



Ostara Nutrient Recovery Solutions



Ohio Nutrients Workshop | November 2018

Rachel M. Lee, P.E.
Ostara Nutrient Recovery Technologies



Operating Experience



Pearl[®] Nutrient Recovery has a Rapidly Growing Installation Base



Today's Phosphorus Cycle is Broken





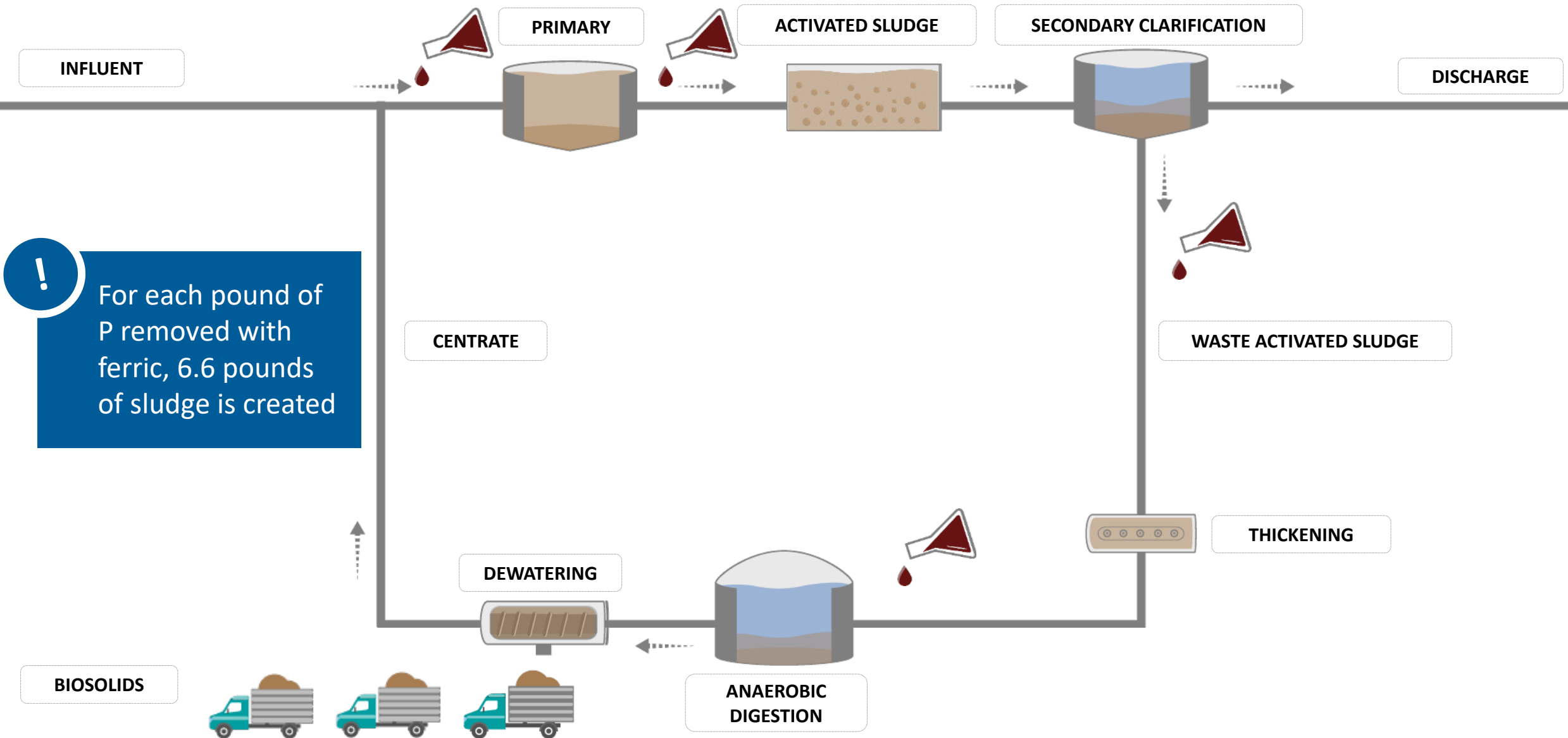
Gulf of Mexico Dead Zone

Currently measured at 5,052 square miles – more than twice the size of Delaware

Ostara Provides a Sustainable, Closed Loop Solution

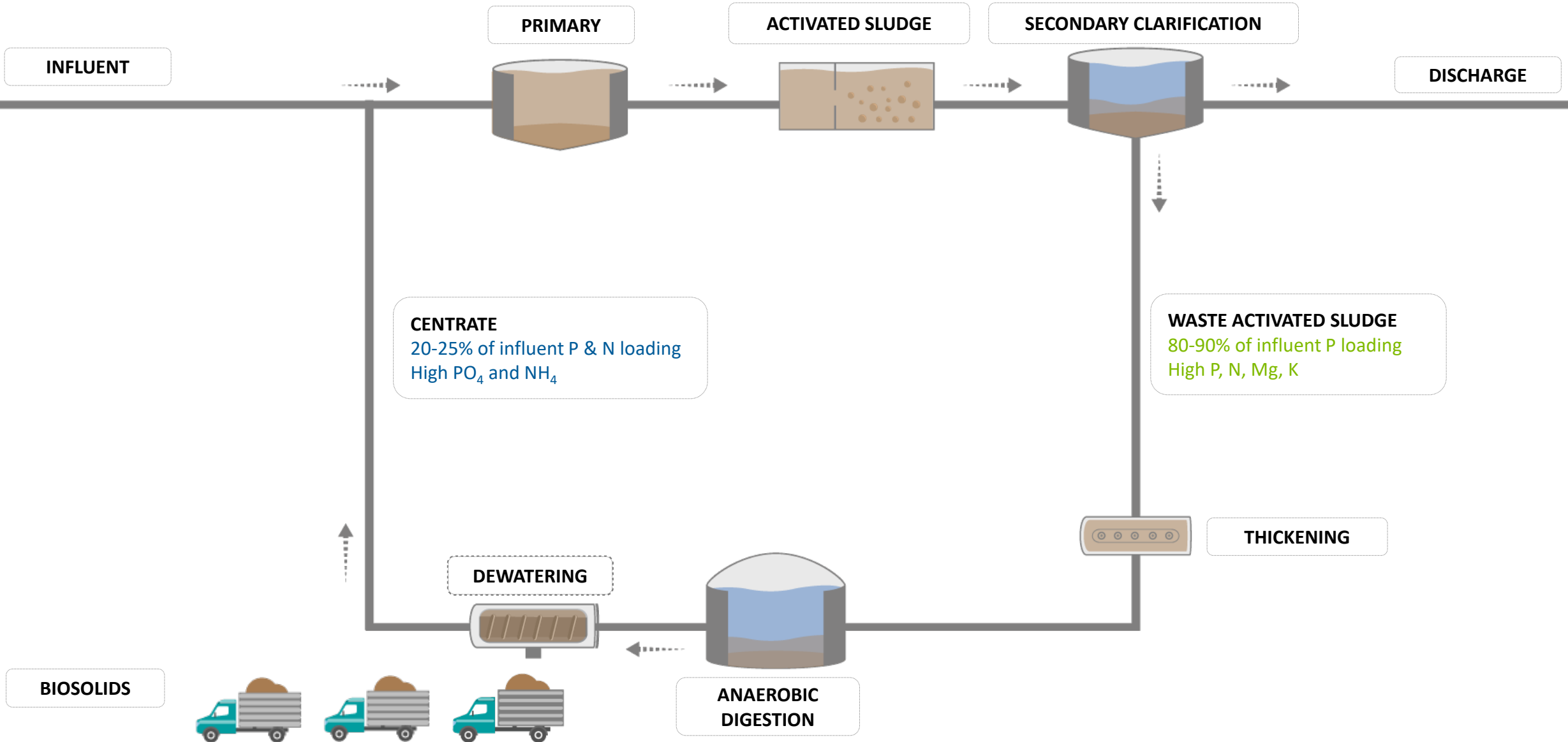


Costly Chemical P Removal Increases Sludge Volumes

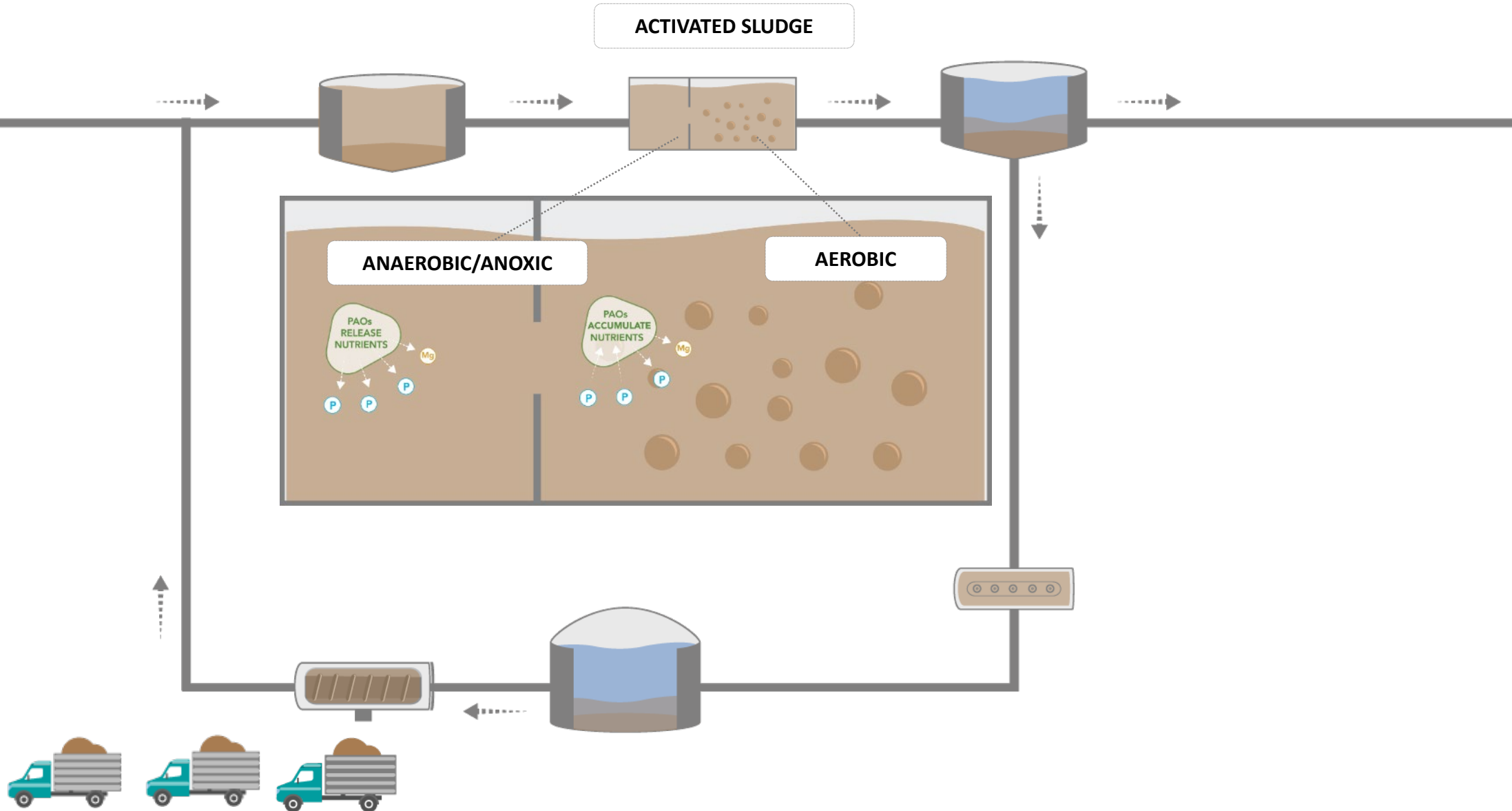




Biological Nutrient Removal Efficiently and Effectively Reduces Effluent Nutrient Concentration



Anaerobic and Aerobic Cycling Selects for Polyphosphate Accumulating Organisms (PAOs)

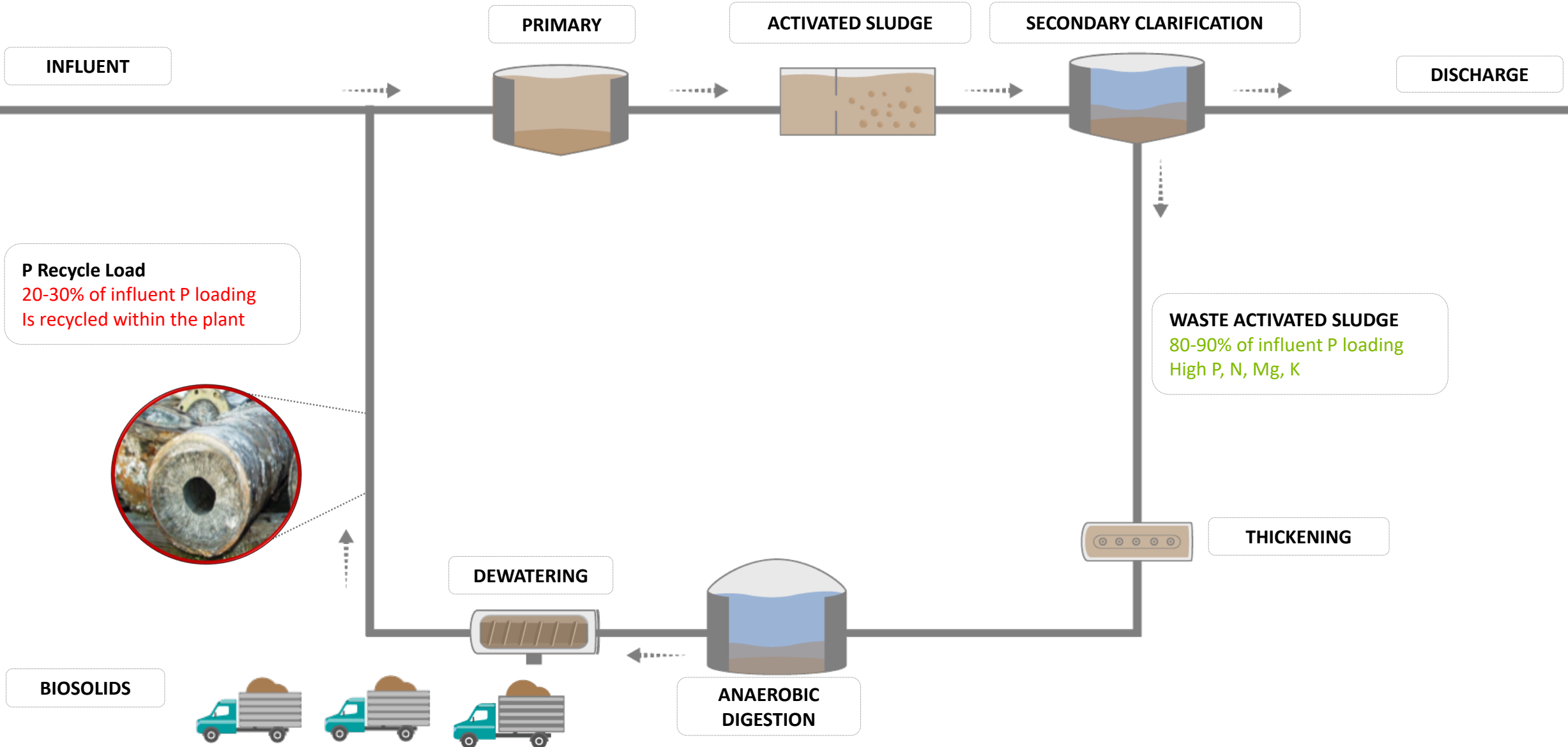




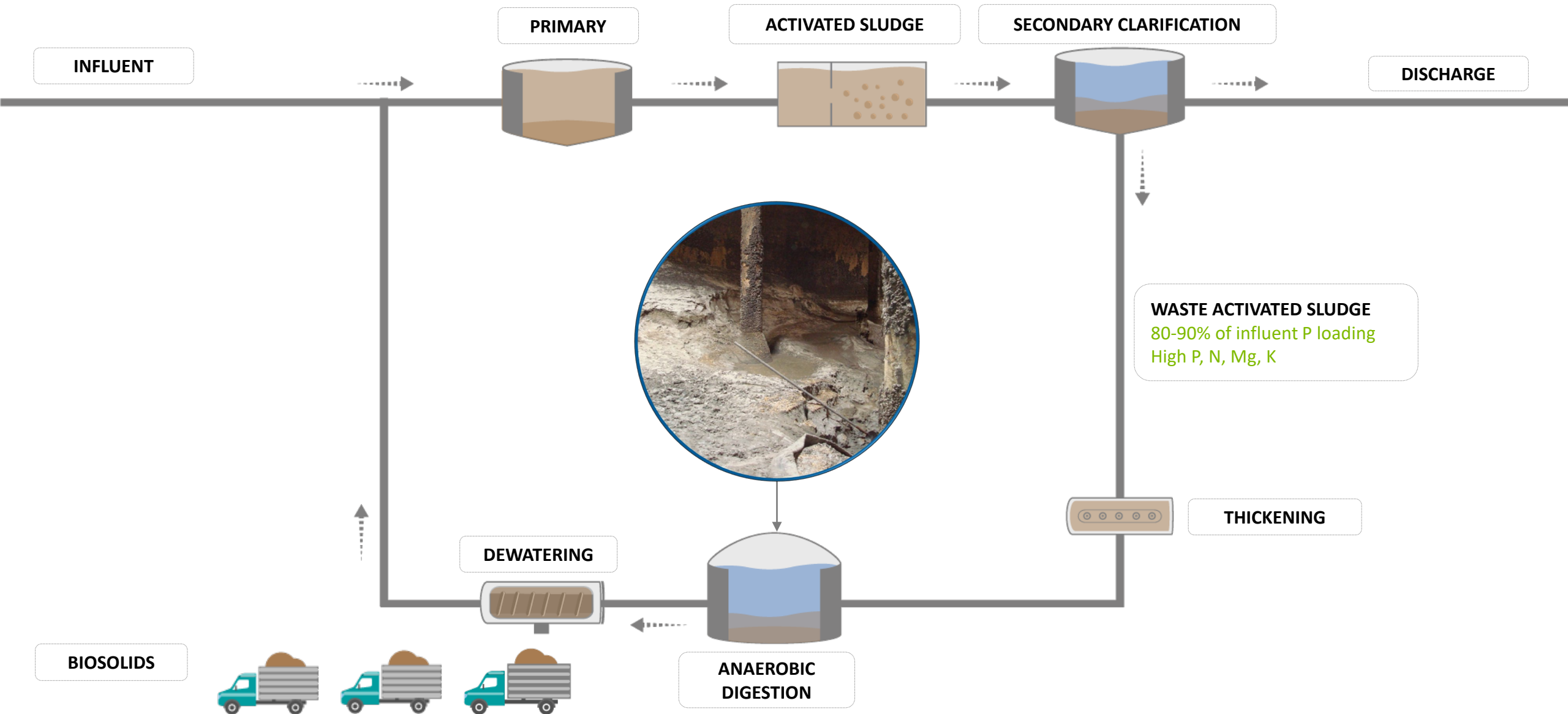
Struvite Happens

This is where Ostara steps in...

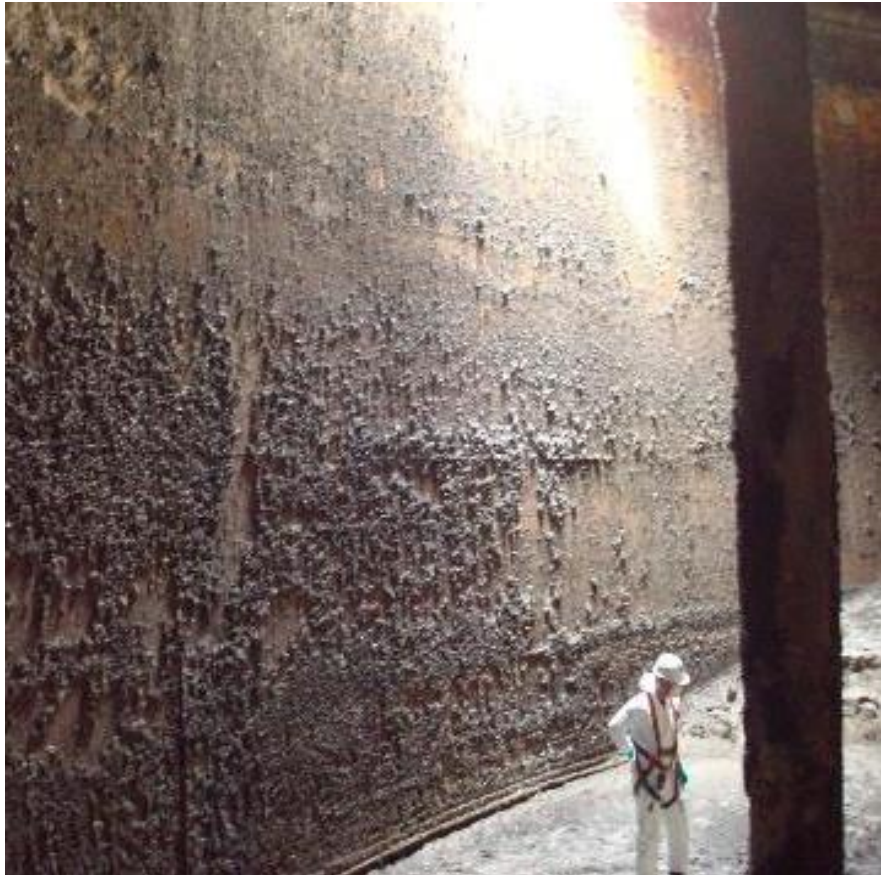
Struvite Formation Creates Serious Operational Challenges



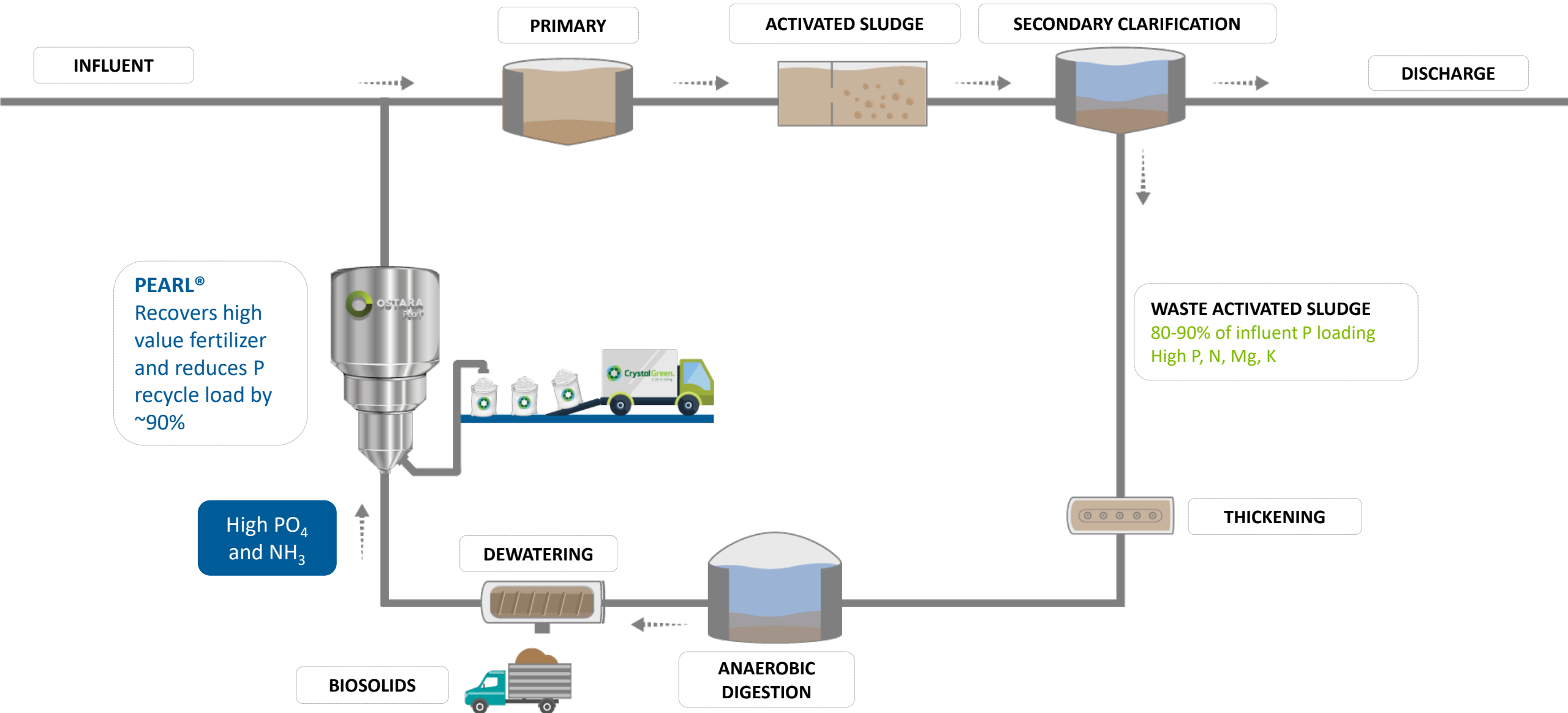
Uncontrolled Struvite Formation Poses Serious Digester Operational Challenges



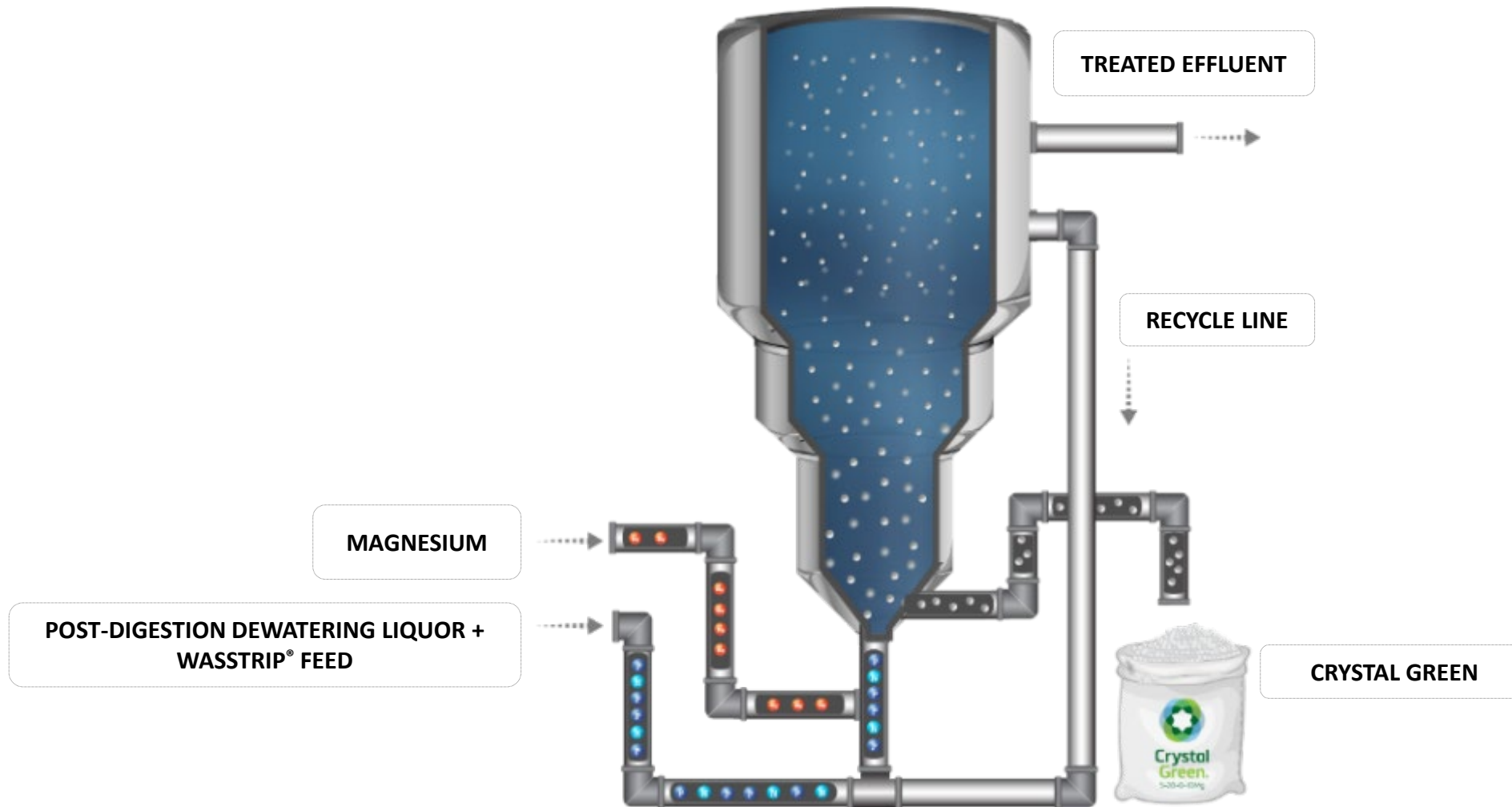
Digester Struvite Build-up in Saskatoon



Pearl[®] Solves Operational Challenges while Optimizing P Recovery

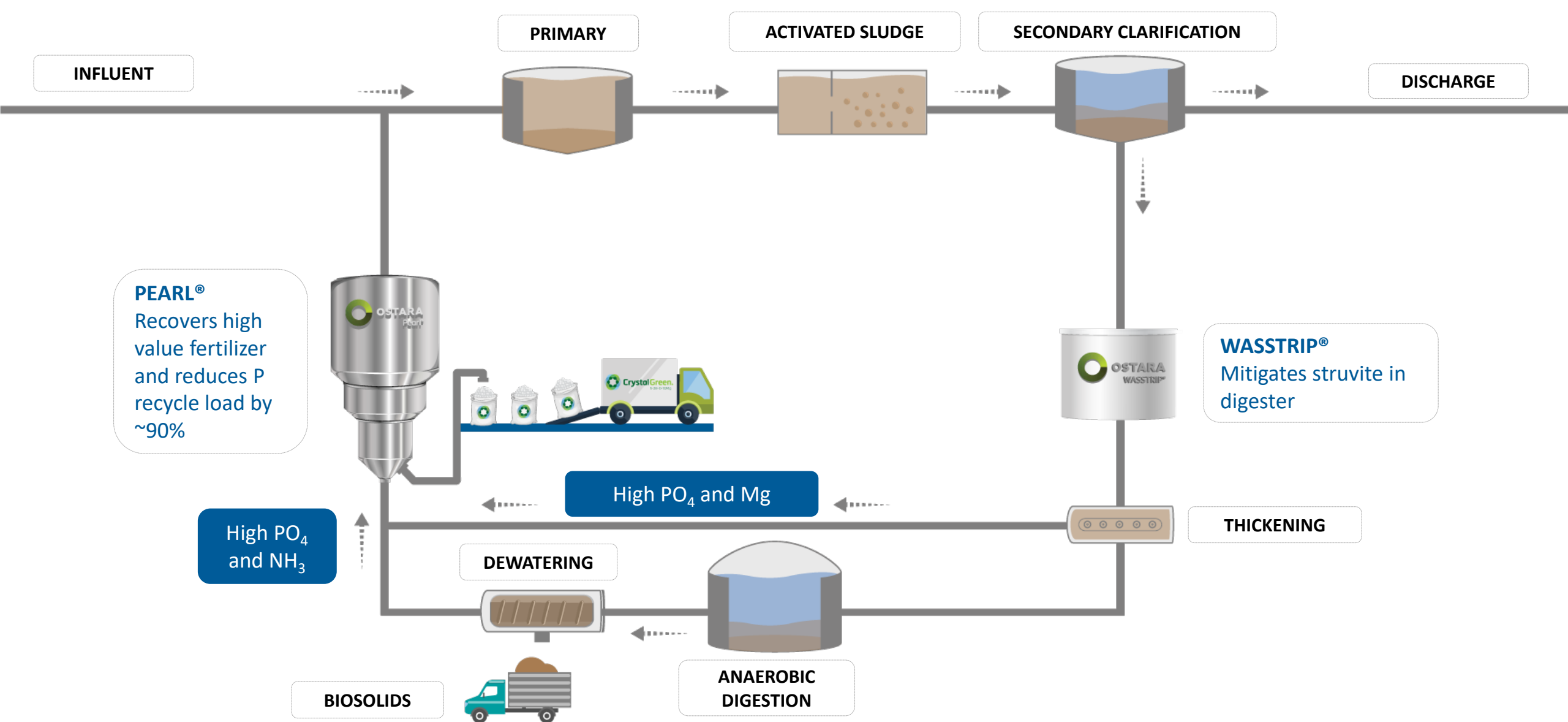


Ostara's Core Technology: The Pearl[®] Reactor



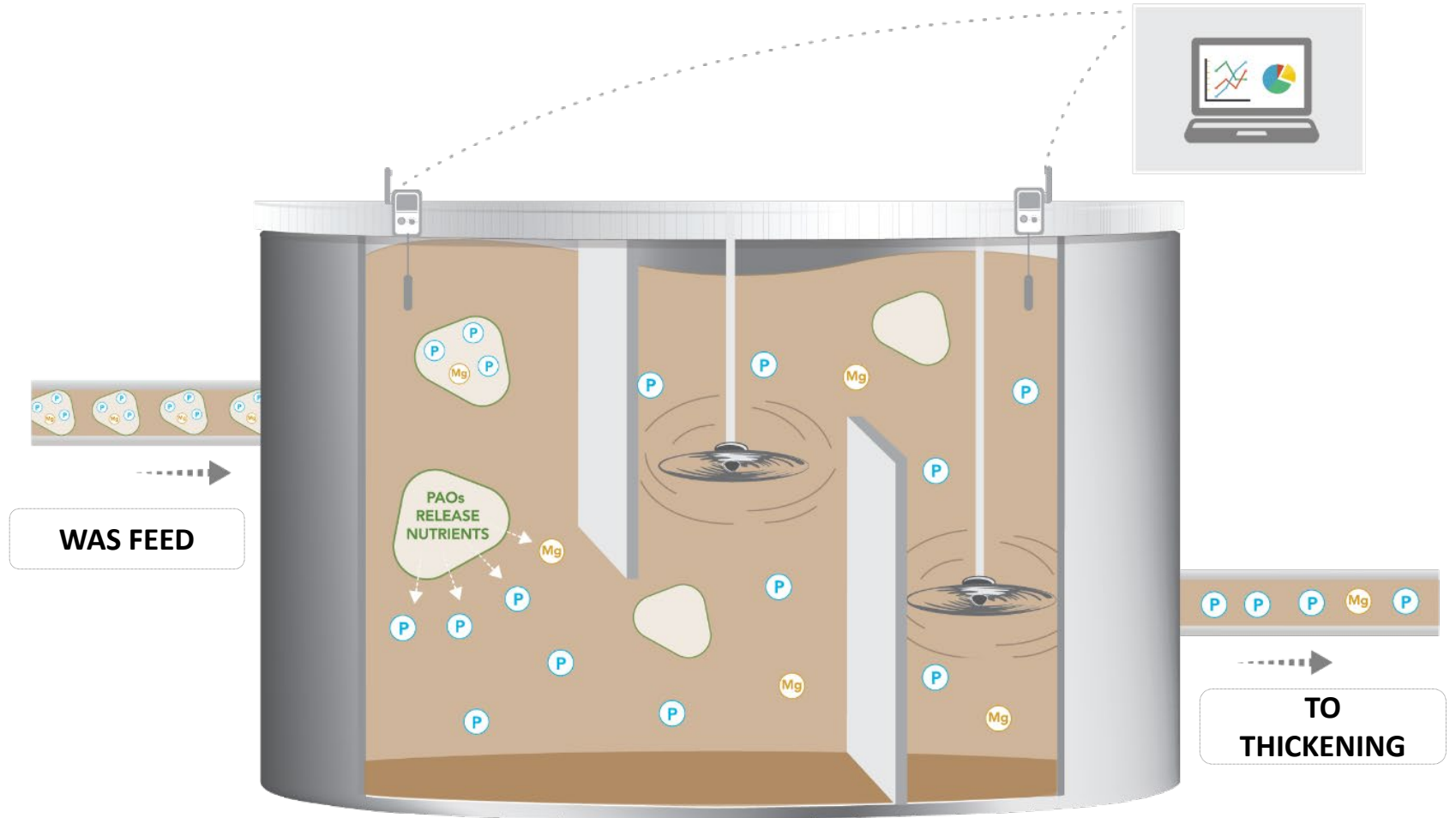


Pearl[®] + WASSTRIP[®] Solves Operational Challenges by Intercepting Upstream of Digester



Design Considerations:

- Precision Mixing
- WAS Pre-thickening
- WAS fermentation
- Optional VFA addition
- Integrated process control system



Waste **A**ctivated **S**ludge **S**tripping to **R**emove **I**nternal **P**hosphorus
(and Magnesium)



Crystal Green is simply a natural, slow release, granular fertilizer

- ✓ Proven to reduce non-point source runoff
- ✓ Registered commercial fertilizer in the US and Canada
- ✓ Established market
- ✓ AAPFCO approved source of slow release nutrients
- ✓ USDA CSP approved input
- ✓ Long-term exclusive distribution partnership with Taurus Agricultural Marketing to market and sell Crystal Green in western Canada and Ontario



Crystal Green is Produced in Market Specific Sizes

SGN
450



SGN
300



SGN
150



SGN
90



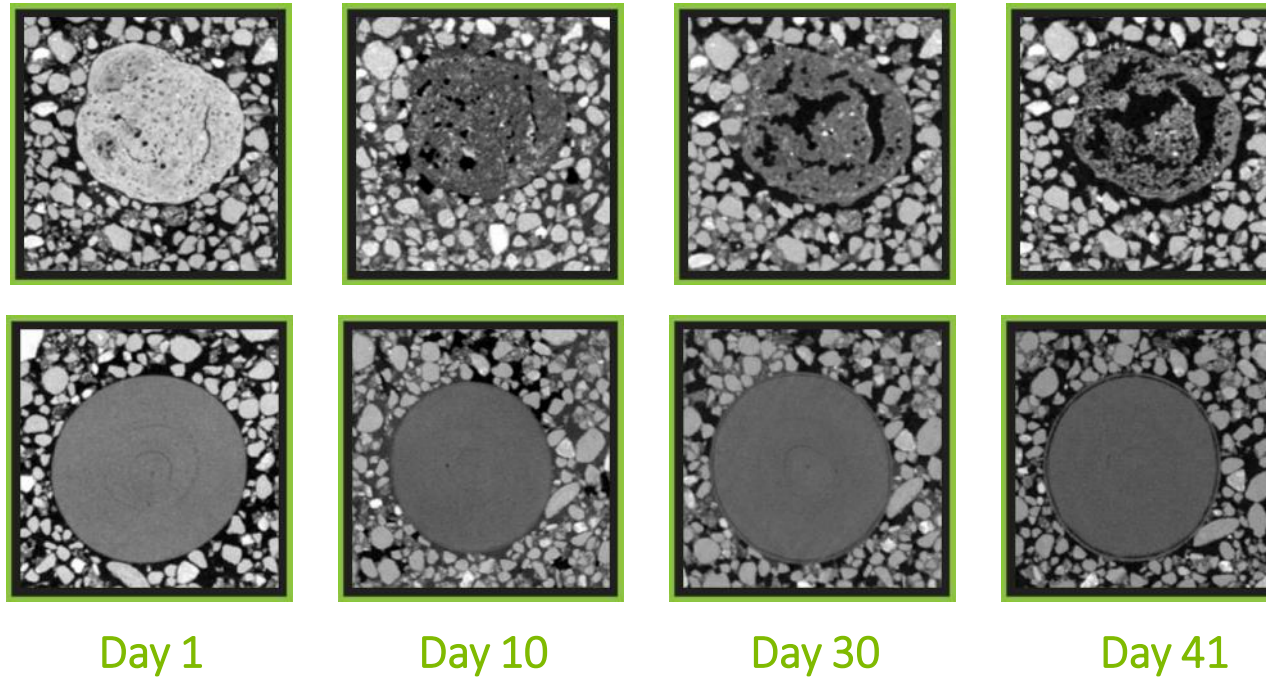
The only uncoated continuous release granular phosphorus fertilizer

- ✓ Root-Activated™ (citrate soluble)
- ✓ 99.6% Purity
- ✓ 0.9, 1.5, 3.0, 4.5 mm prill size
- ✓ Lowest Salt Index of any P source
- ✓ Hardness similar to MAP or DAP
- ✓ High uniformity index

Crystal Green Remains Intact After Intense Watering

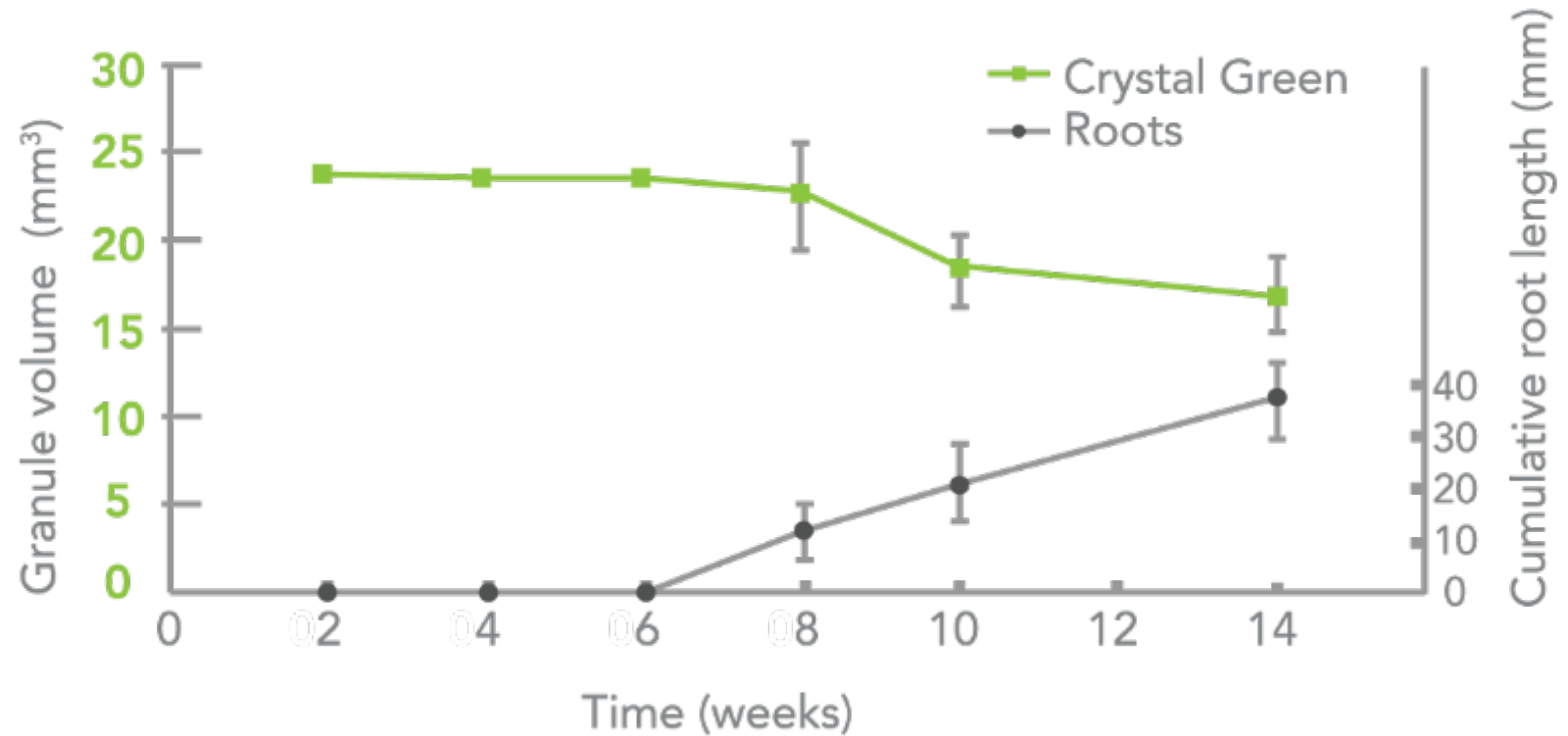
CT-Scan Study – University of Southampton

Commodity
Phosphorus



Crystal Green Release is the Key to Root Growth

Interaction of Growing Roots and Crystal Green Fertilizer



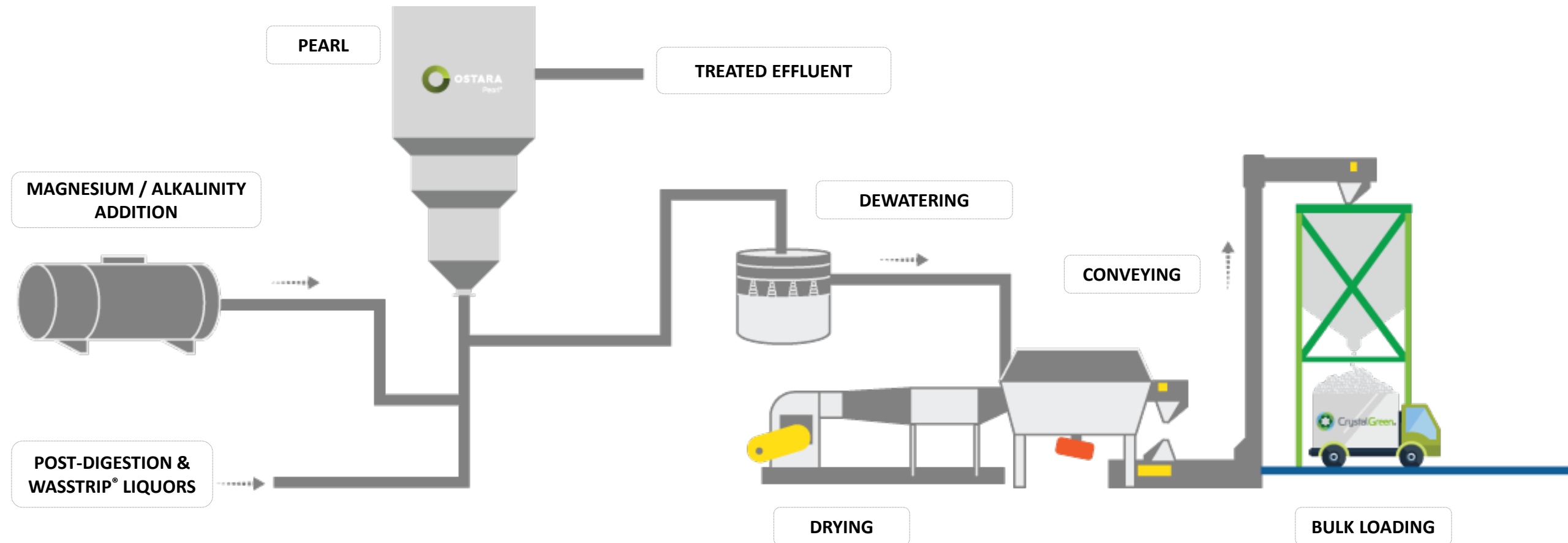
Guaranteed Fertilizer Purchase Optimizes Your Investment



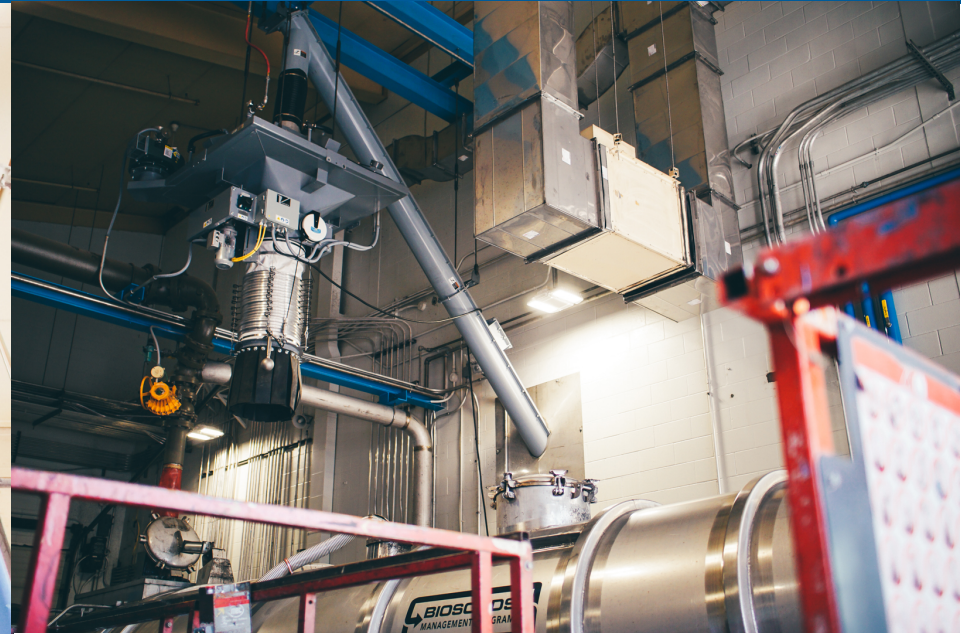
- ✓ Long-term purchase agreement
- ✓ Sales price tied to global fertilizer market value
- ✓ Established sales channel in North America and Europe

Fertilizer Product Handling is Simple and Fully-Automated

Crystal Green is dried, sorted and bagged ready-for-sale on site



Bulk Offloading System at St. Cloud Simplifies Product Handling



- ✓ Product stored in a bulk silo
- ✓ Transported away from site in bulk hopper trucks



OSTARA



PRISM: Cutting Edge Trending Package

User-friendly -
red, yellow, green
for easy issue
identification

Customized
metrics for
effective trend
analysis

Faster, streamlined & more
robust than SCADA

- ✓ No need to export data for customized reporting and analysis
- ✓ Optimize reactor performance by identifying potential issues in real-time
- ✓ Save key performance indicators and reports for easy troubleshooting that minimizes downtime



Who do call when you need help?

Ostara's skilled operations team and customized **PRISM** trend analysis software offers:

- ✓ 24/7/365 support
- ✓ Remote monitoring for convenient trouble shooting
- ✓ Continuous operational improvements to maximize benefits



According to HRSD, PRISM is Essential

“PRISM has quickly become essential to improving the operations at our facility.”

Bill Balzer, P.E.,
Plant Manager, Hampton Roads
Sanitation District





With Ostara, Nutrient Management Partnership Maximizes Your Success



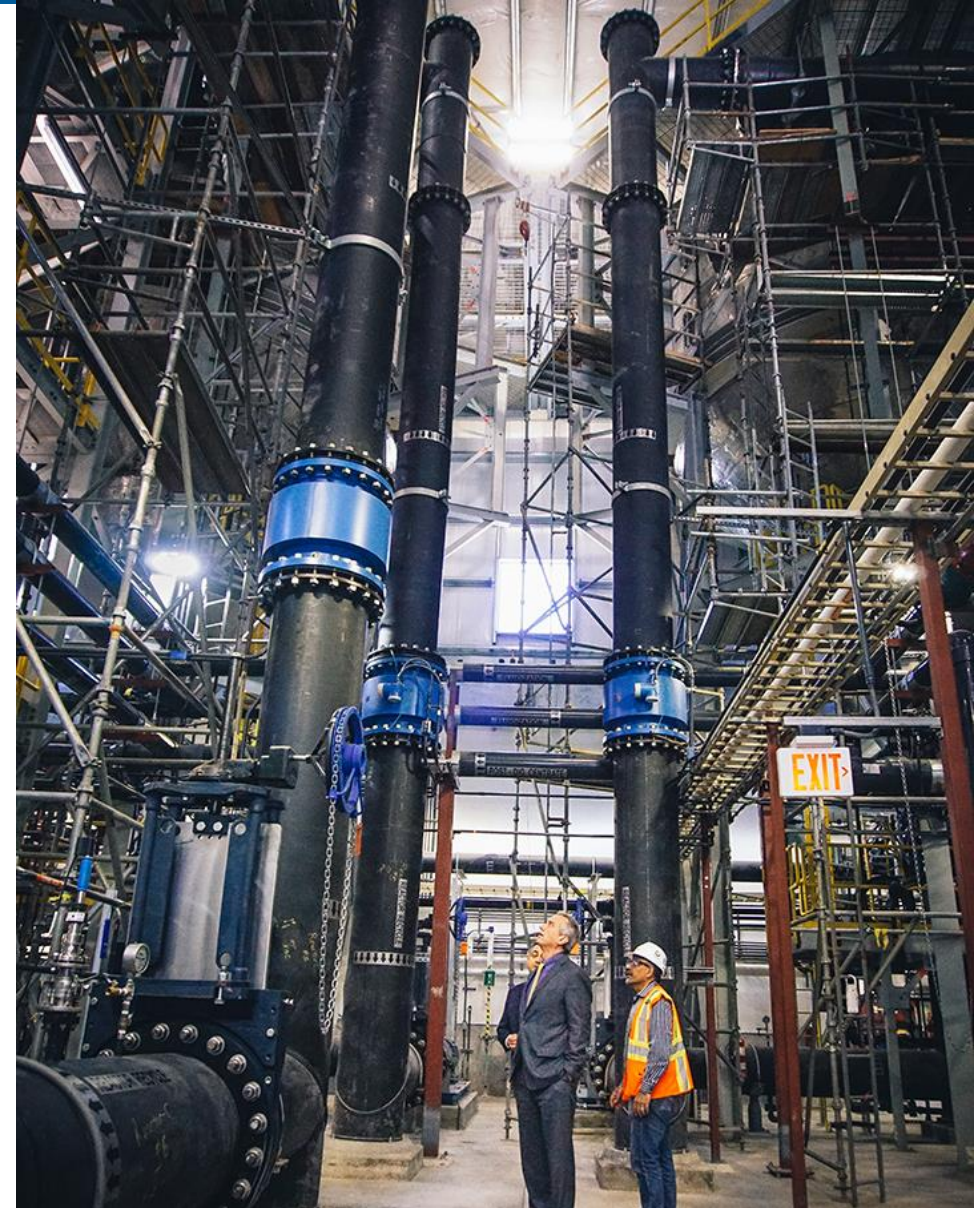


Ostara's Solution Enabled Stickney Water Reclamation Facility to Successfully Meet Nutrient Limits With Bio-P Removal



Metropolitan Water Reclamation District Of Greater Chicago

PARAMETER	VALUE
Design Capacity	1200 MGD
Population Served	4,500,000
Pearl Model	10K
# of Reactors	3
Installation	Greenfield
Installation Year	2016
WASSTRIP	Planned





Pearl[®] 10K

Load Capacity (PO₄-P per day)

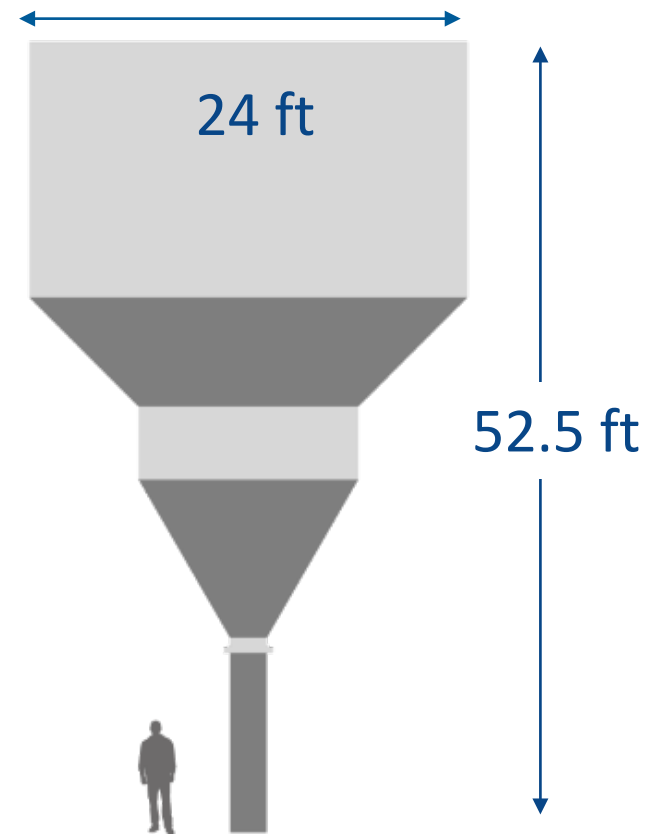
2,800 lbs

**Average Production Capacity
(Crystal Green per day)**

14,000 lbs

Installation Base (2017)

4





3 x Pearl[®] 10K at Chicago

Capacity of 7,500 tons/year of Crystal Green[®]





3X Pearl 10K at Stickney Nutrient Recovery Facility

Achieves MWRD's Project Goals:



1.0mg/L limit for total P in effluent



Plant efficiency and cost-effective implementation of Bio-P



Capacity to produce 7,500 tons/year of Crystal Green



Cost recovery in 5-7 years

Nine Springs Wastewater Treatment Plant

Madison Metropolitan
Sewerage District



Madison, WI

PARAMETER	VALUE
Design Capacity	55 MGD
Population Served	340,000
Pearl Model	2K
# of Reactors	2
Installation	Greenfield
Installation Year	2014
WASSTRIP	Yes





Pearl[®] 2K

Load Capacity (PO₄-P per day)

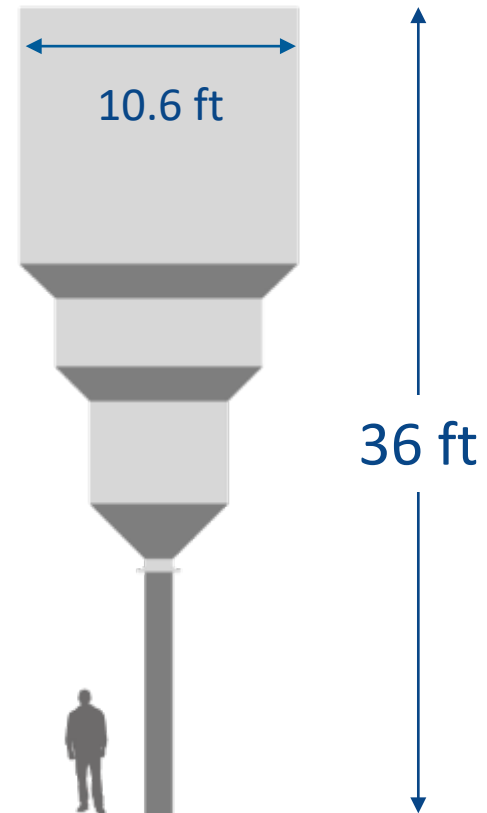
550 lbs

**Average Production Capacity
(Crystal Green per day)**

2,750 lbs

Installation Base (2017)

12



2 x Pearl[®] 2K at Nine Springs WWTP (Madison, WI)

1,000 tons/year of Crystal Green[®] Capacity





Nine Springs WWTP (Madison, WI) Nutrient Recovery Facility

Achieves Project Goals



Delivery of fully functional, revenue generating nutrient recovery facility



Reduces centrate nutrient load returned for treatment



Minimizes use of metal salts for chemical phosphorus removal



Reduces chemical purchase and sludge disposal costs



Reduces the phosphorus content of biosolids, for more balanced N:P ratio and improved land application



Eliminates nuisance struvite formation

Transformation of Amersfoort WWTP into Energy & Nutrient Recovery Factory



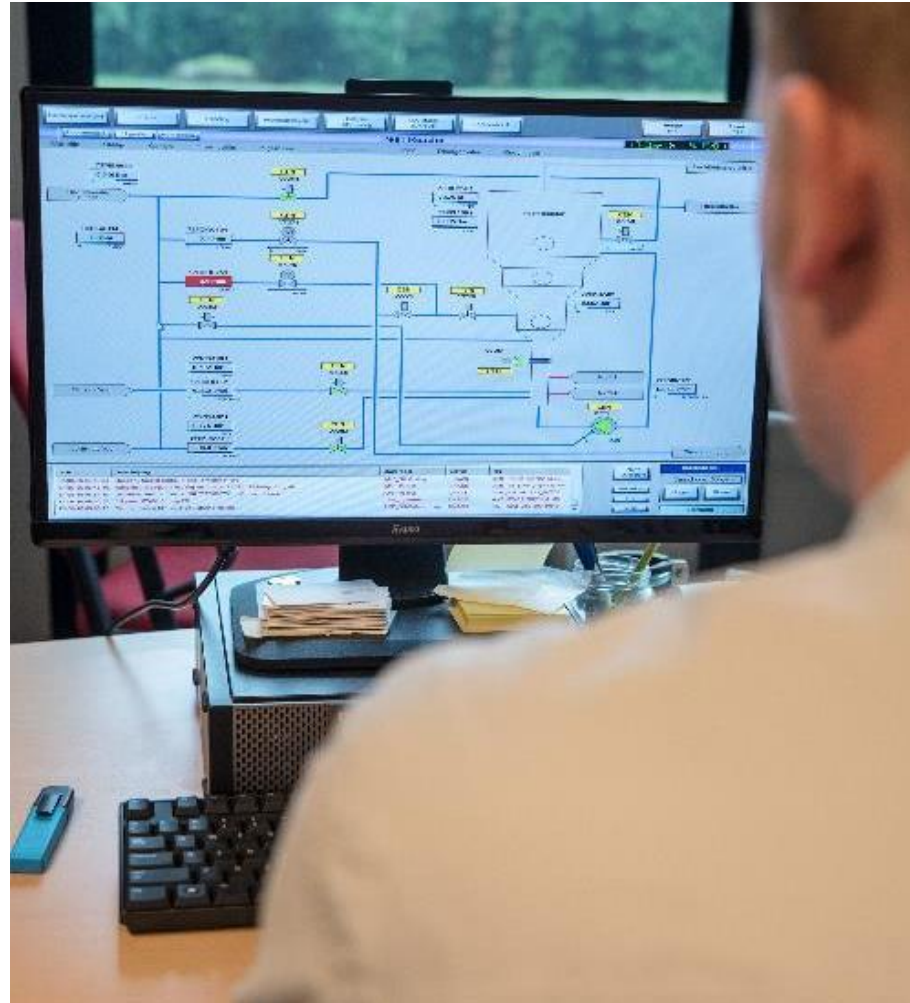
PARAMETER	VALUE
Design Capacity	15 MGD
Population Served	315,000
Pearl Model	2K
# of Reactors	1
Installation	Greenfield
Installation Year	2015
WASSTRIP	Yes





1x Pearl[®] 2K at Amersfoort WWTP (Amersfoort, Netherlands)

Capacity of 500 tons/year of Crystal Green[®]





1 Pearl 2K & WASSTRIP Installed at Amersfoort Energy and Nutrient Factory

Achieves Vallei en Veluwe's Project Goals:



Integrated with THP (improves energy capture and reduces biosolids production)



Reduced P return loads and struvite in the digester



Successfully integrated with Deammonification



WASSTRIP improves sludge dewaterability by up to 4%



Capacity to recover 500 tons/year of Crystal Green



Cost recovery in 5-7 years



What Are Your Next Steps with Ostara?

“The combination of Ostara’s nutrient recovery technology with biological phosphorus removal has significantly reduced costs for our constituents by a factor of 10.”

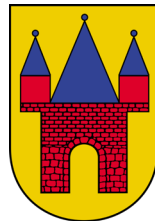
- DAVID ST. PIERRE, EXECUTIVE DIRECTOR, MWRD OF GREATER CHICAGO



Become one of the facilities benefiting from Ostara's Technology and known as Global Resource Recovery leaders



Madison Metropolitan Sewerage District



City of Jarocin, Poland



אגודת מי אזור דן בע"מ
MEY EZOR DAN LTD





THANK YOU

Ohio Nutrients Seminar | November 2018

Rachel M. Lee, P.E. – Manager, Nutrient Recovery Solutions

rlee@ostara.com | ostara.com



Ostara Helps Solve Your Nutrient Challenges

- ✓ Effluent P Limits and Permit Compliance
- ✓ Problem Unintentional Struvite Formation



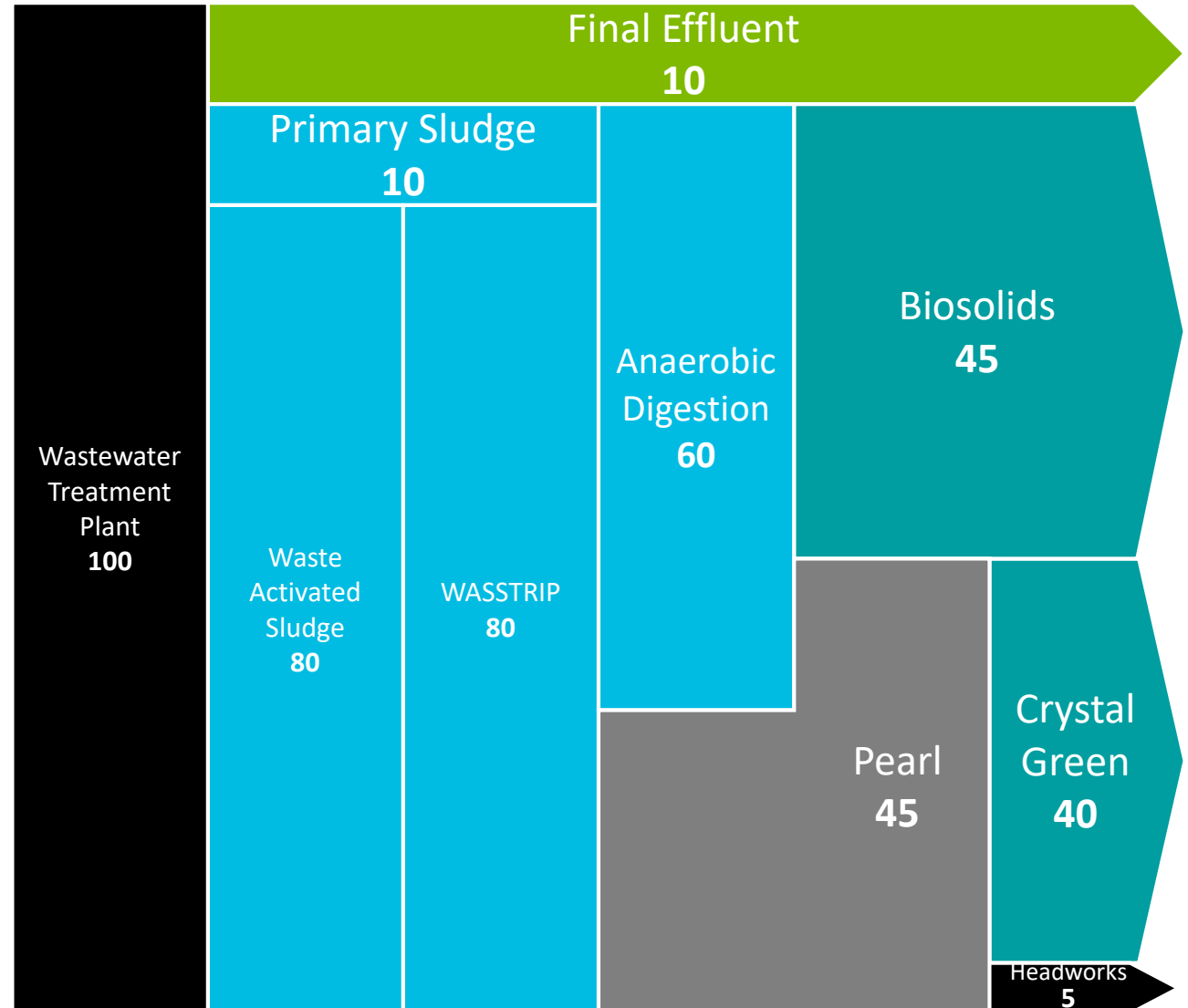
Ostara Turns Problematic Struvite into a High Quality, Market Ready, Fertilizer





Convert Up To 50% Of Influent Phosphorus Into Premium Market-ready Fertilizer, Generating A Long-term Revenue Stream

Example Phosphorus Balance



Today's Agenda

- 1 Why is phosphorus recovery important?
- 2 What problems does Ostara nutrient recovery solve?
- 3 How does Pearl[®] work?
- 4 How does Crystal Green[®] work?
- 5 Success Stories



Today's Agenda

- 1 Why is phosphorus recovery important?
- 2 What problems does Ostara nutrient recovery solve?
- 3 How does Pearl[®] work?
- 4 How does Crystal Green[®] work?
- 5 Success Stories

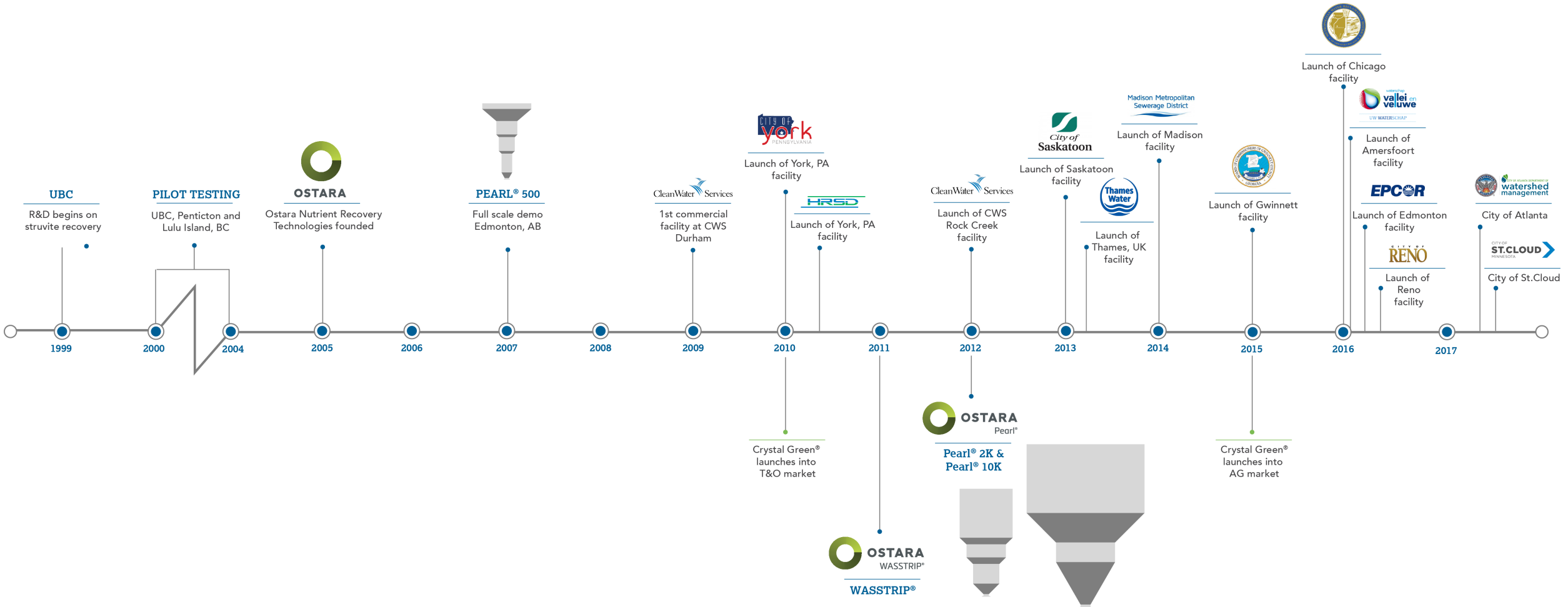


Today's Agenda

- 1 Why is phosphorus recovery important?
- 2 What problems does Ostara nutrient recovery solve?
- 3 How does Pearl[®] work?
- 4 How does Crystal Green[®] work?
- 5 Success Stories

Today's Agenda

- 1 Why is phosphorus recovery important?
- 2 What problems does Ostara nutrient recovery solve?
- 3 How does Pearl[®] work?
- 4 How does Crystal Green[®] work?
- 5 **Success Stories**





Recovery for Reuse

Closing the Loop on Nutrient Management

Produce an end product that is ready for sale when it leaves your facility without any further processing





Unintentional Struvite Happens
(unless you make sure it doesn't)



Phosphorus

Phosphorus is a vital nutrient essential to crop growth and global food security



The Gulf of Mexico

The world's second largest dead zone covering 3 million football fields



+550 Dead Zones Worldwide

Covering an area greater than Great Britain



The World's Largest Dead Zone

Suffocating the Baltic Sea



The Gulf of Mexico

Dead Zone is the size of Connecticut and Rhode Island Combined



Excess Phosphorus

Collapsed Lake Simcoe's fishing industry



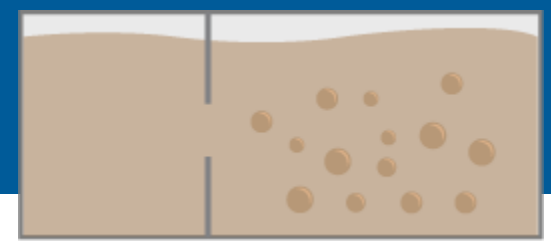
Lake Erie

In danger of dying by suffocation

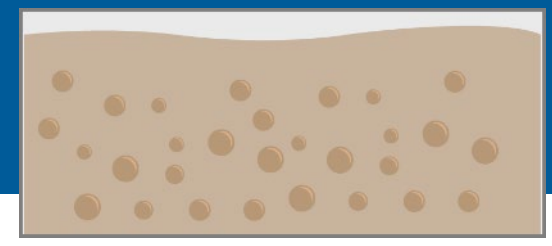


Chesapeake Bay

Has lost more than 90% of its oysters due to nutrient pollution



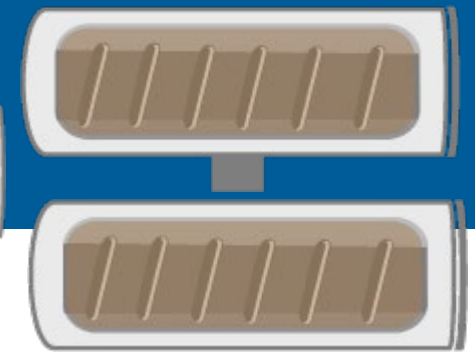
ACTIVATED SLUDGE



ACTIVATED SLUDGE



THICKENING



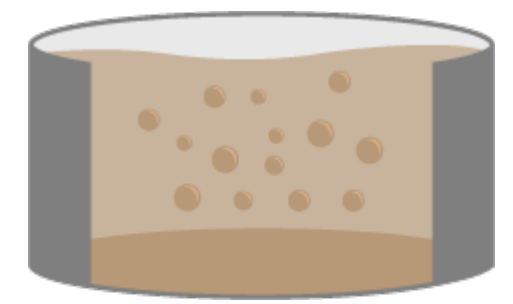
DEWATERING



PEARL®
Recovers high
value fertilizer



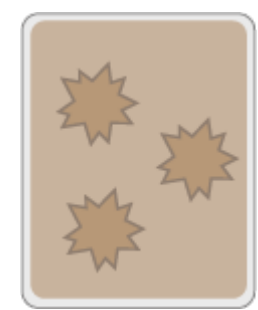
BIOSOLIDS



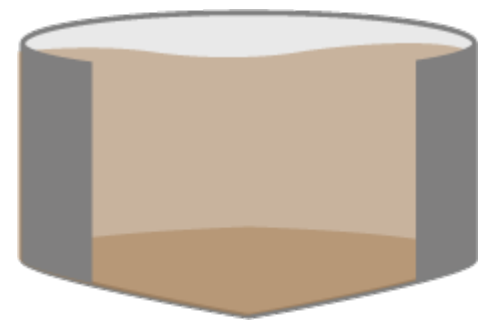
SIDESTREAM
AMMONIA REMOVAL



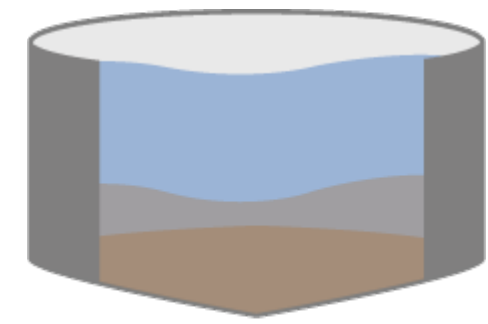
WASSTRIP®
Alleviates struvite
in digester



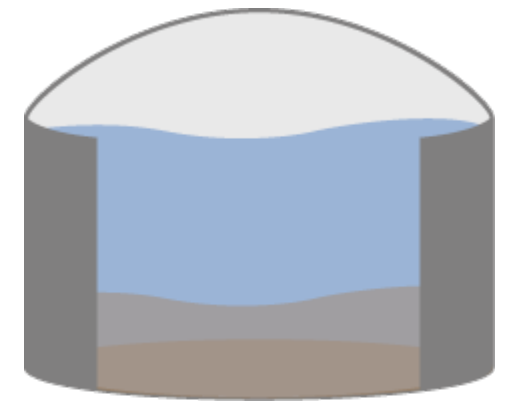
THP



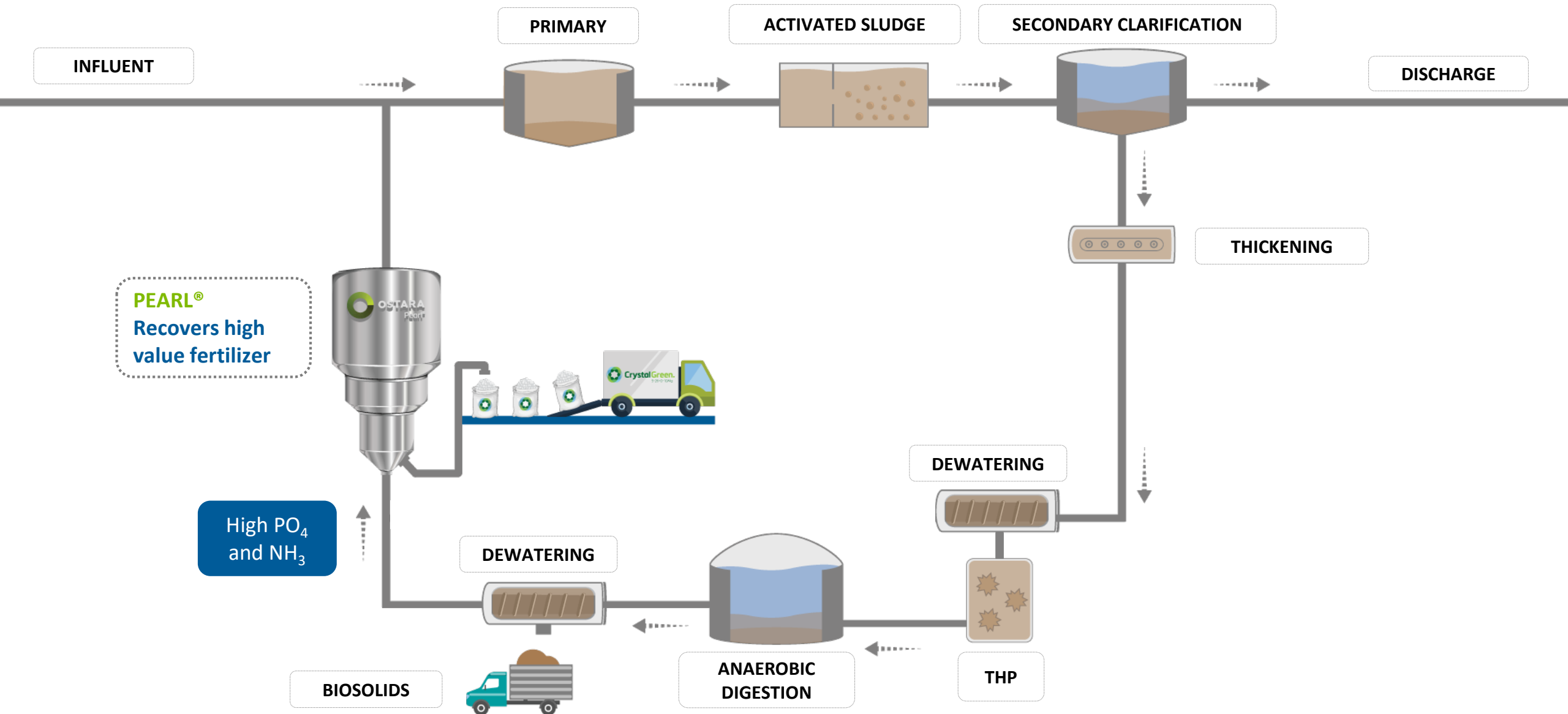
PRIMARY

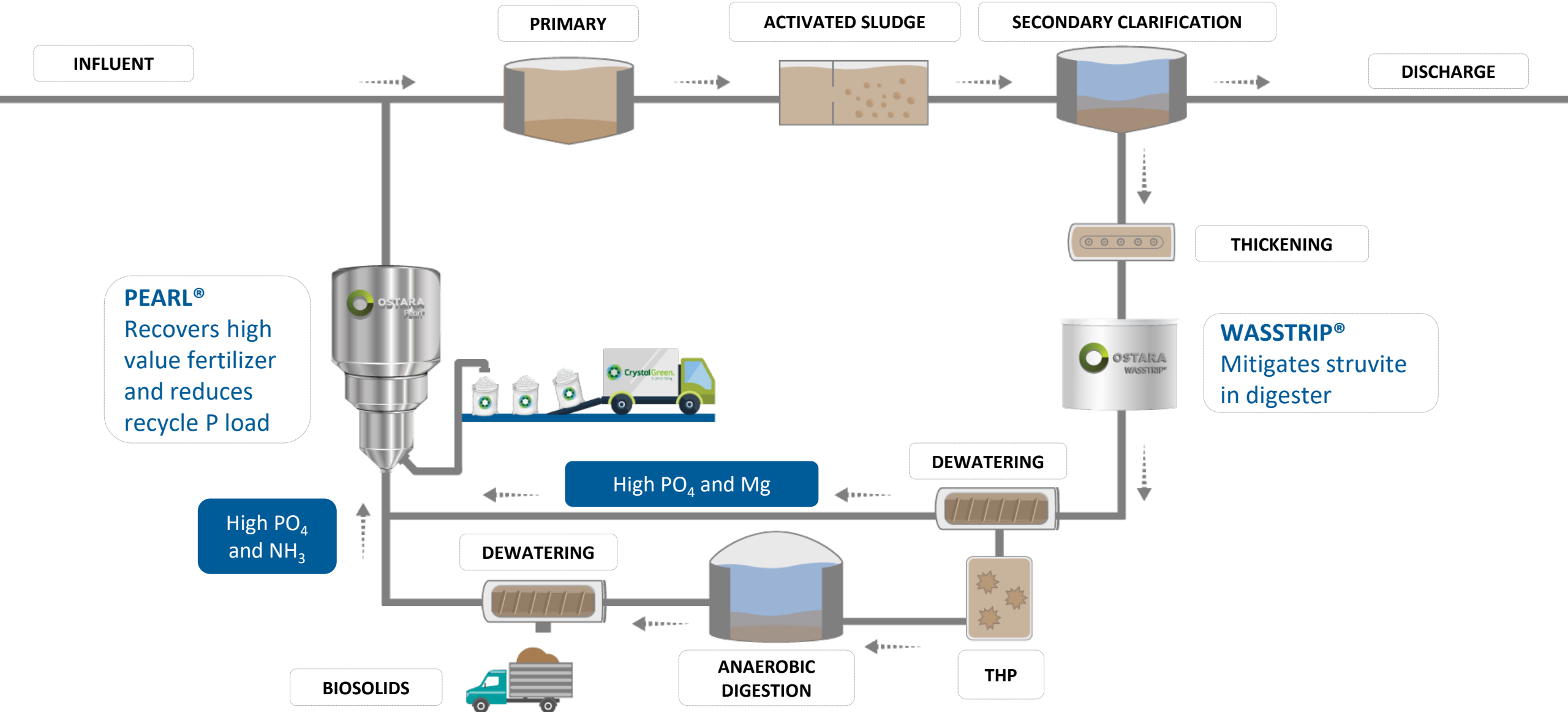


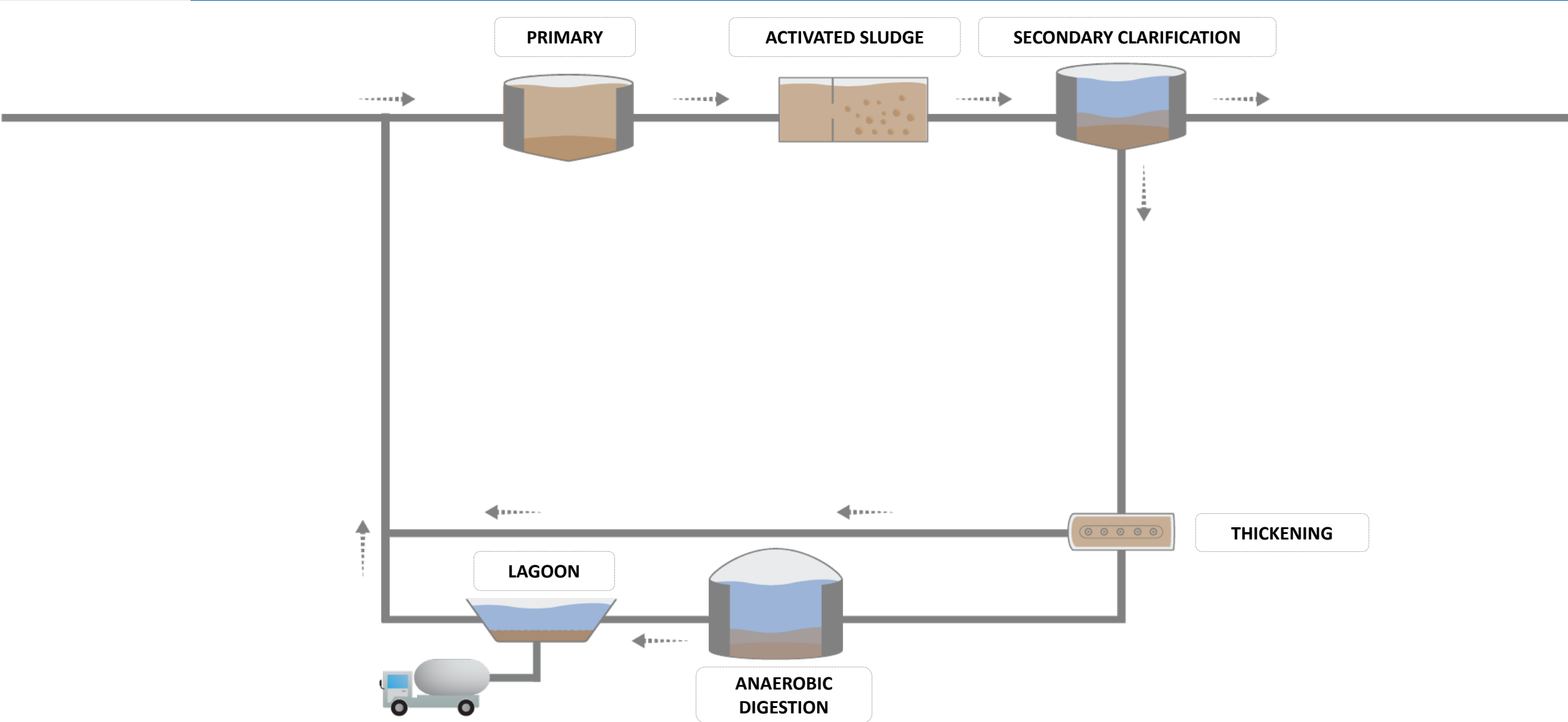
SECONDARY CLARIFICATION



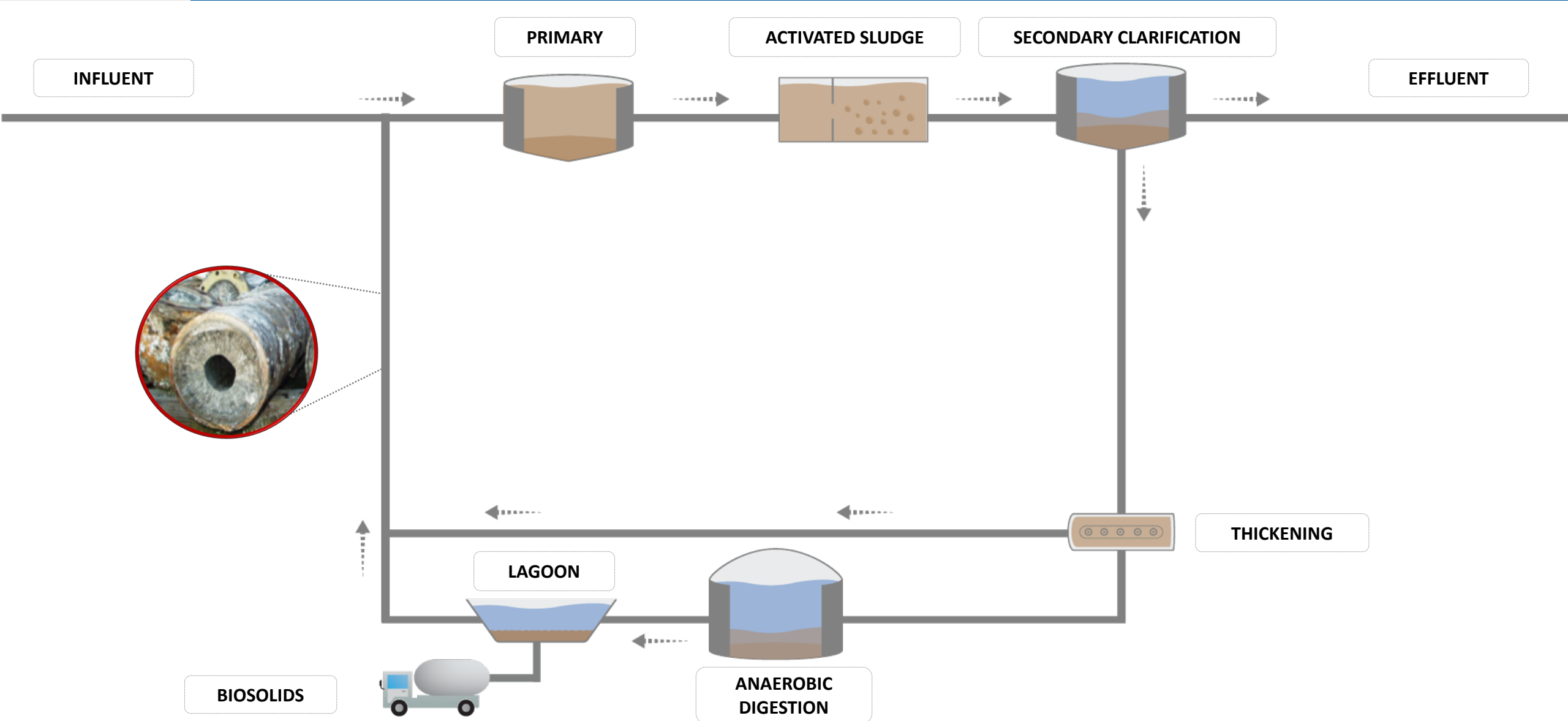
ANAEROBIC
DIGESTION





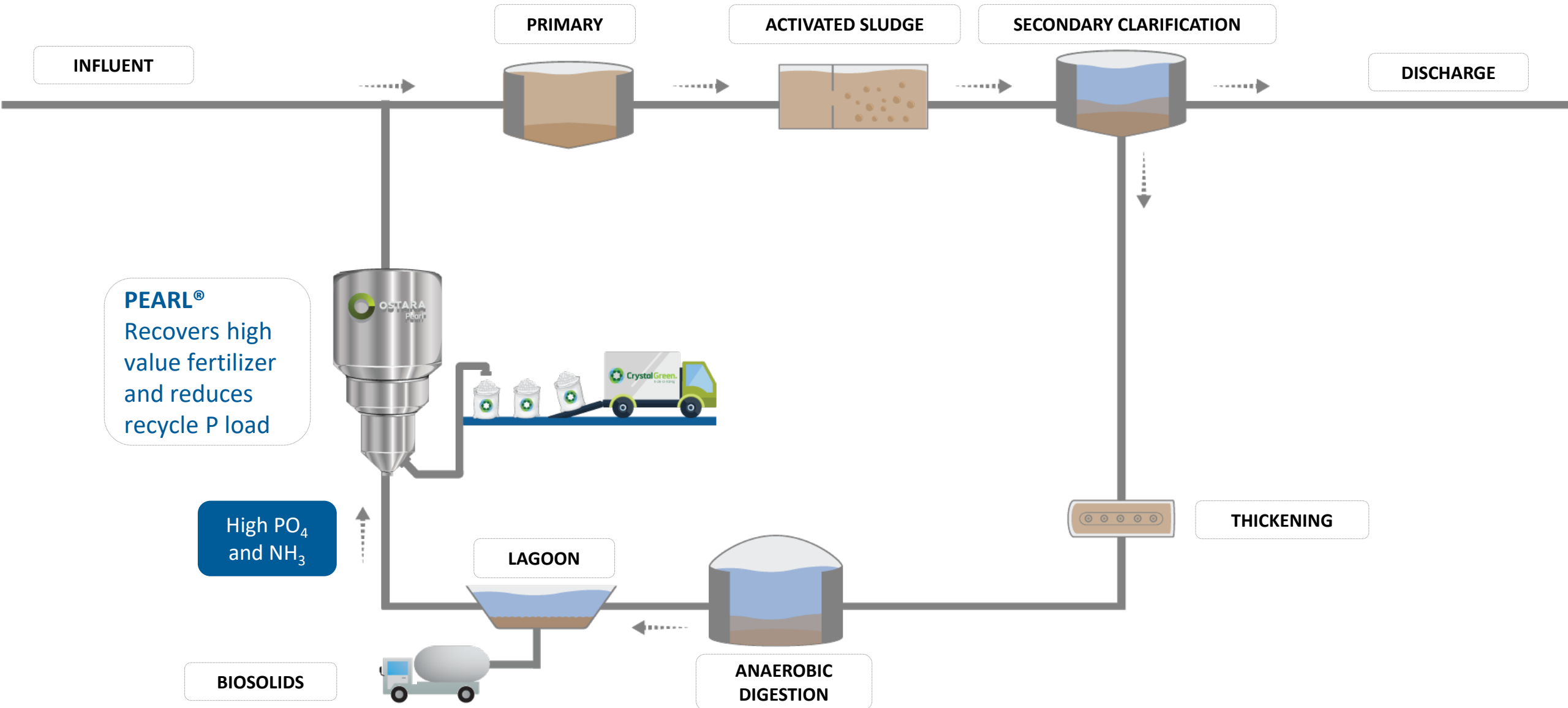


Nuisance Struvite: BNR Can Create Operational Challenges



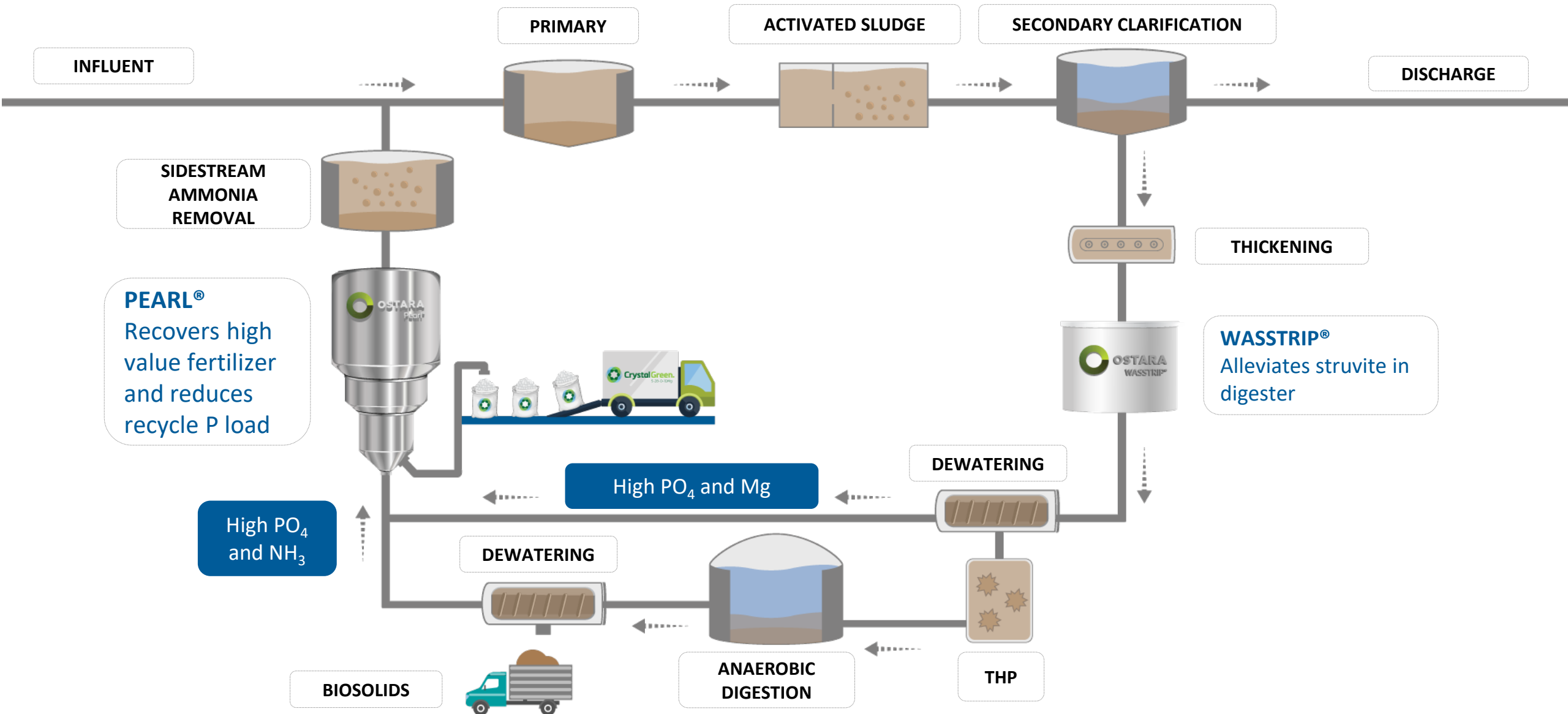


Pearl[®] Nutrient Recovery: Solve Operational Challenges While Recovering a Valuable Resource



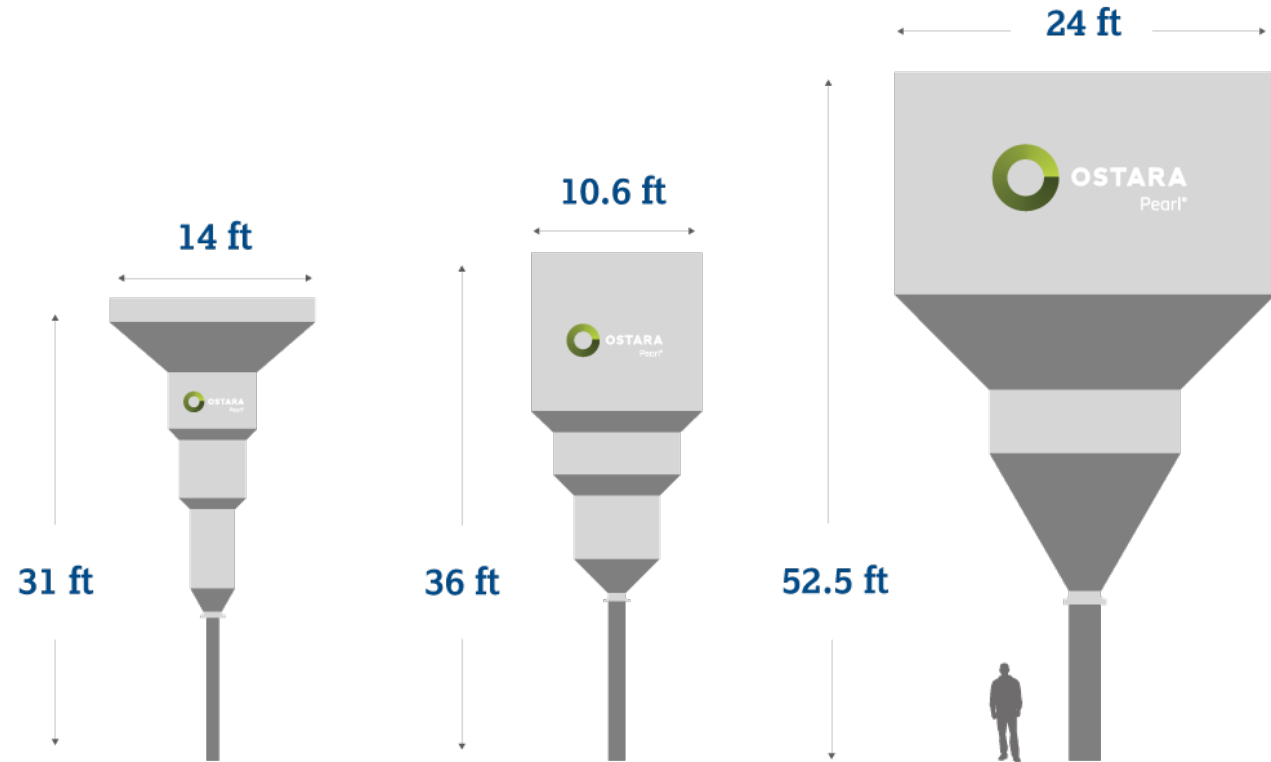


Pearl[®] + WASSTRIP[®]: Integration with Advanced Digestion and Side Stream Ammonia Removal



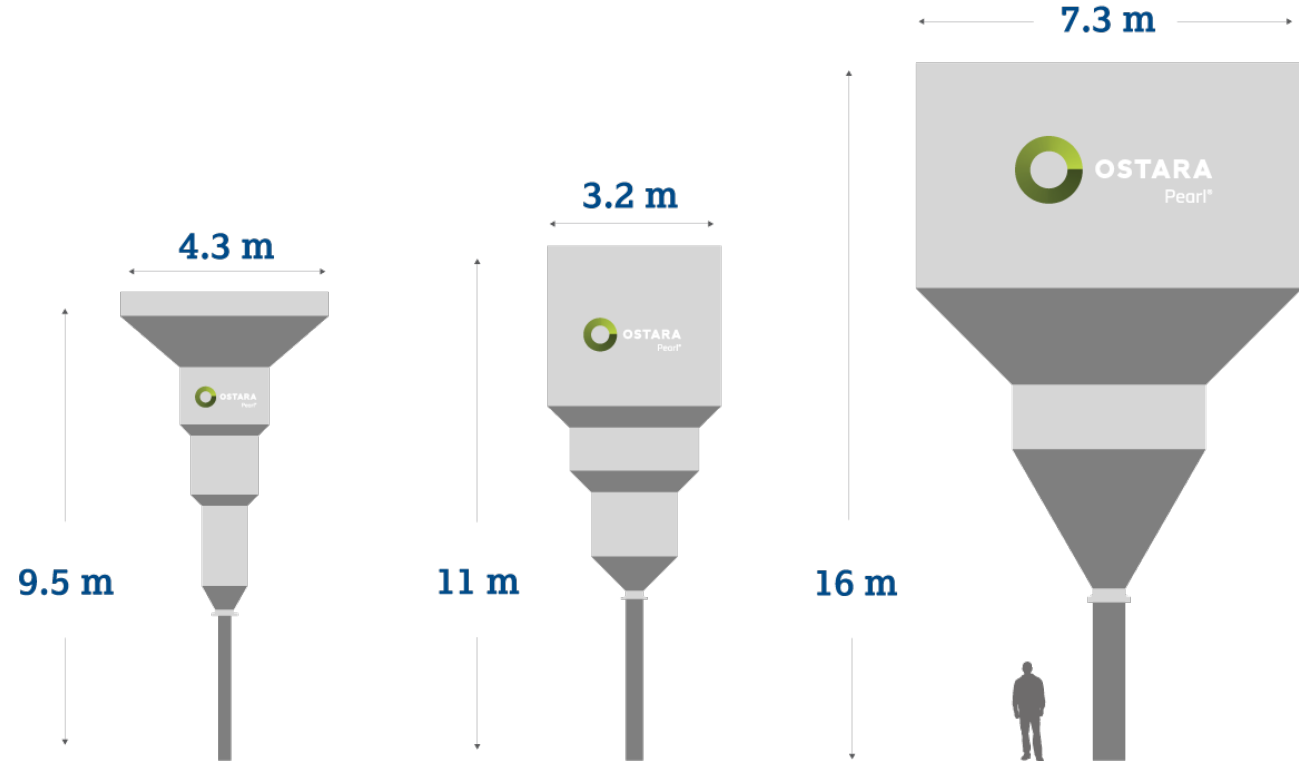


Customized Solution: Range of Pearl Offerings



	Pearl [®] 500	Pearl [®] 2K	Pearl [®] 10K
LOAD CAPACITY (lbs PO₄-P per day)	145	550	2,750
AVERAGE PRODUCTION CAPACITY (lbs Crystal Green per day)	700	2,750	14,000
INSTALLATION BASE (2017)	8	12	4

Customized Solution: Range of Pearl Offerings



	Pearl® 500	Pearl® 2K	Pearl® 10K
LOAD CAPACITY (kg PO₄-P per day)	65	250	1,250
AVERAGE PRODUCTION CAPACITY (kg Crystal Green per day)	325	1,250	6,350
INSTALLATION BASE (2017)	8	12	4



Pearl[®] 500

Load Capacity (PO₄-P per day)

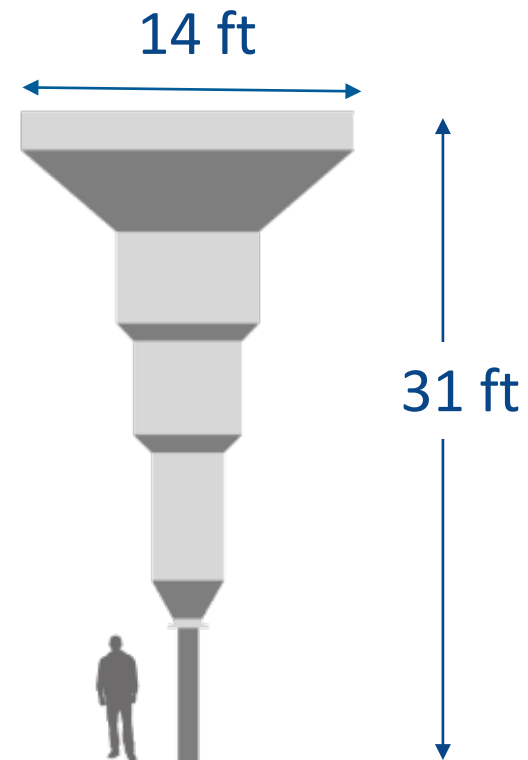
145 lbs

**Average Production Capacity
(Crystal Green per day)**

700 lbs

Installation Base (2017)

8





Pearl[®] 500

Load Capacity (PO₄-P per day)

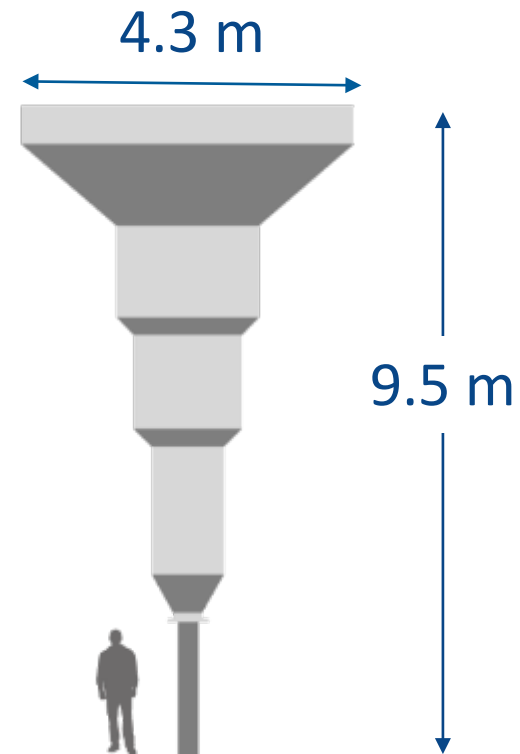
65 kg

**Average Production Capacity
(Crystal Green per day)**

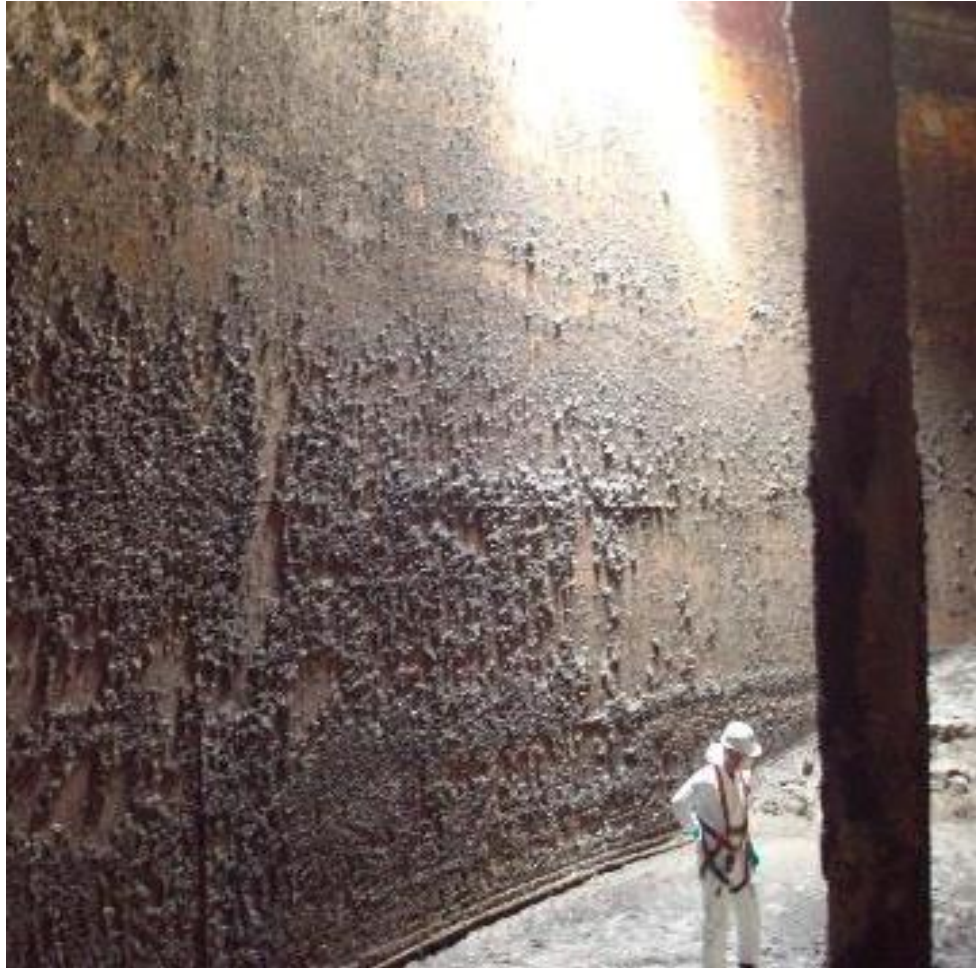
325 kg

Installation Base (2017)

8



Unmanaged Struvite Formation





Your Challenge: Dewaterability

Sludge dewatering – a key operational issue

- High disposal and processing costs
- Increased sludge, more wet tons
- Costly chemical dependence (ferric, polymer)

Benefits Optimize Plant Operations & Achieve Cost Savings

1

Convert up to 50% of influent P into premium market-ready fertilizer

2

Meet stringent P limits

3

Create revenue stream through sale of Crystal Green

4

Reduce chemical and maintenance costs

5

Reduce total biosolids production by 10-20%

6

Reduce polymer consumption by 5-20%

7

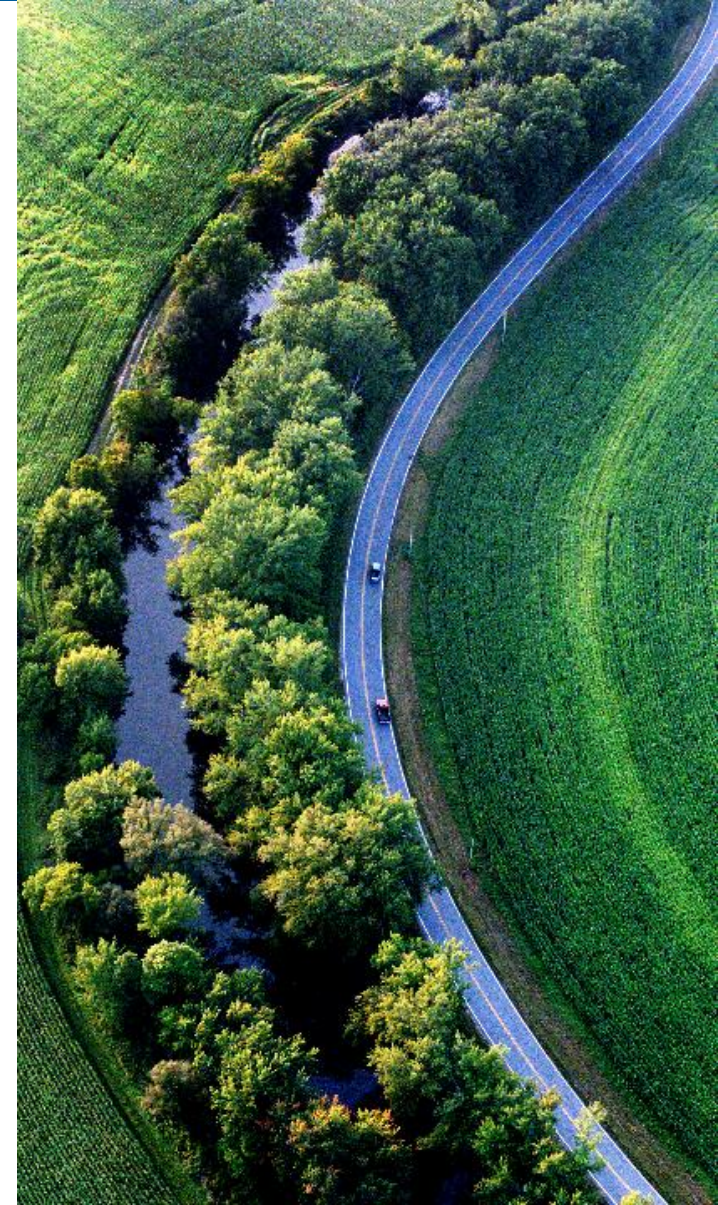
Increase dewaterability by 4%

8

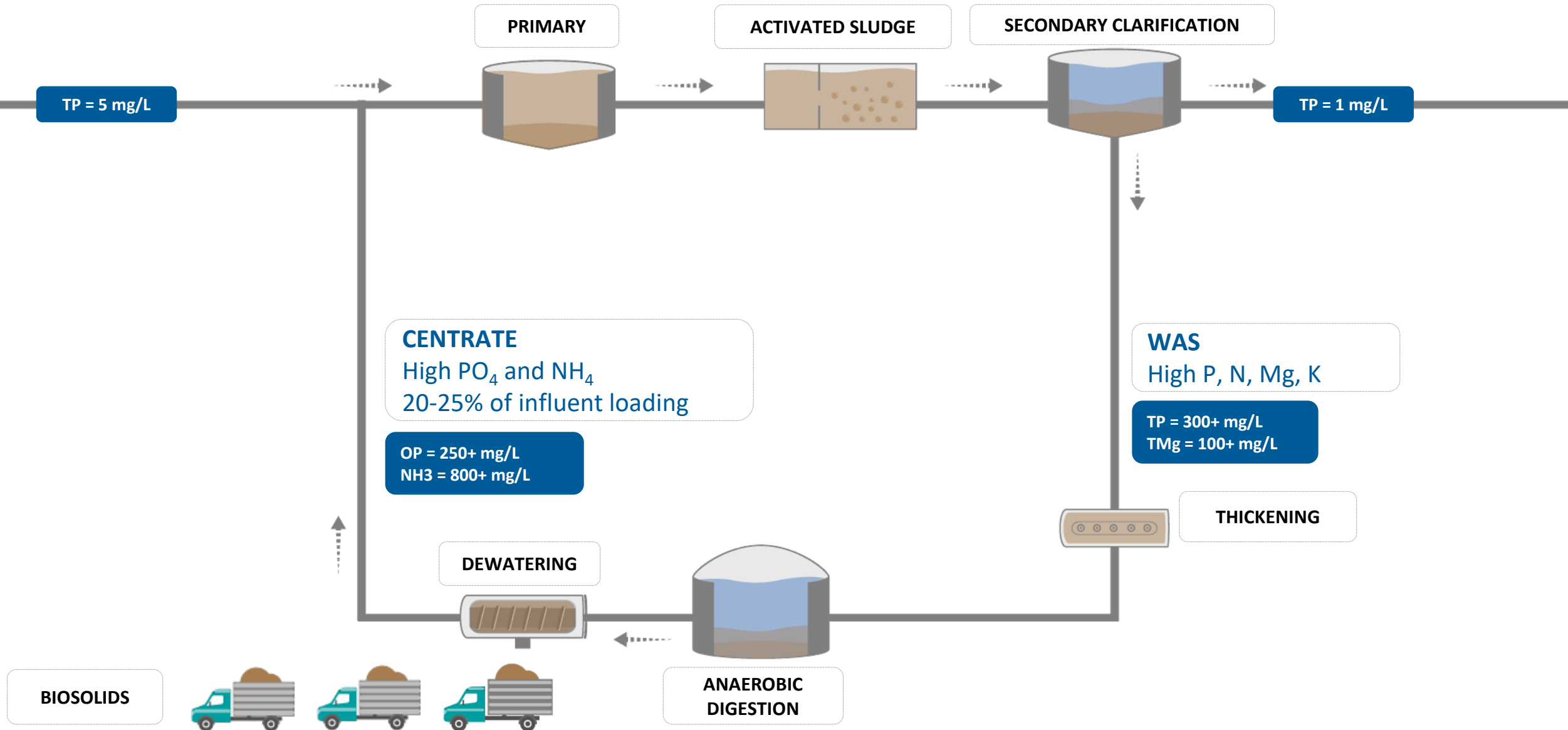
Protect digesters from nuisance struvite

9

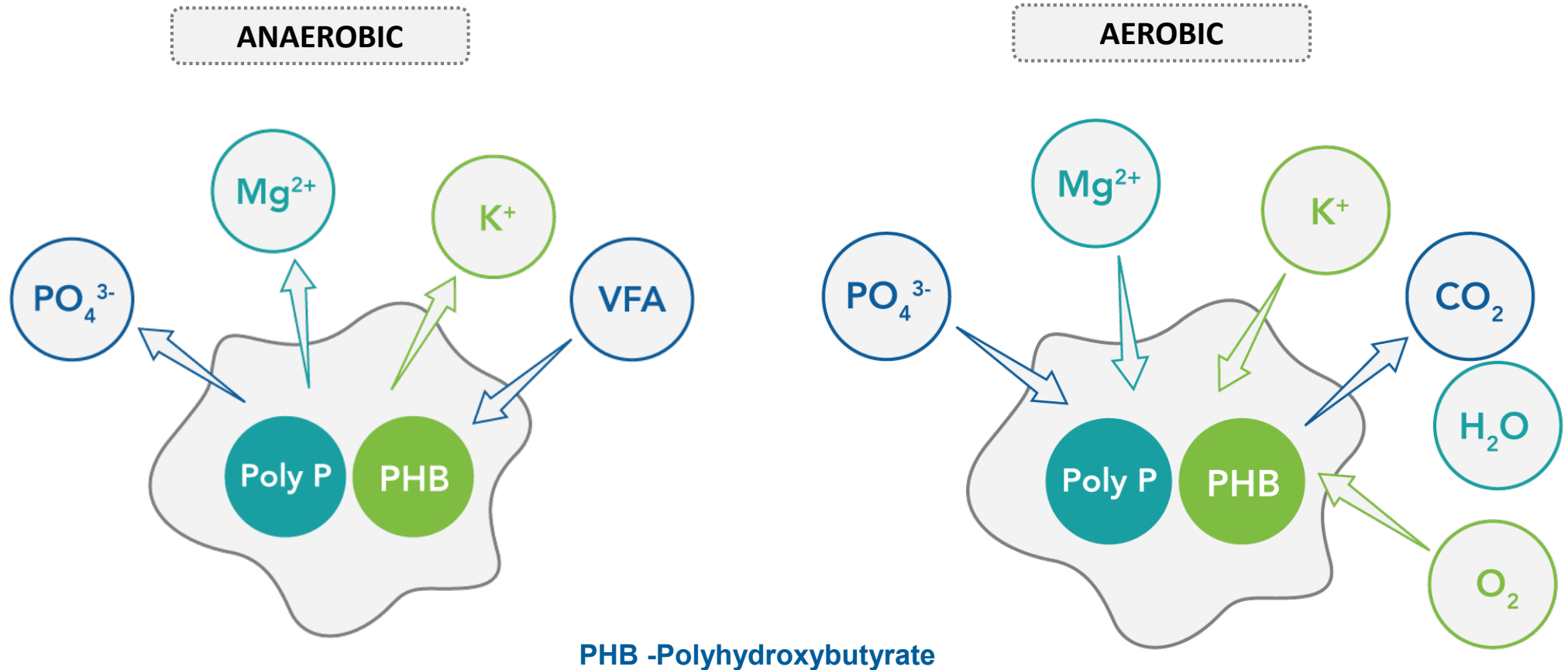
Reduce carbon footprint



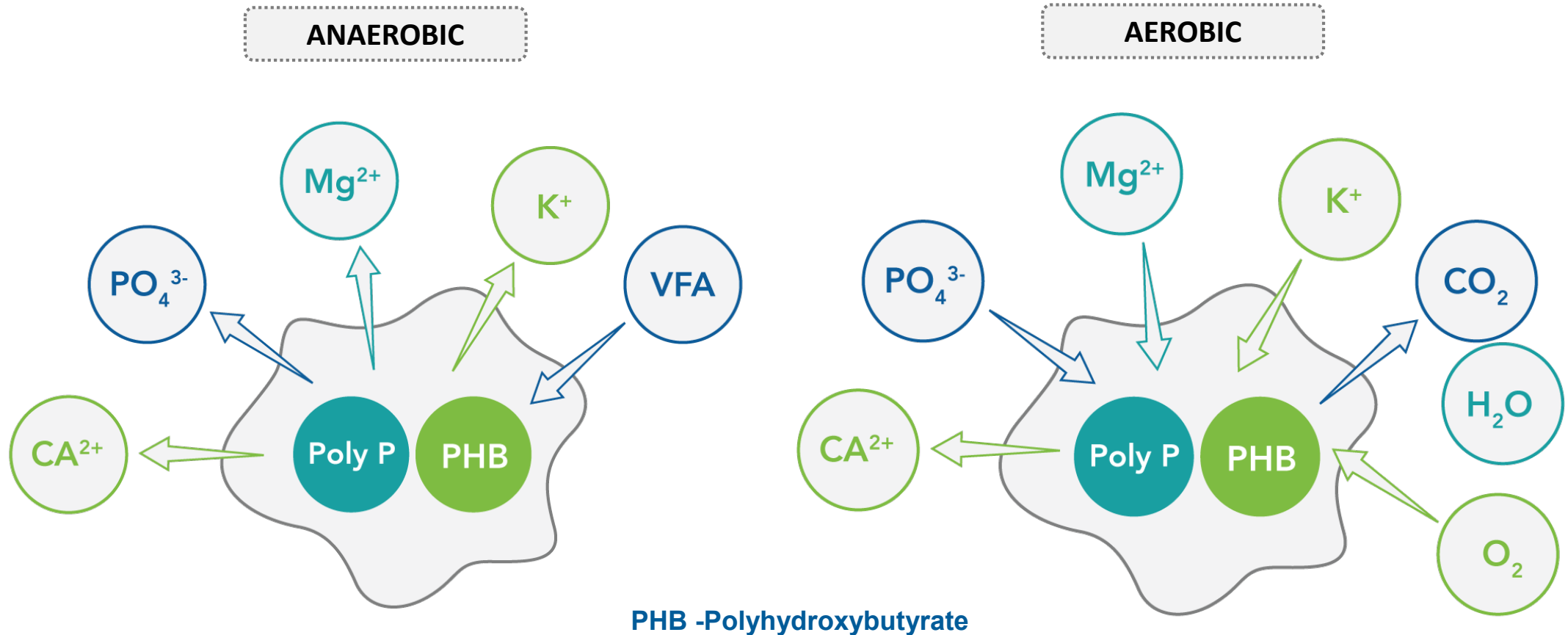
Phosphorus Cycle in Treatment Facility



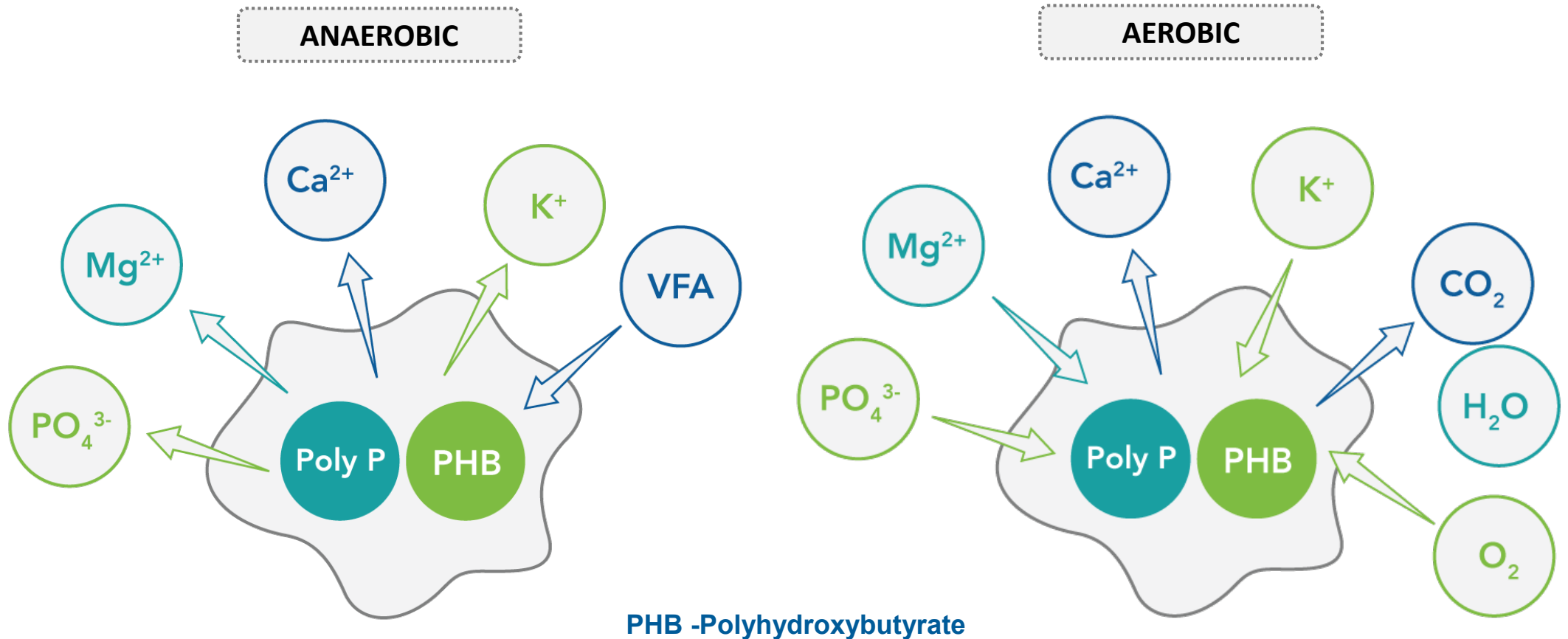
Biological Phosphorus Removal: Leverages Polyphosphate Accumulating Organisms (PAOs)



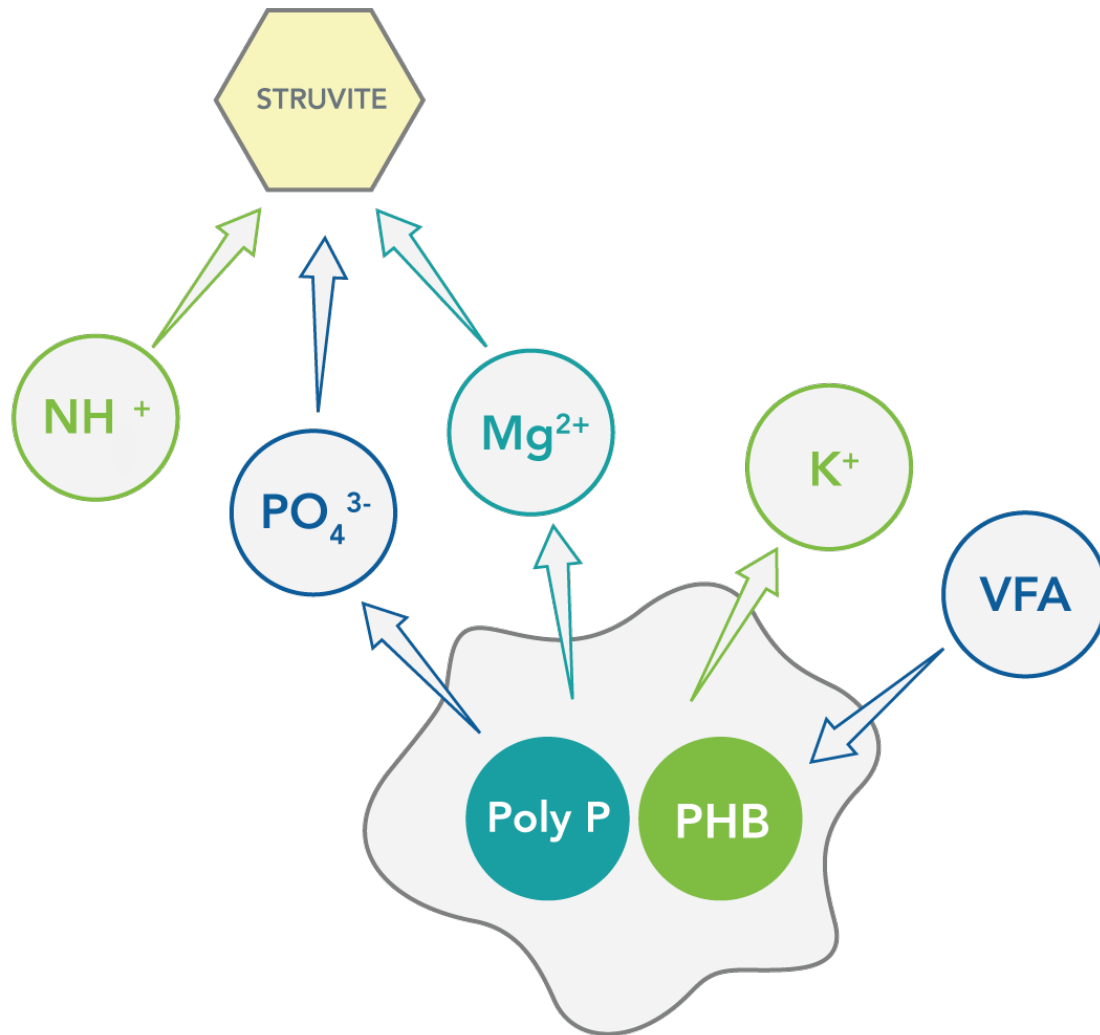
Biological Phosphorus Removal: Leverages Polyphosphate Accumulating Organisms (PAOs)



Biological Phosphorus Removal: Leverages Polyphosphate Accumulating Organisms (PAOs)

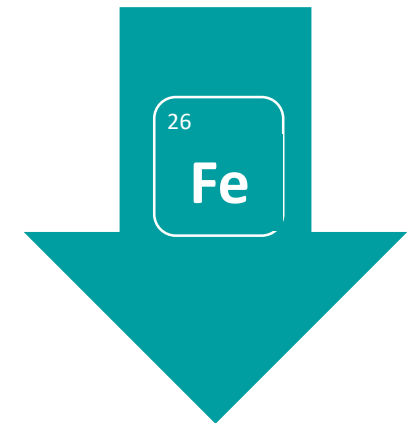
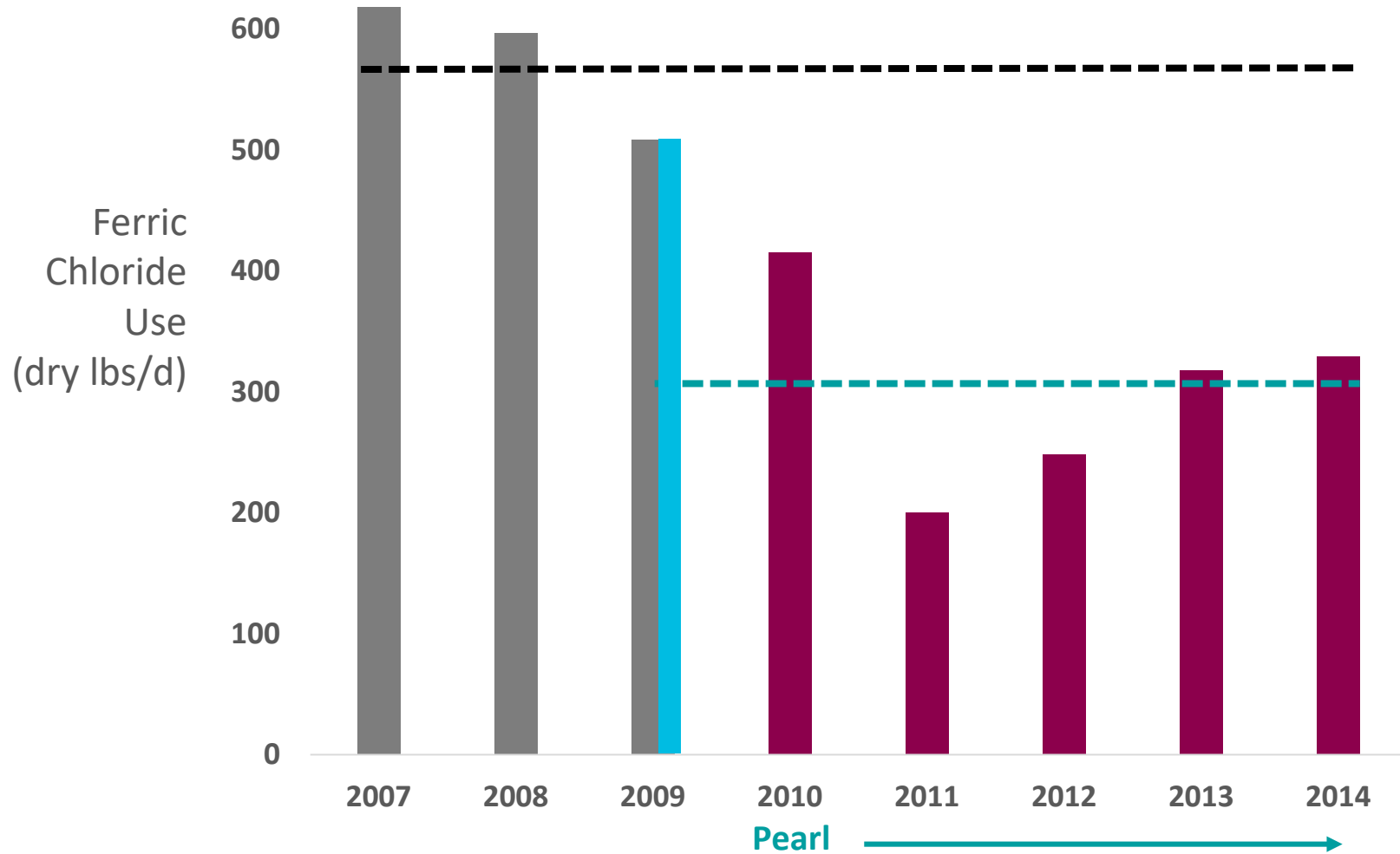


Biological Phosphorus Removal Causes Poor Sludge Dewaterability



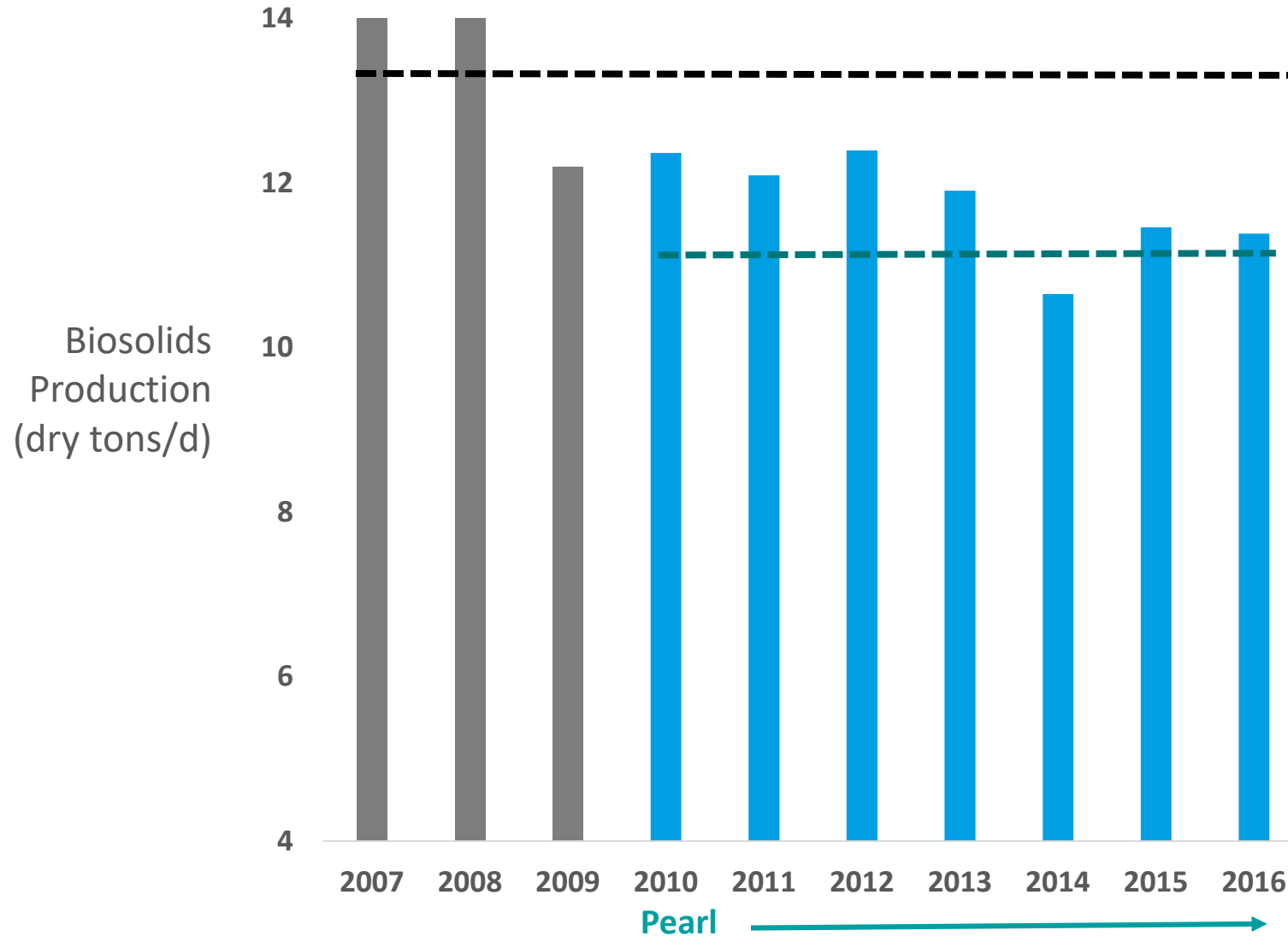
- Released Mg is bound as struvite
- Released K remains free
→ increased M/D ratio

Pearl Reduces Chemical And Maintenance Costs

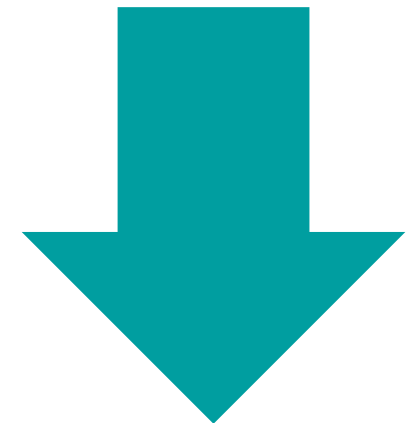




Ostara Technology Saves Money Through Reduced Sludge Quantity



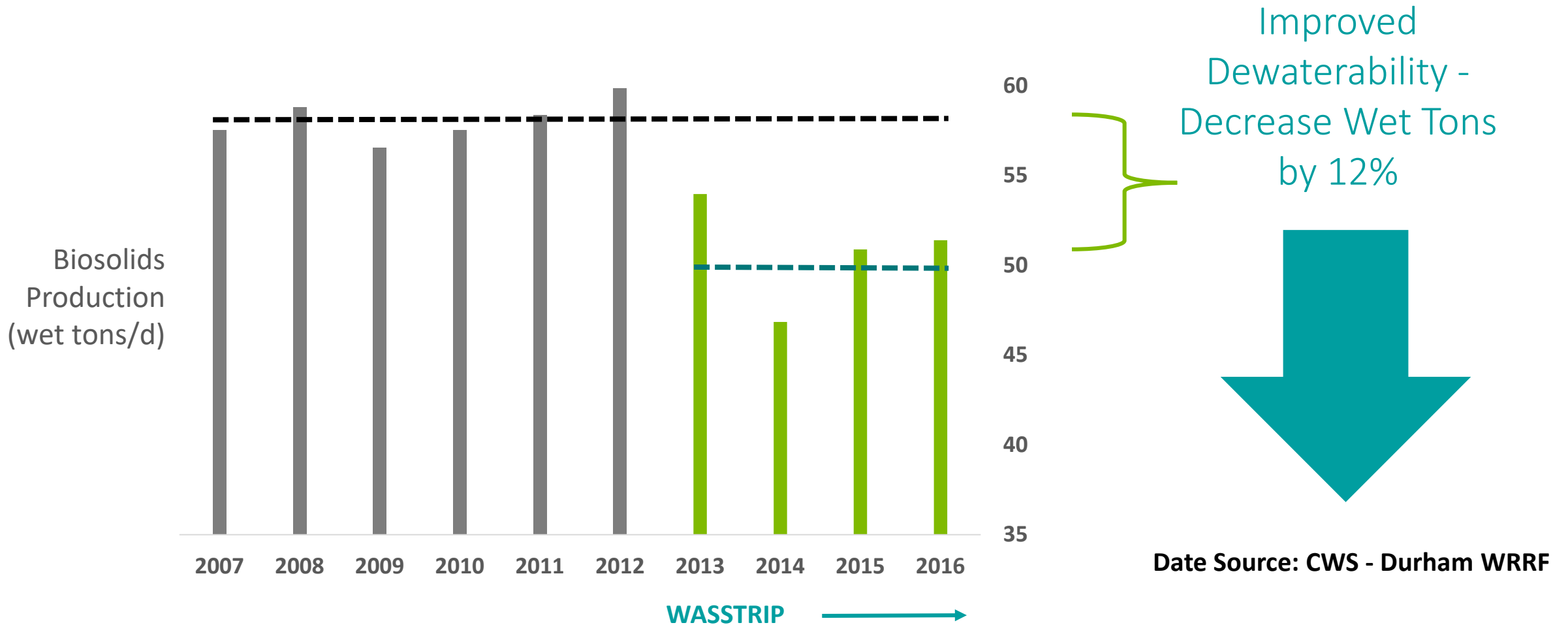
Pearl Reduces Dry Tons By 20%



Date Source: CWS - Durham WRRF



WASSTRIP Saves Money Through Reduced Sludge Volumes



Protect Digesters From Unintentional Struvite Issues

Reduced Struvite in Digester by up to 90%

- ✓ Each ton of Mg diverted around the digester results in 10 ton less nuisance struvite
- ✓ Reduced maintenance and cleaning costs
- ✓ Increased digester capacity

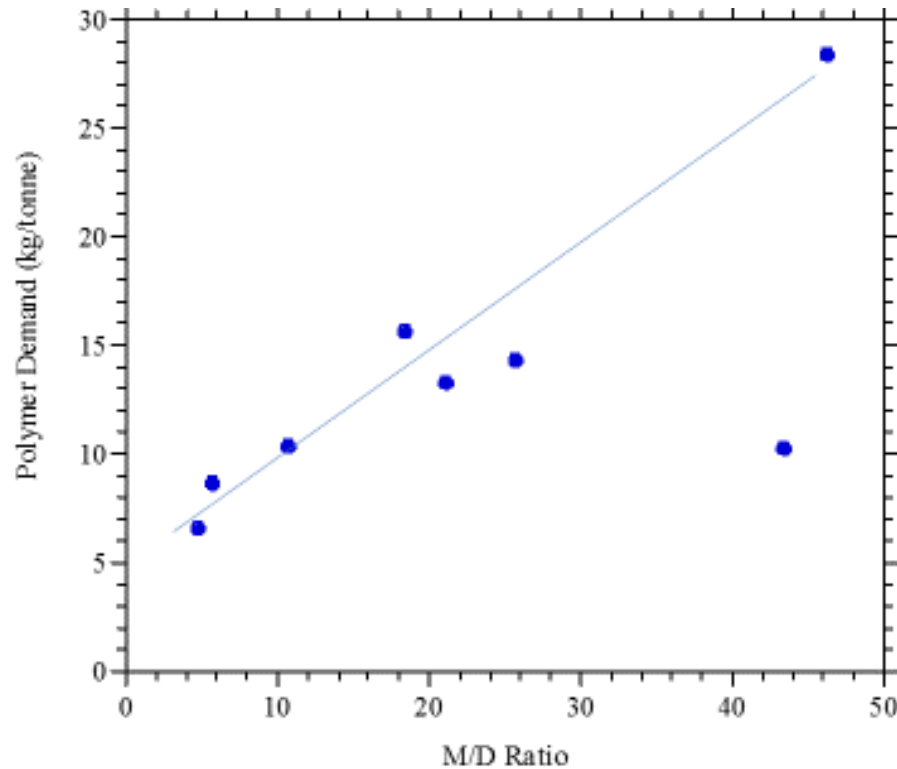


Without
WASSTRIP

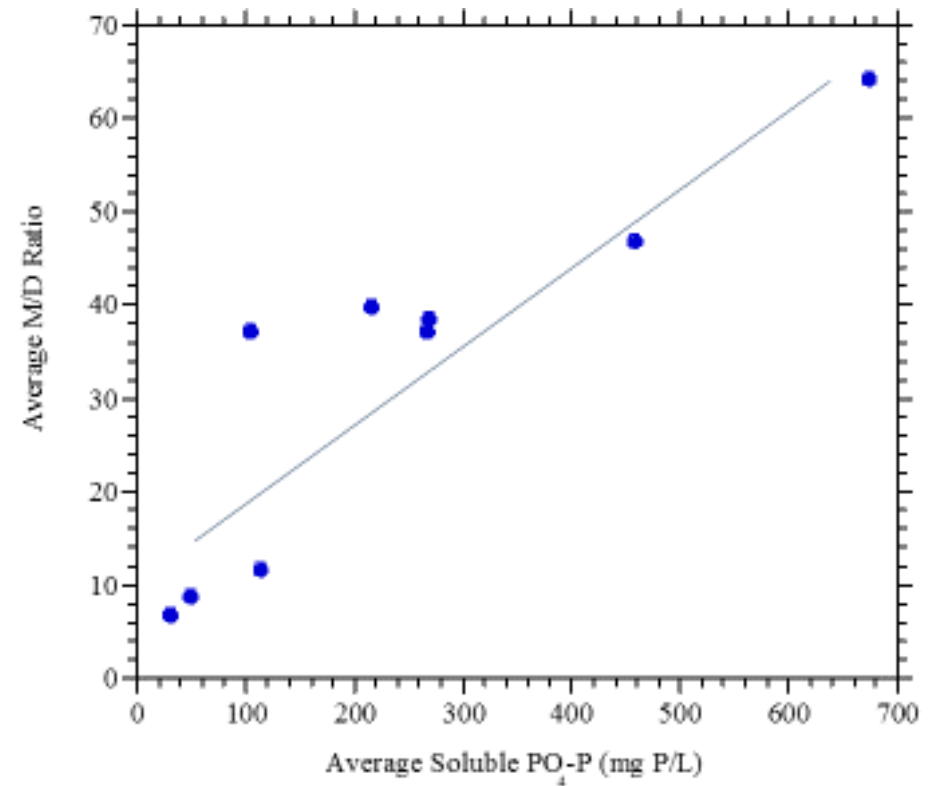
With
WASSTRIP

Excess Monovalent Cations: Reduce Bridging Effect Impairing Biosolids Dewaterability

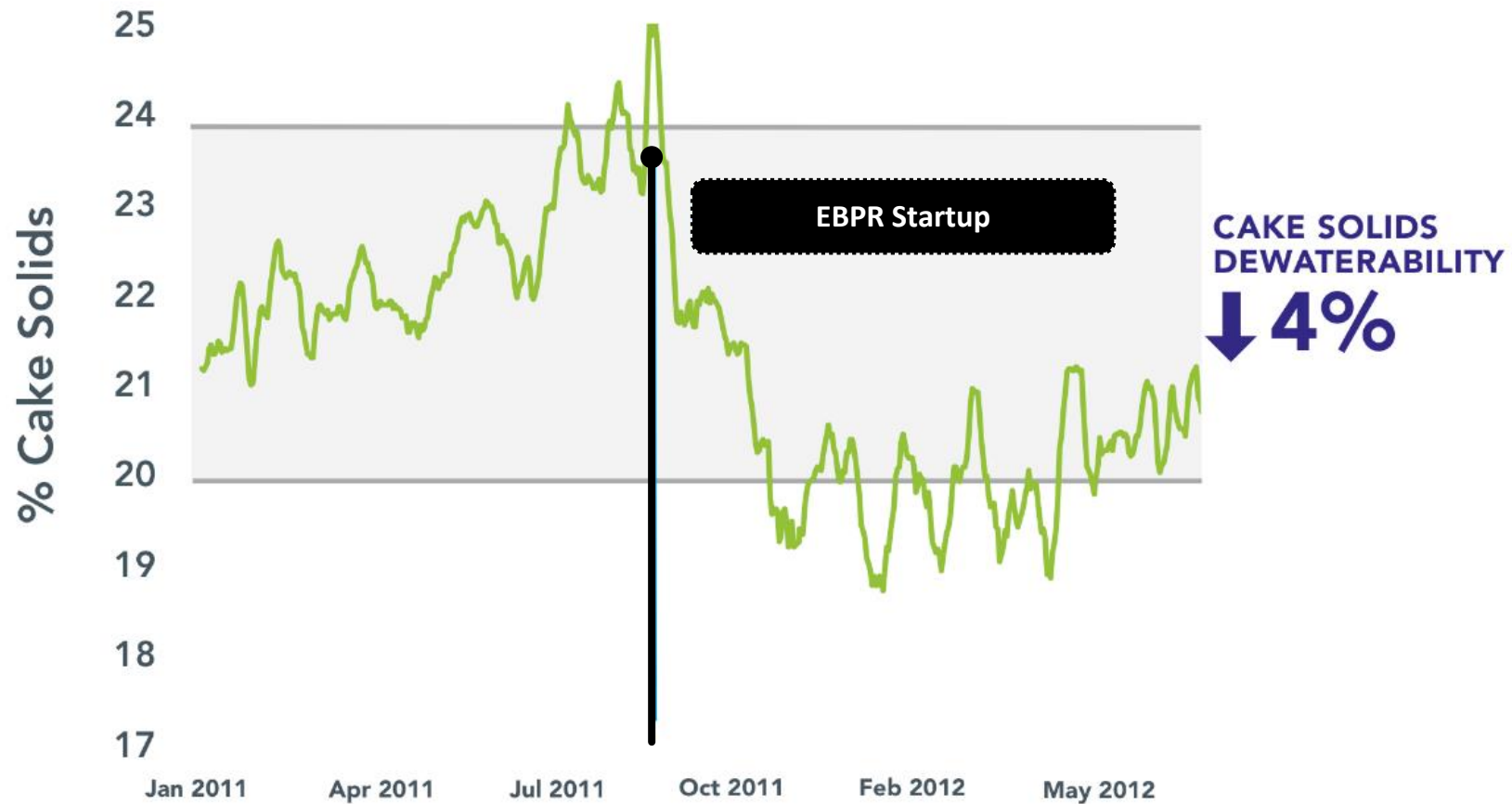
Polymer Demand vs M/D Ratio from WERF Research



Results – M/D Ratio vs PO₄

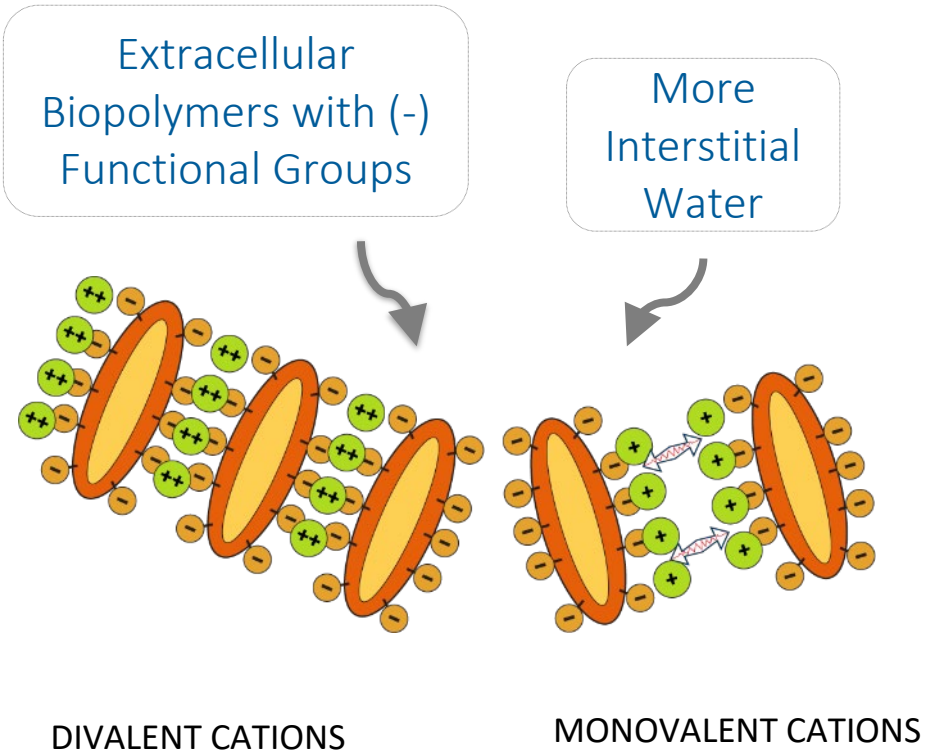


Biological Phosphorus Removal Reduces Biosolids Dewaterability

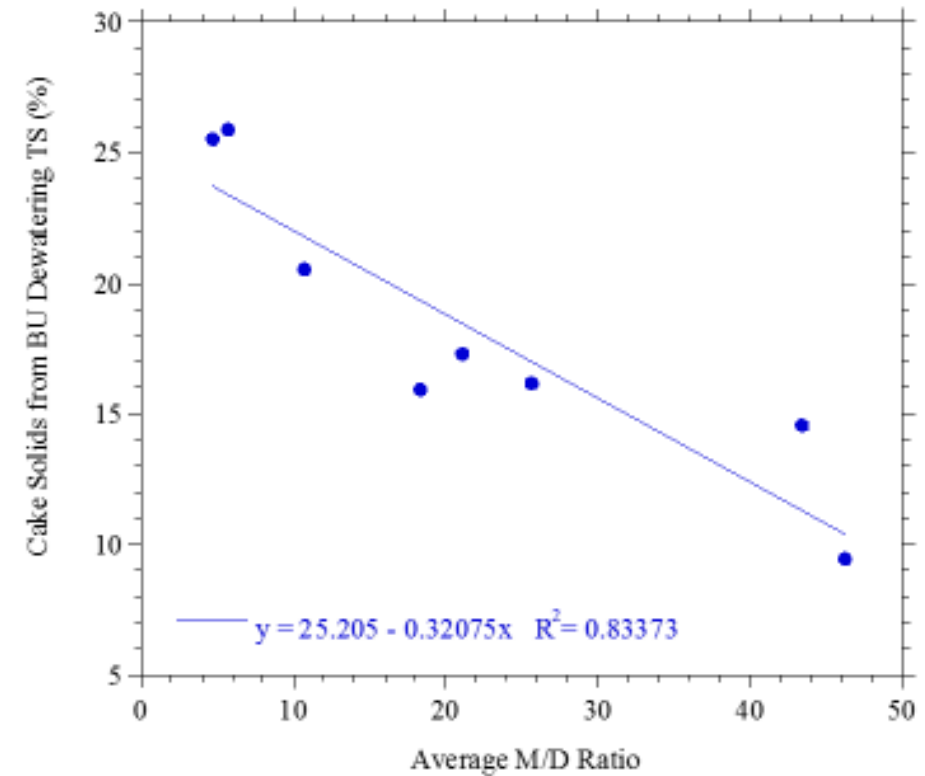


(HDR Engineering and Denver Metro Wastewater Reclamation District)

Excess Monovalent Cations Reduce Bridging Effect Impairing Biosolids Dewaterability



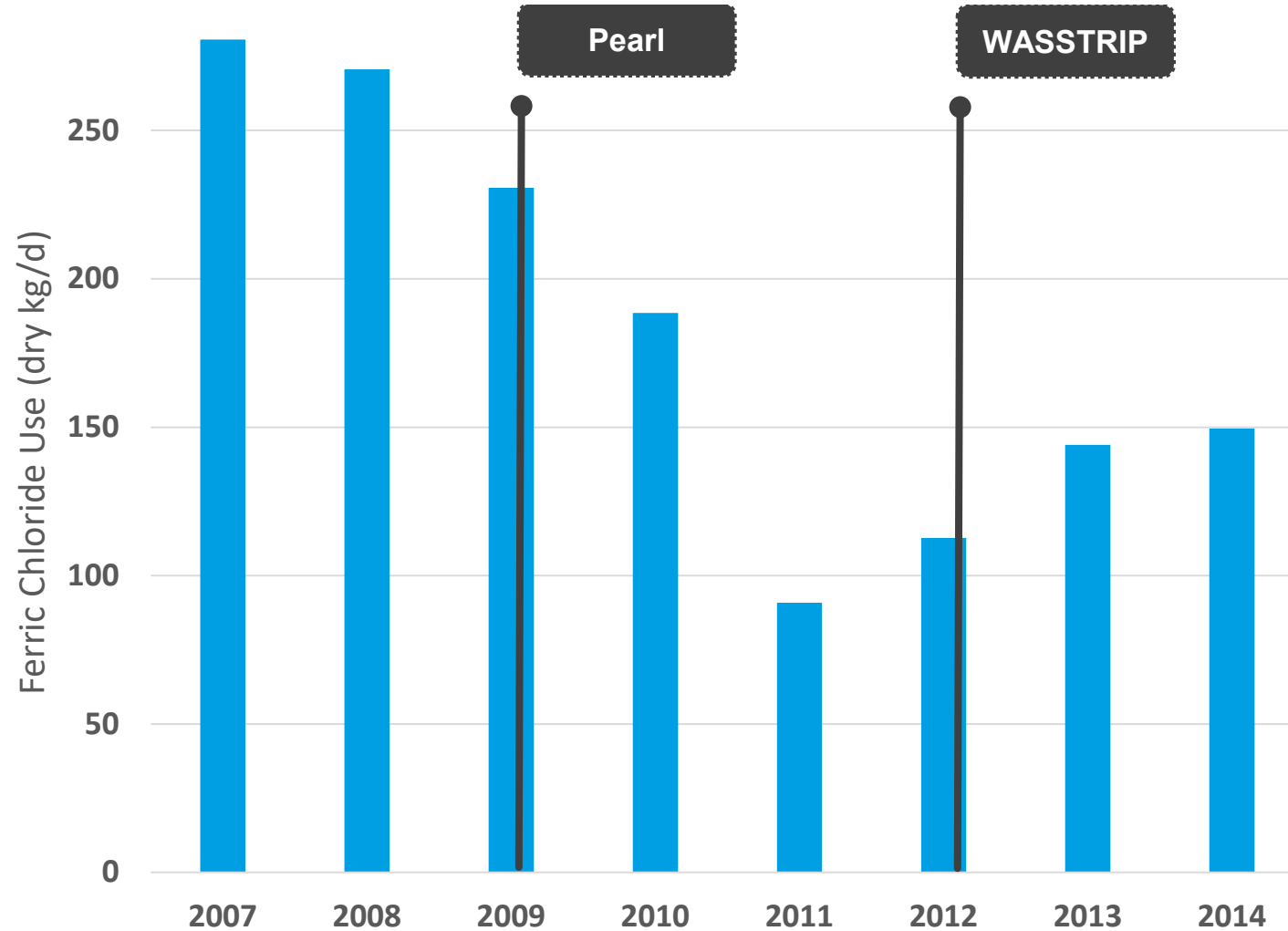
Cake Solids vs M/D Ratio from WERF Research



Examination of three theories of cation-induced bio-flocculation, Sobek and Higgins (2002)

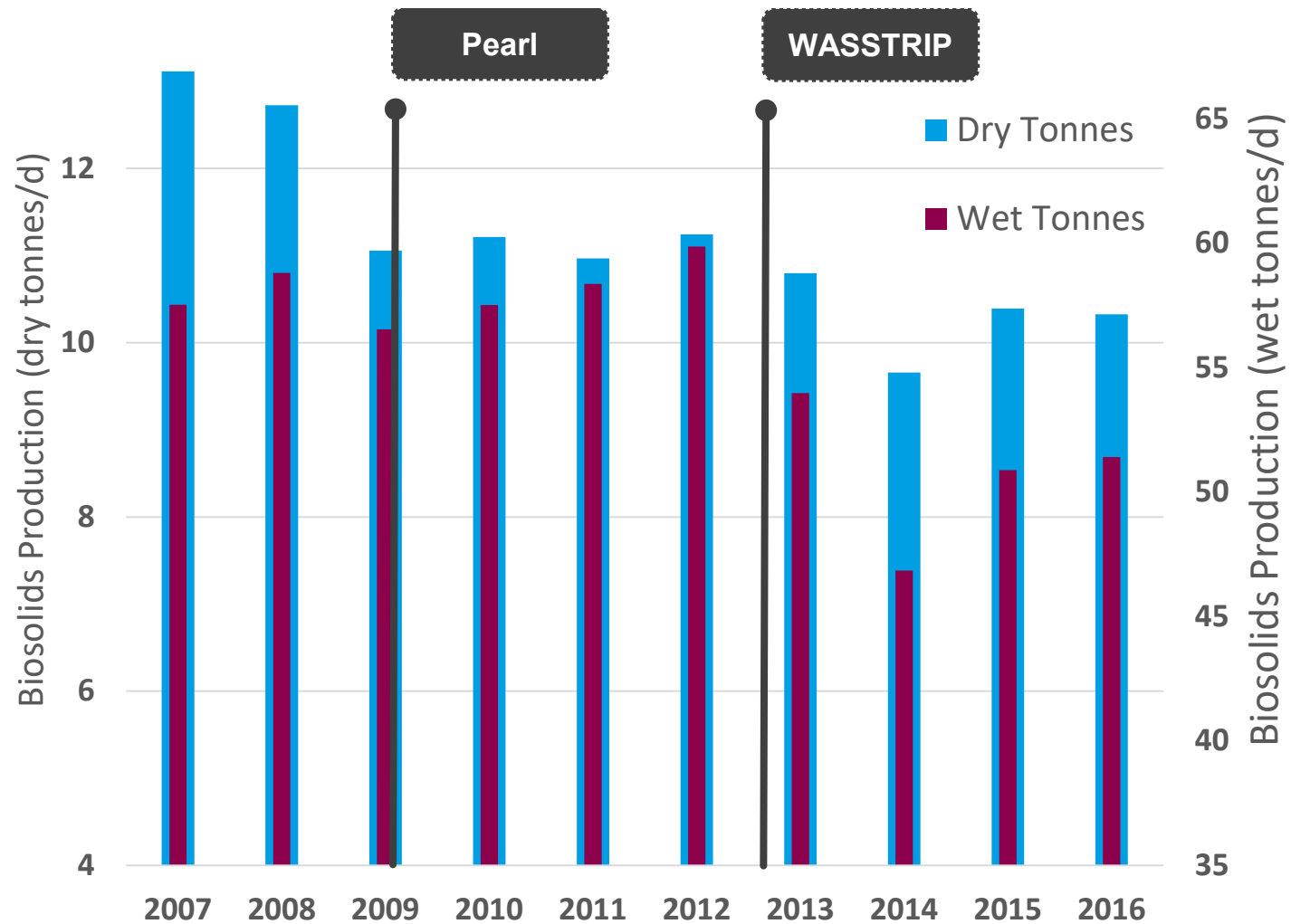
Pearl[®] + WASSTRIP[®] Reduced FeCl₃ Demand by 50%

CWS - Durham WRRF



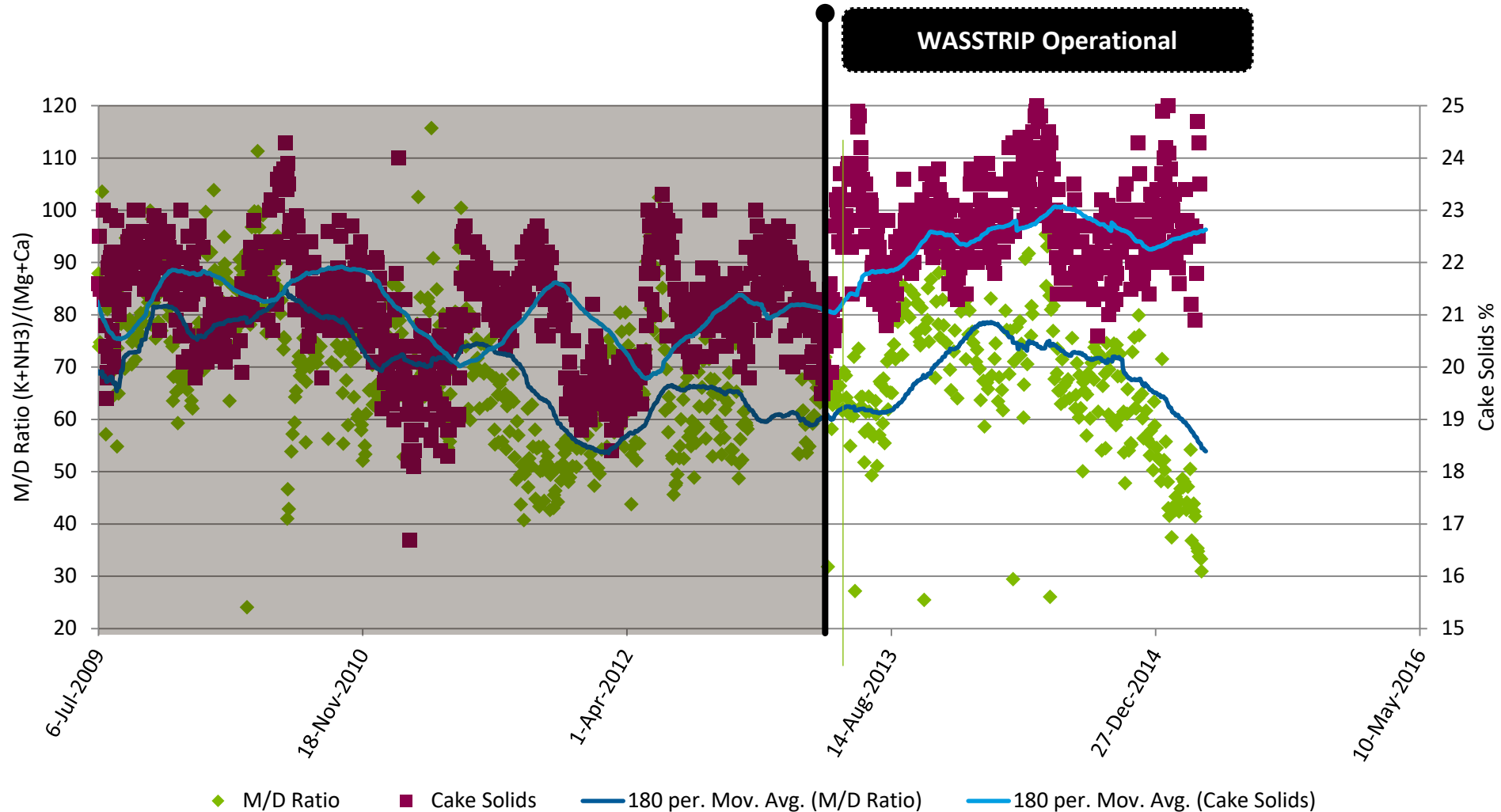
Pearl[®] + WASSTRIP[®] Reduces Biosolids Production

CWS - Durham WRRF



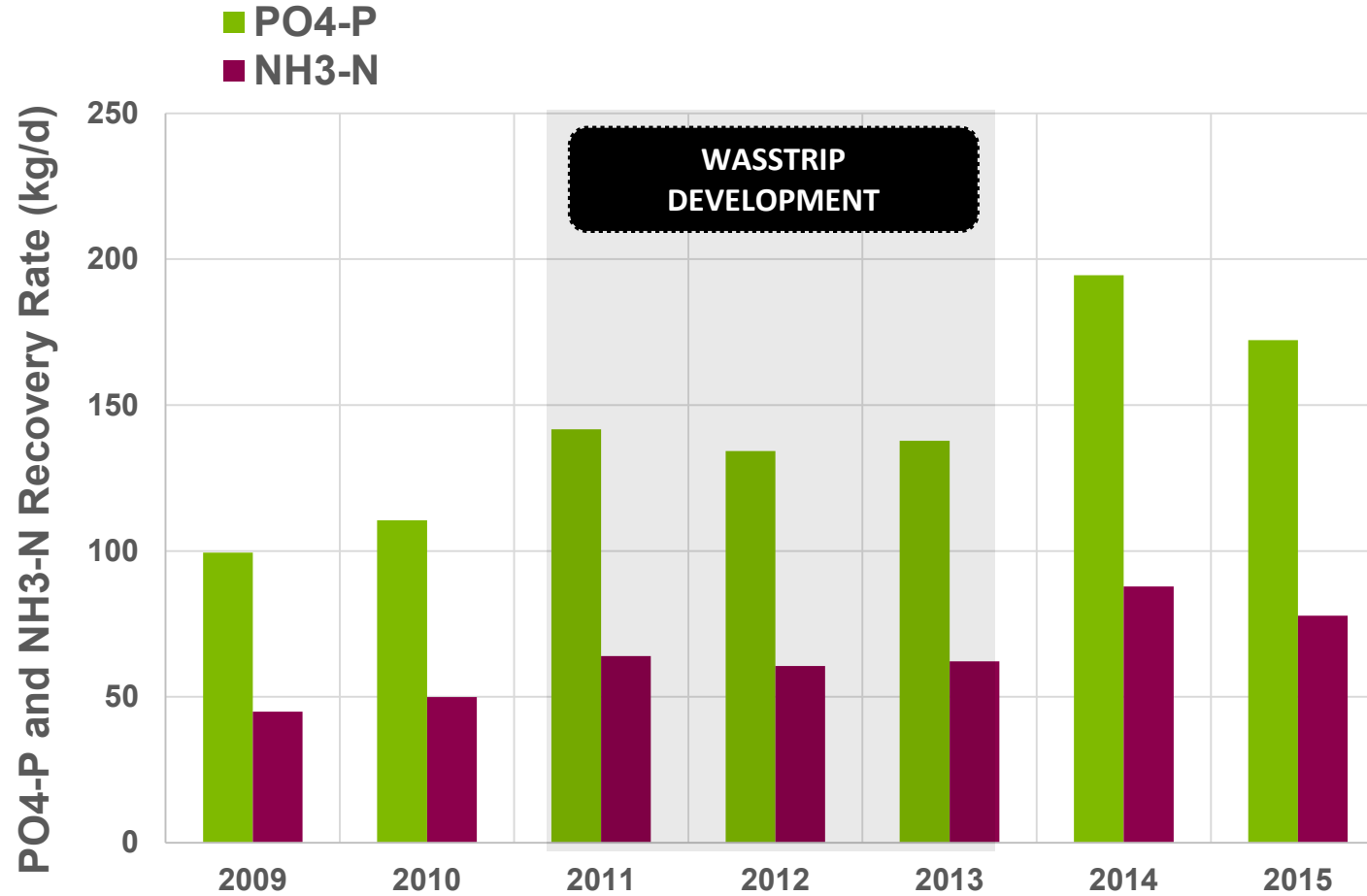


WASSTRIP Impact On Monovalent To Divalent Cation Ratio And Dewatering



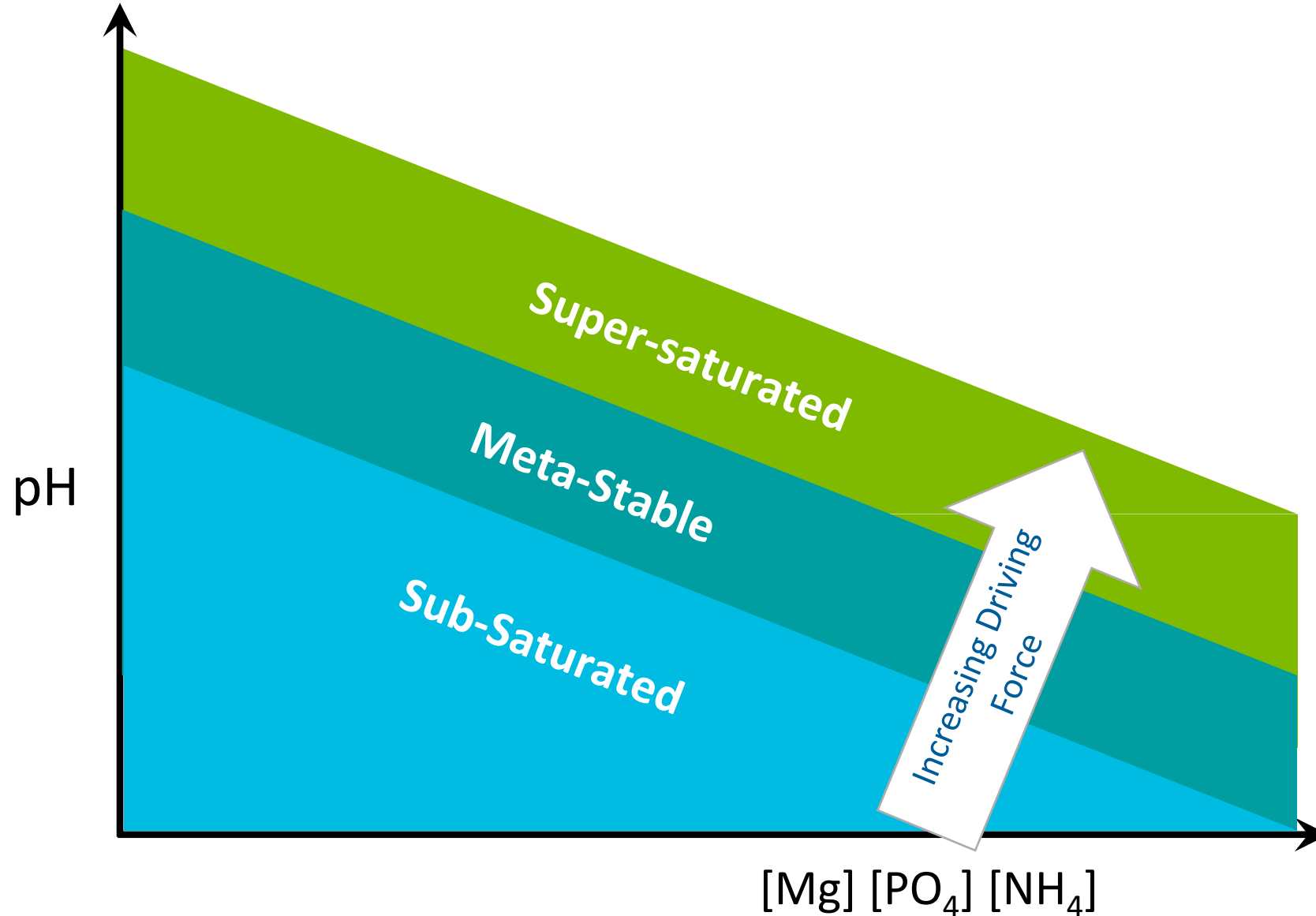
• Data Source: CWS - Durham WRRF

WASSTRIP Increased Nutrient Recovery by 60%

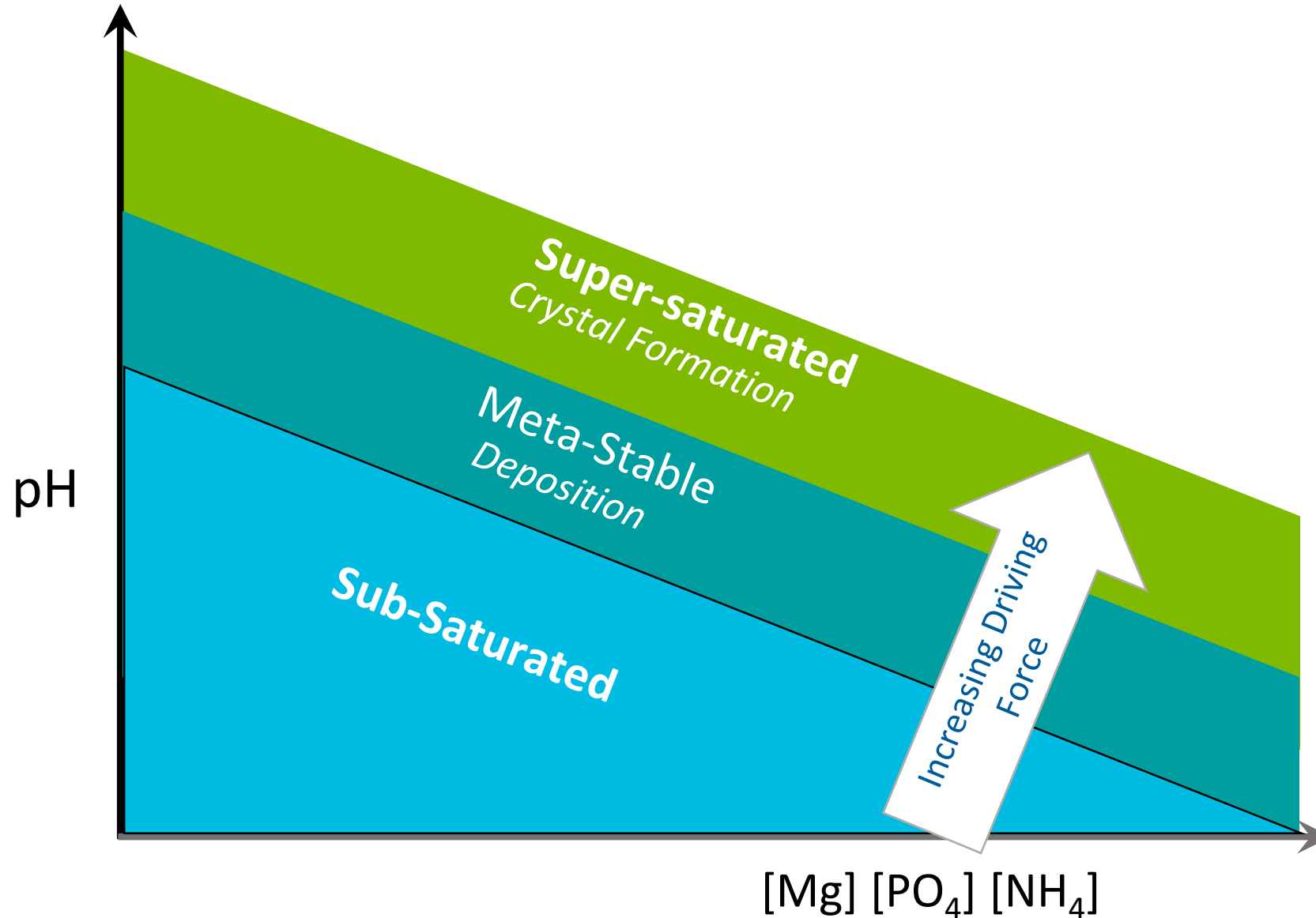


- Data Source: Durham WRRF, Portland, Oregon, USA

Pearl Process Leverages Struvite Precipitation to Produce a Quality Product



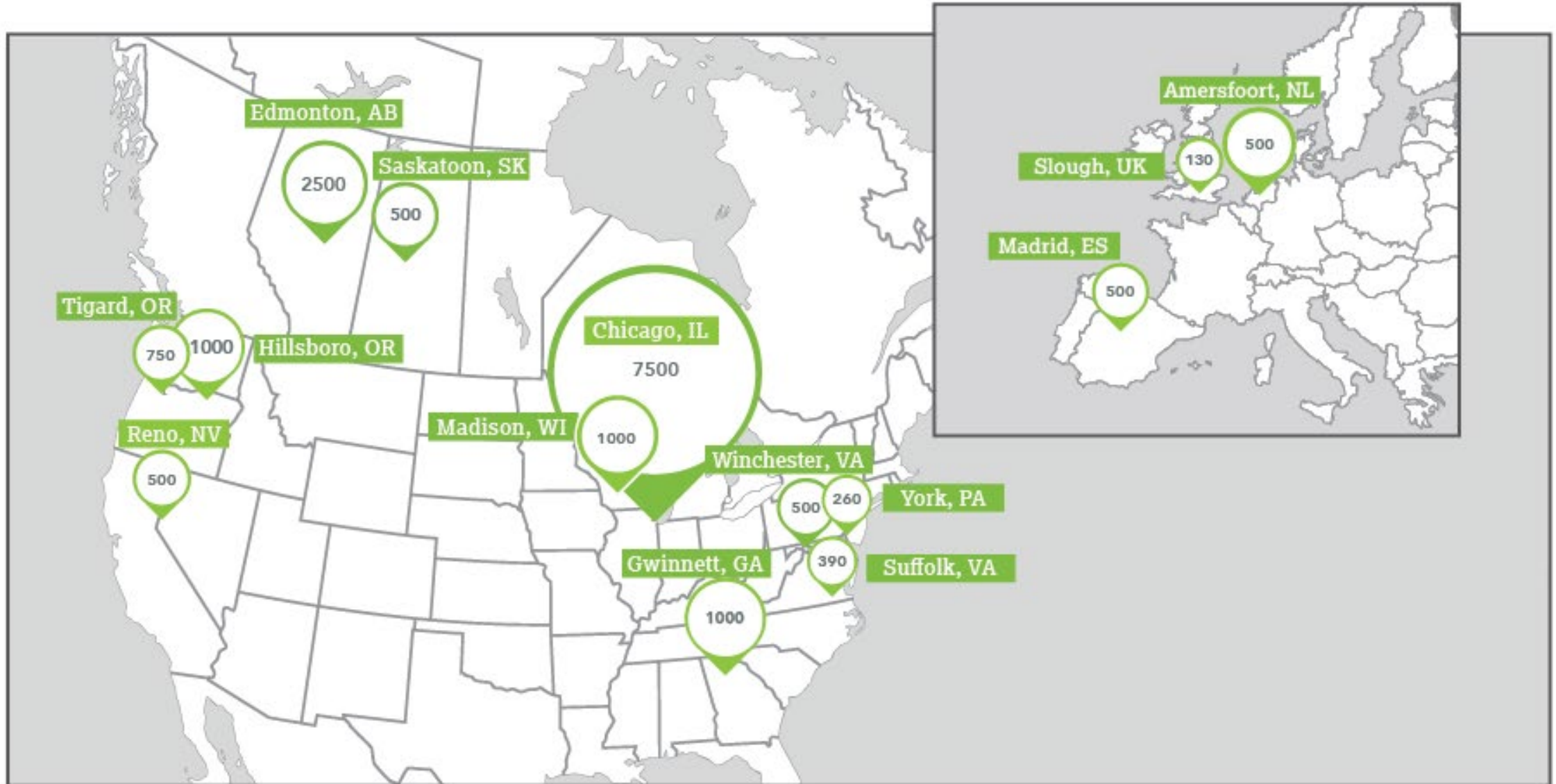
Pearl Process Leverages Struvite Precipitation to Produce a Quality Product





Ostara Facilities

Installed Production Capacity (Tons/Year)





99.6 %
PURE

Nothing but Nutrients

- ✓ Pathogen Free
- ✓ Dust-free
- ✓ Lowest Salt Index of any P source
- ✓ Lowest Heavy Metals Content of any P source



Four Blend-Ready Sizes

SGN 90



SGN 150



SGN 300



SGN 450



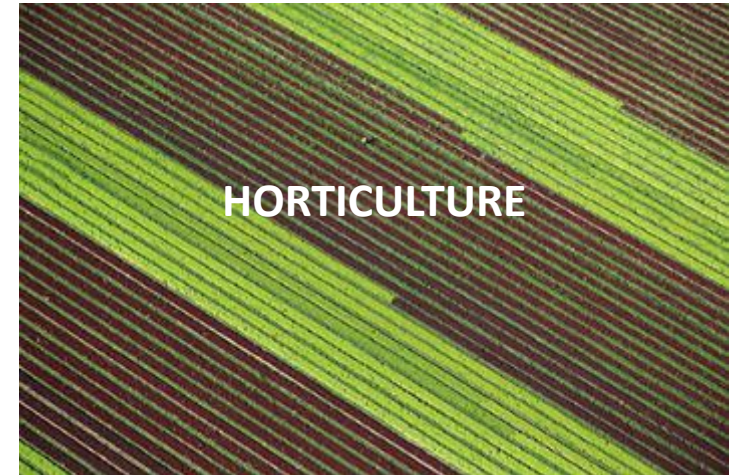
TURF & ORNAMENTAL



AGRICULTURE



HORTICULTURE



Crystal Green is simply a pure, granular fertilizer

Crystal Green is not: a biosolid, compost, sludge or a sandy fine

- ✓ The only recovered fertilizer with distinct marketable sizes
- ✓ Registered as a fertilizer in 44 states, Canada, Mexico, EU, Taiwan, Puerto Rico





Fertiliser Team Sales & Agronomy

Our team of agronomists, researchers, phosphate experts and soil scientists ensure that your phosphorus ends up where it is supposed to; in the fields as a safe and clean fertilizer



MOLLY BIEDENFELD

**VP, Nutrients Market
Development & Sales**



JUSTIN MILLER

**Director, Technical
Sales & Agronomy**



SCOTT BARCLAY

**Technical Sales
Manager**



DEBRA HADDEN

**VP, Marketing
Communications**



PATRICK MITCHELL

**Supply Chain Manager
Finished Products**



Ostara Invests in Fertilizer Market And Agronomic Research To Support Sales

Extensively Funded Market and Agronomic Research to Support Sales



6

Years of research trials



13

Different crops



26

Unique researchers



150+

Replicated small plot trials



United States

OR: Horneck & Associates (3 years)

ID: Hopkins (5 years)

WA: Pavek: (3 years)

ND: Robinson (4 years)

MN: Rosen (4 years)

WI: Bussan and Bellman (3 year)

MI: Steinke (3 years)

FL: Zotarelli and Ozores-Hampton (4 years)

AZ: Sanchez (3 years)



Canada

Alberta: Michelle Konschuh (3 years)

Manitoba: Darin Gibson (Gaia) (3 years)

Manitoba: Ginter (1 year)

PEI: Steve Watts (3 years)

E. Canada: Judith Niyaraneza et al (2016-18)



United Kingdom

Scotland: Robin Walker

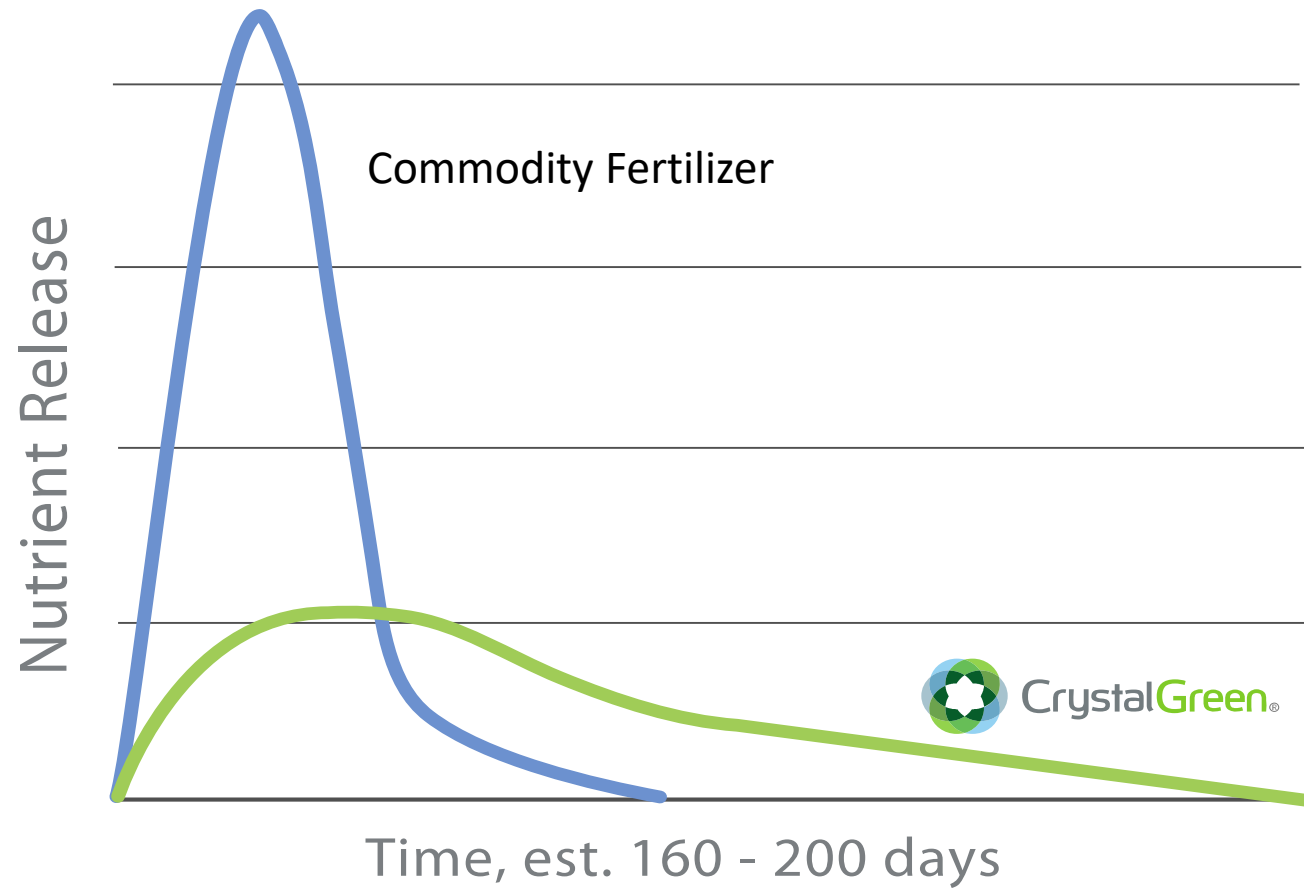
Ireland

England

Crystal Green is Virtually Water Insoluble

Conventional P Solubility	Crystal Green Solubility
Water	Citrate Root-Activated™
<ul style="list-style-type: none">• Highly water soluble• Quickly releases nutrient early on in the growth cycle• Potential tie-up in low and high pH soils (Al, Fe and Ca)	<ul style="list-style-type: none">✓ Virtually water insoluble✓ Requires citric acid from a growing root zone in order to release it's nutrients✓ Continuous nutrient release throughout the growing season✓ Minimizes P tie-up and loss

Continuous Release Provides Season-Long Supply of Phosphorus





Saskatoon, SK

PARAMETER	VALUE
Design Capacity	20 MGD
Population Served	300,000
Pearl Model	2K
# of Reactors	1
Installation	Retrofit
Installation Year	2013
WASSTRIP	Yes





1x Pearl[®] 2K at Saskatoon WWTP (Saskatoon, SK)

500 tons/year of Crystal Green[®] Capacity



Saskatoon WWTP (Saskatoon, SK) Nutrient Recovery Facility

Achieves Project Goals



Sustainable solution to prevent struvite formation



Reduces supernatant nutrient load returned for treatment – improved efficiency and reliability



Minimizes need for chemical dosing – lower chemical and solids disposal costs



Improves system capacity



Lowers operating and maintenance costs



System generates revenue from up to 500 tons/year of Crystal Green production



CleanWater  Services

Tigard, OR

PARAMETER	VALUE
Design Capacity	20 MGD
Population Served	250,000
Pearl Model	500/2K
# of Reactors	3
Installation	Retrofit
Installation Year	2009
WASSTRIP	Yes



Pearl[®] 2K at Durham (Tigard, OR)

750 tons/annum of Crystal Green[®] Capacity



Durham (Tigard, OR) Nutrient Recovery Facility



Achieves Project Goals



Helps meet stringent 0.1 mg/l discharge limit on the Tualatin River.



Maximizes capacity and reduce operational costs



Decreases centrate nutrient load returned for treatment (reducing the biological phosphorus removal requirement by ~25%)



Reduces phosphorus content of biosolids for more balanced N:P ratio



Minimizes use of metal salts for chemical phosphorus removal

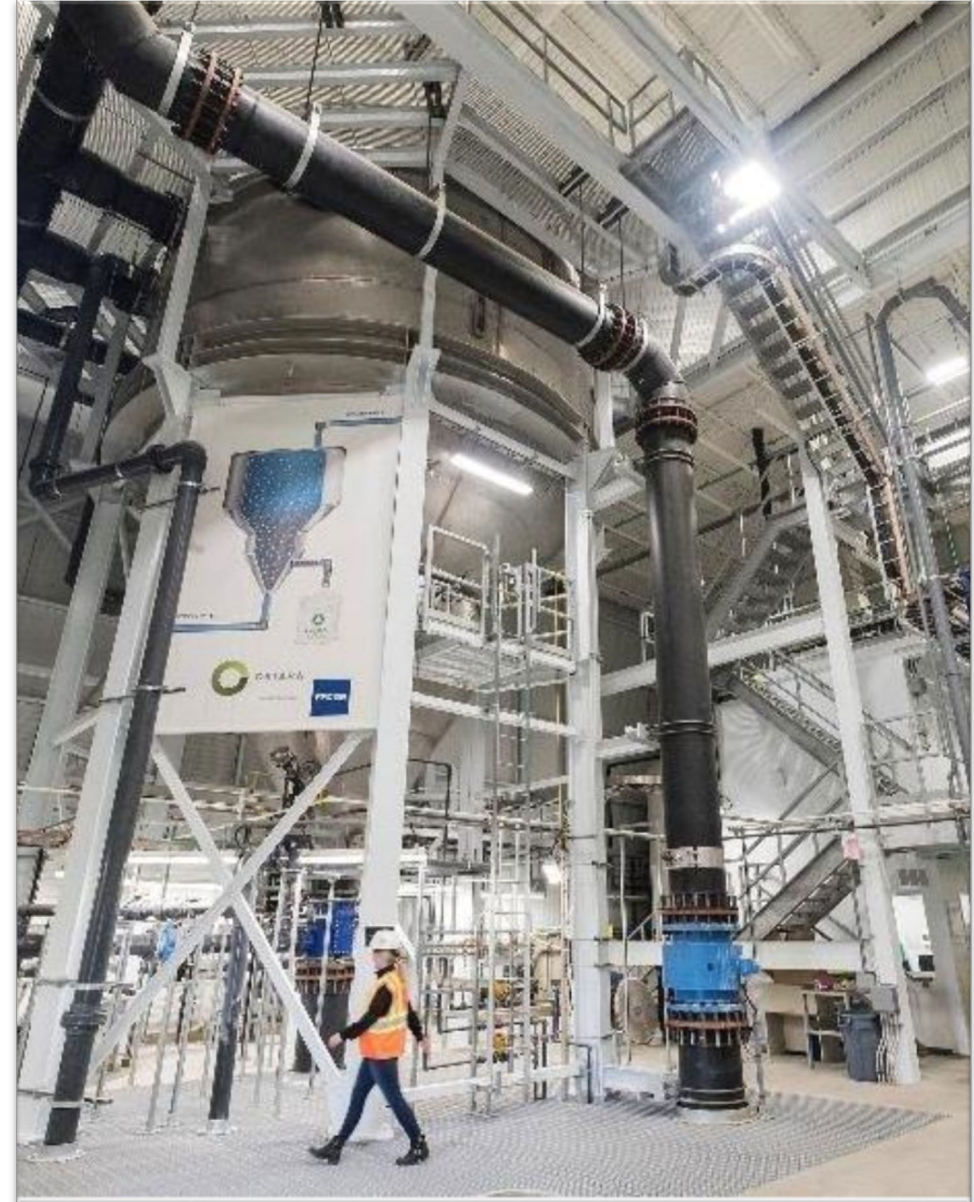


Lowers chemical purchase and sludge disposal costs



Edmonton, AB

PARAMETER	VALUE
Design Capacity	80 MGD
Population Served	700,000
Pearl Model	10K
# of Reactors	1
Installation	Greenfield
Installation Year	2015
WASSTRIP	No



Pearl[®] 10K at Gold Bar (Edmonton, AB)

2,500 tons/annum of Crystal Green[®] Capacity





City of Reno and
City of Sparks

PARAMETER	VALUE
Design Capacity	45 MGD
Population Served	190,000
Pearl Model	2K
# of Reactors	1
Installation	Greenfield
Installation Year	2016
WASSTRIP	No





Suffolk, VA

PARAMETER	VALUE
Design Capacity	30 MGD
Population Served	280,000
Pearl Model	500
# of Reactors	3
Installation	Greenfield
Installation Year	2010
WASSTRIP	Planned





3 x Pearl[®] 500 at Nansemond (Suffolk, VA)

390 tons/year of Crystal Green[®] Capacity





York, PA

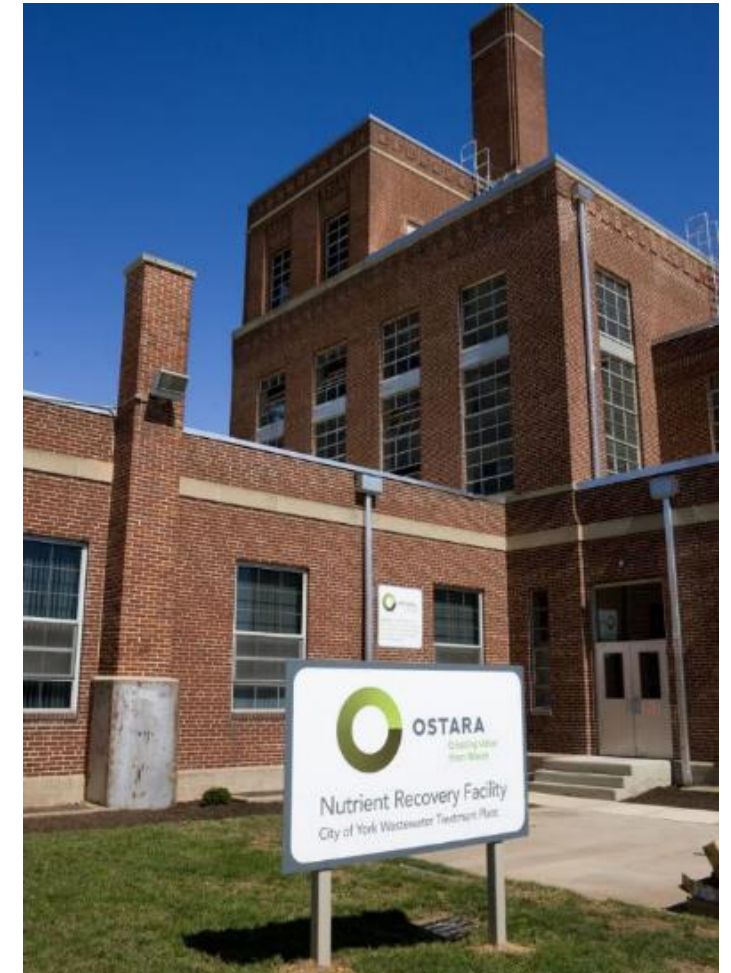
PARAMETER	VALUE
Design Capacity	25 MGD
Population Served	94,000
Pearl Model	500
# of Reactors	2
Installation	Retrofit
Installation Year	2010
WASSTRIP	Planned





2 x Pearl[®] 500 at York WWTP (York, PA)

260 tons/annum of Crystal Green[®] Capacity



CleanWater  Services Hillsboro, OR

PARAMETER	VALUE
Design Capacity	40 MGD
Population Served	400,000
Pearl Model	2K
# of Reactors	2
Installation	Greenfield
Installation Year	2012
WASSTRIP	Yes



2 x Pearl[®] 2K at Rock Creek (Hillsboro, OR)

1,000 tons/annum of Crystal Green[®] Capacity





Slough, UK

PARAMETER	VALUE
Design Capacity	15 MGD
Population Served	240,000
Pearl Model	500
# of Reactors	1
Installation	Greenfield
Installation Year	2012
WASSTRIP	No



1 x Pearl[®] 500 at Slough (UK)

130 tons/annum of Crystal Green[®] Capacity



F. Wayne Hill Water Resources Centre



Gwinnett County, GA

PARAMETER	VALUE
Design Capacity	50 MGD
Population Served	220,000
Pearl Model	2K
# of Reactors	2
Installation	Greenfield
Installation Year	2013
WASSTRIP	Yes



2 x Pearl[®] 2K at F. Wayne Hill WRC (Georgia)

1,000 tons/annum of Crystal Green[®] Capacity





Madrid, Spain

PARAMETER	VALUE
Design Capacity	110 MGD
Population Served	2,900,000
Pearl Model	2K
# of Reactors	1
Installation	Greenfield
Installation Year	2016
WASSTRIP	No





Winchester, VA

PARAMETER	VALUE
Design Capacity	8 MGD
Population Served	200,000
Pearl Model	2K
# of Reactors	1
Installation	Retrofit
Installation Year	2016
WASSTRIP	Yes



St. Cloud Wastewater Treatment Facility



St. Cloud, MN

PARAMETER	VALUE
Design Capacity	18 MGD
Population Served	100,000
Pearl Model	2K
# of Reactors	1 under construction
Installation	Retrofit
Installation Year	2018
WASSTRIP	Yes





Our Purpose

A FULL CIRCLE SUSTAINABLE SOLUTION

An economic and environmental solution to global nutrient issues.

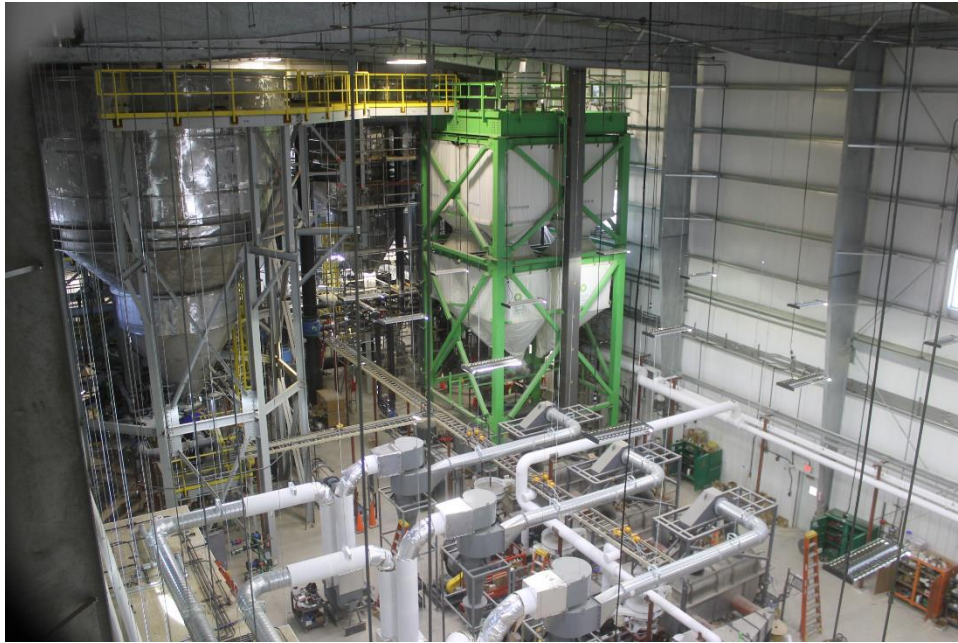


- Market Leading
 - Patented Technology
 - Significant Value Proposition
- Large Fertilizer Market Opportunity
 - Recurring Revenue
 - High Margin



Largest Nutrient Recovery Facilities North America

CHICAGO, USA | Q2 2016



EDMONTON, CAN | Q3 2016



AMERSFOORT, NL | Q2 2016



MADRID, ES | Q3 2016



Creating a Circular Economy

