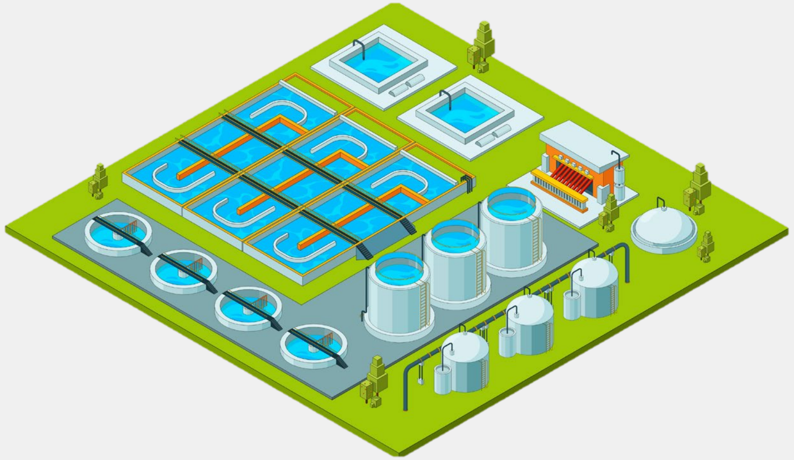
Webinar: Coagulant Technology for Targeting Phosphorus



Drinking Water Facility	Key Aspects	USALCO's Offering	Resulting In
	Coagulation Filtration	Industry-leading Coagulant Portfolio Filter Performance Revival	Maximize facility production Lower Maintenance Lower Energy Consumption Lower Sludge Disposal Costs Reduce pH control cost 24/7 Optimal dosing Reduced CO_2 from Freight Fewer deliveries Process Resiliency
	pH Control		
	Disinfection		
	Chemical Process Control Operating Personnel	Automated Coagulant Dosing Expert Support and Training	

DelPAC® UltraPAC® G-PAC™

Delta-Floc® UltraFLOC®

Aluminum Coagulants

- Sulfated Polyaluminum Chloride
- Polyaluminum Chloride
- Aluminum Chlorohydrate
- Aluminum Chloride
- Aluminum Sulfate
- Dry Aluminum Sulfate
- Sodium Aluminate

Iron Coagulants

- Ferric Sulfate 10%
- Ferric Sulfate 12%
- Ferric Sulfate 13%
- Ferric Chloride 40%
- Ferrous Sulfate 5%
- Ferrous Sulfate 7%
- Ferrous Chloride

Polymers

- Melamine Resins
- Polyamine (epiamines)
- PolyDADMAC

LEADERS IN CLEAN WATER SOLUTIONS

Agenda

1. Nutrient Removal Overview
2. Phosphorus – Definition / Types
3. Phosphorus Removal – Biological / Chemical & Mechanism of Reaction
4. Difference between Al and Fe
5. Key Considerations / Chemical Removal
6. Typical Coagulants Used
7. Bench Testing
8. Dosage Calculations

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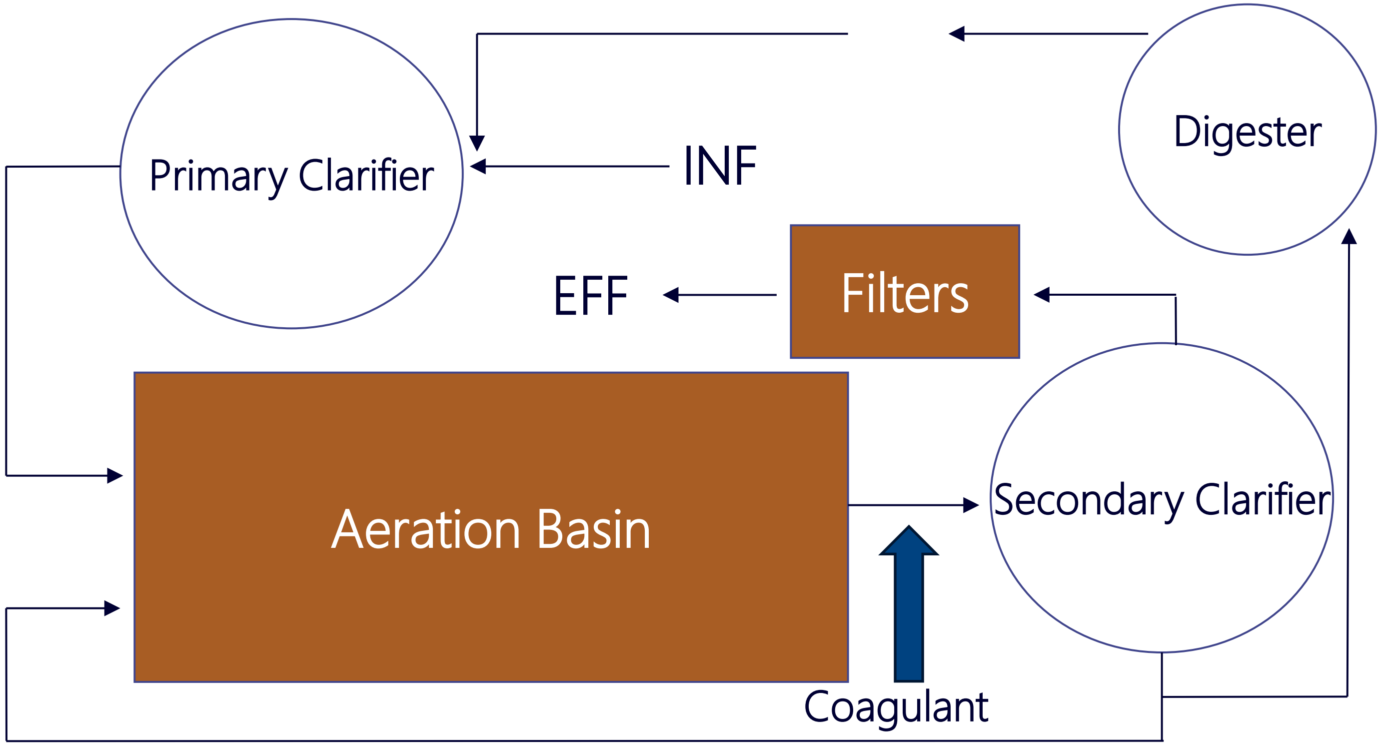
Municipal Wastewater Process

- Typical coagulant application is phosphorus removal



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Water Quality Goals

Wastewater Plant

- Phosphorus Removal
- Improved Settling Rate*
- Less Alkalinity Impact*
- Sludge Reduction
- Overall Clarification – BOD, COD, FOG Removal (Industrial Applications)

Nutrient Removal

- Nitrogen / Phosphorus are Essential Nutrients for Aquatic Plant Growth
- When Available in Excess, water can become "eutrophic"
    - Excess Algae Growth Results in Loss Oxygen for Fish, Unsightly Growth and Odor
    - Potential for Toxins (microcystin) / Public Health
- Algae Growth is Limited by Nutrient that is Least Available
    - Usually Phosphorus in Fresh Water
- Prevent Eutrophication, nutrients from Wastewater must be controlled

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Defining Phosphorus

- Pure, "elemental" phosphorus (P) is rare. In nature, phosphorus usually exists as part of a phosphate molecule (PO4). Phosphorus in aquatic systems occurs as organic phosphate and inorganic phosphate.

- Organic phosphate consists of a phosphate molecule associated with a carbon-based molecule, as in plant or animal tissue. Phosphate that is not associated with organic material is inorganic. Inorganic phosphorus is the form required by plants. Animals can use either organic or inorganic phosphate.

- Both organic and inorganic phosphorus can either be dissolved in the water or suspended (attached to particles in the water column).

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Operational *Definitions*

"Orthophosphate"

- Mostly orthophosphate ("ortho-P"; $H_2PO_4^-$ and HPO_4^{2-})
- Mostly Dissolved
- Highly Reactive

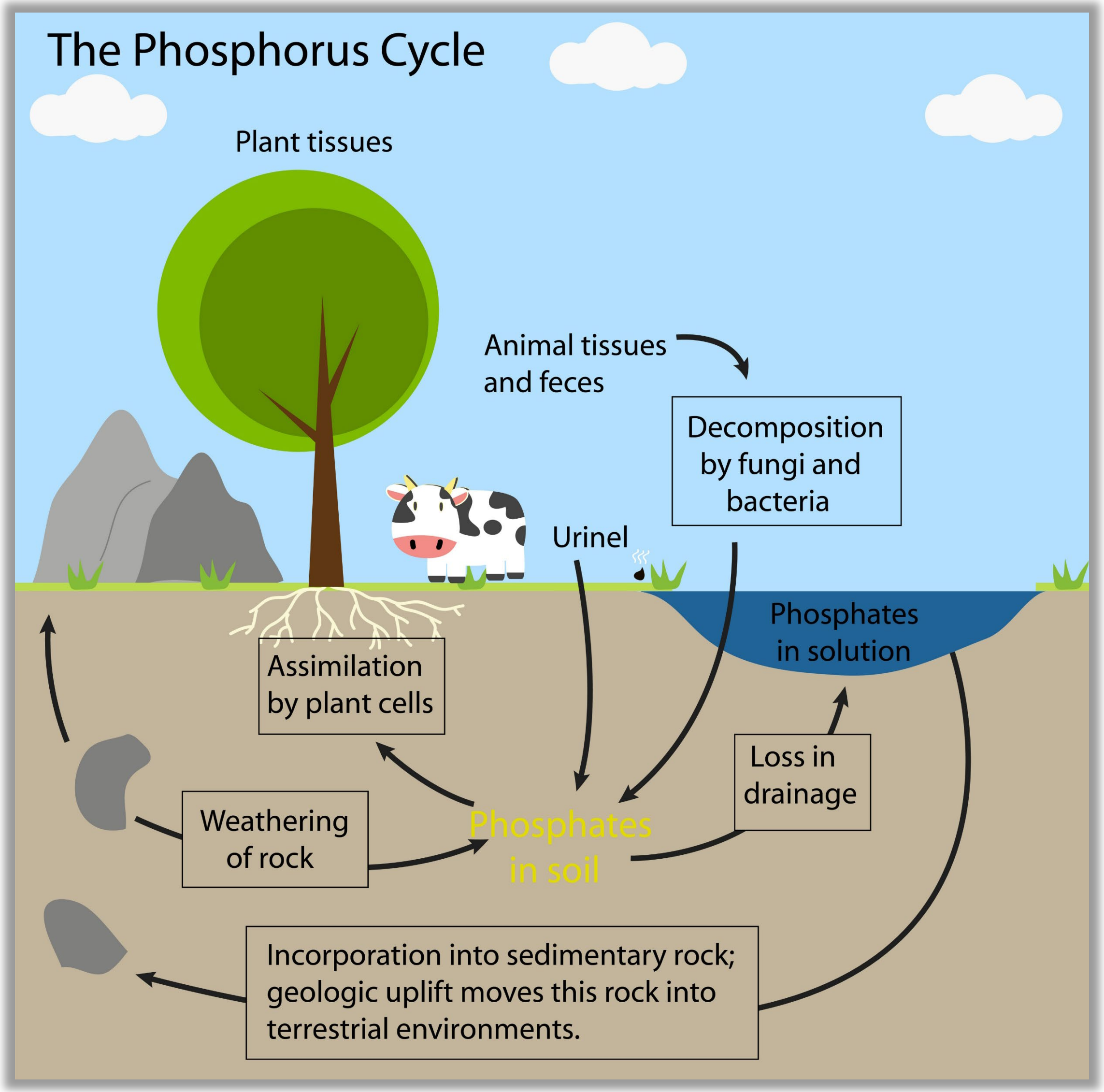
"Acid-hydrolyzable"

- Mostly "condensed" phosphates: polyphosphates and metaphosphates
- Dissolved and particulate
- Somewhat reactive

"Acid-hydrolyzable"

- Phospholipids, Nucleotides
- Mostly Particulate
- Least Reactive

The Phosphorus Cycle



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Monitoring Phosphorus – Common Methods

Total Orthophosphate Test

- Largely a measure of orthophosphate because the sample is not filtered, the procedure measures both dissolved and suspended orthophosphate. Known as the ascorbic acid method.

Total Phosphorus Test

- Measures all the forms of phosphorus in the sample (orthophosphate, condensed phosphate, and organic phosphate). The sample is not filtered, the procedure measures both dissolved and suspended orthophosphate.

Dissolved Phosphorus Test

- Measures the fraction of total phosphorus which is in solution (as opposed to being attached to suspended particles). Analyze a filtered sample for total phosphorus.

Insoluble Phosphorus

- Calculated by subtracting the dissolved phosphorus result from the total phosphorus results.

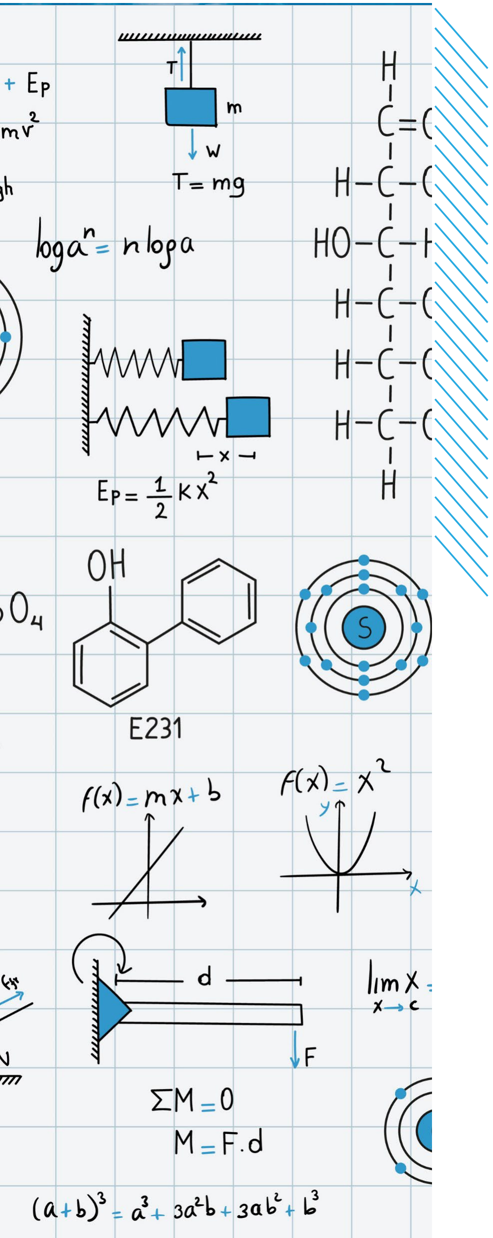
Phosphorus Removal

EPA – mandated PO_4 in plant effluent

- Restrictions Increasing Over Time
- Dependent on Destination of Discharge Water

PO_4 Removal Techniques

- Biological
- Chemical



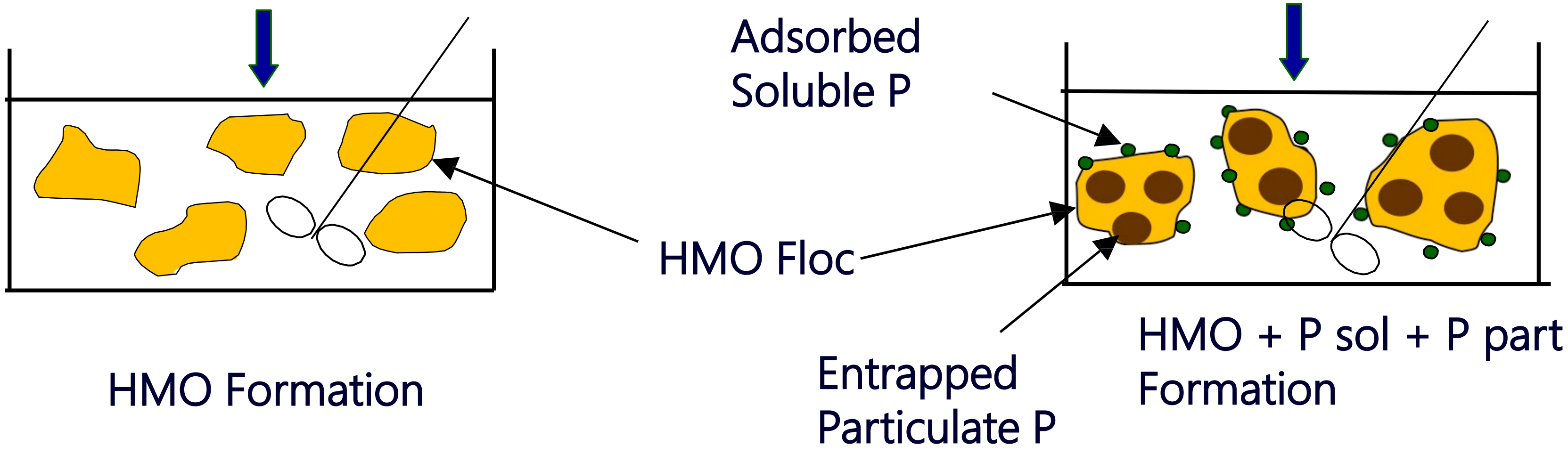
Reaction of Phosphorus w/Al and Fe

Recent plant data does not support the long-held view that P is precipitated. Actual mechanism involves:

1. Reaction with Alkalinity to form Hydrous Metal Oxide (HMO) floc
2. Soluble P Adsorbs to HMO Reactive Sites
3. Co-precipitation: HMO Enmeshes Colloidal & Particulate P

- Penn, C. J., & Camberato, J. J. (2019). A Critical Review on Soil Chemical Processes that Control How Soil pH Affects Phosphorus Availability to Plants. Agriculture, 9(6), 120. USDA-ARS National Soil Erosion Research Laboratory, Purdue University. https://doi.org/10.3390/agriculture9060120

Mechanism of Reaction



Therefore, good mixing is required for HMO formation and chemical dose optimization

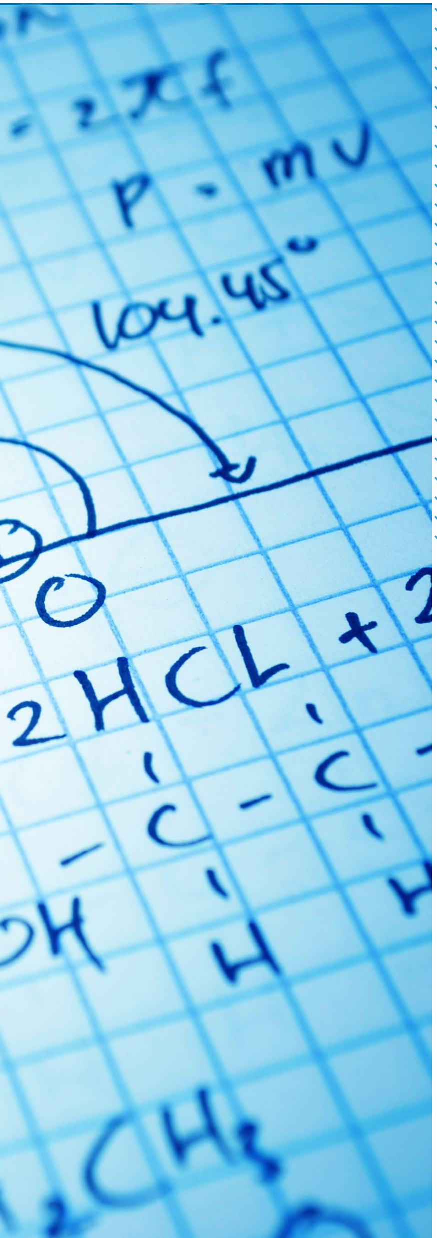
Municipal Wastewater Treatment Plants

Typical P Concentrations

- Raw Domestic Wastewater 2-6ppm
- May be higher due to industry such as food or metal processing
- Focus should be on allowing treatment process to remove as much particulate and soluble P as possible. Chemical treatment is for removing soluble P as a polishing agent

What portion of your effluent total P is soluble vs. insoluble?

- Depending on the result you may also have a settling issue which will dictate the type of chemical needed



Coagulants used for Phosphorus Removal

Aluminum Salts

- Aluminum Chloride
- Aluminum, Sulfate
- Polyaluminum Chloride
- Sodium Aluminate

Iron Salts

- Ferric and Ferrous Chloride
- Ferric and Ferrous Sulfate

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Aluminum vs Iron

Iron Negatively affects UV Disinfection

- Iron salts often precipitate onto the UV system's quartz tubes forming an adsorbing film
- Dissolved iron molecules adsorb UV radiation in the critical wavelength
- Iron can be adsorbed into suspended solids and bacterial floc, where it can prevent UV light from reaching embedded target micro-organisms
- UV disinfection units are more efficient with aluminum-based coagulant

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Aluminum vs Iron

Equal Dosage of Aluminum will Combine with Twice as much Phosphorus vs Iron

- Al molecule weighs less than half Fe molecule, therefore twice as many molecules in pound of LSA as pound of $FeCl_3$
- Ratio is typically 0.87 lbs. aluminum or 1.8 lbs. iron to remove 1 lb. of phosphorus

Unlike Iron Phosphate, Aluminum Phosphate does not re-dissolve under anoxic conditions

- Increased flexibility / efficiency

Not as Corrosive or Likely to Stain as $FeCl_3$

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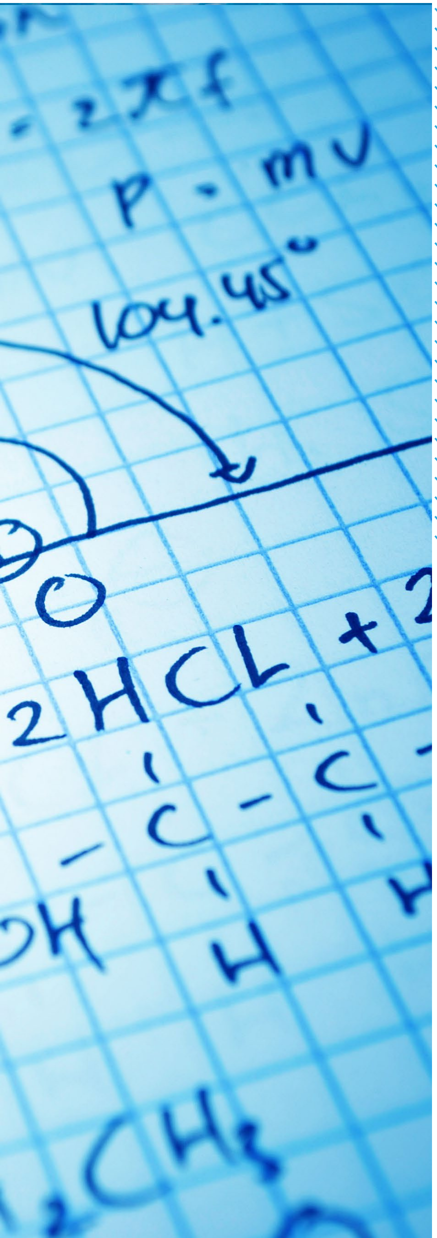

Coagulant Selection

Which is best for your application?

Product	% Al_2O_3 / % Fe_2O_3	Specific Gravity	PPM NaOH 100% Rqd. To Offset	ppm of Sludge / ppm Product
Aluminum Chloride	10.80	1.27	0.254	0.1652
DelPAC XG (ACH)	23.20	1.34	0.097	0.3550
DelPAC 1525	13.66	1.30	0.219	0.2090
DelPAC 2020	10.50	1.23	0.074	0.1607
Sodium Aluminate 38%	19.87	1.48	-0.325	0.3040
DelPAC 1842	17.02	1.37	0.232	0.2604
Ferric Chloride	18.58	1.43	0.279	0.2487
Ferric Sulfate 60%	17.93	1.56	0.269	0.2400

Key Considerations for Successful Chemical Removal of Phosphorus

- Thoroughly understand raw water P Sources, type, and fluctuations (seasonal/otherwise). Look for side stream contributors (filter press)
- Conduct Extensive testing of Al+ based coagulants to find the best performing coagulant for your water/treatment process. Are needs only for P removal or is a settling aid also required?
- Evaluate / test each product based on the metal to phosphorus ratio. (1:1, 2:1, 3:1 etc). Best performer at the lowest ratio. Keep in mind that below 0.3 ppm P the molar ratio increases significantly, as does the dosage requirement.

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Key Considerations for Successful Chemical Removal of Phosphorus

- Feed point and mixing are key. Feeding at the headworks will “work” but other constituents (BOD, COD) are competing with P for aluminum. Good mixing require for efficient HMO formation. Both, impact chemical usage.
- Examine intended or unintended consequences:
  - Impact of chemical on effluent pH and system alkalinity (ammonia removal
  - Sludge dewatering and generation
  - Efficiency of UV system impact
- Thoroughly review current delivery systems for compatibility and or design around best coagulant.
- Review / Discuss Final Clarification-limiting factor in P removal
- Monitoring and Control Protocol

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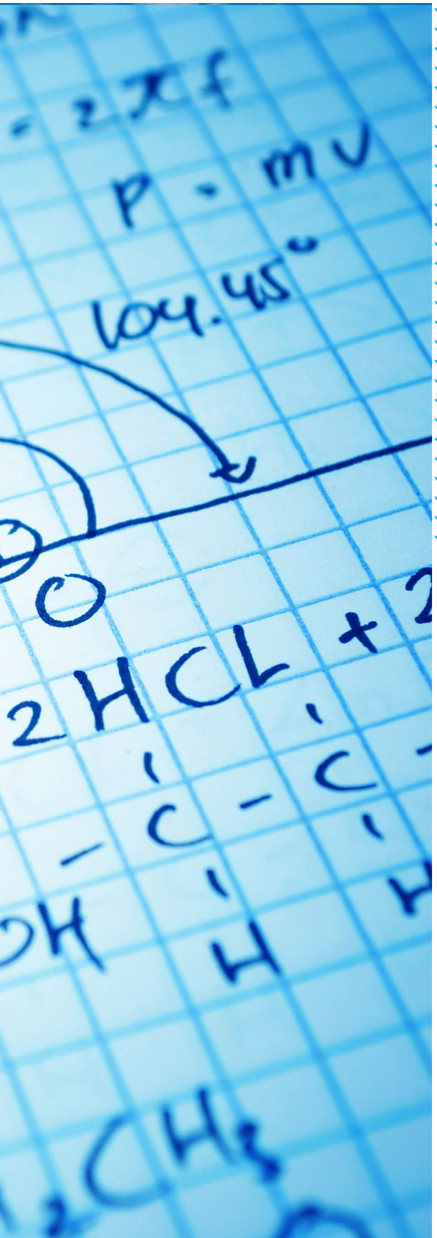

Jar Testing – Critical for Water & Wastewater

Let us Help!

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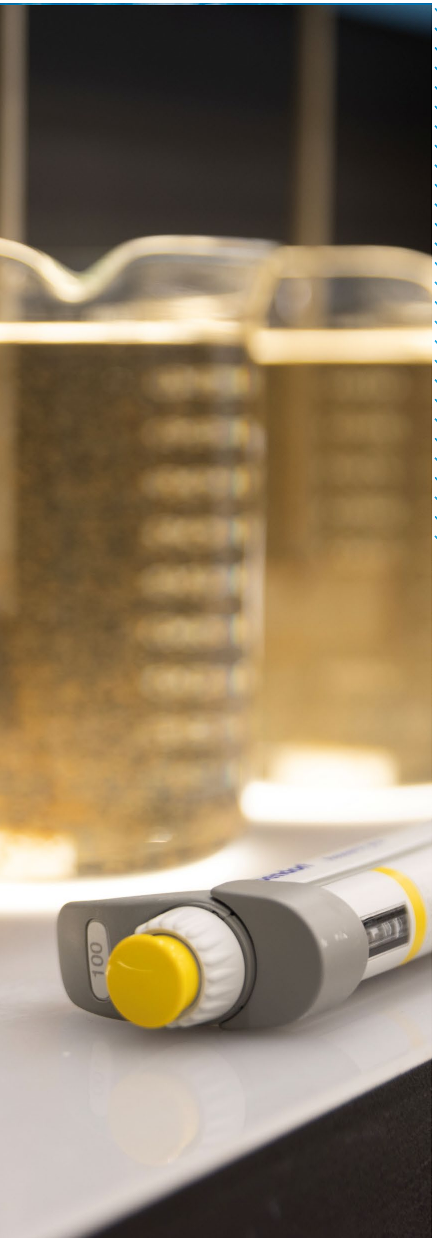
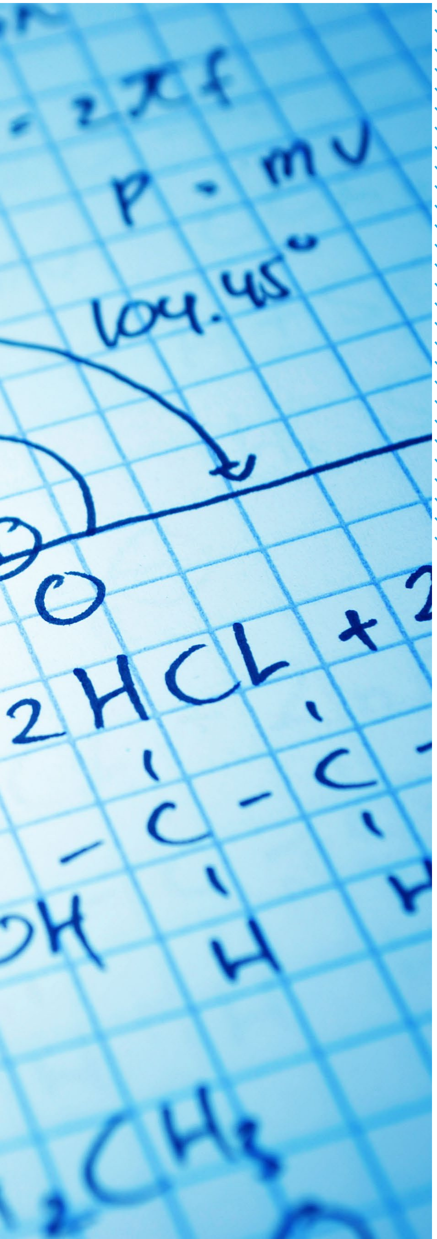


Wastewater Testing

- Focused on Phosphorus Removal
- Coagulants Screened on Critical Variable: Molar ratio of Metal to P (Al:P)
- Sample Collection Point is Critical. Mindful of Removal of Insoluble P
- Test the Sample of Filtered and Unfiltered P. The filtered P is your baseline. The amount you want to remove is the filtered P minus the plant's effluent target
- Dose the jars according to plan. Mix ~20 minutes. Settle ~10 min
- Using the syringe to collect water and filter to test each jar for soluble phosphorus that still remains.
- Comparing your baseline filtered P to the Jar P provides a evaluation of Soluble Phosphorus Reduction Efficacy of the Chemical at the Specific Dosage and Al:P ratio



Dosage Rate Calculation

- Example: A 1.5 MGD plant has an influent Total Phosphorus Concentration of 8 ppm, and a discharge limit of 1 ppm.
  - Desired P reduction of 7+ ppm
  - Start with a Al:P ratio of 2:1
  - Al atomic weight: 27 g/mole
  - P atomic weight: 31 g/mole

- Weight of P/day to be removed

  = Flow in MGD x Desired P Removal in ppm x Density of Water

  = 1.5 MGD * 7 ppm * 8.34 / gallon = 88 lbs / day

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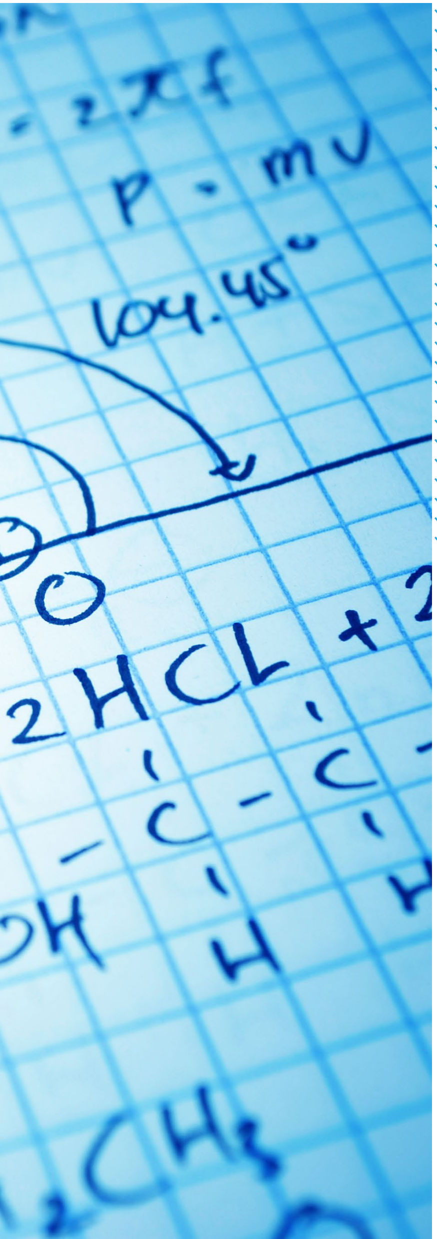

Dosage Rate Calculation

- Required weight Al/day for desired P removal

  = (Atomic weight ratio of Al to P) * (Al:P feed ratio) * (lbs of P/day to be removed)

  = 27/31 * 2 * 88 = 153 lbs of Al per day required to remove 88 pounds of P / day

- Dosage of 38% LSA to remove 153 pounds of Al per day

  = (Wt. of Al / day) / (Weight of 38% Sodium Aluminate / gal * % Al in 38% Sodium Aluminate) = 117 gal / day 38% Sodium Aluminate

Application

- Common feed points
    - Primary clarifier
    - Aeration basin
    - Return activated sludge
    - Aeration effluent into final clarifier

- Best fed neat if possible
- Address recycle streams (filter presses)
- Mixing is Critical for efficiency of HMO formation

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