

Comparison of struvite fertilizer products available in the global marketplace

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Introduction

Phosphorus is known to be a major source of pollution in the environment. It mostly originates from various agricultural and industrial activities as well as from sewage wastewater. At the same time, phosphorus is an essential nutrient for all forms of life and one of the major nutrients used in the agriculture industry. Due to rapid increase in global population and food production, the demand for phosphorus is currently increasing. However, over the past decades many studies have predicted that current phosphorus reserves would be depleted within the next few hundred years, deeming phosphorus a scarce resource. Therefore, phosphorus recovery from wastewater is currently an important issue for many sectors of the economy. Among the reasons for nutrient recovery are increasing prices and limited supply of fertilizers (particularly phosphorus) in many markets, regulatory demand for wastewater treatment facilities to meet more and more restrictive discharge limits, and the reduction of environmental pollution in natural water bodies. Phosphorus recovery in the form of struvite (magnesium ammonium phosphate) is currently considered one of the most promising processes for nutrient recovery from wastewater. Struvite is a white crystalline substance that contains essential nutrients for plant growth and can be applied directly to soil. It is considered an excellent fertilizer since it minimizes the loss of nutrients due to its slow-release nature and its low water solubility. Unlike traditional water-soluble fertilizers, struvite dissolves very slowly, hereby preventing the loss of the nutrients in the soil and at the same time providing sufficient nutrition to the plants. The slow-release nature of struvite further prevents environmental problems such as eutrophication, thus relieving policy and economic pressure regarding environmental impact of agricultural activities and waste management.

Currently, there are several technology providers globally that offer technologies for struvite recovery from wastewater. The providers use various techniques and methods to recover struvite, many of which greatly vary in the quality of the recovered struvite product. Therefore, not all of these products are sold as fertilizers. The table below summarizes some of the major struvite fertilizer products currently available in the marketplace.

Brand	Producer	Origin (raw material)	NPK ratio	Purity	Granule size	Heavy metal content	Certification status	Typical application	Retail price
Crystal Green Pearl	Ostara, Canada (produced in USA, Canada, and Europe)	Municipal sewage	5-28-0 +10 Mg	99.6%	Available as: 0.9 mm, 1.5 mm, 3 mm, 4.5 mm	Meets USA, Canada, and EU fertilizer regulations	Certified as organic in Germany, Spain, Denmark, Austria, Netherlands	Turf, ornamental, horticulture, agriculture (wheat, corn, soy beans, potato, sugar beets, peas, lentils, canola, alfalfa)	96 USD per 50 lb bag of 0.9 mm size
Crystal Green	Ostara, Canada (produced in USA)	Synthetically manufactured from industrial chemicals	7-33-0 +9 Mg	n/a	3 mm	Meets USA fertilizer regulations	Not certified as organic		n/a
Emerge	Watercare, New Zealand	Municipal sewage	5-28-0 + 10 Mg	About 95% (based on P content)	Not granular, estimated between 0.2-1.0 mm	Meets New Zealand fertilizer regulations	Recognized as normal fertilizer in New Zealand	Lawn, turf, pasture, trees, shrubs. No information on agricultural use	20 NZD per 2.5 kg bag
PhosphorCare (Production shut down in 2024 due to high costs)	Suez, France (produced in Denmark using PhosphoGreen technology)	Municipal sewage	5-28-0 +10 Mg	About 99% (based on P content)	1-3 mm	Meets Denmark fertilizer regulations	Registered as fertilizer in Denmark	n/a	n/a
SmartPhos DG	The Andersons, USA	Municipal sewage, with additional granulation factory processing	4-22-0 +8 Mg	80%, the rest is organic matter and binding agents	0.75-0.85 mm	Meets USA fertilizer regulations	Not certified as organic	Lawn, turf, horticulture. Not for agricultural use	59-70 USD per 18 lb bag; 81 USD per 40 lb bag
PHOSTONE	PHOSMAG, China	Municipal sewage, livestock and poultry manure, industrial wastewater	5-26-0 +12 Mg	93-96% depending on source	0.5-2.5 mm	Meets fertilizer regulations in China, Europe, USA, Canada	tbd	Successfully tested on rice, wheat, and pomelo	tbd

Crystal Green and Crystal Green Pearl by Ostara

Ostara is considered a global leader in recovery of marketable struvite product from wastewater streams. Their technology is capable of extracting a high-quality product that meets most fertilizer regulations around the world. Their original product, Crystal Green Pearl, is extracted exclusively from municipal sewage sources. It is currently certified as an organic fertilizer in some European countries and sold at a premium price.

The main advantage of Ostara is that, unlike many other recovered struvite products, Crystal Green Pearl can be recovered in a granular form which is market-ready and does not need further processing. The granular form also ensures that the product can be easily separated from wastewater and other impurities in it, which guarantees high purity. The high struvite purity also allows for its safe use in agriculture for food production, which not all waste recovered fertilizer products can guarantee. Another advantage of a granular product is that it can easily be blended with other commercial fertilizers which often come in a granular form, in order to provide various nutrient ratios needed for different field applications. All standard fertilizer spreading equipment used in agriculture is designed for a certain granule size, therefore struvite size must fit within the expected size range for the effortless land application.

The other factor that guarantees the purity is related to the fact that Ostara struvite is recovered mainly from sludge dewatering liquid, which is mostly free from biosolids. The presence of biosolids and other organic matter in the sewage can have significant negative impact on the struvite product quality. As a result, Ostara technology can only recover phosphorus from the liquid portion of sewage sludge, which significantly limits the overall phosphorus recovery rate from sewage as well as struvite production. Another disadvantage of Ostara technology is its high capital cost and complexity as compared to other processes for phosphorus removal from wastewater, which often limits its industrial application. Currently, Ostara has no operational plants in any other wastewater sectors apart from municipal sewage.

In order to meet the demand for its product in the USA, Ostara has recently established a struvite production facility in St. Louis, Missouri, where granular struvite is synthetically produced at a granulation plant and sold under the Crystal Green brand. This product differs from the original Crystal Green Pearl in that it is not recovered from wastewater but entirely produced from industrial chemicals. Although very similar in properties to the original struvite, the product slightly varies

in composition due to its production method; it is not certified as organic and it is intended mainly for the US market.

Both brands of Crystal Green struvite have been extensively tested over many years in the field for a large variety of crops and proved to be efficient in increasing crop yields, as well as in reducing environmental impacts of agricultural runoffs. Many traditional phosphorus and nitrogen fertilizers are easily soluble in water. This causes a large amount of nutrients to be lost in the soil and they eventually end up in natural water bodies where they create environmental pollution. The nutrient loss prompts farmers to apply excessive fertilizer amounts which increase the costs for the farmers and make the environmental pollution problem even worse. Unlike the traditional water-soluble fertilizers, struvite is mainly insoluble in water and therefore does not generate the runoff pollution. The nutrients are not lost with runoffs but rather remain in the soil. Struvite is 100% citrate soluble; so, when the plants need nutrients, they can acidify the soil with their roots and solubilize phosphorus to make it available for uptake. The fertilizer granules that are not in contact with the roots will remain in the soil until the roots can reach them; therefore, the nutrients will not be lost. These unique properties of struvite allow for less fertilizer application and cost savings for farmers, as significantly less fertilizer is required to achieve the same crop yield. These properties of Crystal Green have been extensively demonstrated by R&D and marketed by Ostara, which allowed them to sell their product at a premium price much higher than conventional phosphate fertilizers.

Emerge by Watercare

Watercare is a utility company that provides sewage treatment services in Auckland area of New Zealand. Unlike other struvite producers, it is not a technology provider nor a fertilizer manufacturer. They are capitalizing on sales of a wastewater treatment byproduct that they recover themselves. The product is marketed under the brand Emerge. It is recognized by New Zealand regulators as a normal fertilizer. There is no publicly available information regarding the technology being used for struvite recovery, but some judgement can be made based on the struvite product that is being extracted.

The product is not granular, but rather a powder, with particle size similar to sand. This type of struvite product is typically produced using generic wastewater or chemical process equipment, such as a mix tank, which is very simple in design. Unlike most proprietary technologies for recovery of granular struvite, this process

is likely not IP protected and was designed in-house by the wastewater plant engineers.

Emerge nutrient content is very similar to that of pure struvite, so the purity is estimated to be over 95%. This is an indication that struvite is most likely recovered from sludge dewatering liquid, similar to the water source used by Ostara. Due to its non-granular characteristics and small particle size, such product would have limited applications, specifically due to the following points:

- Struvite products recovered from wastewater in the form of powder typically have lower purity and high concentrations of contaminants, since it is harder to dewater such product than a granular struvite and the contaminants present in the wastewater would partially remain in the final product. Although the purity of Emerge is relatively high and heavy metal content is within the standard limits, this fertilizer product is only marketed for non-agricultural applications possibly out of abundance of caution. Some emerging substances of concern might still be present in the product.
- Due to its sand-like appearance, Emerge cannot be blended with other granular fertilizers for a large-scale application in agriculture. Therefore, it is sold only in retail as a standalone fertilizer which can be blended by an end-consumer for individual application if needed.
- Due to lower quality its price is limited, as compared to premium products such as Crystal Green. Although the retail price for both is similar, the reported wholesale price of Emerge is much lower than some of the reported wholesale prices for Ostara struvite (up to several thousand USD according to some reports).

In addition, since Emerge production is limited to just one specific wastewater treatment plant, the struvite production capacity will be limited to phosphorus availability in the plant wastewater. With the lack of IP and a technology provider entity, the technology and product adoption will be minimal, so as the growth opportunities for sales.

PhosphorCare by Suez Phosphogreen

PhosphorCare is a brand name of struvite produced by the French utility company Suez Environment using their proprietary PhopshoGreen technology for struvite recovery. As of 2024, it was reported that production of PhosphorCare has stopped due to poor cost efficiency caused by increased prices in chemicals

used for the process. Most of the struvite recovery facilities were in Denmark. The recovered struvite was in granular form and had high quality similar to the Ostara products. It was recovered from sludge dewatering liquids, similar to the technologies described above. The product was officially registered in Denmark as a fertilizer. The product was in the process of receiving organic certification in Europe when the production was terminated. There are reports that the product was sold in retail in Denmark but the prices are not available.

SmartPhos DG by the Andersons

SmartPhos DG is the product produced by the fertilizer manufacturer and distributor The Andersons in the USA. The product is based on struvite recovered from municipal wastewater, as claimed by the manufacturer. The origin of struvite and the technology used for its recovery is not disclosed. This product differs from other struvite brands in that it is produced from wastewater recovered struvite powder but later granulated with binders and organic matter using their patented technology. As a result, the product is not pure struvite. It consists of 80% struvite, 10% humic substances and 10% binder. According to the manufacturer, the advantage of this product as compared to other granular struvite fertilizers is its smaller particle size. Upon contact with water, each granule disperses into thousands of microparticles that quickly move through the turf canopy into the root zone for superior coverage and enhanced efficacy. As a result, more surface area of plant roots would be covered by struvite. The technology allows for a quick distribution of struvite in the soil while still maintaining the slow-release properties of struvite. Due to these properties, the manufacturer is able to sell the fertilizer at a premium price even higher than Ostara's Crystal Green. While having these benefits, there are the following disadvantages:

- The product is still based on struvite recovered from sewage in the form of powder, which can have high concentration of impurities. Although the heavy metal content is in compliance with the US fertilizer requirements, the product is labelled not for use in agriculture. The primary uses are lawns, turf, and horticulture.
- The need for further struvite processing and granulation adds extra costs and introduces ingredients into the final product that may limit its use as a fertilizer for some types of application, particularly for food production.
- The granule size of the product designed specifically for lawn and turf applications and may be too small for blending it with some other types of

fertilizers. The Andersons uses SmartPhos to create and sell its own blends as a sales strategy to discourage an end user from purchasing other fertilizer brands.

- As the Andersons does not own the means of struvite production and has to sequester it from wastewater treatment plants, the production capacity for SmartPhos may be limited to their struvite sources.

Other struvite technology providers

There are several technology providers globally that have developed and commercialized struvite recovery processes. The vast majority of them only operate in the municipal sewage market segment, although some systems operate in manure processing and food production facilities. Due to more stringent phosphorus discharge regulations in Europe, many companies are located in European countries, with a few companies operating in North America and Japan. The majority of these technologies recover phosphorus only from the liquid portion of the sewage sludge since recovery from the solids is often associated with much higher costs. Typically, technology providers are responsible for sale and marketing of the struvite product they recover from wastewater and the profit from the fertilizer sales is shared with the wastewater treatment facilities or manure processing facilities. Many of these technologies recover struvite in the form of powder, or small granules, which significantly affects the product quality for the reasons described above. The low-quality product is normally sold to fertilizer companies at a very low price for further processing before it can be made marketable. In some cases, the product is even treated as a chemical sludge due to its poor quality, so the sewage treatment plants simply dispose of it. Some struvite recovery facilities focus solely on phosphorus removal from wastewater and do not adopt struvite recovery for the purpose of obtaining any financial benefits from struvite production. For example, the world's largest struvite recovery system in Denver, Colorado (USA), which operates the MagPrex technology (formerly known as AirPrex), is not harvesting struvite for commercial purposes due to a very poor quality of the product, although the facility may take advantage of it in the future. So, these types of products do not normally make it to the marketplace and are not considered as competition to high quality products.

PHOSTONE by PHOSMAG

PHOSMAG has developed a technology that can selectively extract phosphorus from waste streams in the form of a valuable struvite fertilizer called PHOSTONE, which is ready for the market and does not require any further processing or purification. Unlike many other technologies, PHOSMAG is capable of extracting struvite from a wide variety of waste streams such as livestock and poultry manure, sewage sludge, and various industrial wastewater streams. The technology is currently patented in the US, Canada, Japan, Israel, Malaysia, Vietnam, and South Africa, with patents pending in 13 more jurisdictions around the world, including Europe and Asia. One of the main advantages of PHOSMAG process is that it is capable of extracting struvite in the form of a granular fertilizer product similar in size and composition to Ostara's Crystal Green. 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.

Struvite fertilizer product produced by PHOSMAG is free of contaminants and meets all relevant standards in China, Europe, USA, and Canada. The nutrient content of PHOSTONE is nearly identical to other high quality struvite fertilizer brands. The granule size is also in the range of regular commodity fertilizers. Chemical analysis of multiple product samples indicated that the contents of heavy metals and organic pollutants in struvite were in accordance with all the relevant standards. The purity of PHOSTONE varied depending on the wastewater source and the extraction process, but still remained very high – above 93%, which was not detrimental to the product quality. An independent two-year field study conducted to investigate the effects of PHOSTONE combined with phosphorus reduction under a rice–wheat rotation system in eastern China found that PHOSTONE application could improve the soil phosphorus availability and crop nutrient uptake then promote the crop yield. To increase the nutrient use efficiency of crops while ensuring crop yield and soil fertility, appropriate phosphorus reduction combined with struvite as a phosphorus fertilizer could be sustainable in the rice–wheat rotation system in the long run. In addition, another independent study was performed on the effect of struvite on honey pomelo. The results were analyzed based on the growth physiological indicators, yield, quality and other related indicators. Years of multi-site test results show that compared with control treatment, PHOSTONE treatment significantly increased the yield of honey pomelo. Its application could significantly increase the single fruit weight and fruit number of honey pomelo.

Unlike other technologies, PHOSMAG process is capable of struvite recovery at relatively low capital cost and operational expenses while at the same time producing a high-quality granular fertilizer product. PHOSMAG 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 wastewater streams 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 all of the current technologies. 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, PHOSMAG 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 extraction. Phosphorus release from the solids allows for maximizing the recovery efficiency and struvite production. In addition, PHOSMAG 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 (SS).

PHOSMAG process has successfully been piloted in China in 2019 for treatment of chicken manure. The first 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%.

PHOSMAG is capable of producing a high-quality struvite product identical to Ostara which was proven in pilot tests and field trials. Therefore, PHOSMAG can position its PHOSTONE product in the same marketplace as Crystal Green and use this opportunity to capitalize on the growing market demand for a high-quality struvite fertilizer.

Conclusions

Struvite recovery from waste is an increasing global trend to address the problem of phosphorus scarcity and its diminishing natural sources. In addition to recovering this valuable resource, struvite recovery also offers environmental

benefits of reducing the environmental pollution through both nutrient removal from wastewater and mitigation of agricultural runoffs. Although multiple technologies for struvite recovery from wastewater are currently applied in the industry, not many of them are capable of producing a marketable product. Technology providers who are mainly focused on phosphorus removal rather than recovery often generate a low-value product which is not suitable for the market. Such low-quality products need additional processing and often contain unwanted contaminants that significantly limit the use of struvite as a fertilizer. Contrary to this approach, the technology providers who put much emphasis on the quality and marketability of their struvite product have seen much better success. Global leaders in struvite recovery such as Ostara have essentially created a new market for struvite by focusing on its end use as a high-quality fertilizer. Producing a high purity granular product is the key to entering this fertilizer market. Based on superior properties of such product the providers are able to charge a premium price for it and make struvite recovery from wastewater economically viable through generating a value-added by-product which offsets the recovery costs. However, due to some economic and technological limitations, only a few technology providers are currently able to produce a high-quality product. Some lack the technology to make a granular product (e.g. Emerge by Watercare), while others cannot economically sustain the production of a high-quality product (e.g. PhosphorCare by Suez). On the other hand, companies like Ostara that have both the technological capabilities and the high market demand for their struvite product have been very successful. Currently, PHOSMAG has equivalent or even better technological capabilities and capacity to produce a high-quality struvite fertilizer product identical to Ostara's Crystal Green but with a lower cost. As such, PHOSTONE can take advantage of the demand for a high-quality struvite fertilizer which will be well positioned to have a share of this market and potentially dominate it in the future.