BONDED CHEMICALS Inc.

A ChemGroup Company

2645 Charter St.
Columbus OH 43228

Phone: (614) 777-9240
www.chemgroup.com
Brett McMillen – Columbus / Medina
Ryan Newcomer – Columbus / Medina
Charlie Miller - Cincinnati

Safety First

- Wear your PPE -- Even Clint Eastwood or Chuck Norris aren’t tough enough to beat chemicals

- Goggles are the best eye protection.
- If you do have an accident – TELL SOMEONE, and GET HELP

Horse Race – and they're off

Chemicals That Can Be Used For Phosphorous Reduction

- Ferrous Chloride
- Ferric Chloride 38%
- Aluminum Sulfate 48%
- PAC – Poly Aluminum Chlorides
- ACH – Aluminum Chloro Hydrates
- Sodium Aluminate 37-45%

What Info Is Needed?

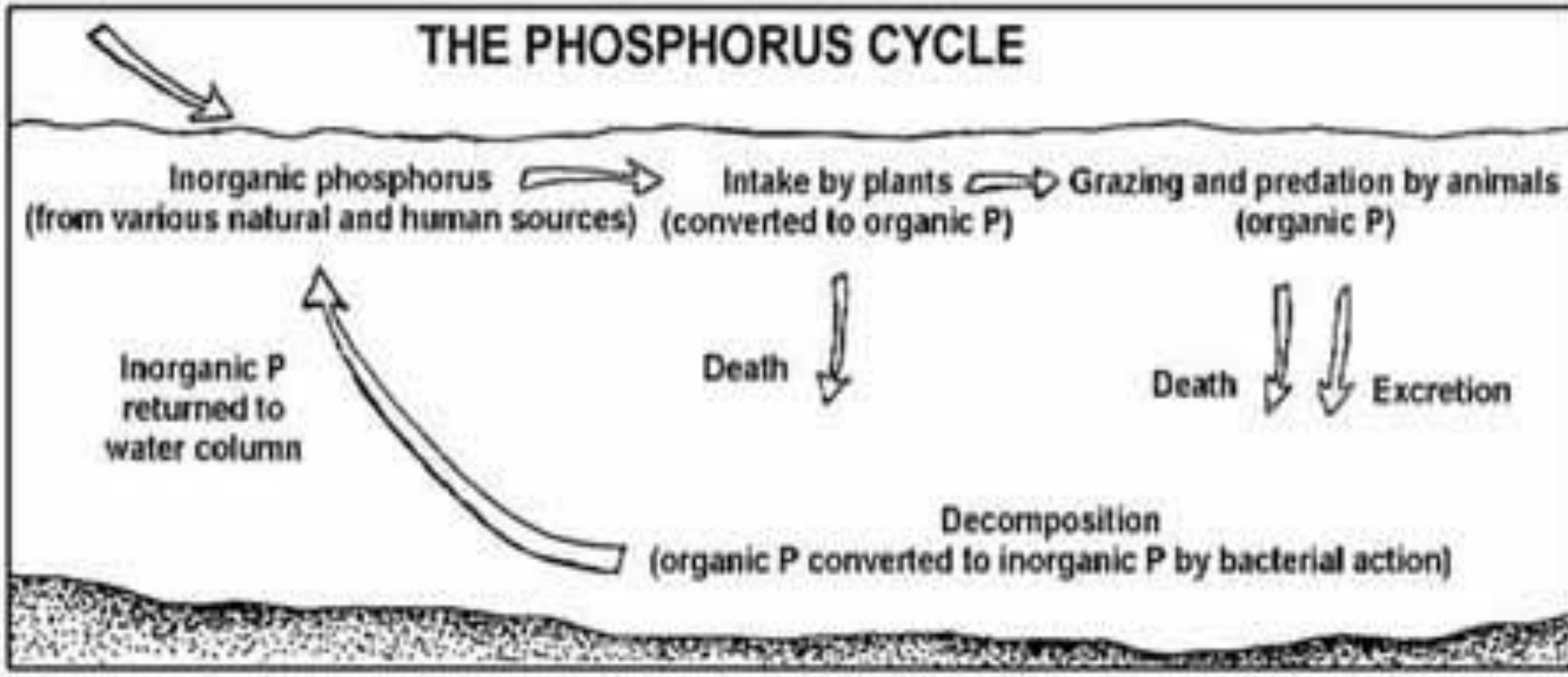
- Flow (normal & max)
- P Influent Concentration
- P Effluent – Limit
- pH Limits (low – high)

Phosphorus Removal

- EPA-mandated <1 ppm PO_4 in plant effluent
  - Restriction will tighten in future
  - Depends on discharge water (stream vs. lake, etc.)
- PO_4 Removal Techniques
  - **Biological**
    - High capital expense ($$$)-system configuration
    - Limited effectiveness (typically removes <1 ppm PO_4)
    - Better for nitrogen (N) removal
    - Requires volatile fatty acids to work
  - **Chemical -** Aluminum or Iron

Nutrient Removal

- Nitrogen / phosphorus are essential nutrients for aquatic plant growth
- When available in excess, water body can become “eutrophic” – literally “well-fed”
  - Excess algae growth results in loss of oxygen for fish, unsightly growth and odor problems
  - Potential for toxins (microcystin) that can jeopardize public health (water supply, contact)
- Algae growth is limited by nutrient that is least available
  - In fresh water, this is usually phosphorus
- In water bodies where eutrophication is a problem, nutrient load from wastewater (point source discharge) must be controlled
  - Phosphorus in WWTP effluent, therefore, can cause eutrophication of lakes and rivers


THE PHOSPHORUS CYCLE
Inorganic phosphorus
(from various natural and human sources)
Intake by plants
(converted to organic P)
Grazing and predation by animals
(organic P)
Inorganic P
returned to
water column
Death
Death
Excretion
Decomposition
(organic P converted to inorganic P by bacterial action)

Municipal Wastewater Treatment Plants

- Typical P Concentrations

  Raw domestic wastewater: 4-8 ppm

  - Will be higher with certain types of industry dischargers (food, metal processing)
- Focus should be on allowing treatment process to remove as much particulate and soluble P as possible. Chemical treatment applied to remove soluble P. A polishing agent if you will.
- 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.

Qualifying Opportunities

- Do a people and technical survey prior to running any tests.
- Type of system- conventional, oxidation ditch, trickling filter
- Flow, Influent P, Effluent P (are they getting any BNR?)
- Current status of treatment /removal?
- Using caustic or any other pH adjustment chemicals.
- Do they have UV for disinfection
- Do they need just a P removal agent or also a solids settling aid. (coagulant)
- Industrial applications- BOD,COD, FOG removal ?

Testing Protocol

- Sample collection point is critical. If currently using a chemical we want to collect a testing sample PRIOR to addition. (Consider any recycle)
- Test the sample for filtered and unfiltered PO4. The filtered PO4 is your baseline. The amount you want to remove is the filtered PO4 minus the plant's effluent target. This is the value you put into the dosage calculator.
- Dose the jars according to plan. Mix ~20 minutes. Settle ~10 min.
- Using the syringe collect water and filter to test each jar for soluble phosphorus remaining.
- Comparing your baseline filtered PO4 to the jar PO4 provides a evaluation of soluble phosphorus reduction efficacy of the chemical at the specific dosage and Al:P ratio

Aluminum vs. Iron

- Iron negatively affects UV disinfection
  - Iron salts can precipitate onto the UV system's quartz tubes forming an adsorbing film.
  - Dissolved iron molecules adsorb UV radiation in the critical wavelength, aluminum doesn't
  - Iron can be adsorbed into suspended solids and bacterial floc, where it can prevent UV light from reaching embedded target microorganisms
  - UV disinfection unit more efficient with aluminum based chemicals
- Same 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 $FeCl_3$
  - Takes 0.87 lbs. aluminum / 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 / messy as $FeCl_3$
  - Can use metal storage tanks / piping / valves
- Fewer contaminants = reduced sludge generation

Key Considerations for Successful Chemical Removal of Phosphorus

- Thoroughly understand raw water P sources, type, and fluctuations (seasonal/otherwise). Look for sidestream contributors (filter press)
- Conduct extensive testing of a few Al+ based coagulants to find the best performing and cost effective product for your water/treatment process. Are your needs solely for P removal or do you also need a settling aid?
- 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 PO4 the molar ratio increases significantly, as does the dosage requirement*
- 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 required for efficient HMO formation. Both of the above impact chemical dosage/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

Impact of Secondary Clarifiers on P and TSS in Effluent

- Effective Solids Capture is critical- understand final clarifier operation/history
- Function: Clarification, Thickening(sludge wasting and return), and Storage (catch solids in high flow)
- Downward velocity of solids vs. upward velocity of water
- Failure

> If overflow velocity (flow/surface area of clarifier) is higher =

carryover of solids

> Thickening- putting more solids in than taking out

P Removal Info

Average Total Flowrate, MGD	2.250
P Influent Concentration, mg/l	3.50
Daily Flowrate, gpm	10.410
P Effluent concentration, mg/l (target)	0.7
Ferric Solution Concentration, %	38
Weight Ratio, g Fe/g P	1.8
Feed Safety Margin	1.5
Solution density, lb/gal	10.91
lb FeCl3 per gal of solution	4.1458
lb Fe III per gal of solution	1.427

Using Ferric Chloride 38%

Ferric Chloride 38% Solution				
Average P Loading per Day, lbs	65.67750			
Average P Loading per hour, lbs	2.73656			
Total Peak Influent Loading, lbs/hr	2.73656			
Total Peak FeCl3 Solution Required, gal/hr	3.45081			
Total Peak FeCl3 Solution Required, gpm	0.05751			
Concentration P to Precipitate, mg/L	2.80			
Amount P to Precipitate per day, lbs	52.542			
FeCl3 Solution Required, gal/day	99.4	412	Dry pounds Ferric Chloride/day	
FeCl3 Solution Required, gal/week	695.7	2,884	Dry pounds Ferric Chloride/week	
FeCl3 Solution Required, gal/month	2956.7	12,258	Dry pounds Ferric Chloride/month	

Using Alum

Aluminum Sulfate Solution				
Concentration P to Precipitate, mg/L	2.80	11.1	Pounds per gallon	
Amount P to Precipitate per day, lbs	52.5420			
Aluminum Sulfate required, gal/day	132.0	706	Dry pounds Aluminum sulfate/day	
Aluminum Sulfate required, gal/week	924.1	4,944	Dry pounds Aluminum sulfate/week	
Aluminum Sulfate required, gal/month	3927.6	21,013	Dry pounds Aluminum sulfate/month	

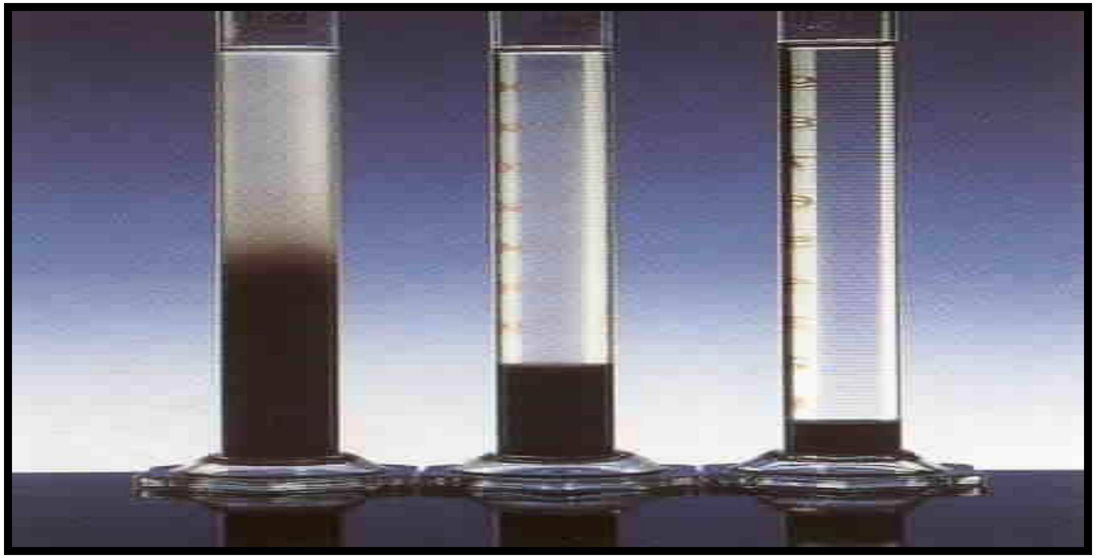
Using Sodium Aluminate 38%

Sodium Aluminate 38%		
Million Gallon per Day MGD	2.250	
Desired ppm P removal	2.80	ppm
Weight of Water	8.34	lb/gal
Weight of P per day:	52.542	P in pounds per day
Al Atomic Wt.:	27	g/mole
P Atomic Wt.:	31	g/mole
Al2O3 Atomic Wt.:	102	g/mole
%Al203 in USALCO 38	20%	20 percent
USALCO 38% density	12.3	Lb/gal
Desired Al:P Ratio	2	
Required Al/day	91.5	Pounds
% Al in USALCO 38	0.106	
Sodium aluminate 38%/day	70.2	gallons per day
Sodium aluminate 38%/week	491.4	gallons per week
Sodium aluminate 38%/month	2063.8	gallons per month

Cost Comparison

Costs	price/pound	Day	Week	Month
Ferric Chloride	$ 0.21	$227.70	$1,593.88	$6,773.98
Aluminum Sulfate	$ 0.21	$307.74	$2,154.16	$9,155.19
Sodium Aluminate	$ 0.48	$414.45	$2,901.16	$12,184.88

Product Name: Ferric Chloride
Synonyms-Iron (III) Chloride Solution
Chemical Formula-$FeCl_3$
CAS Number-7705-08-0



Ferric Chloride-Advantages

- Odor Control
- Increased Dewatering
- Quick P Reduction

Phosphorus Removal

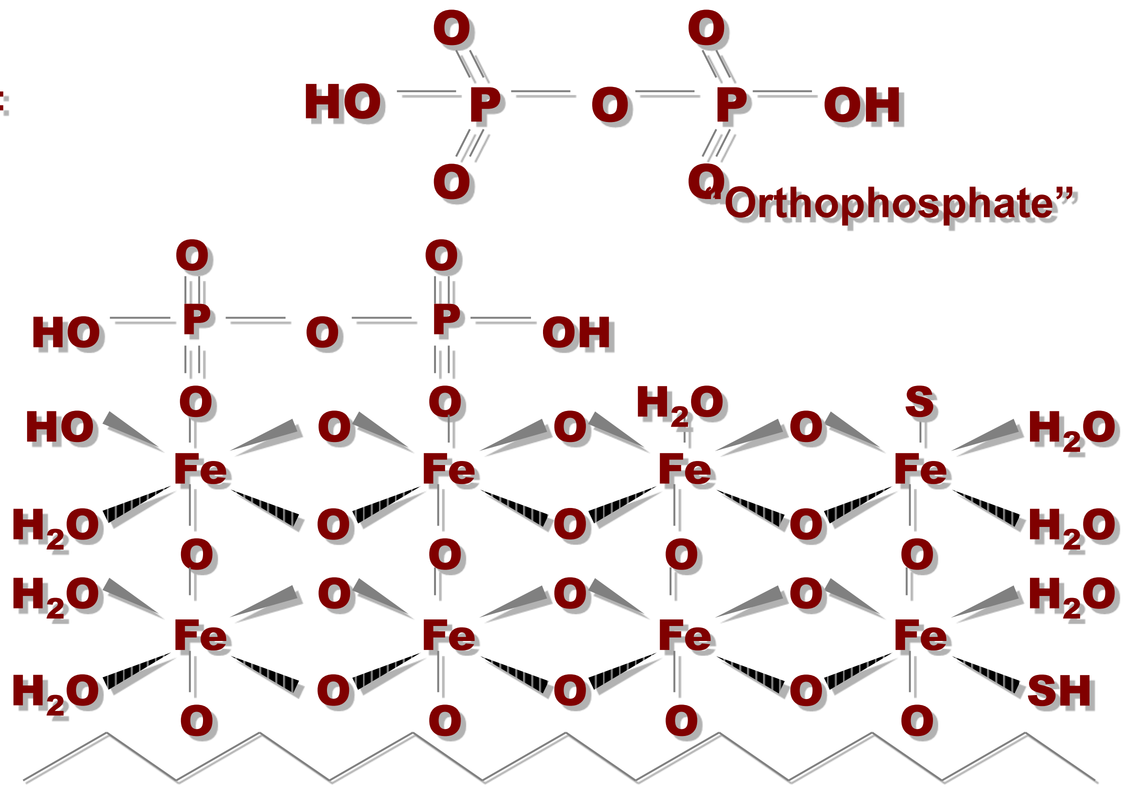
Phosphorus

- Nutrient which can accelerate eutrophication
- Many states require its removal
- Chesapeake Basin plants meeting .18 mg/l discharge limits using Ferric Chloride
- Precursor to “struvite” formation in certrifuge centrate lines

Phosphorus Removal

- Ferric Chloride will adsorb orthophosphates onto the “iron oxyhydroxide surface”

Method 1:



“Orthophosphate”

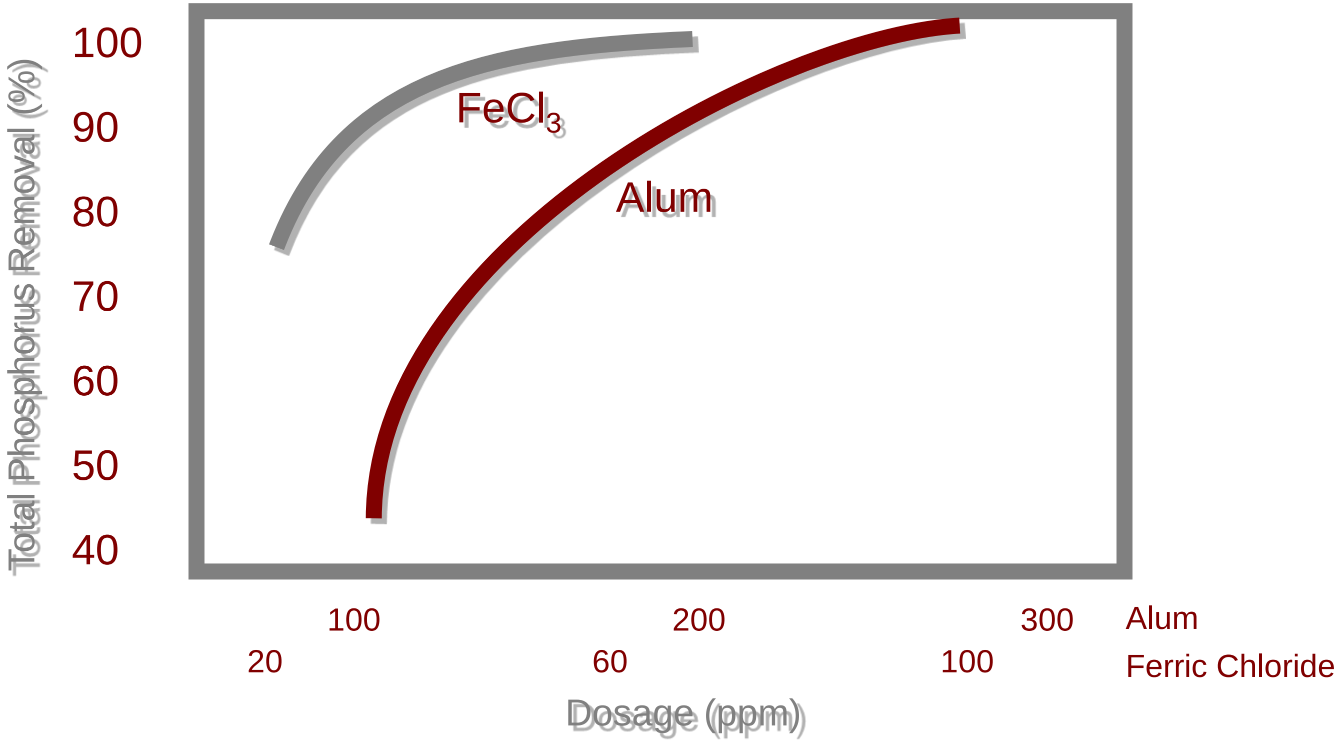
Iron oxy-hydroxide surface

Method 2:

$$Fe^{2+}_{(aq)} + HPO_4{}^{2+}_{(aq)} \rightleftharpoons FeHPO_{4(ppt)}$$

PVS TECHNOLOGIES

Phosphorus Removal



- **Proven more effective than alum**
- **Each pound of phosphorus removed requires:**
  - **5.6 pounds of Ferric Chloride or 9.6 pounds of alum**

PVS TECHNOLOGIES

Ferric Chloride

Odor Control

PVS TECHNOLOGIES

Odor Control

Sulfur Based Odors:

- Inorganic H_2S most prevalent
- Caused by dissolved sulfides
- Present in many waste streams
- Increased community pressure
- Industrial hygiene concerns

Odor Control

H_2S Chemistry

$H_2S(g) \rightleftharpoons H_2S(l)$

$H_2S(l) \rightleftharpoons HS^- + H^+$

$HS^- \rightleftharpoons S^{2-} + H^+$

Dissolved sulfide

- **Equilibrium**

- **Dissolved sulfide can come from**
- **anaerobic sulfate reduction**

- **Aided by low oxidation/reduction**
- **potential (ORP) of waste water**

Odor Control

How Ferric Chloride Helps

Step 1: Fe^{3+} + Waste Water ⟶ Fe^{2+}

- Oxidizes waste water
- Raises ORP
- Not possible with Ferrous Chloride

Odor Control

How Ferric Chloride Helps

Step 2: Fe^{2+} + Sulfides → Iron Sulfide Precipitate

- Effectively binds up sulfides
- Shifts equilibrium to reduce gaseous H_2S

Odor Control

Advantages:

- Coagulant action
  - Not possible with ferrous salts
  - Not possible with Sodium Hydrochlorite
  - Not possible with Potassium Permanganate
- Does not add sulfates to the process

Why Use Ferric Chloride *Instead of:*

ALUM

- Ferric Chloride flocculates over broader pH and temperature range
- Ferric Chloride typically forms heavier, denser floc allowing better performance in settlers and thickeners
- Typically lower doses of Ferric Chloride are needed to achieve similar removals producing less chemical sludge.
- Ferric Chloride is more efficient in control of trihalomethanes (drinking water).
- Ferric Chloride reacts with dissolved sulfides providing odor control benefits.

Why Use Ferric Chloride *Instead of:*

FERRIC SULFATE

- Ferric Chloride molecule has higher percentage of iron than Ferric Sulfate.

  ADDS LESS CHEMICALS TO THE PROCESS

- Ferric Chloride does not add sulfates to your process. ***SULFATES MAY BE REDUCED TO SULFIDES EVENTUALLY FORMING ODOROUS HYDROGEN SULFIDE***

PVS TECHNOLOGIES

Why Use Ferric Chloride *Instead of:*

FERROUS CHLORIDE

- Pickling Liquor" sources may vary in concentration causing difficulty in dosing.

- Ferric Chloride floc typically settles faster, allowing for less carryover of flocculated material.

- Ferric Chloride is a mild oxidizer.

  CAN HELP RAISE WASTEWATER ORP

  ADDED BENEFIT OF HELPING CONTROL ODORS

- Ferric Chloride can reduce polymer consumption when used for dewatering system odor control.
  Ferrous Chloride does not.

Why Use Ferric Chloride

Instead of:

POLYALUMINUM CHLORIDE (PAC)

- Ferric Chloride can provide similar or better performance in many cases.
- Ferric Chloride is significantly less expensive then PAC.

PVS TECHNOLOGIES

CHEMICAL REPLACEMENT

REFERENCE CHART

USE	ALUMINUM SULFATE	FERRIC SULFATE	FERROUS CHLORIDE	PAC
Odor Control	-	+	+	-
Coagulation	+	=	-	=
Phosphorus Removal	+	=	=	=
Sludge Conditioning	+	=/+	-	=
Heavy Metal Removal	+	=	-	=
Struvite Control	+	=/+	+	=
Trihalomenthane Control	+	+	-	+

+ Ferric Chloride is an IMPROVED replacement

= Ferric Chloride is an drop-in replacement (similar performance)

- Categorical Chemical will NOT do this, Ferric Chloride WILL

PVS TECHNOLOGIES

Product Information

Product	% Me	% Bas	Specific Gravity
Alum (as liquid)	4.38	0	1.33
Alum (as dry)	9.01	0	1.33
FeCl3 (40% avg)	13.20	0	1.41
DelPAC 2020	5.57	70	1.23
DelPAC 801	5.29	70	1.20

What is PAC ?

- Polyaluminum Chloride (PACL) are inorganic polymers or polyaluminum complexes that carry a high positive (cationic) charge. Ideal for neutralizing negative charged particles in raw water sources. PAC is a broad family or category of chemicals that differ in basicity, molecular weight, Al2O3 content, and thus functionality. Products from low basicity “PAC” to ACH. (aluminum chlorohydrate)

- Unlike inorganic coagulants, namely alum and ferric chloride, PAC requires virtually no alkalinity to develop cationic charge and precipitate as floc.

- Given PAC’s very different mechanism of reaction compared to alum/ferric it performs much better in cold water. Cold water slows the reaction of alum/ferric with water’s alkalinity thus taking longer to develop the required charge for effective turbidity removal. PAC’s come pre charged.

Let's Talk About Sodium Aluminate- "It's a Bit Different"

- Highest Al+ content (outside of ACH)
- Only P removal agent that does not consume alkalinity
- Great for phosphorus removal, not so good as a coagulant for solids settling
- Superstar in conventional RAS plants, especially when alkalinity and effluent pH are an issue.
- Struggles in trickling filter plants
- Application and storage considerations

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 x 8.34 lbs./gallon)

  = 88 lbs./day

Dosage Rate Calculation

- Required weight Al/day for desired P removal

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

  = 27/31 x 2 x 88

  = 153 pounds of Al per day required to remove 88 pounds of P per day.

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

  = (Wt. of Al/day) / (Weight of 38% LSA/gal x % Al in 38% LSA)

  = (153 pounds of Al/day) / (12.3 pounds/gal x 0.106)

  = 117 gallons/day 38% LSA

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 efficient HMO formation !!

Where's The Best Place to Feed?

Sodium Aluminate Handling and Storage

- Tanks
- Piping
- Valves
- Pumps

Storage & Handling

- Sodium Aluminate solutions are viscous solutions which should be stored at the following temperatures:
  - 38% LSA should be kept above 45^{o} F

Sodium Aluminate Tanks

- Stainless Steel
- Carbon Steel
- Polyethylene
- Rubber-lined (check compatibility)
- Glass-lined
- Fiberglass (check type of resin)

Tanks cont.

- Extend fill pipe to about 6”-12” off the bottom of the tank to minimize air contact.
- Bottom fill.
- Bend vent pipe to prevent precipitation from entering the tank.

Sodium Aluminate Piping

- Carbon Steel (Schedule 40)
- Stainless Steel
- Fiberglass
- CPVC (Schedule 80)
- Teflon-lined
- Use 304 or 316 stainless steel fittings for all hose fittings

Sodium Aluminate - Valves

- Lug body butterfly valves recommended
  - 316 stainless steel disc
  - EPDM seat
- Do not use ball valves!

Sodium Aluminate Pumps

- Recommended: Centrifugal pump (stainless steel, cast iron, or ductile)
- Diaphragm
- Piston

Preventive Maintenance

- Inspect tanks/lines every 3 months.
- Do not flush lines with hot water or steam unless they can be fully dried or flushed with caustic.

Others Are Depending On You!