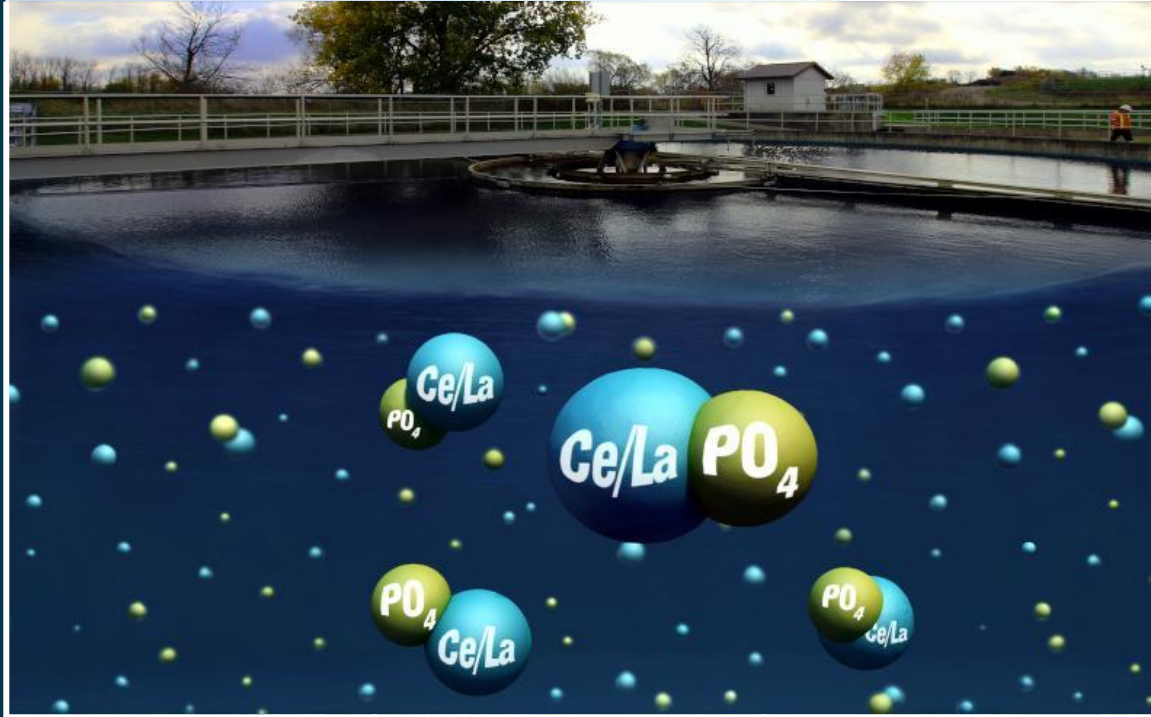
MWWA 2024

ClariPhos™
Rare Earth Coagulant

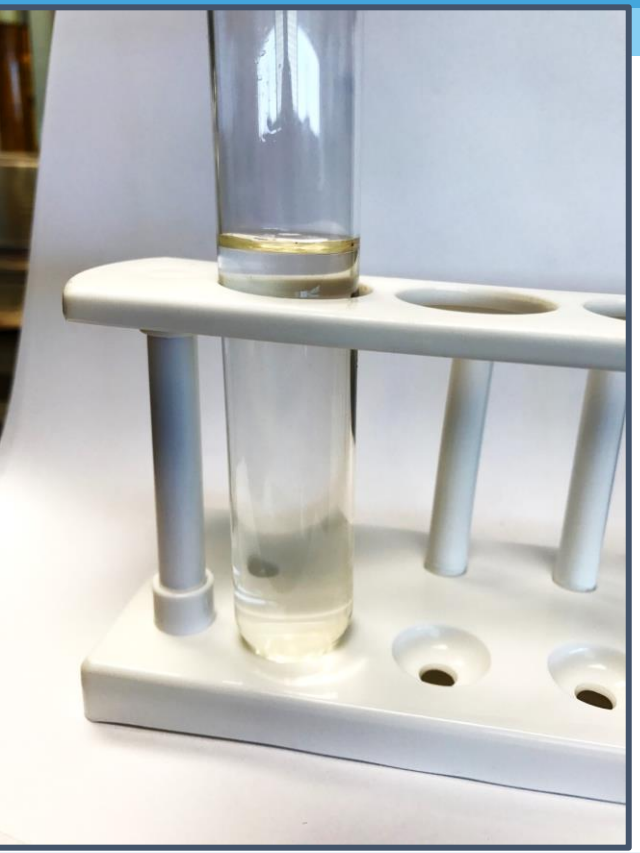
Remove more phosphorus.
Produce less sludge.

Presented by:
Jordan Van Shane

BISHOPWATER



Overview of ClariPhos



- A new coagulant technology made with rare earth elements, **lanthanum** and **cerium**
- Has a high affinity for phosphorus allowing it to achieve ultra low levels (<0.07 ppm) at only a **1:1 molar ratio**
- **No tertiary filtration equipment required** and minimal associated ongoing operating costs
- Offers a **simple, affordable** way to reduce phosphorus in treated effluent

The Cost of Phosphorus Compliance

Municipalities are faced with the costly burden of upgrading their treatment plants to meet stringent water quality criteria for phosphorus

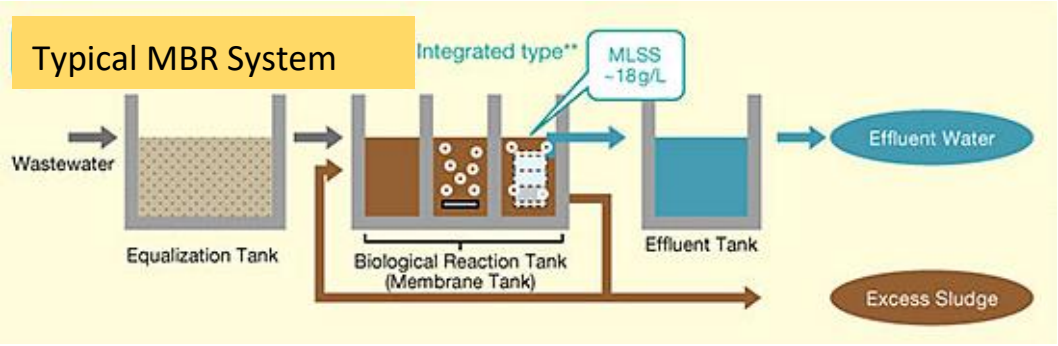
- Tertiary filters, increased chemical costs & sludge handling requirements
- Major facility renovations and upgrades = $$$
- Energy and operational costs would also skyrocket to support new equipment and processes
- Estimates to upgrade WWTPs to meet tough phosphorus limits range from **$5,000 to $45,000** per kg of P removed

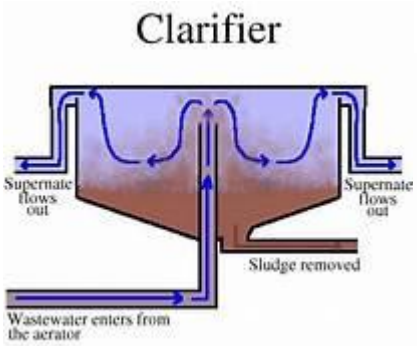
ClariPhos offers capital and operational cost savings

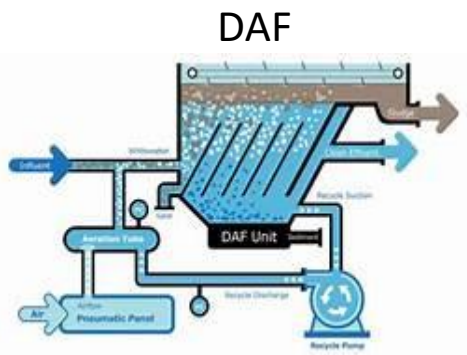
Wastewater plants that have switched to ClariPhos have realized significant savings in several areas:

- **Eliminate capital and annual operating costs of adding tertiary filtration systems**
- **Lower sludge production by up to 50%**
  - Enhance clarifier performance and capacity
  - Improve sludge dewaterability by up to 40%
- **Reduced maintenance costs compared to alternative coagulants**
  - Doesn't stain or discolor facility structures/equipment
  - No pH adjustment necessary
  - Safer, it is ~100x less acidic than Alum/Ferric

Where can ClariPhos be used?







Summary of Key Benefits

Conventional WWTP

- Improved clarifier performance
- Reduce or eliminate pH adjustment
- Reduced sludge processing costs
- No staining (UV)
- Prevent struvite

Membrane Bioreactors

- Stable pH for optimized bacterial proliferation
- Reduce or eliminate pH adjustment
- Reduced membrane cleaning

Lagoons

- Rapid Settling
- Reduced TSS in effluent
- Less sludge accumulation
- Stable pH for optimized bacteria proliferation

Industrial Clarifiers

- Rapid Settling
- Improved dewatering (filter press etc.)
- Reduce / eliminate pH adjustment
- No staining of infrastructure

- **Achieve ultra-low phosphorus limits without expensive capital investment or tertiary treatment**
- **Reduce coagulant consumption and maintenance costs**

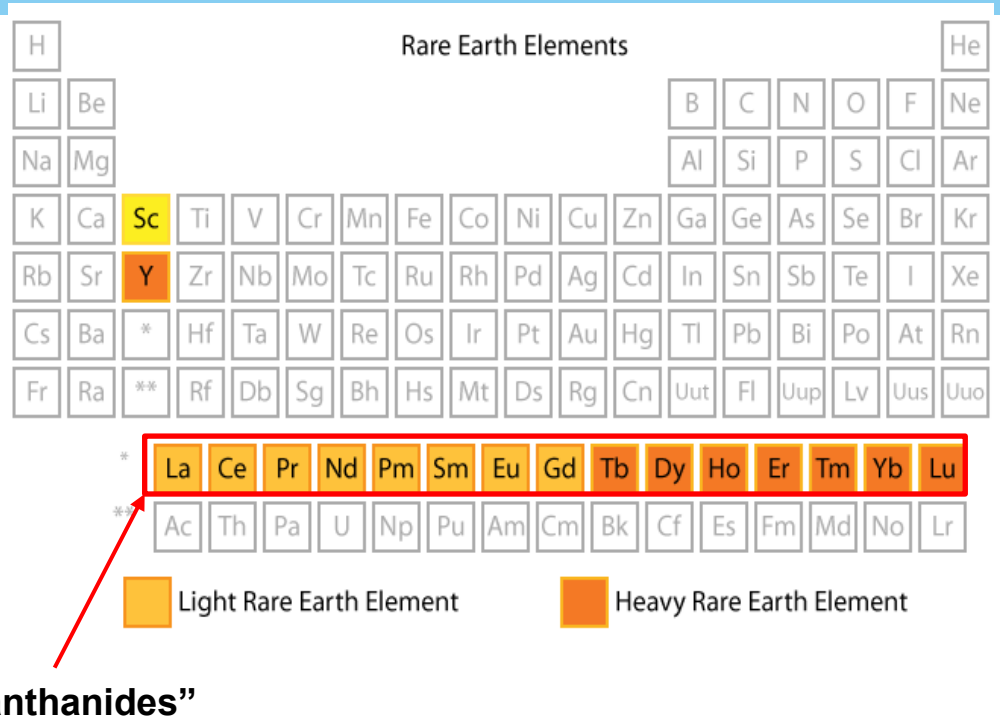
Rare Earths in ClariPhos: Lanthanum and Cerium

ClariPhos is a salt solution of lanthanum and cerium.

Lanthanum (La) and **cerium (Ce)** form strong, crystalline bonds with **phosphate,** making them ideal for wastewater treatment applications.

First: What are Rare Earth elements?

- 17 RE elements (not all that ‘rare’)
- All have similar properties—often found complexed together in nature
- Very difficult to separate from one another once complexed



ClariPhos - How does it work?

ClariPhos Phosphorus Removal Mechanism

- La and Ce form strong mineral complexes with **phosphorus**
- They bind **specifically with P** to create a **dense, insoluble precipitate** that **rapidly settles out of solution**

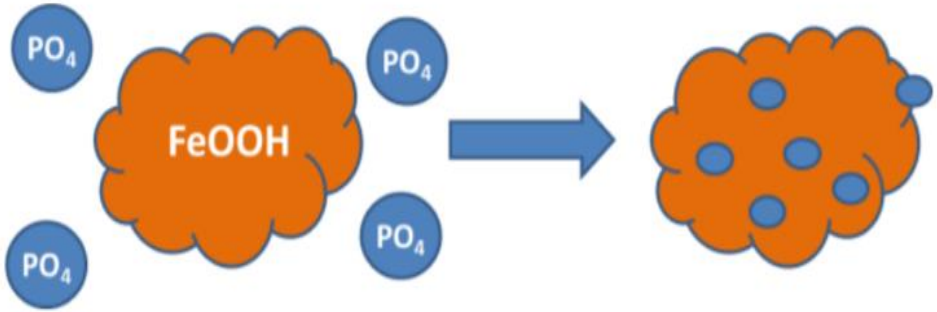
(Ce,La)PO4•(H2O)

ClariPhos preferentially targets phosphorus to form an insoluble rhabdophane precipitate

How does it compare to traditional precipitation methods?

Iron and aluminum salts form an amorphous "cloud" in solution

- Fe and Al-based products work by forming hydroxide intermediates
- Phosphate **weakly adsorbs** onto these surfaces via **non-specific** interactions

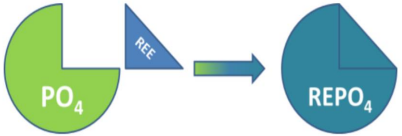


PO_4 only adsorbs to the surface of Al or Fe intermediate

<u>Result:</u> High chemical dose required to get low effluent P!

ClariPhos vs Iron and Aluminum Salts

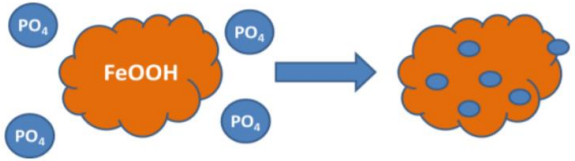
ClariPhos



Forms rhabdophane precipitate via **a strong crystalline ionic bond**
($RE^{3+} + PO4^{3-} \rightarrow REPO_4 \cdot H_2O$)

- Forms irreversible ionic bonds
- Preferentially reacts with phosphorus
- Achieves **1:1 molar ratio of La/Ce:PO4**
- **Less chemical sludge** is produced

Iron and alum-based products



Form amorphous "cloud" in solution which only **adsorbs** P onto floc

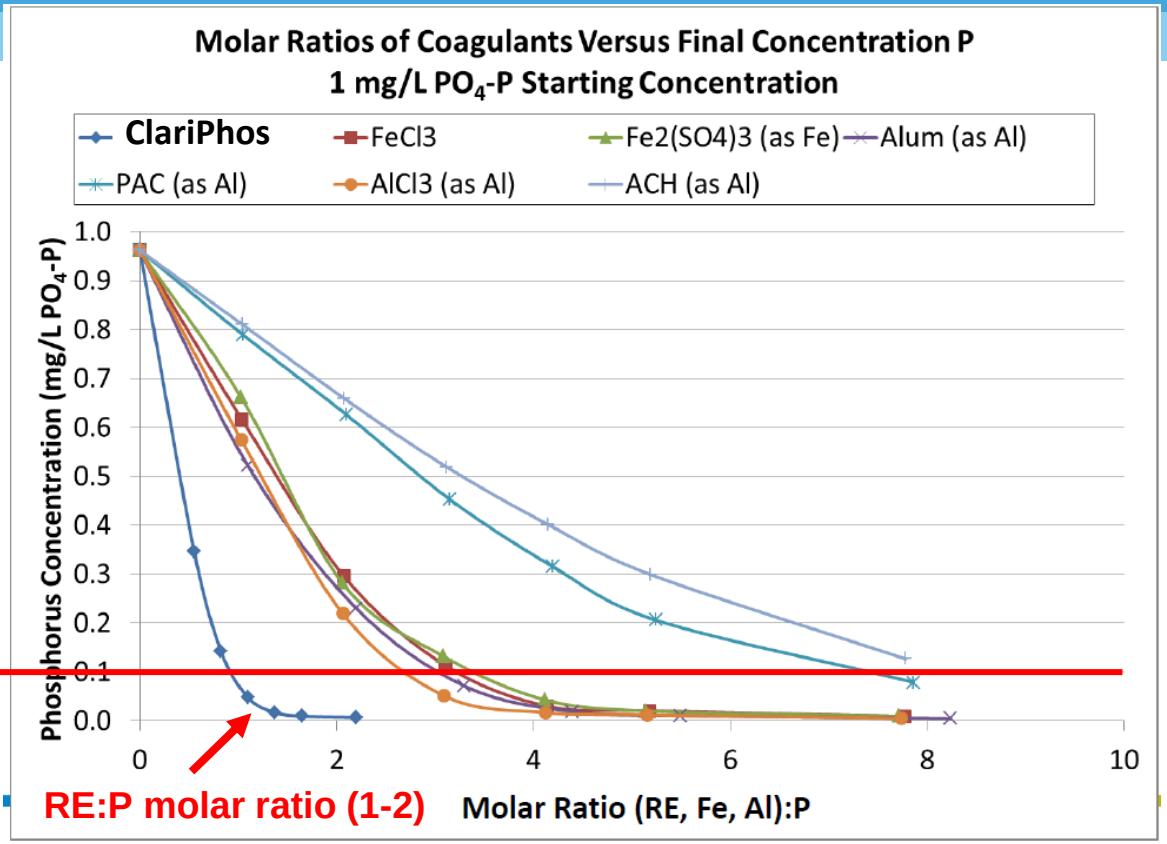
- Adsorption via surface chemistry
- Requires approx. **5:2 ratio of Fe/Al to P**
- High sludge production

ClariPhos creates a stronger bond to P than ferric or alum, meaning **less chemical is needed** and **less sludge is produced**

Molar Dose Ratios

At 0.05 mg/L P, the required **RE:P dosage** remains at 1.

Even below 0.05 mg/L, the **required molar ratio** is still significantly lower than Fe and Al.



Molar Dose Ratios - Impact on Sludge Formation

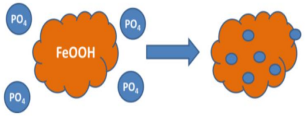
Rare Earth coagulant will produce up to **51% and 34% less sludge** than the amount produced by Fe and Al addition, respectively.

Approximately **40%** of a wastewater treatment plant's total annual operating cost is spent on **solids management**.

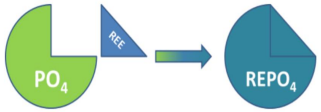
A Report to the Legislature on Wastewater Treatment Sludge and Septic Management in Vermont
July 16, 2016

High settleability

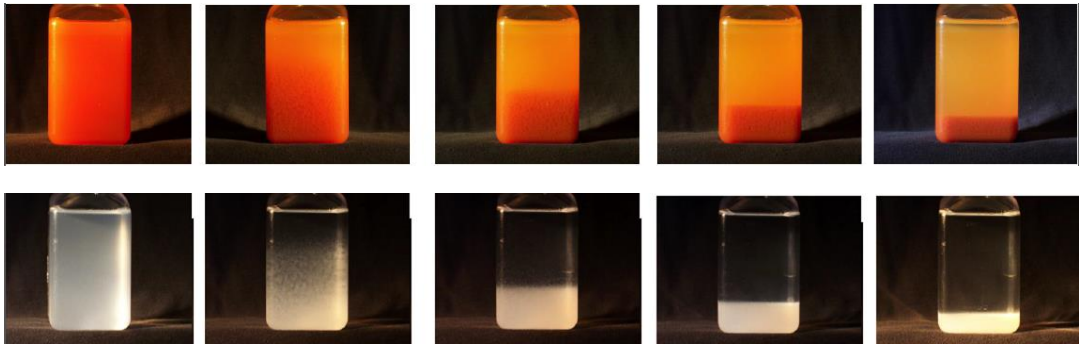
Rare Earth metals enable rapid settling — even for fine particulates

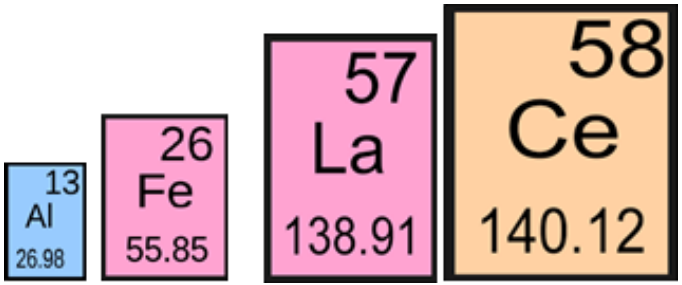


Ferric Chloride



ClariPhos





- High MW of RE metals compared to Al and Fe
- Precipitate is denser, settles better in clarifiers

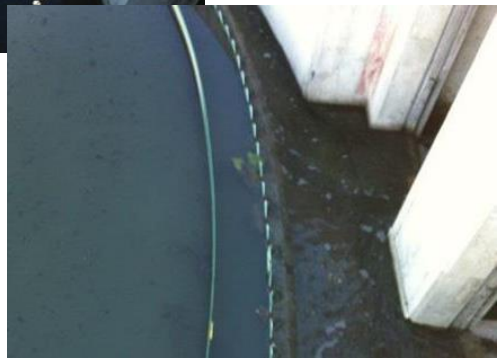
ClariPhos enables clarifiers to operate more efficiently

Rare Earth metals allow for rapid settling of even fine particulates

Table 2. Molecular weights and density of solids generated from coagulant addition

Precipitate formed	Molecular Weight of Metal (g/mol)	Density of Solids (g/ml)
Aluminum hydroxide $Al(OH)_3$	27	2.42
Aluminum phosphate $AlPO_4$	27	2.57
Iron phosphate dehydrate $FePO_4 \cdot 2H_2O$	55.85	2.87
Iron hydroxide oxide Fe(O)OH	55.85	3.4-3.9
Rare Earth phosphate $REPO_4 \cdot H_2O$	138-175	4
Rare Earth hydroxide $RE(OH)_3$	138-175	~4.3

Conventional coagulant



After switching to ClariPhos

- Heavier ClariPhos floc settles about 2x faster than conventional coagulants
- Faster settling enables clarifiers to operate more efficiently
- Reduced carryover of suspended solids
- Eliminates need for costly tertiary filtration systems

ClariPhos- bye bye, struvites!

ClariPhos inhibits struvite formation

- ClariPhos has a **much stronger** bond with soluble P, meaning that it is not released in digesters
    - Conventional coagulants release soluble ortho-phosphorus, leading to struvite precipitation
- Struvite formation is prevented, improving operations and reducing maintenance costs

Top: 18 days of operation without ClariPhos struvite control.
Bottom: Pump after 1 year of operation with ClariPhos struvite control.

ClariPhos improves dewaterability

Example: 2.9 MLD plant

Using ferric:

- Belt press ran 8hrs/day, 5 days/wk
- Average 15% solids

Using ClariPhos:

- Belt press runs 8hrs/day, 1 day/wk = 80% reduction
- Average 21% solids = 40% improvement
- 20 yd containers of sludge sent to landfill decreased from 75 to 31 annually = 59% reduction
- $70,000 annual savings

ClariPhos sludge is easy to handle

	RE 100	RE 300
% active ingredient (w/w)	33%	40.5%
Density (lbs/gal)	11.9	13.2
pH	3 - 4	
Freezing Point	-40°C	

- Low freeze temperature -40°C (-40°F)
- Minimizing “gelling” at cold temperatures
- Eliminates heated storage or pipe heat tracing
- Can be stored outdoors in colder climates

ClariPhos sludge is easy to handle

ClariPhos sludge can be safely land applied as soil amendments

- Rare earths have been shown to have low toxicity and low environmental impact
  - Municipal plants using ClariPhos repeatedly pass whole effluent toxicity testing at 100% effluent concentration
- Rare earth metals are not bioavailable to crops and do not add foreign metals to the soil

Hazardous material classification (Scale of 0-4)

Readily replaces conventional coagulants

- Low corrosivity -- ClariPhos is compatible with existing equipment
  - Simply replace Al or Fe coagulants with ClariPhos
- Small adjustments to dose location or mixing may be beneficial to ClariPhos performance

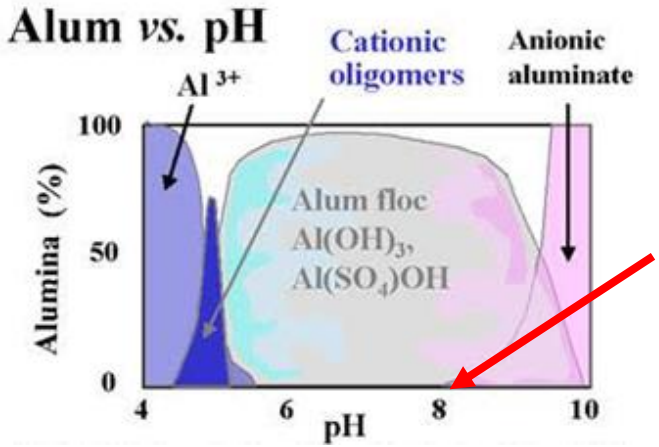
No pH adjustment or alkalinity dosing is required

- ClariPhos (pH 3-4) is **100x less acidic** than Fe or Al coagulants (pH 1.5 - 2.2)

- Strong ionic bond requires 3 - 5x less chemical (1 molecule of ClariPhos per molecule of P removed)

  = **300 to 500 times less acid added**, reduced impact to alkalinity

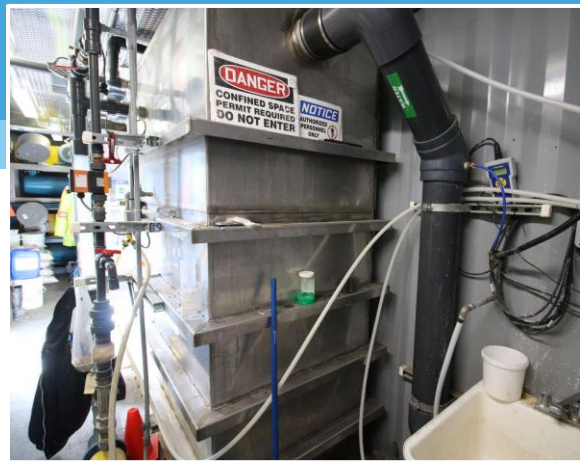
- ClariPhos doesn't require alkalinity to precipitate phosphorus
- ClariPhos speciates at a higher pH, meaning that it will still be effective in high pH wastewaters (up to 11)



At pH >8, alum becomes aluminate ion, which is negatively charged and repels phosphate (PO_4^-)

Case Study - MBR Plant

- MBR system, 30-40 m3/day
- DAF pre-treatment
- High levels of FOG, BOD, TSS and P
- Inconsistent results with alum
- Excess foaming, large pH swings, biological upsets



After Switching to ClariPhos

- ClariPhos dosage is ¼ to ⅕ of Alum.
- **Eliminated** a tertiary treatment system
- **Eliminated** pH adjustment
- **Eliminated** need for polymer dosing
- Less sludge
- Outside storage during cold months
- Easier/safer handling to the running tank
- Overall, maintenance for the WWT plant was reduced significantly.
- **Cost Savings** - chemicals and plant maintenance

Case Study #2 - Biofilter System

- 20 m3/day max.
- Sodium aluminate coagulant
- Inconsistent treatment results
- Carryover of solids caused media fouling
- High sludge production, frequent pump outs

ClariPhos restores performance

- Consistently meeting P target
- Significantly less sludge
- No carry over of solids or fouling of media

Case Study #3 - Avoiding Costly Upgrades

- 1.25 MGD MBR (Kubota)
- Issued new TP limit of 0.07 mg/L (May - Sept), 0.35 mg/L (Oct - April) starting May 2025
- No coagulant currently used
- Evaluated several options

MBR - 20 Year Life Cycle Cost Comparison

Item	Scenario 1: Alum and Tertiary Filter	Scenario 2: RE coagulant and Tertiary Filter	Scenario 3: Alum in MBR	Scenario 4: RE coagulant in MBR
sitework	$ 110,000.00	$ 110,000.00	$ 30,000.00	$ 30,000.00
building	$ 800,000.00	$ 800,000.00	$ 420,000.00	$ 420,000.00
chemical feed equipment (installed)	$ 100,000.00	$ 100,000.00	$ 110,000.00	$ 110,000.00
filtration equipment (installed)	$ 1,330,000.00	$ 1,330,000.00	$ -	$ -
Electrical/Controls	$ 260,000.00	$ 260,000.00	$ 80,000.00	$ 80,000.00
general conditions (10%)	$ 260,000.00	$ 260,000.00	$ 70,000.00	$ 70,000.00
contigency (30%)	$ 860,000.00	$ 860,000.00	$ 220,000.00	$ 220,000.00
contractor OH&P (15%)	$ 560,000.00	$ 560,000.00	$ 140,000.00	$ 140,000.00
Construction subtotal	**$ 4,280,000.00**	**$ 4,280,000.00**	**$ 1,070,000.00**	**$ 1,070,000.00**
soft costs (engineering and CMS: 22%)	$ 950,000.00	$ 950,000.00	$ 240,000.00	$ 240,000.00
total project cost	**$ 5,230,000.00**	**$ 5,230,000.00**	**$ 1,310,000.00**	**$ 1,310,000.00**
annual chemicals	$ 30,000.00	$ 41,000.00	$ 171,000.00	$ 83,000.00
annual electricity	$ 4,000.00	$ 4,000.00	$ 1,000.00	$ 1,000.00
annual parts	$ 19,000.00	$ 19,000.00	$ 7,000.00	$ 7,000.00
annual labor	$ 9,000.00	$ 9,000.00	$ 3,000.00	$ 3,000.00
annual additional sludge disposal	$ 2,000.00	$ 1,000.00	$ 14,000.00	$ 3,100.00
total 20 year life cycle cost	$ 6,510,000.00	$ 6,710,000.00	$ 5,230,000.00	$ 3,252,000.00

Thank you! Any questions?

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