Chapter 19

The Pearl® and WASSTRIP® processes (Canada)

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19.1 INTRODUCTION

The Pearl® process is the core of Ostara's nutrient recovery solution. The Pearl process is operating at 14 municipal wastewater treatment plants (WWTPs) in North America and Europe, where it extracts phosphorus and ammonia from nutrient-rich flows, converting these nutrients into high-purity struvite pellets. Ostara manages this recovered material, and sells it as premium quality, slow release fertilizer, branded Crystal Green®. We commit to purchase every tonne of Crystal Green produced by the WWTP for a guaranteed price.

The waste activated sludge stripping to recover internal phosphorus (WASSTRIP®) process complements the Pearl process by releasing phosphate, magnesium, and potassium from waste activated sludge (WAS) prior to thickening. Thickening separates these soluble components from the solids, preventing them from entering the digester, where they can adversely impact performance. Thickening liquor

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is treated in the Pearl process with digested sludge dewatering liquors, avoiding nutrient return to the plant and increasing Crystal Green production.

19.2 THE PROCESS

19.2.1 The Pearl process description

The Pearl process recovers phosphorus from nutrient rich wastewater liquors, through the controlled precipitation of struvite. Primary system feed streams include post-anaerobic digestion sludge dewatering liquors, and WAS thickening liquors after phosphate release using the WASSTRIP process. The process has also been successfully applied to mainstream wastewater treatment when nutrient concentrations are high.

The Pearl reactor is an expanding up-flow fluidized-bed reactor. Two principles are fundamental in the process – maximizing efficient nutrient removal and consistently recovering high quality, commercial fertilizer. The Pearl process design incorporates features that support these objectives, such as reactor geometry and process control methodology.

The Pearl process is controlled through chemical addition: soluble magnesium salts are added to affect ionic concentration and, if required, sodium hydroxide is added to adjust pH. The chemicals and side-stream influent are then introduced into the bottom of the reactor, where struvite crystallization begins to occur.

Treated effluent is discharged from the top of the reactor and returned to the WWTP for further treatment. A portion of treated effluent from the top of the reactor is returned to the bottom of the reactor in a recycle loop. This allows for

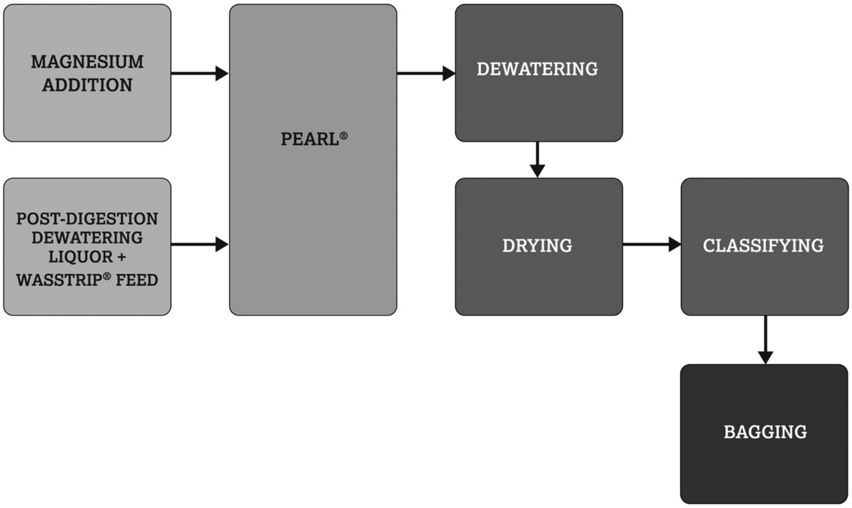

Figure 19.1 Process scheme.

control of product size, as well as adaption of the system to variable feed flow rates. Recycle rates are automatically controlled by the Pearl Control System, and do not impact overall phosphorus removal efficiency.

Growing fertilizer pellets in the reactor are held in suspension using the recycle stream. The inventory of fertilizer in the reactor is measured using instrumentation. When a target fertilizer inventory in the reactor is reached, the reactor will automatically harvest the fertilizer by sending it to the product handling system. The product is dewatered, heat dried, sorted by size, and optionally stored in silos in a simple and fully automated process. Periodically the silo contents are bagged in one tonne flexible intermediate bulk containers (IBCs) and stored until sale. During harvest, the reactor will continue to be fed side-stream nutrients and perform nutrient removal without interruption or loss of efficiency.

The entire system process flow is shown schematically in Figure 19.1.

19.2.2 The WASSTRIP process description

The waste activated sludge stripping to recover internal phosphate (WASSTRIP) process releases phosphate from WAS. The WASSTRIP process consists of a mixed tank maintained in an anaerobic condition. Phosphate accumulating organisms (PAOs) in enhanced biological phosphorus removal (EBPR) sludge readily release stored phosphate (together with magnesium and potassium counter ions) in WASSTRIP's anaerobic conditions. Subsequent sludge thickening diverts released nutrients into thickening liquor, which the Pearl process recovers. Due to the fact that the WASSTRIP liquor is low in ammonia, the stream needs to be combined with dewatering liquors in Pearl in order to precipitate struvite.

WASSTRIP controls struvite precipitation throughout the sludge treatment stream by reducing the phosphate and magnesium content of the WAS before anaerobic digestion (where ammonia forms). This improves sludge treatment performance, tackles struvite related maintenance, and significantly reduces sludge production. WASSTRIP also reverses the negative impact of EBPR on dewaterability.

The WASSTRIP process hydraulic retention time (HRT) is influenced by WAS phosphorus content and volatile fatty acid (VFA) availability. PAOs cannot release phosphate unless sufficient VFAs are present to be absorbed. VFAs are created as WAS ferments. WASSTRIP can operate endogenously on WAS only, or VFAs can be added to the WASSTRIP process (e.g. from primary sludge fermentate, acid phase digestate, etc.) to accelerate phosphate release and reduce HRT.

19.2.3 Crystal Green

The Pearl process produces struvite in a market-ready fertilizer granule branded as Crystal Green. The production of a granule of specific size (>0.5 mm in diameter) allows it to be easily separated from wastewater biosolids, resulting in a product that is completely free of organic matter.

As a high-value fertilizer, Crystal Green is registered in Canada, 44 US states, Taiwan and Puerto Rico. It complies with European fertilizer Regulation (EC) No 2003/2003 and meets required limits for organic and inorganic constituents. Ostara's precise crystallization and heat treatment process ensures only nutrients are extracted, resulting in an end product that is 99.6% pure with no pathogens, and lower salts and heavy metals than any other phosphate fertilizer available on the market. The sizes harvested in the Pearl reactor are specific to meet market demands in turf and agriculture, ensuring market demand. All Crystal Green produced by Ostara's facilities meets regulatory and market requirements.

Crystal Green has attributes that are superior to commercially available inorganic fertilizers. Crystal Green is not water soluble – it is root activated. When a plant needs nutrients, its roots excrete organic acids that dissolve nutrients from the soil. When a plant excretes organic acids, Crystal Green releases nutrients so the plant can absorb them. Traditional phosphorus fertilizers are water soluble. When it rains or the soil is irrigated, the nutrients dissolve into the water. When the plants cannot use all the dissolved nutrients, they are washed away with the water, ending up in the water environment or leaching into the soil beyond the root zone or the phosphorus may bind with other constituents in the soil that render it unavailable to plants. Crystal Green not only eliminates diffuse phosphorus pollution; it provides a much more efficient nutrient delivery mechanism to the plant. This sets up a positive feedback loop where less phosphorus is applied, more gets to the plant, and less gets into the water environment.

Concurrently with the construction of an Ostara facility, Ostara enters into a long-term fertilizer offtake agreement with the facility owner. Under the terms of this agreement, Ostara agrees to buy the fertilizer produced by the facility and the owner agrees to sell the fertilizer to Ostara. The agreement sets out a pre-agreed price for the fertilizer (either fixed throughout the term or indexed to commodity fertilizer prices, depending on customer preferences). While the customer takes responsibility for operating the facility, Ostara continues to provide high-level production support to the owner through the life of the offtake agreement. This arrangement ensures a steady, reliable stream of revenue to the facility owner and relieves the owner of the risks and challenges surrounding the marketing and distribution of the fertilizer. At the same time, the agreement guarantees a steady supply of fertilizer to Ostara. By taking advantage of the scale afforded by aggregating the supply from multiple facilities, Ostara is able to access markets which would be inaccessible to any individual facility operating on its own behalf.

19.2.4 Key figures of the process

The Pearl reactor is available in standard models sized by PO4-P mass loading. Current models are available ranging from 65 to 1260 kg PO4-P per day in capacity. The reactors are modular and can be arranged with fertilizer processing equipment (i.e. dewatering, sorting, storage and bagging) to accommodate WWTPs of any

Table 19.1 Key figures of the process.

General	WASSTRIP Input Material	Waste/Surplus Activated Sludge (WAS/SAS)	–
	Pearl Input Material	WAS/SAS thickening liquor and digested sludge dewatering liquor	–
	Type of Process	Anaerobic WAS/SAS P release (WASSTRIP) and struvite crystallization (Pearl)	
Operating	Electricity demand	1.6	[kWh/kg $P_{recovered}$]
	Heat demand	3.0	[kWh/kg $P_{recovered}$]
	Chemical demand	2.4	[kg $MgCl_2$/kg $P_{recovered}$]
		0.7:1	[molar ratio Mg:P]
		0–2	[kg NaOH/kg $P_{recovered}$]
Product	Type	struvite	
	Morphology	0.9–4.5 mm pellets	
	P-concentration	12.6%	% P/DM
	P-recovery rate	45–60%	% of P in sludge input
	Distribution of the product	Distributed by Ostara, though a purchase agreement with the plant owner, to turf, ornamental, and agricultural markets	
Residuals	Phosphorus and nitrogen depleted sludge liquors		
Reference	Location	Slough, UK	–
	Scale	250,000	PE
	Start of operation	2012	–

(*Continued*)

Table 19.1 Key figures of the process (*Continued*).

Outstanding features	Combines a Pearl reactor with capacity to recover 65 kg PO4-P, and a simplified fertilizer dewatering, dryer, sorting and bagging operation in less than 150 m^2		
Reference	Location	Amersfoort, NL	–
	Scale	500,000[a]	PE
	Start of operation	2016	–
Outstanding features	Combines a Pearl, WASSTRIP, thermal hydrolysis and downstream deammonification in a single energy and nutrient recovery installation.		
Reference	Location	Madrid, ES	–
	Scale	1,200,000	PE
	Start of operation	2016	–
Outstanding features	Constructed in partnership with Veolia Water Technologies, Pearl enables the wastewater plant to use lower cost biological phosphorus removal in place of existing chemical phosphorus removal by eliminating phosphorus return streams.		
Reference	Location	Chicago, IL, USA	–
	Scale	2,300,000	PE
	Start of operation	2016	–
Outstanding features	The world's largest nutrient recovery facility, with a capacity to produce 30 tonnes of Crystal Green a day.		
Reference	Location	Portland, OR, USA	–
	Scale	500,000	PE
	Start of operation	2009	–
Outstanding features	Pearl's and WASSTRIP's longest running installation.		

[a]PE has been adjusted to reflect impact of sludge imports

size. An economy of scale means that capital and operating costs decrease with increasing population served. The values in Table 19.1 are representative for a WWTP serving a population equivalent (PE) of 250,000.

19.3 OUTLOOK – FURTHER DEVELOPMENTS

Pearl nutrient recovery technology has 49 years of cumulative operating experience at 14 facilities around the world. This experience has resulted in continuous improvements to the system design to optimize cost and operational reliability. On average Pearl facilities achieve a payback on capital investment in 3–7 years and operate with over 95% uptime.

Future developments are aimed at improving the capital cost for facilities of less than 100,000 PE, further quantifying the net financial benefit of Pearl and WASSTRIP and wastewater treatment plant operations, and developing industrial wastewater solutions.