Phosphorus Extraction Technologies

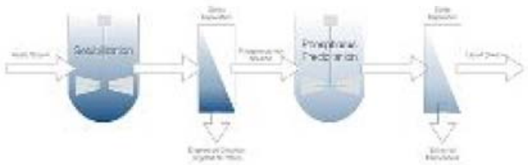
WE TOFFEY 23 MARCH 2020

Shout Out to Tradition

- Class B cake to farms: This is low cost, proven approach to phosphorus recycling
- Class A biosolids-derived products: Compost and heat-dried pellets are marketable P-rich products for soil improvement and plant fertilization

Challenge: Nutrient Balance

CNP AirPrex in Berlin



Renewable Nutrients QuickWash

Ostara's Pearl Process

The balance of N and P in biosolids is agronomically wrong. The engineering challenge of the day is to extract phosphorus and to retain nitrogen in the biosolids. We are still waiting for the right combination of technologies…

Drivers for P Extraction

- Meet effluent discharge standards
- Reduce struvite mineralization of equipment
- Improve the dewaterability of Bio-P sludges (higher % solids, lower polymer usage)
- Recover marketable P fertilizer
- Improve N to P ratio in biosolids product
- Achieve local and global sustainability goals

Starting Point: How You Meet Effluent Discharge Standards

Enhanced Biological Phosphorus Removal

- Phosphorus Accumulating Organisms (PAO) release extracellular polymeric substances (EPS) with highly soluble phosphorus under stress
- EPS interferes with dewatering
- Dewatering releases soluble P into filtrate/centrate
- P in biosolids highly soluble and leachable

Chemical Phosphorus Removal

- Use iron or aluminum salts to precipitate phosphorus as an insoluble mineral, incorporated into biosolids
- Iron adds to biosolids mass, but aids dewaterability
- Iron bound P will not solubilize and cannot be extracted from biosolids

Ending Point: How You Use Biosolids Resources

- Landfill disposal: Biosolids-borne P “lost to agriculture” forever
- Agricultural land spreading: Biosolids-borne P can build up soil to high concentrations after repeated applications
- Land restoration: Biosolids-borne P restores missing P
- Incineration: Generally landfilled, but P value can be used.

P Treatment Approaches

Controlled chemical precipitation to avoid struvite build up within treatment plant

- Sidestream precipitation as struvite after dewatering
- Precipitation of P mineral post digestion, but before dewatering
- Precipitation of P mineral pre-digestion.

Distinction of Phosphorus Minerals

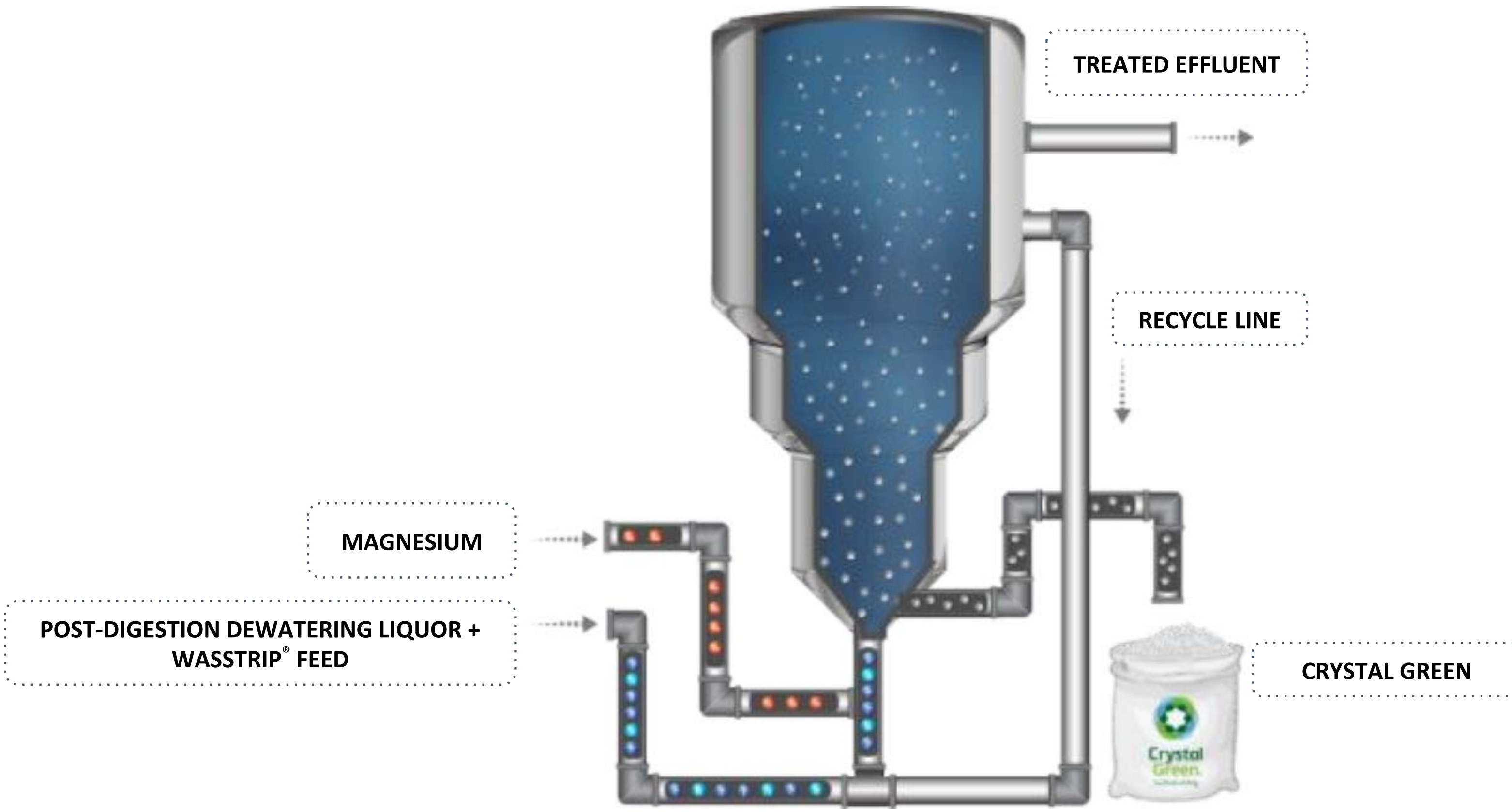
- Brushite (dicalcium phosphate dihydrate or DCPD) forms in slightly acidic conditions of pH 4.5 – 6.5 and is a good fertilizer.

$$Ca^{2+} + H_2PO_4^{-} + 2H_2O \rightleftharpoons CaHPO_4 \cdot 2H_2O + H^{+}$$

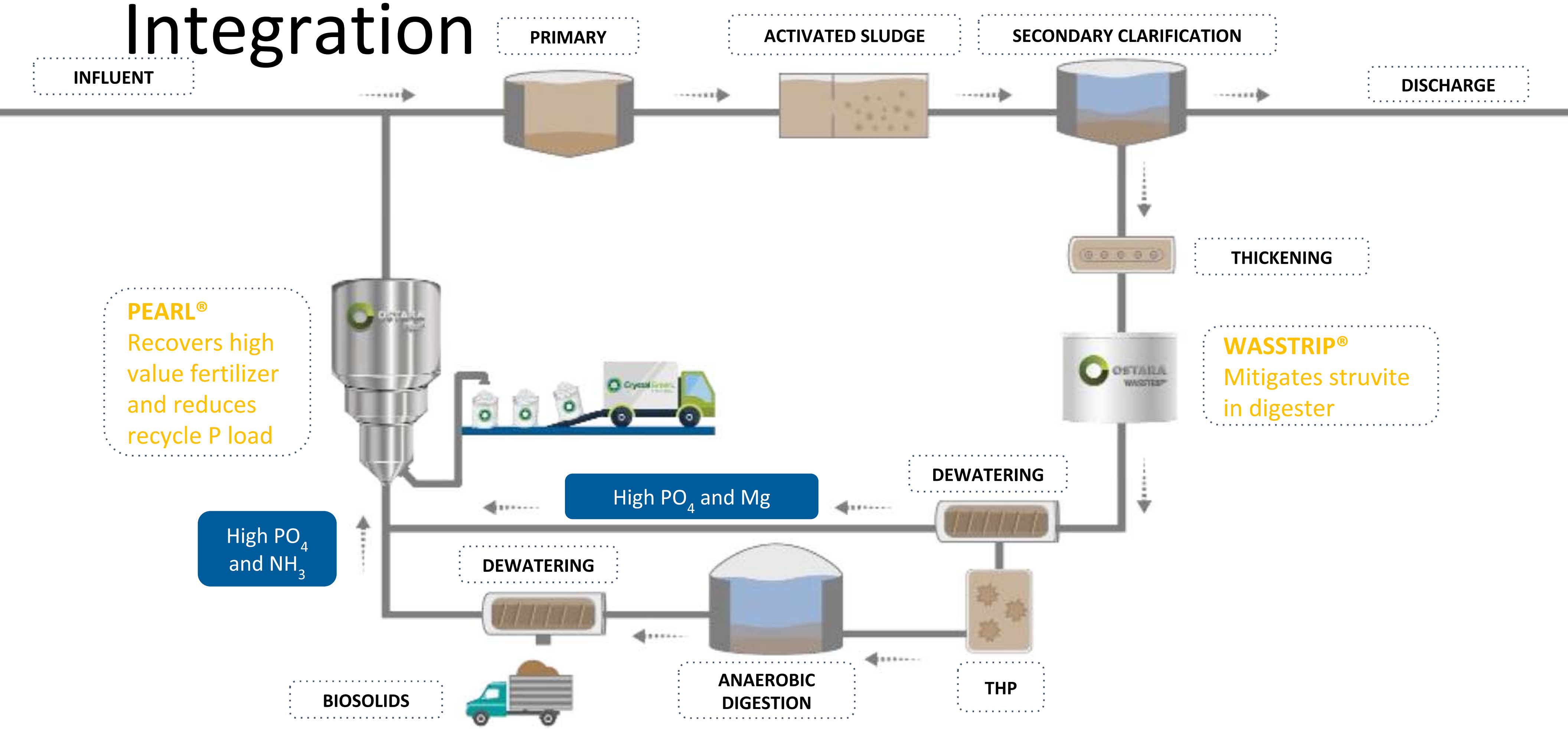
- Struvite (magnesium ammonium phosphate) forms in slightly alkaline conditions of around pH 8 and is a good fertilizer.

$$NH_4^{+} + Mg^{2+} + HPO_4^{2-} + 6H_2O \rightleftharpoons NH_4MgPO_4 \cdot 6H_2O + H^{+}$$

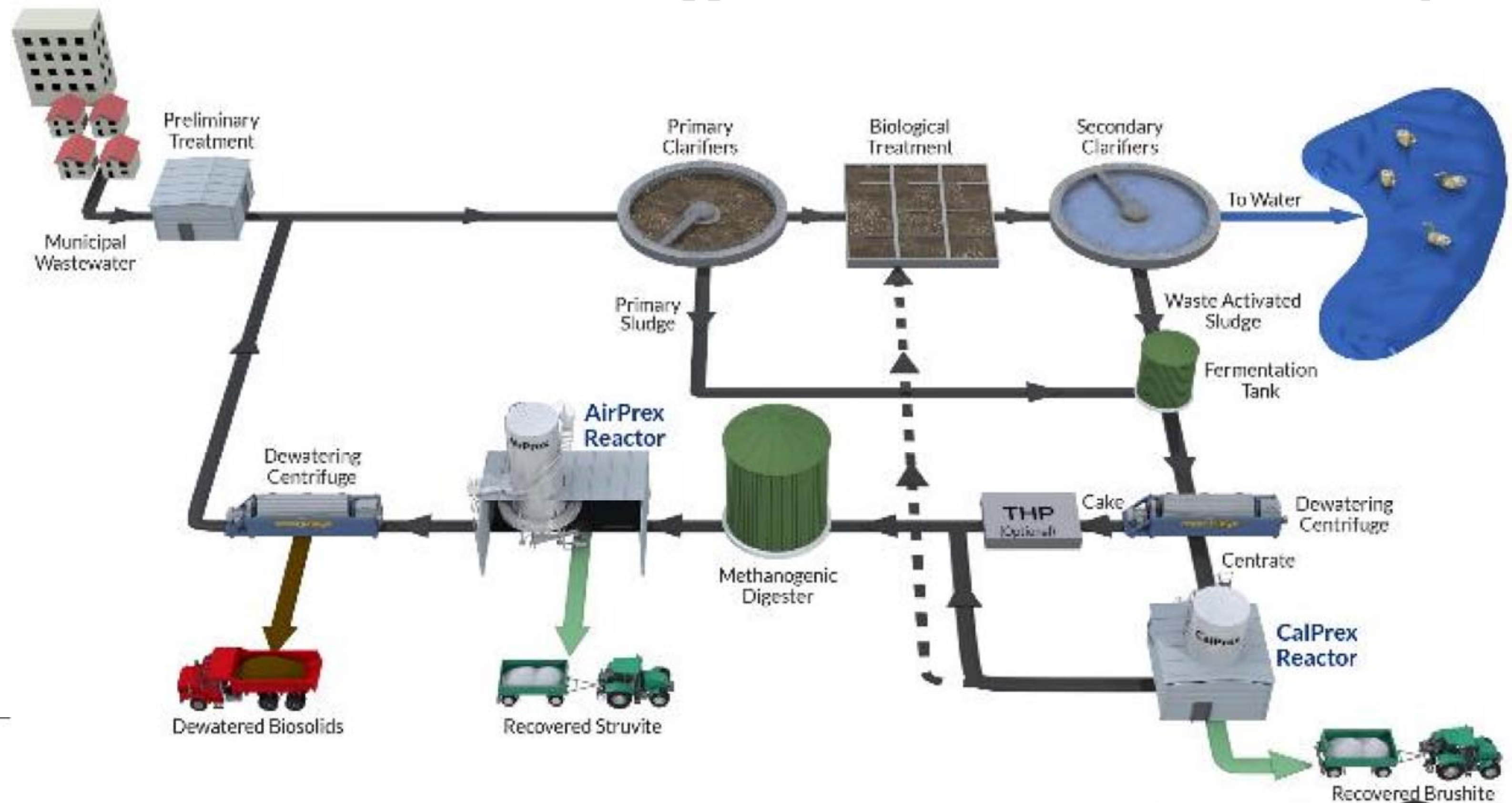
Ostara Technology: The Pearl® Reactor



Pearl® + WASSTRIP® Advanced Digestion Integration



CNP Pre and Post Digestion P Recovery



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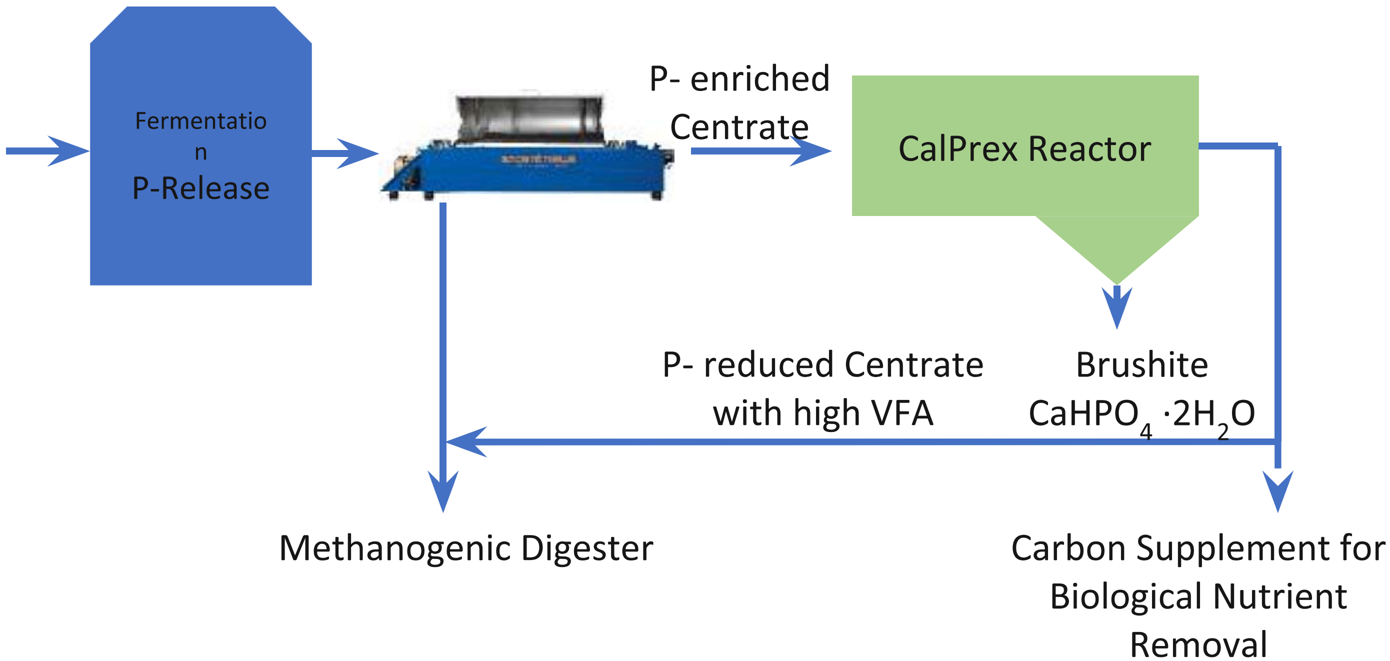
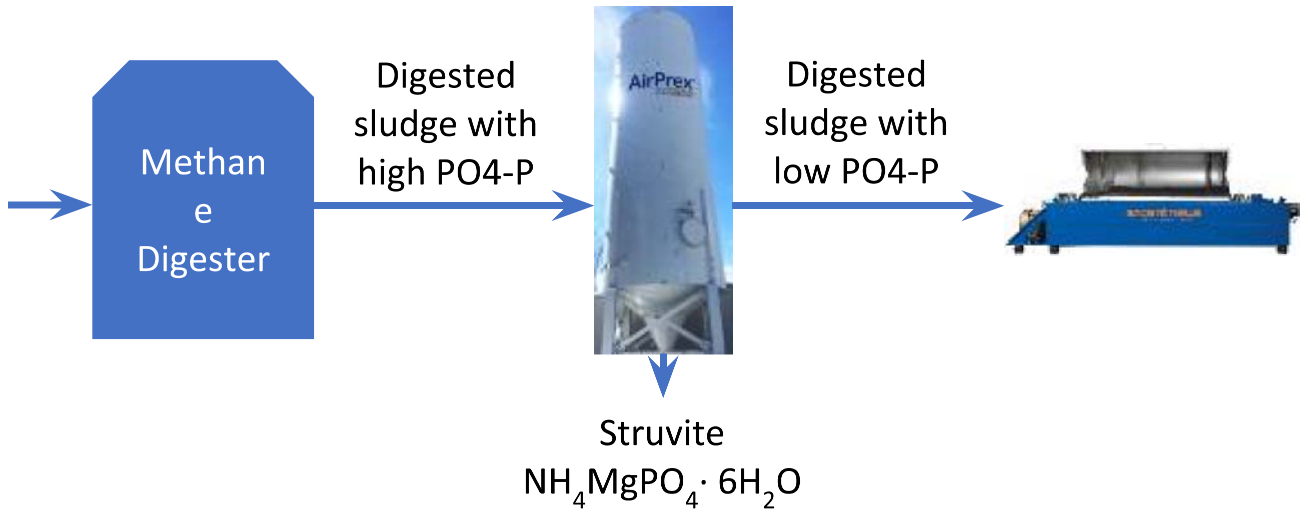
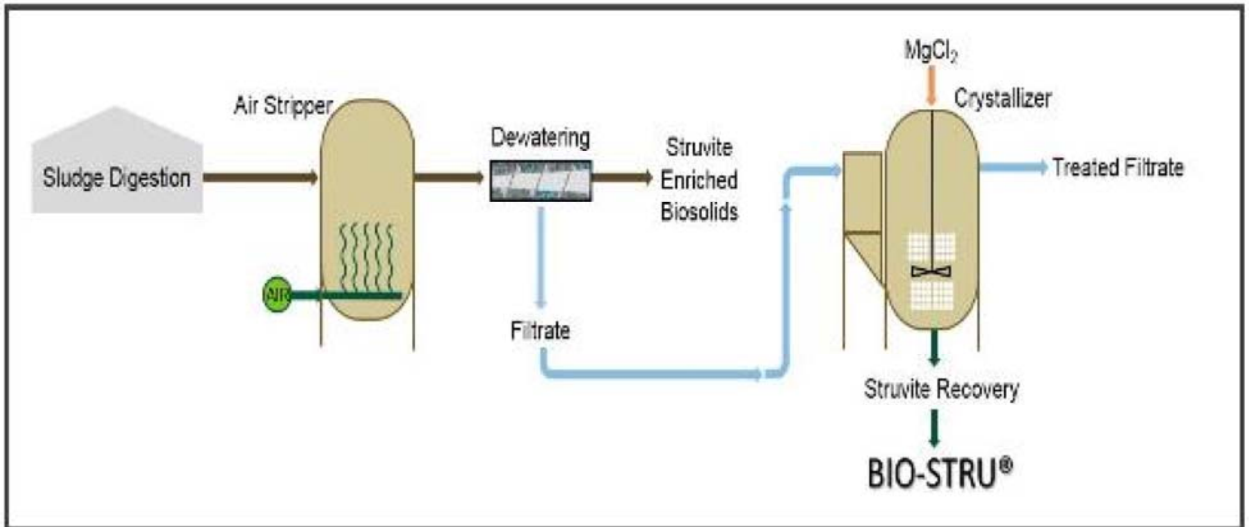
CalPrex™ P Recovery



AirPrex® P-Recovery



Schwing Bioset NuReSys



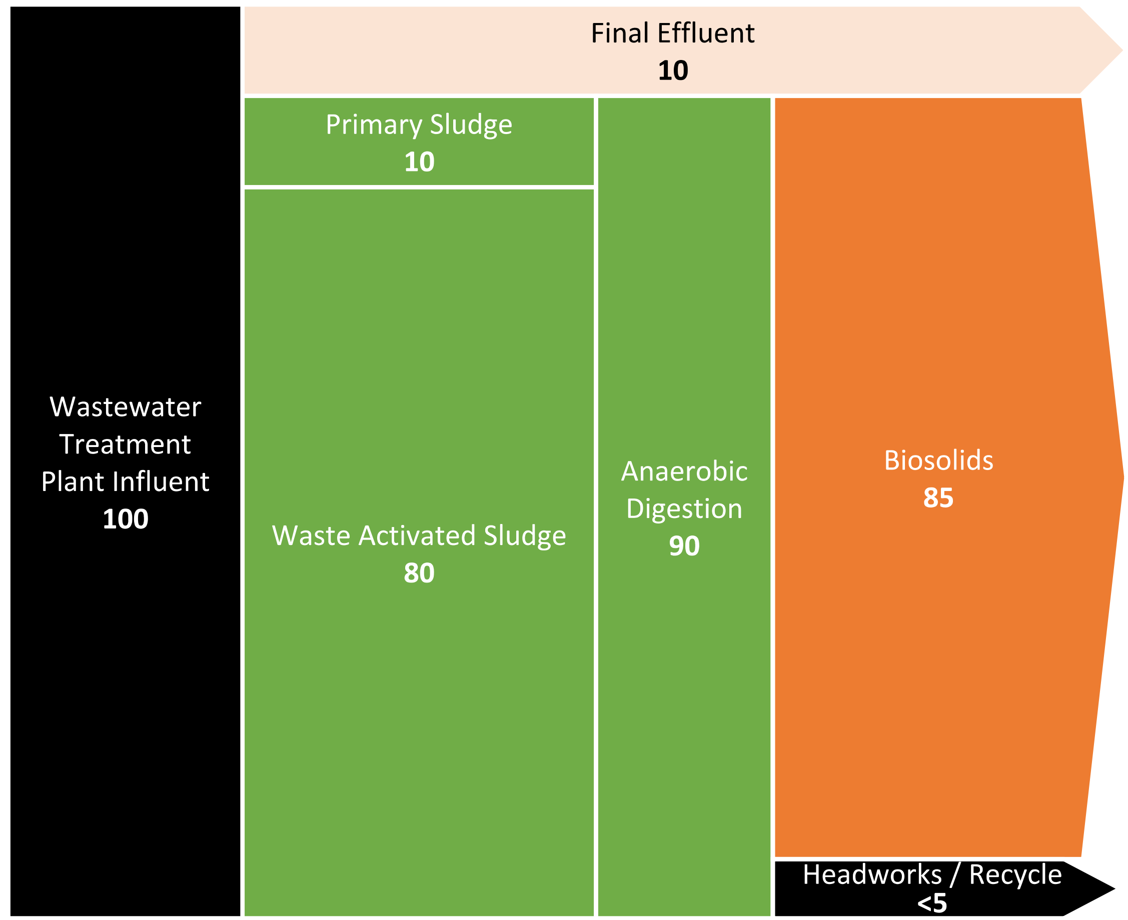
Three primary configurations: Hybrid

- Air Stripper has 2-hr HRT; Crystallizer has 1-hr HRT
- PO4-P levels down to ~15 ppm regardless of starting concentration
- Prevents scaling in upstream equipment AND centrate lines
- Harvest 90+% of struvite produced w/ optional cyclone
- Same lower $MgCl_2$ dose as centrate option
- Can convert Digestate to Hybrid configuration in future
- Does not help dewatering performance as $MgCl_2$ added downstream

Conventional P Mass Balance

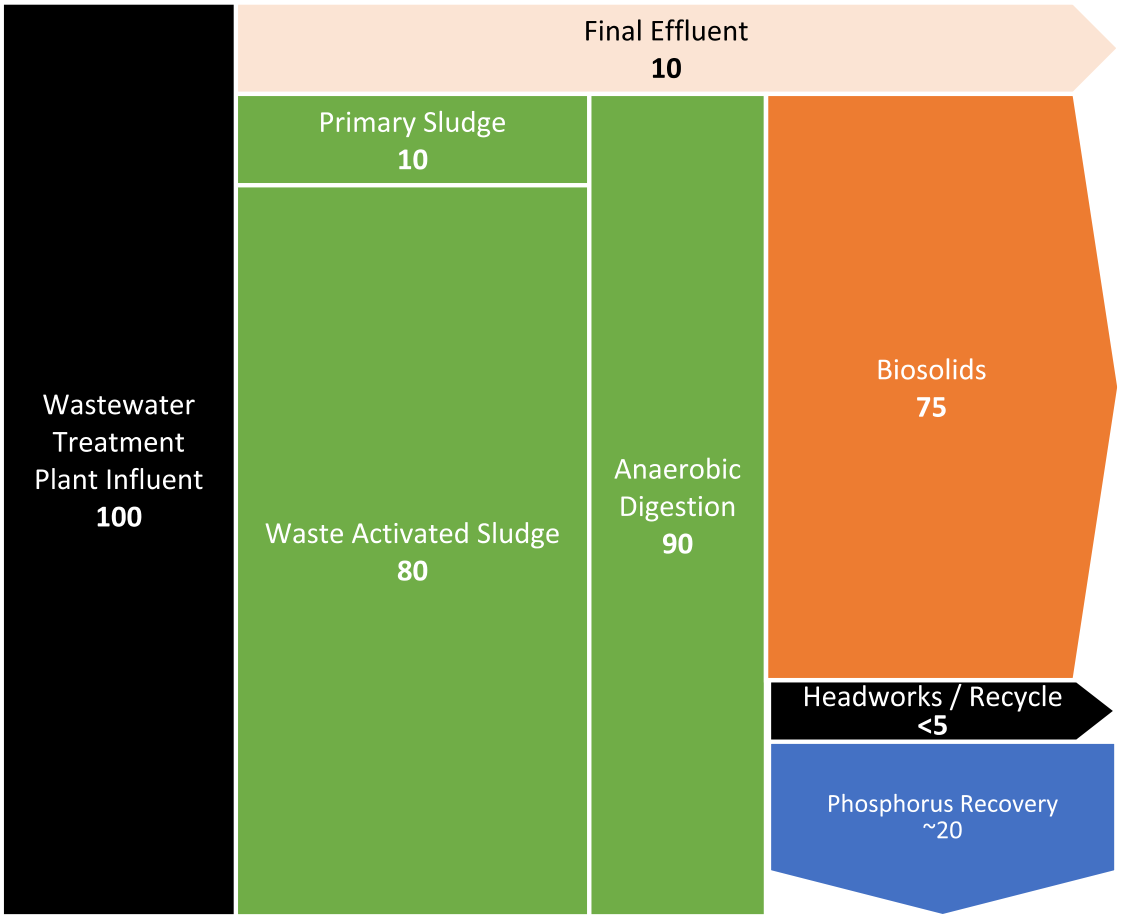
With no other exit, P mass is removed in biosolids through:

- chemical sequestration
- unintentional struvite formation
- biomass accumulation



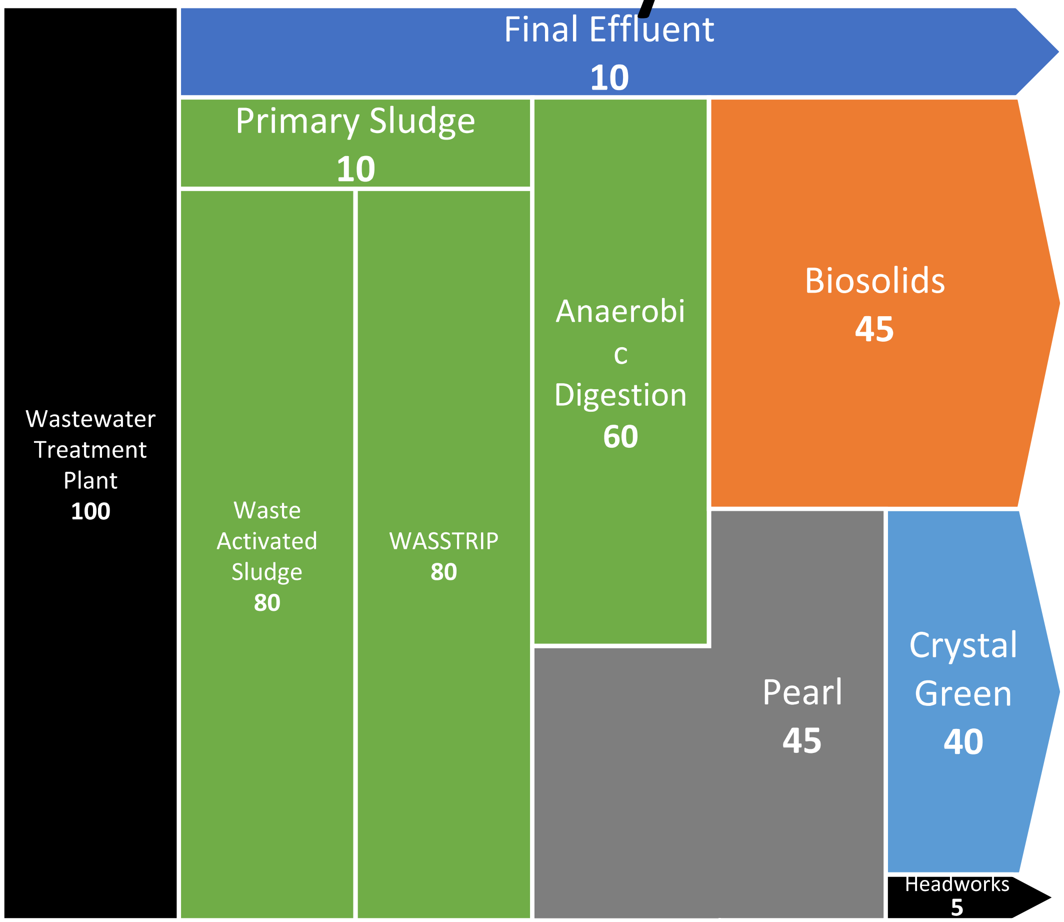
P Balance with Side Stream Recovery

Side stream recovery converts approximately 15% percent of influent phosphorus into marketable P fertilizer product.



P Balance with Combined System

Converts Approximately 40% Of Influent Phosphorus Into Extracted Fertilizer Product



P Mass Balance with CNP Pilot

*Averages of 8 mass balance samplings based on field testing by CNP engineers

Validation Criteria	Target Value	Average Field Value
Solubilization of P in Bio-P Sludge	at least 60%	66%
Soluble P in CalPrex™ Reactor	50-100 mg/L	50 mg/L
Reduction of Total P in Biosolids	up to 50%	TBD*

87% of the ortho-P entering the reactor was precipitated

92% particulate capture rate in clarifier

65% average recovery of ortho P that could otherwise precipitate as struvite downstream

43% average recovery of total P from sludge feed

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Case Studies – Ostara

- HRSD Nansemond Plant,
- Madison, WI
- Clean Water Services, OR
- MWRD Greater Chicago Stickney Plant
- Gwinnett County GA
- Atlanta, GA
- 19 others in North America

Case Studies – CNP AirPrex

- Howard County DPA
- Denver Metro
- European Reference Facilities

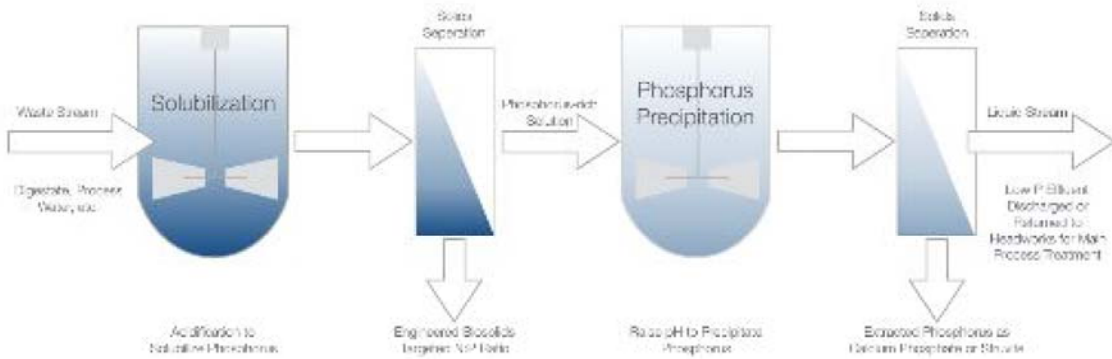
Case Studies – Schwing NuReSys

- Tuscon, AZ
- Grand Rapids, MI

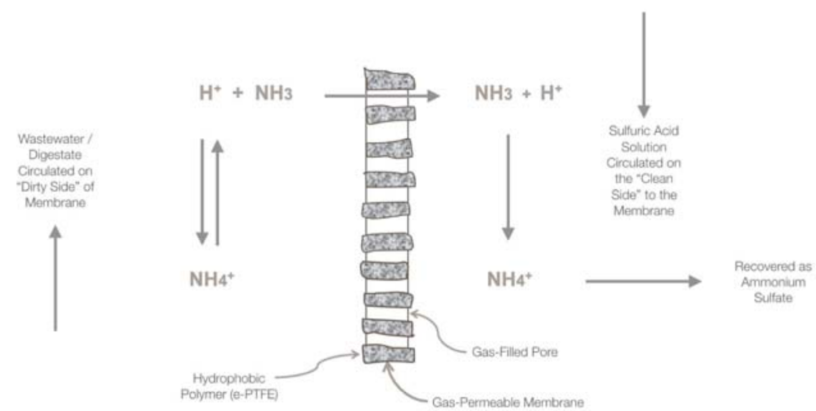
Other Extraction Technologies

- Renewable Nutrients – “Quick Wash”: Project development at stand-alone food digester in NE US and at WRRF in mid-West
- Thermal Process Systems – “Targeted P Removal”: Pilot plant in Indiana
- Absorbents -

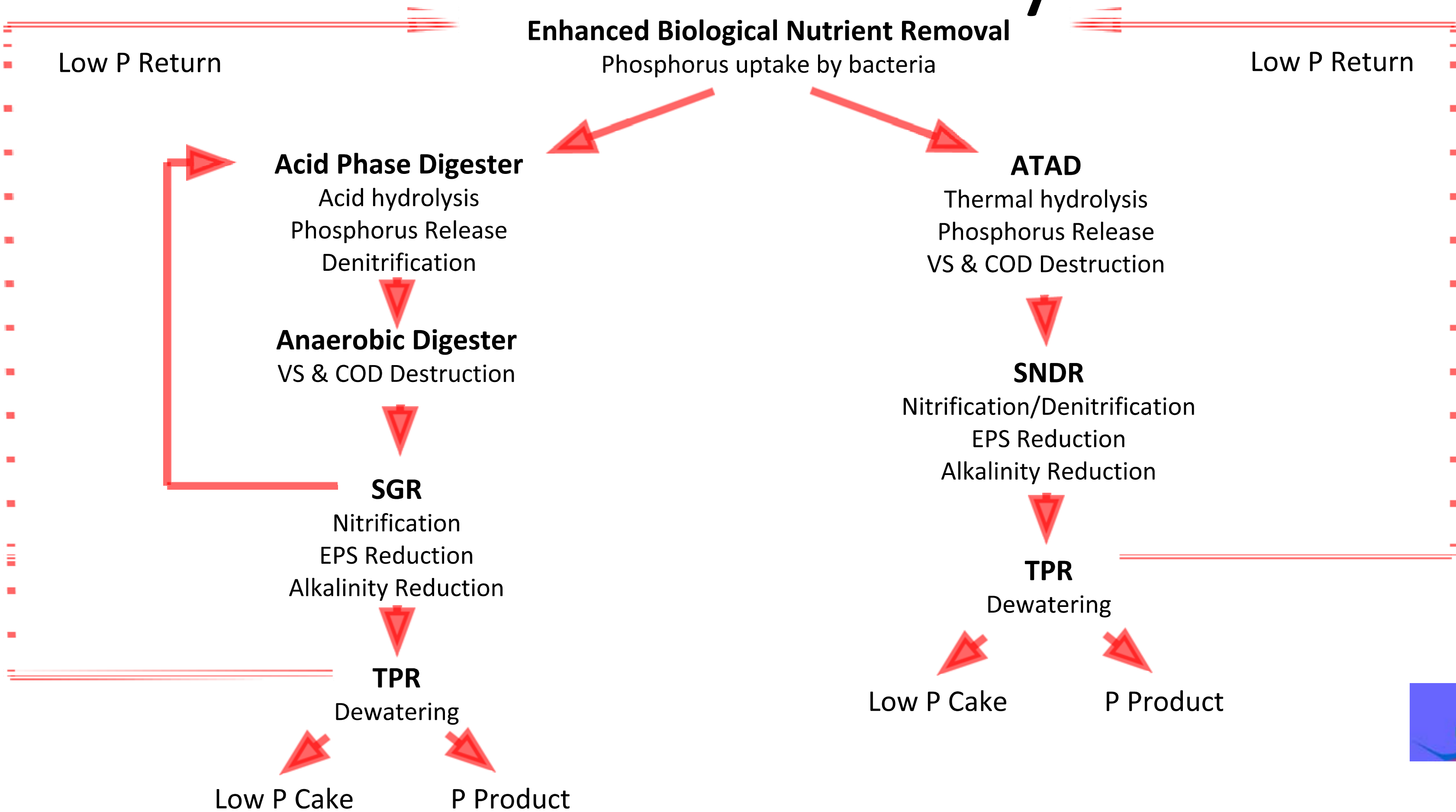
Renewable Nutrients Quick Wash



Using both P extraction and Nitrogen extraction approaches for digestate or filtrate, or combined treatment



Thermal Process System



Case Study – SSI Ash

- German Policy Directive: example, TetraPhos from Remondis Aqua, wet chemical extraction of P from SSI Ash; also EasyMining Sweden, and Outotech GmbH.
- Direct Use of SSI Ash for P fertilization: NEORSD Southerly, Cleveland, OH (Nick Basta, The Ohio State University); Metro Council Environmental Services, Minneapolis, MN (Persephone Ma, University of Minnesota)