning DHV	CrystaLactor
Schwing Bioset / Green Tile BV	NuReSys
Colsen	ANPHOS
Sustec	NutriTec
Paques	PHOSPAQ
Veolia	STRUvia
Suez Environnement	PhosphoGREEN
Naskeo Environnement (FR)	
Watercare (NZ)	

Although Ostara is considered a global leader, the capital and operational costs of their process are relatively high, compared to other technologies. Technologies like MagPrex generally have lower costs. However, such technologies normally produce low quality struvite product which requires further processing before it can be sold as a fertilizer. The struvite product is rather recovered as a powder which contains many impurities and is hard to dewater. In such cases, struvite is not harvested for commercial purposes due to a very poor quality of the product and the technology is essentially a phosphorus removal process rather than recovery process.

Unlike other technologies, MINEPHOS is capable of struvite recovery at low capital and operational costs while at the same time producing a high-quality granular fertilizer product. The lower costs are typically associated with treatment of only liquid portion of the waste, such as anaerobic digester supernatant or dewatering liquid, industrial wastewater with solids content below 2%, or other waste streams where phosphorus extraction from the solids is not required. The cost would

increase when treating the solids together with the liquid but the production capacity of the struvite fertilizer would also increase. Unlike many other technologies, *MINEPHOS* is capable of struvite recovery from both the liquid and the solid, thereby maximizing phosphorus recovery efficiency and struvite production. Most of the phosphorus in waste streams such as sewage sludge or manure is normally contained in the solid portion of the waste, so the overall phosphorus recovery efficiency from the entire slurry is actually quite low for the technologies that either do not treat the solid portion or treat it insufficiently. Even the world's leading struvite recovery technologies such as Ostara WASSTRIP do not extract more than 50% of the total phosphorus from waste streams. Unlike these technologies, *MINEPHOS* is capable of extracting more than 80% of total phosphorus from the entire waste slurry by using its know-how phosphorus release process prior to struvite recovery. Phosphorus release from the solids enables to maximize the recovery efficiency and struvite production. In addition, *MINEPHOS* technology is capable of treating wastewater streams that are normally difficult to treat due to high amounts of contaminants and suspended solids. The technology can extract high quality struvite from wastewater with as high as 2% suspended solids which, for example, Ostara Pearl process is unable to handle.

MINEPHOS Technology Benefits

In general, the key advantages of *MINEPHOS* technology can be summarized as follows:

- Ability to treat a variety of wastewater streams (sewage, livestock manure, industrial streams)
- Ability to treat challenging waste streams and extract high quality struvite product
- Low capex and opex as compared to other similar technologies
- High phosphorus recovery efficiency over 90%
- Simple design, small footprint, automated operation, low maintenance
- Modular process design and simple scalability
- Reducing environmental pollution of water bodies
- Reduction in GHG emissions from fertilizer and manure handling

MINEPHOS technology is applicable to many waste sources and specific benefits for each of them are presented below.

Livestock and poultry manure:

PHOSMAG offers a sustainable waste management solution for resource recovery from agricultural waste. It integrates innovative technologies in order to extract valuable resources from manure. Anaerobic digestion process for energy recovery in the form of biogas is combined with our state-of-the-art proprietary nutrient recovery technology MINEPHOS that selectively extracts high quality struvite fertilizer as well as organic biosolids suitable for land application. The main benefits of our manure management and resource recovery solution include:

- When combined with anaerobic digestion, energy recovery and reduction of organic waste
- Over 90% combined phosphorus recovery from manure as struvite and organic fertilizer
- Recovery of value-added fertilizer products with balanced nutrient content
- Reduced reliance on synthetic fertilizers through sustainable reuse of resources
- Reducing excessive land application of manure and mitigating environmental pollution of water bodies
- Reduction in GHG emissions resulting from fertilizer and manure application

Sewage sludge:

MINEPHOS technology can remove over 90% of soluble phosphate from sludge dewatering liquid after anaerobic digestion and reduce phosphorus load to the mainstream process by up to 15%. This allows for significant maintenance and operating cost reduction for sewage treatment plants while meeting the regulatory discharge limits for phosphorus. Furthermore, converting waste into a value-added fertilizer product creates additional revenue stream and enables the concept of a circular economy. Benefits of struvite recovery for sewage treatment plants with sludge anaerobic digestion include the following:

- Reduction of phosphorus load to the mainstream process by 10-15% through phosphorus removal from the sidestream dewatering liquid
- Over 90% removal of phosphorus from the dewatering liquid
- Reduction of operation and maintenance costs from elimination of struvite deposits in pipes and equipment of the sidestream process
- Over 20% reduction of chemical consumption of coagulants such as PAC or ferric salts for chemical phosphorus removal

- Significant reduction in production of chemical sludge (up to 90%)
- Improved dewaterability of anaerobically digested sludge by 4%
- Resource recovery from waste and additional revenue from recovered value-added product
- Positive environmental impact through reduction of nutrient pollution from sewage discharge
- Meeting regulatory discharge limits for pollutants

Industrial wastewater:

MINEPHOS is capable of treating a wide variety of liquid waste often deemed too challenging for other phosphorus removal and recovery technologies to treat. There is no upper limit for phosphorus content in the waste and high phosphate concentrations are preferred. The following types of wastewaters can be treated:

- Phosphate mining wastewater and phosphogypsum leachate
- Food processing wastewater
- Pharmaceutical wastewater
- Other wastewater streams with high content of phosphate

Conclusions

There is currently a global need for phosphorus recovery technologies from wastewater for a number of reasons. First, there are regulatory requirements for wastewater treatment facilities to meet nutrient discharge limits and a need to reduce operational and maintenance costs associated with high nutrient content in the wastewater. Second, due to many geopolitical factors, as well as diminishing natural resources, there is a limited availability of fertilizers, particularly phosphate, in the global marketplace and their ever-increasing costs. In this context, phosphorus recovery from waste via struvite crystallization offers an attractive opportunity for tapping into this renewable recourse. However, some of the challenges for wide industrial adoption of struvite recovery technologies include economic viability and the ability to take advantage of generating this value-added product. The economic feasibility of struvite recovery depends on fertilizer market prices and regulatory incentives, but also on the technological capability to extract high quality struvite product. Cost of chemicals as well as other capital and operational expenses impact the return on investment.

MINEPHOS technology offers the advantage of producing a high-quality struvite product at a minimum cost while generating multiple benefits for sewage treatment plants and other waste processing facilities. Not only the waste is

treated to create environmental benefits, it also provides economic benefits through extracting valuable products from the waste and generating revenue streams. While many waste management technologies only remove contaminants and do not recover any costs of the treatment, the MINEPHOS process is both economically and environmentally sustainable and works for a wide variety of industrial applications where other similar technologies fail to deliver full benefits.