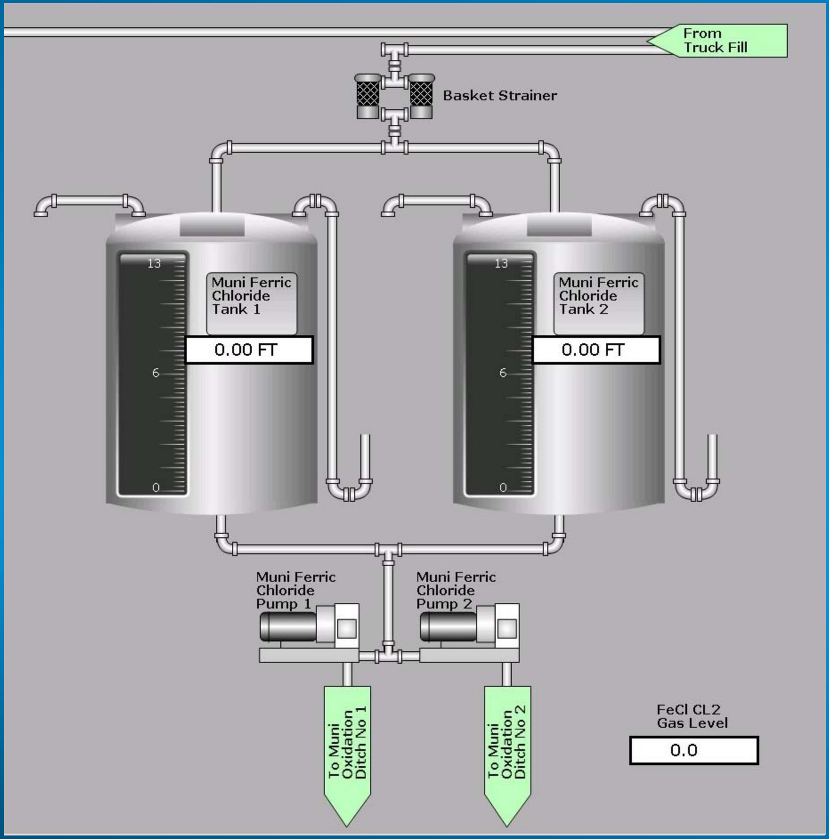
Phosphorus Removal – Operations and Spreadsheets



Wisconsin Wastewater Operators Association
45th Annual Conference
La Crosse, WI
October 5, 2011

Tom Crouse
Eric Lynne

DONOHUE & ASSOCIATES

Outline

- Reason for Phosphorus Removal
- Sources of Phosphorus
- Chemical Removal
- Chemistry of Phosphorus Removal
- Metal Salt MSDS Review

Reason for Phosphorus Removal

- Clean Water Act
- NPDES Permit
  - Reduce environmental harm
  - Cause of Algal Blooms
  - Low Dissolved Oxygen Causes Fish Kills
  - Stream Degradation
  - Hypoxia in Gulf of Mexico

Current Phosphorus Issues

- **NR 217 Promulgated ~1993**
  - Standardized 1 mg/L TP Limit Statewide
- **2010 Revision Establishes**
  - Water Quality Based Limits (WQBLs)
  - Total Maximum Daily Load Allocations
  - Adaptive Management
  - Trading?

2010 Revisions

- **WQBLs**
  - 0.100 mg/L TP for Large Streams
  - 0.075 mg/L TP for Small Streams
- **TMDLs – Possible Limits**
  - 1.0 mg/L TP in When Already Meeting Criteria
  - 0.4-0.6 mg/L TP Likely Range Through TMDL Process When Not Meeting Criteria
- **Up to 9 (+???) Years to Comply**

Effluent Phosphorus Comprised of Two Main Components

- Phosphorus Tied Up in Solids – Particulate Phosphorus (PP)
- Phosphorus in Solution – Soluble (Reactive) Phosphorus (SP)

$$TP = PP + SP$$

Phosphorus Removal As We Know It

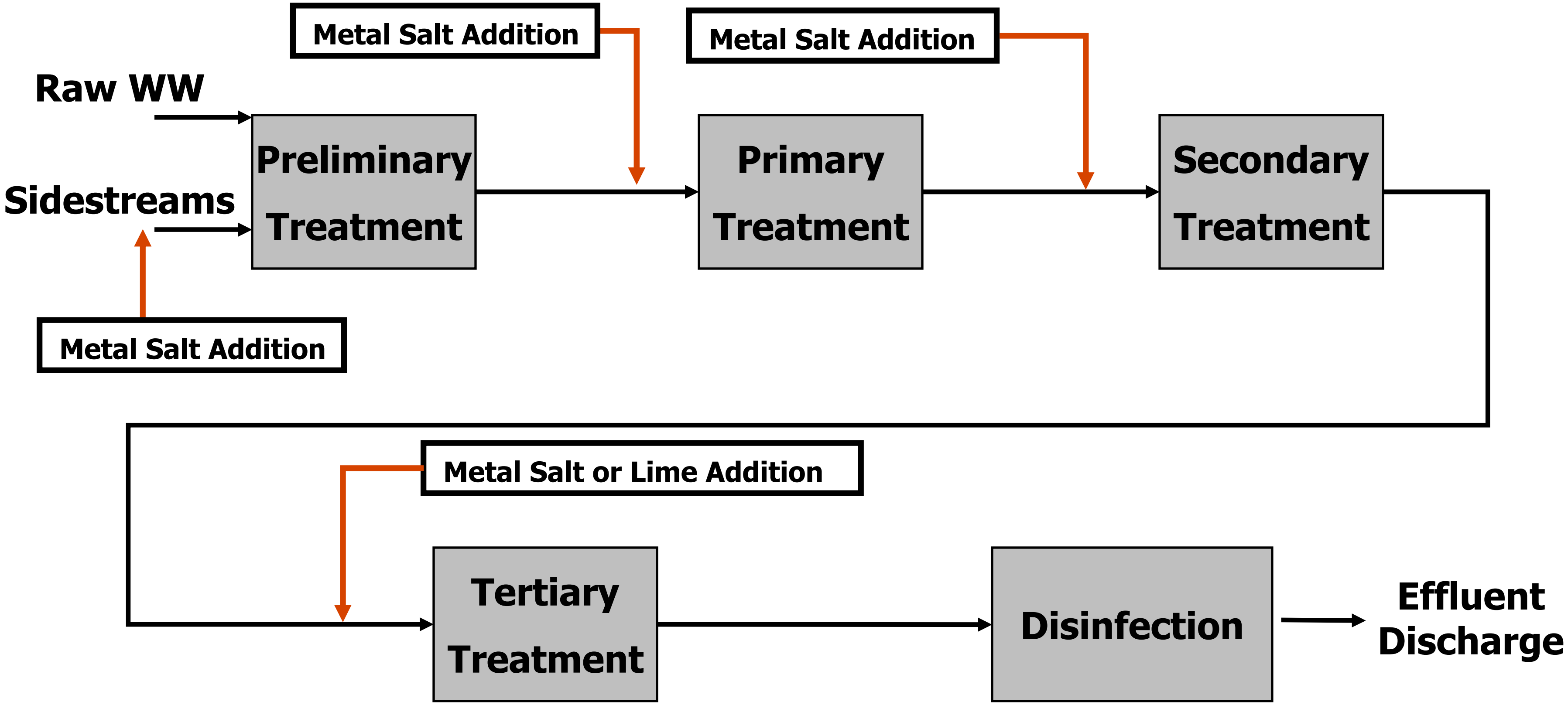
Standard Treatment

- Chemical Phosphorus Removal (Chem P)
- Enhanced Biological Phosphorus Removal (Bio-P, EBPR) with Chem P Backup

Both Approaches Involve Same Strategy

- Convert SP to PP
- Remove PP with TSS (in Sludge or Effluent Filtration)

Typical Chemical Phosphorus Removal Options



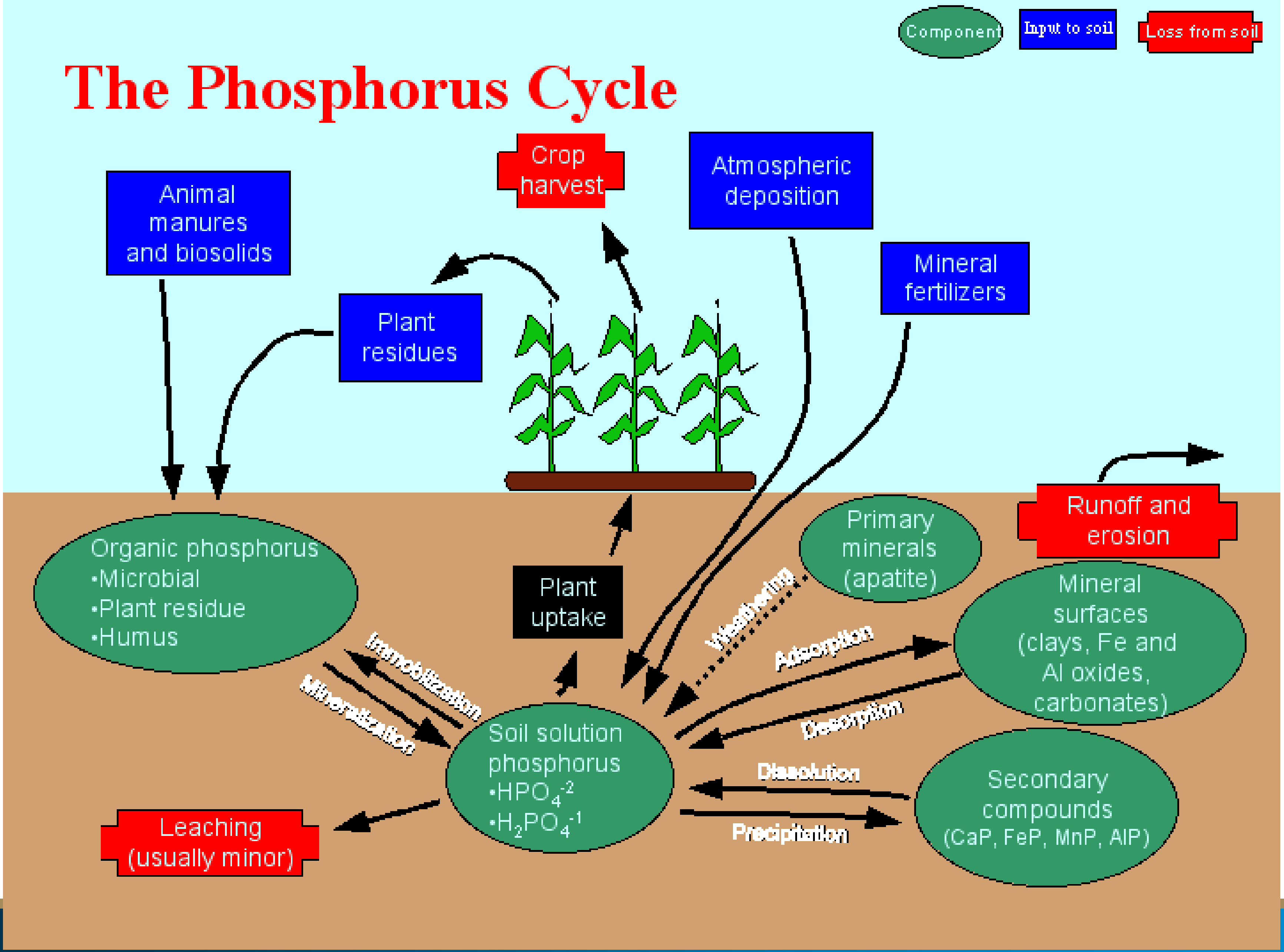
Common Metal Salts Added

- **Iron**
  - Ferric Chloride/Sulfate (Fe^{+3})
  - Ferrous Chloride/Sulfate (Fe^{+2})
    - > Pickle Liquor
    - > Vivianite Issues
- **Aluminum**
  - Aluminum Sulfate/Alum (Al^{+3})

Commonly Assumed Phosphorus Removal Capabilities

- **No Effluent Filtration**
  - Chemical P Removal: 0.5 mg/L TP
  - Bio-P: 1.0 mg/L TP
- **With Effluent Filtration**
  - Chemical P Removal: 0.1 mg/L TP
  - Bio-P: 0.3-0.5 mg/L TP
- **Chem/Bio-P Plus Tertiary Treatment**
  - Water Treatment Systems: 0.05 mg/L TP
  - Iron Filters or R/O: 0.01-0.02 mg/L TP

The Phosphorus Cycle



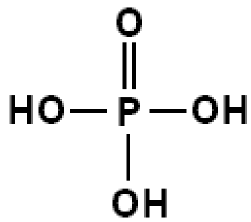
Effects of Excess Phosphorus in Wastewater Effluent

Chemistry of Phosphorus Removal

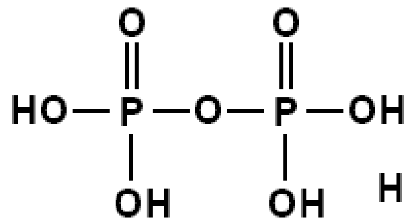
Phosphorus in wastewater occurs in three forms:

- Organic Phosphate
  - Phosphate bound to plant or animal tissue.
- Inorganic Phosphate
  - Polyphosphate (particulate P)
    - Not associated with organic material.
    - Eventually convert to orthophosphate.
  - Orthophosphate (phosphoric acid)
    - Inorganic P, used by organisms.

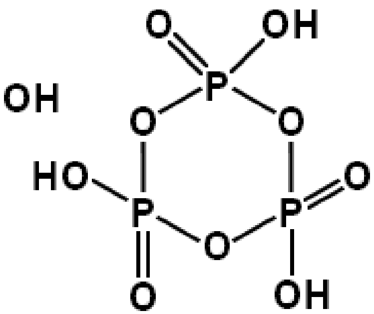
Chemistry of Phosphorus Removal



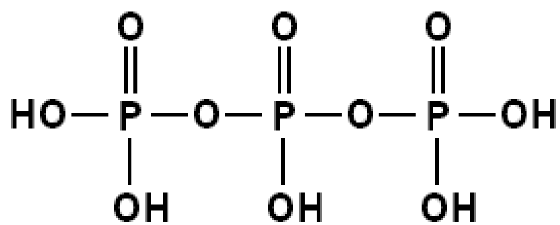
orthophosphoric acid



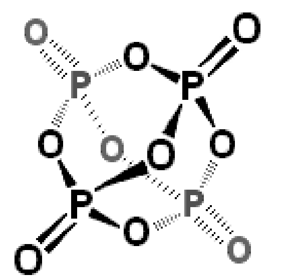
pyrophosphoric acid



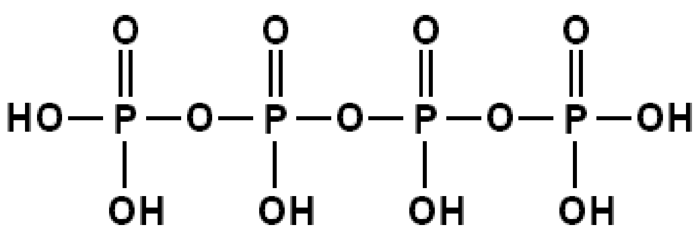
trimetaphosphoric acid



tripolyphosphoric acid



phosphoric anhydride
(P_4O_{10})



tetrapolyphosphoric acid

Chemistry of Phosphorus Removal

K_3PO_4

$Mg_3(PO_4)_2$

$Ca_3(PO_4)_2$

Na_3PO_4

$\longrightarrow$

K^+

Mg^{2+} + PO_4^{3-} + H^+

Ca^{2+}

When the molecules disassociate, an orthophosphate ion (PO_4^{3-}) is formed.

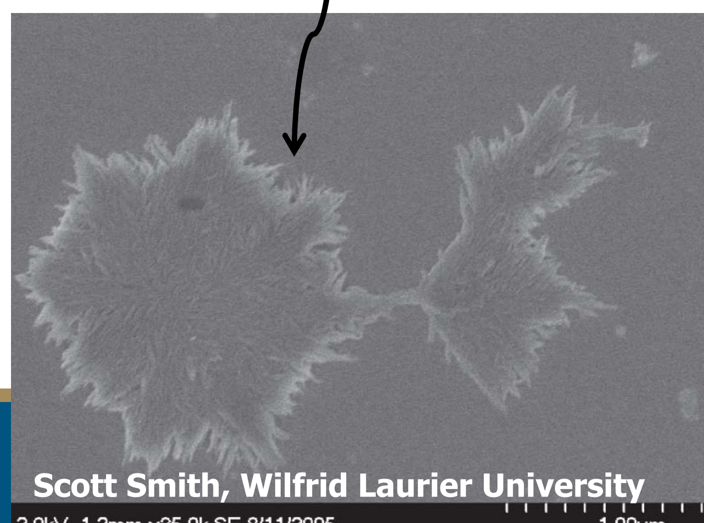
Chemistry of Phosphorus Removal

- **Three common chemicals used:**
  - **Alum $Al_2(SO_4)_3 \cdot 14\ H_2O$**
    - $Al_2(SO_4)_3 \cdot 14\ H_2O + 2PO_4^{3-} \rightarrow 2AlPO_4 + 3SO_4^{2-} + 14\ H_2O$
  - **Ferrous Sulfate $FeSO_4 \cdot 7\ H_2O$**
    - $3(FeSO_4 \cdot 7\ H_2O) + 2PO_4^{3-} \rightarrow (Fe_3PO_4)_2 + 3SO_4^{2-} + 21\ H_2O$
  - **Ferric Chloride $FeCl_3$**
    - $FeCl_3 + PO_4^{3-} \rightarrow Fe_3PO_4 + 1.5\ Cl_2$

Chemistry of Phosphorus Removal
Ferric Chloride

$FeCl_3$

$$\begin{matrix} K^{+} \\ Mg^{2+} \\ Ca^{2+} \\ Na^{+} \end{matrix} + PO_4^{3-} \xrightarrow{FeCl_3} Fe_3PO_4 + \begin{matrix} K^{+} \\ Mg^{2+} \\ Ca^{2+} \\ Na^{+} \end{matrix} + Cl^{-}$$



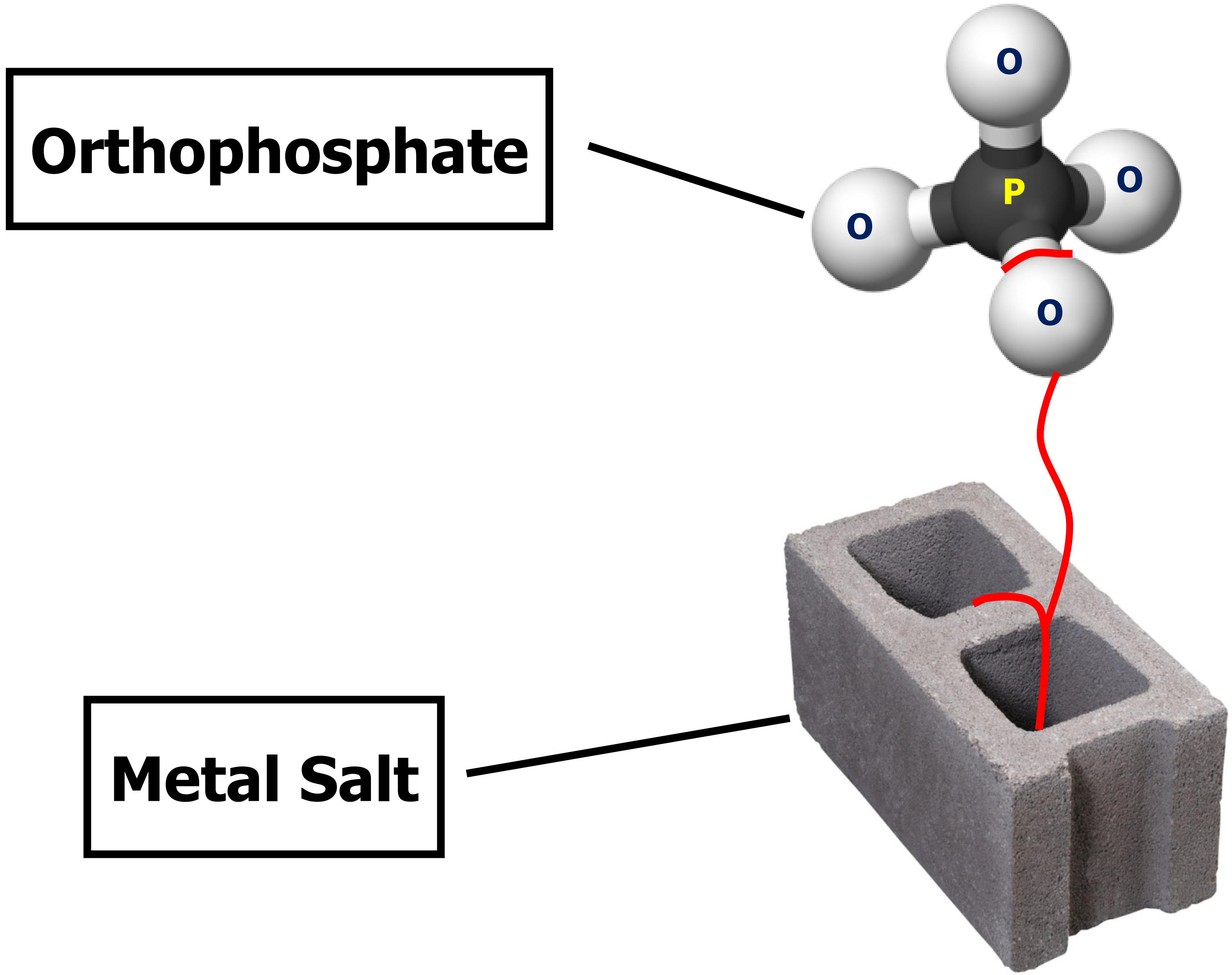
Chemistry of Phosphorus Removal
Ferric Chloride

$FeCl_3$ (acid)

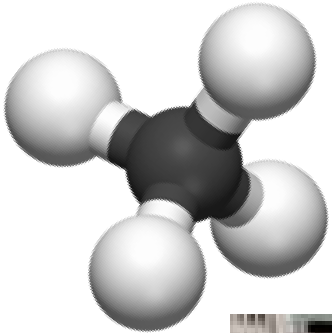
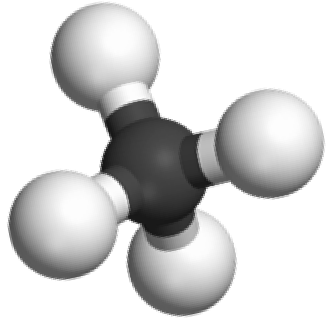
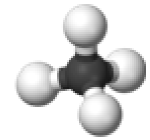
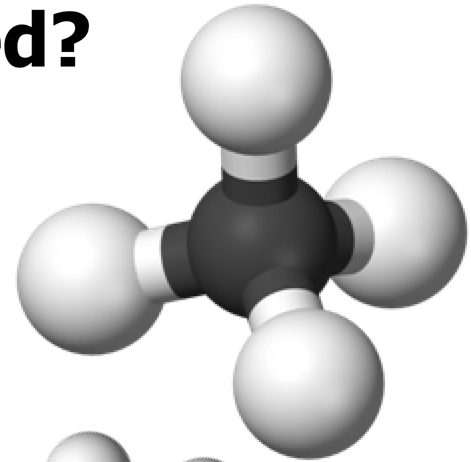
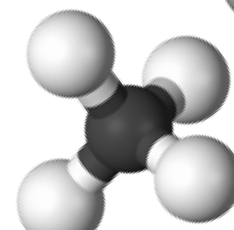
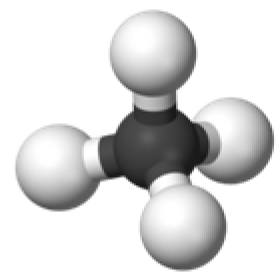
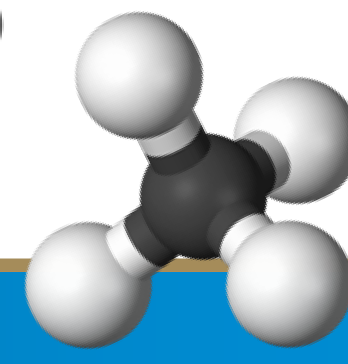
Wastewater (Alkalinity) → $Fe_3(OH)_3$

Hydrous Ferric Oxide (HFO)

- Reduces alkalinity


Orthophosphate
O
O
P
O
O
Metal Salt

How much metal salt do we need?


An easy way to count lots of things.

When counting a pile of coins, it would time consuming to count them one by one.

A smarter strategy is to weigh them. If you know the mass of a penny, then you can count them without counting them.

For example, let's say a penny weighs 2.5 grams. If this stack weighed 2,500 grams, then that means this stack contains 1,000 pennies.

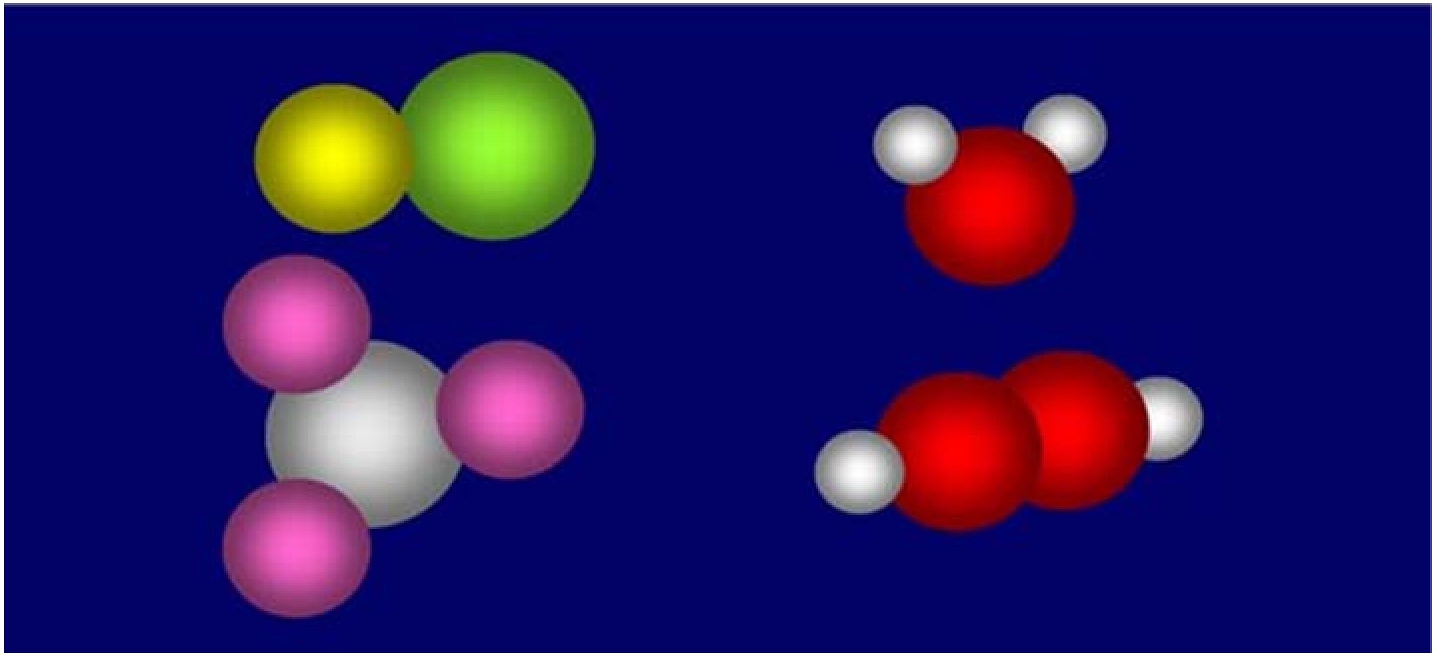
$$2{,}500 \, \cancel{\text{grams}} \times \frac{1 \text{ penny}}{2.5 \, \cancel{\text{grams}}} = 1{,}000 \text{ pennies}$$

At the molecular level, there are only whole numbers.

Atoms combine in simple ratios

1:1, 1:2, 2:2, 3:1, etc.

There are no fractions.



What is a mole (mol)?

The mol is the name for a really big number:

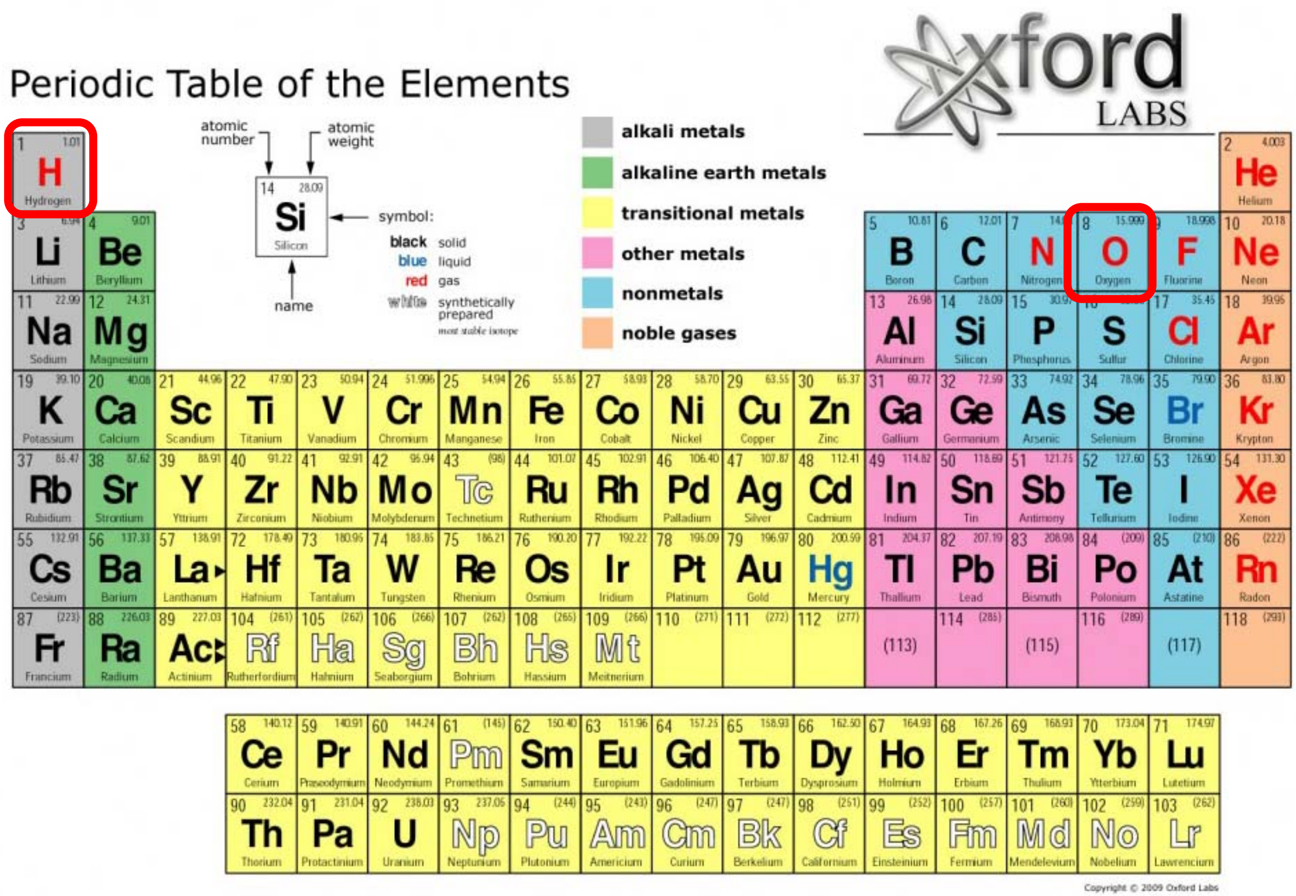
- **602,200,000,000,000,000,000,000**
- **602 sextillion 200 quintillion**
- **6.022×10^{23}**

Why do we need to know what and how big a mol is?

- Molecules are really, really small.
- We can't measure just one or two molecules.
- We like to work with units such as pounds and gallons.

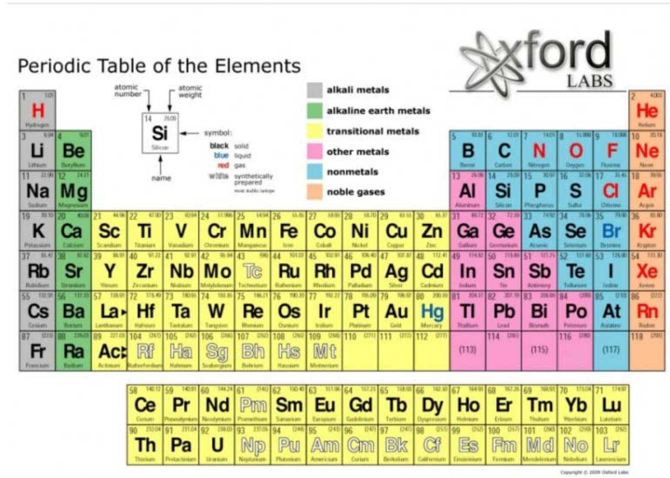
How many molecules of water are in a gallon?

Converting #'s of water to molecules of water.



- **We need to know a few things:**
  - Atomic weight of H
  - Atomic weight of O
  - H = 1.01 #'s/mol
  - O = 16.00 #'s/mol

1 gallon water	= 8.34 #'s
Water	= H_2O
2 H @ 1.01 #'s/mol	= 2.02 #'s H/mol H_2O
1 O @ 16.00 #'s/mol	= 16.00 #'s O/mol H_2O
Water	= 18.02 #'s H_2O/mol



$$8.34\ \cancel{\#\text{'s } H_2O} \times \frac{1\ \text{mol } H_2O}{18.02\ \cancel{\#\text{'s } H_2O}} = 0.46\ \text{mol } H_2O$$

454 mol/#mol

$$0.46\ \#\cancel{\text{mol}}\ H_2O \times \frac{454\ \text{mol}}{\cancel{1\ \#\ \text{mol}}} = 208\ \text{mol } H_2O$$

$$208\ \cancel{\text{mol } H_2O} \times \frac{6.022 \times 10^{23}\ \text{molecules } H_2O}{\cancel{\text{mol } H_2O}} = 1.25 \times 10^{26}\ \text{molecules } H_2O$$

Biological Assimilation

- **Biological assimilation is the amount of phosphorous necessary for biological growth.**
  – BOD:P ratio is 100:1
  – Influent BOD 220 mg/l for a P of 2.2 mg/l
- **If influent phosphorous is 7.6 mg/L:**
  – 7.6 mg/l – 2.2 mg/l = 5.4 mg/l

Typical municipal influent phos. ranges from 5 – 10 mg/L

Enough with the math!
How's this spreadsheet thing work?

- **Some information needs to be gathered:**
  - Influent Phosphorous
  - Influent Flow
  - Influent BOD
  - Bill of lading

Metal Salt Additon for Phosphorus Remova Based on % Metal

The following calculator gives a theoretical amount of chemical to add to remove a desired amount of phosphorus.

Molar Ratio	
Chemical	Metal : P
Alum	0.87 : 1
Ferric Chloride	1.8 : 1
Ferrous Chloride	2.7 : 1
Ferrous Sulfate	2.7: 1

Bill of Lading

Bill of Lading

Flow	2.000	MGD
Influent P	8.0	mg/L
Influent BOD	200	mg/L
% metal in solution	12.5	%
Metal : P ratio	1.8	Molar Ratio
Specific gravity	1.350	SG
#mol metal : #mol Compound	1	Ratio
Atomic Weight	55.85	grams/mol

Chemical	Formula	# mol metal / # mol Coumpound
Alum	$Al_2(SO_4)_3 \cdot 14H_2O$	2
Ferric Chloride	$FeCl_3$	1
Ferrous Chloride	$FeCl_2 \cdot 4 H_2O$	1
Ferrous Sulfate	$FeSO_4$	1

Element	Grams / mol
Aluminum (Al)	26.98
Iron (Fe)	55.85

Step 1. Determine the amount of influent phosphorus in pounds.

2.00 MG / day x 8.0 mg P / Liter x 8.34 L • #s / gallon • MG = 133 #s P / day

Step 2. Determine the amount of influent BOD in pounds.

2.00 MG / day x 200 mg BOD / Liter x 8.34 L • #s / gallon • MG = 3,336 #s BOD / day

Step 3. Determine the amount of P needed for biological assimilation in pounds. 100 #s BOD : 10 #s N : 1 #s P

3,336 #s BOD / day x 1 # P / 100 #s BOD = 33 #s P / day

Step 4. Determine the amount of P to be chemically removed in pounds per day.

133 #s P / day - 33 #s P assim / day = 100 #s P to chemically remove / day

Step 5. Determine the amount of # mol P to be chemically removed per day.

100 #s P to chemically remove / day x 1.00 # mol P / 30.97 # P = 3.23 # mol P to remove / day

Step 6. Determine # mol metal needed to remove P based on molar ratio of metal to P.

3.23 # mol P to remove / day x 1.8 # mol metal / 1.0 # mol P = 5.82 # mol metal / day

Step 7. Determine pounds of metal needed per day

5.82 # mol metal / day x 55.85 #s metal / 1 # mol metal = 324.86 #s metal / day

Step 8. Determine the #s of solution based on bill of lading % needed per day.

325 #s metal @ 100% / day x 100 #s soln / 12.5 #s metal = 2,599 #s soln / day

Step 9. Determine gallons of metal salt solution needed per day.

2,599 #s soln / day x 1 gallon / 8.34 #s x 1 SG soln / 1.350 = 231 gal. soln / day

Step 10. Determine gallons of sol'n needed / hour.

231 gal soln / day x 1 day / 24 hours = 9.62 gal soln / hour

Step 11. Determine milliliters of metal salt sol'n needed per minute.

9.62 gal soln / hour x 3,780 mL / 1 gallon x 1 hour / 60 minutes = 606 mL soln / minute

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SHEBOYGAN, WI 53081
920-208-0402

OR

Metal Salt Additon for Phosphorus Removal Based on % Solution

The following calculator gives a theoretical amount of chemical to add to remove a desired amount of phosphorus.

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Alum	0.87 : 1
Ferric Chloride	1.8 : 1
Ferrous Chloride	2.7 : 1
Ferrous Sulfate	2.7: 1

Bill of Lading

Bill of Lading

Flow	2.000	MGD
Influent P	8.0	mg/L
Influent BOD	200	mg/L
% solution	35.0	%
Metal : P ratio	1.8	Molar Ratio
Specific gravity	1.350	SG
#mol metal : #mol Compound	1	Ratio
Moleculart Weight	162.20	grams/mol

Chemical	Formula	# mol metal / # mol Coumpound	Molecular Weight
Alum	$Al_2(SO_4)_3 \cdot 14H_2O$	2	594.42
Ferric Chloride	$FeCl_3$	1	162.20
Ferrous Chloride	$FeCl_2 \cdot 4 H_2O$	1	198.82
Ferrous Sulfate	$FeSO_4$	1	151.91

Step 1. Determine the amount of influent phosphorus in pounds.

2.00 MG / day x 8.0 mg P / Liter x 8.34 L • #s / gallon • MG = 133 #s P / day

Step 2. Determine the amount of influent BOD in pounds.

2.00 MG / day x 200 mg BOD / Liter x 8.34 L • #s / gallon • MG = 3,336 #s BOD / day

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3,336 #s BOD / day x 1 # P / 100 #s BOD = 33 #s P / day

Step 4. Determine the amount of P to be chemically removed in pounds per day.

133 #s P / day - 33 #s P assim / day = 100 #s P to chemically remove / day

Step 5. Determine the amount of # mol P to be chemically removed per day.

100 #s P to chemically remov / day x 1.00 # mol P / 30.97 # P = 3.23 # mol P to remove / day

Step 6. Determine # mol metal needed to remove P based on ratio of metal to P.

3.23 # mol P to remove / day x 1.8 # mol metal / 1.0 # mol P = 5.82 # mol metal / day

Step 7. Determine the # mol of solution needed / day.

5.82 # mol metal / day x 1 # mol metal compound / 1 # mol metal = 5.82 # mol metal compound / day

Step 8. Determine the #s of solution @ 100% needed / day.

5.82 # mol metal compound / day x 162.20 # compound / 1.0 # mol metal compound = 943 #s compound @ 100 % / day

Step 9. Determine the #s of solution @ bill of lading % needed / day.

943 #s compound @ 100% / day x 100 # soln / 35.0 # compound = 2,696 #s soln / day

Step 10. Determine gallons of metal salt solution needed per day.

2,696 #s soln / day x 1 gallon / 8.34 #s x 1 SG soln / 1.350 = 239 gal. soln / day

Step 11. Determine gallons of sol'n needed / hour.

239 gal soln / day x 1 day / 24 hours = 9.98 gal soln / hour

Step 12. Determine milliliters of metal salt sol'n needed per minute.

9.98 gal soln / hour x 3,780 mL / 1 gallon x 1 hour / 60 minutes = 628 mL soln / minute

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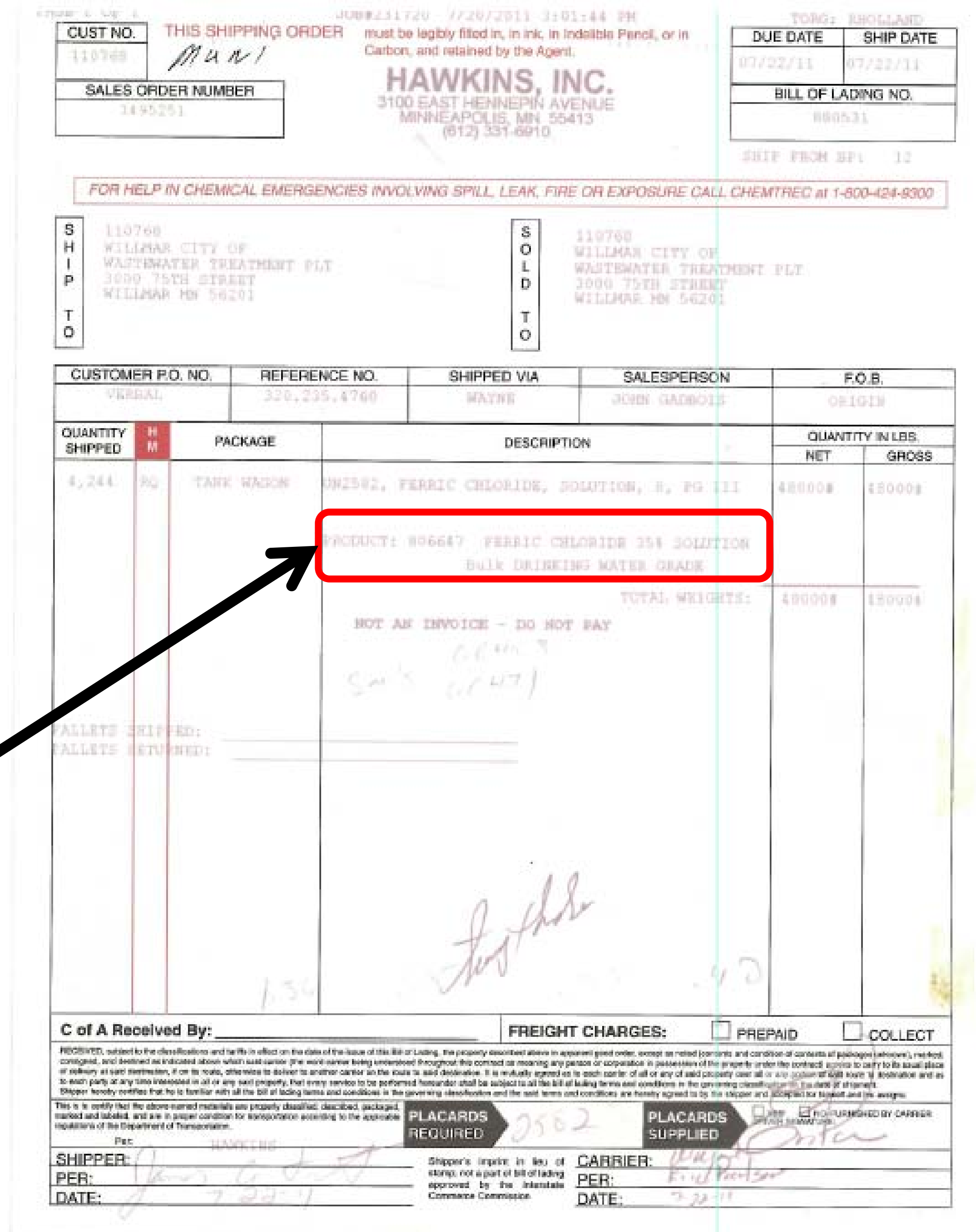
Important!

- % Metal?
- % Solution?

Bill of Lading



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TORG: RHOLLAND

CUST NO. 110760

THIS SHIPPING ORDER must be legibly filled in, in ink, in Indelible Pencil, or in Carbon, and retained by the Agent.

SALES ORDER NUMBER 1495251

HAWKINS, INC.
3100 EAST HENNEPIN AVENUE
MINNEAPOLIS, MN 55413
(612) 331-6910

DUE DATE	SHIP DATE
07/22/11	07/22/11

BILL OF LADING NO. 880531

SHIP FROM BP: 12

FOR HELP IN CHEMICAL EMERGENCIES INVOLVING SPILL, LEAK, FIRE OR EXPOSURE CALL CHEMTREC at 1-800-424-9300

SHIP TO:
110760
WILLMAR CITY OF
WASTEWATER TREATMENT PLT
3000 75TH STREET
WILLMAR MN 56201

SOLD TO:
110760
WILLMAR CITY OF
WASTEWATER TREATMENT PLT
3000 75TH STREET
WILLMAR MN 56201

CUSTOMER P.O. NO.	REFERENCE NO.	SHIPPED VIA	SALESPERSON	F.O.B.
VERBAL	320.235.4760	WAYNE	JOHN GADBOIS	ORIGIN

QUANTITY SHIPPED	HM	PACKAGE	DESCRIPTION	QUANTITY IN LBS. NET	QUANTITY IN LBS. GROSS
4,244	RQ	TANK WAGON	UN2582, FERRIC CHLORIDE, SOLUTION, 8, PG III	48000#	50000#
			PRODUCT: 806647 FERRIC CHLORIDE 35% SOLUTION Bulk DRINKING WATER GRADE		
			TOTAL WEIGHTS:	48000#	50000#

NOT AN INVOICE - DO NOT PAY

PALLETS SHIPPED:
PALLETS RETURNED:

C of A Received By:

FREIGHT CHARGES: PREPAID COLLECT

PLACARDS REQUIRED 2582

PLACARDS SUPPLIED

Per: HAWKINS

SHIPPER:
PER:
DATE: 7-22-11

CARRIER:
PER:
DATE: 7-22-11

Metal Salt Additon for Phosphorus Removal Based on % Solution

The following calculator gives a theoretical amount of chemical to add to remove a desired amount of phosphorus.

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Chemical	**Metal : P**
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Ferrous Chloride	2.7 : 1
Ferrous Sulfate	2.7: 1

Bill of Lading

Bill of Lading

Chemical	Formula	# mol metal # mol Coumpound	Molecular Weight
Alum	$Al_2(SO_4)3 \cdot 14H_2O$	2	594.42
Ferric Chloride	$FeCl_3$	1	162.20
Ferrous Chloride	$FeCl_2 \cdot 4\ H_2O$	1	198.82
Ferrous Sulfate	$FeSO_4$	1	151.91

Flow	2.000	MGD
Influent P	8.0	mg/L
Influent BOD	200	mg/L
% solution	35.0	%
Metal : P ratio	1.8	Molar Ratio
Specific gravity	1.350	SG
#mol metal : #mol Compound	1	Ratio
Moleculart Weight	162.20	grams/mol

Yellow column with colored numbers indicates where data needs to be entered.

Flow	*2.000*	MGD
Influent P	*8.0*	mg/L
Influent BOD	*200*	mg/L
% solution	*35.0*	%
Metal : P ratio	*1.8*	Molar Ratio
Specific gravity	*1.350*	SG
#mol metal : #mol Compound	*1*	Ratio
Moleculart Weight	*162.20*	grams/mol

Step 1.

Remember the pounds formula?

MGD X mg/L X 8.34 #'s/gallon

Step 1. ***Determine the amount of influent phosphorus in pounds.***

$$\frac{2.00\ \text{MG}}{\text{day}} \times \frac{8.0\ \text{mg P}}{\text{Liter}} \times \frac{8.34\ \text{L} \cdot \text{\#'s}}{\text{gallon} \cdot \text{MG}} = \frac{133\ \text{\#'s P}}{\text{day}}$$

Flow	2.000	MGD
Influent P	8.0	mg/L
Influent BOD	200	mg/L
% solution	35.0	%
Metal : P ratio	1.8	Molar Ratio
Specific gravity	1.350	SG
#mol metal : #mol Compound	1	Ratio
Moleculart Weight	162.20	grams/mol

Step 2.

Pounds formula again.

MGD X mg/L X 8.34 #'s/gallon

Step 2. Determine the amount of influent BOD in pounds.

$$\frac{2.00 \text{ MG}}{\text{day}} \times \frac{200 \text{ mg BOD}}{\text{Liter}} \times \frac{8.34 \text{ L} \cdot \text{\#'s}}{\text{gallon} \cdot \text{MG}} = \frac{3{,}336 \text{ \#'s BOD}}{\text{day}}$$

Flow	2.000	MGD
Influent P	8.0	mg/L
Influent BOD	200	mg/L
% solution	35.0	%
Metal : P ratio	1.8	Molar Ratio
Specific gravity	1.350	SG
#mol metal : #mol Compound	1	Ratio
Moleculart Weight	162.20	grams/mol

Step 3.

Nutrient Ratio #'s BOD:N:P

100:10:1

#'s BOD ÷ 100

Step 3. Determine the amount of P needed for biological assimilation in pounds. 100 #'s BOD : 10 #'s N : 1 #'s P

$$\frac{3{,}336 \text{ \#'s BOD}}{\text{day}} \times \frac{1 \text{ \# P}}{100 \text{ \#'s BOD}} = \frac{33 \text{ \#'s P}}{\text{day}}$$

Flow	*2.000*	MGD
Influent P	*8.0*	mg/L
Influent BOD	*200*	mg/L
% solution	*35.0*	%
Metal : P ratio	*1.8*	Molar Ratio
Specific gravity	*1.350*	SG
#mol metal : #mol Compound	*1*	Ratio
Moleculart Weight	*162.20*	grams/mol

Step 4.

Determine pounds of phosphorus to be chemically removed per day.

#'s Influent P - #'s P needed for bugs

133	#'s P
day	

\-

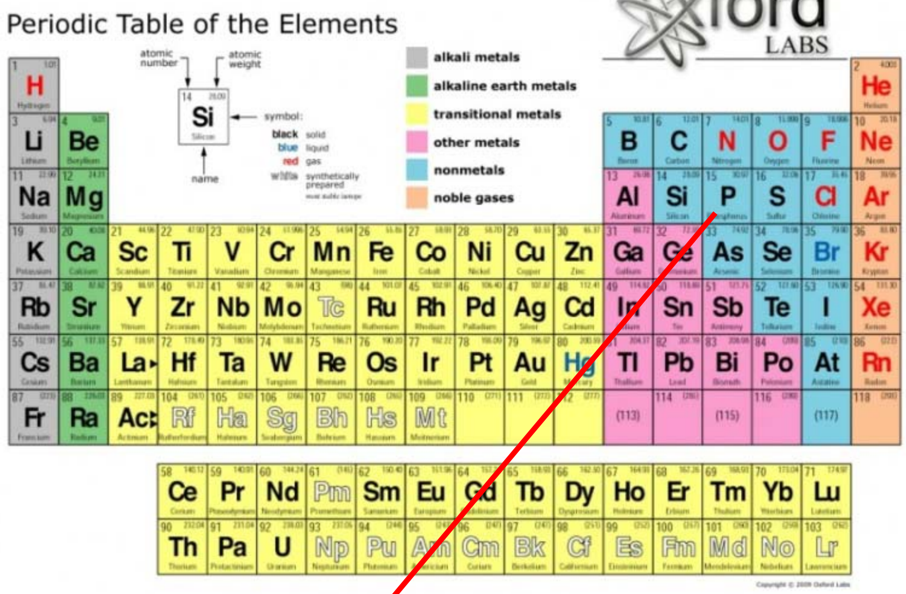
33	#'s P assim
day	

=

100	#'s P to chemically remove
day	

Step 5.

Determine # mols of phosphorus to be chemically removed per day.



#'s P ÷ Atomic Weight of P

100 #'s P to chemically remove	x	1.00 # mol P	=	3.23 # mol P to remove
day		30.97 # P		day

Flow	2.000	MGD
Influent P	8.0	mg/L
Influent BOD	200	mg/L
% solution	35.0	%
Metal : P ratio	1.8	Molar Ratio
Specific gravity	1.050	SG
#mol metal : #mol Compound	1	Ratio
Moleculart Weight	162.20	grams/mol

Step 6.

Determine # mols metal needed to remove P based on ration of metal to P.

#mol P x (#mol metal/#mol P)

3.23	# mol P to remove	x	1.8	# mol metal	=	5.82	# mol metal
day			1.0	# mol P		day	

Flow	2.000	MGD
Influent P	8.0	mg/L
Influent BOD	200	mg/L
% solution	35.0	%
Metal : P ratio	1.8	Molar Ratio
Specific gravity	1.350	SG
#mol metal : #mol Compound	1	Ratio
Moleculart Weight	162.20	grams/mol

Step 7.

Determine # mols solution needed per day.

#mol metal x (#mol metal compound/#mol metal)

5.82	# mol metal	x	1	# mol metal compound	=	5.82	# mol metal compound
day			1	# mol metal		day	

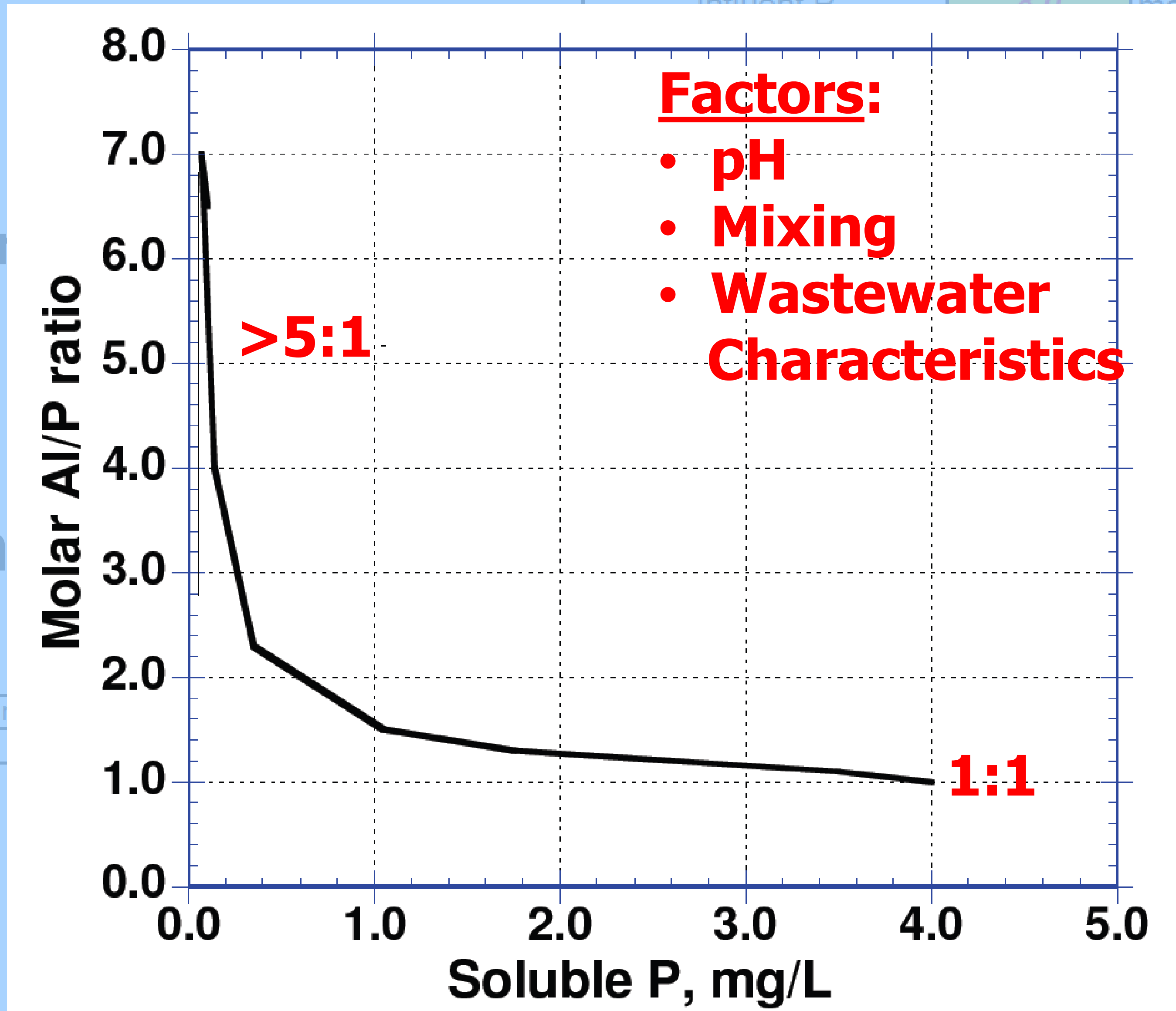
Flow	2.000	MGD
Influent P	8.0	mg/L
		/L
		lar Ratio
		tio
		ms/mol

Step 7.

Determine
needed pe

#mol m
metal)

5.82	# mol	al compound
day		



Flow	2.000	MGD
Influent P	8.0	mg/L
Influent BOD	200	mg/L
% solution	35.0	%
Metal : P ratio	1.8	Molar Ratio
Specific gravity	1.350	SG
#mol metal : #mol Compound	1	Ratio
Moleculart Weight	162.20	grams/mol

Step 8.

Determine # solution at 100% needed per day.

#mol metal compound x (#'s compound/#mol metal compound)

5.82	# mol metal compound	x	162.20	# compound	=	943	#'s compound @ 100 %
day			1.0	# mol metal compound		day	

Flow	2.000	MGD
Influent P	8.0	mg/L
Influent BOD	200	mg/L
% solution	35.0	%
Metal : P ratio	1.[illegible]	Molar Ratio
Specific gravity	1.350	SG
#mol metal : #mol Compound	1	Ratio
Moleculart Weight	162.20	grams/mol

Step 9.

Determine #'s solution at bill of lading % needed per day.

#compound @ 100% ÷ # compound bill of lading %

$$\frac{943 \text{ \#'s compound @ 100\%}}{\text{day}} \times \frac{100 \text{ \# sol'n}}{35.0 \text{ \# compound}} = \frac{2{,}696 \text{ \#'s sol'n}}{\text{day}}$$

Flow	2.000	MGD
Influent P	8.0	mg/L
Influent BOD	200	mg/L
% solution	35.0	%
Metal : P ratio	1.8	Molar Ratio
Specific gravity	1.350	SG
#mol metal : #mol Compound	1	Ratio
Moleculart Weight	162.20	grams/mol

Step 10.

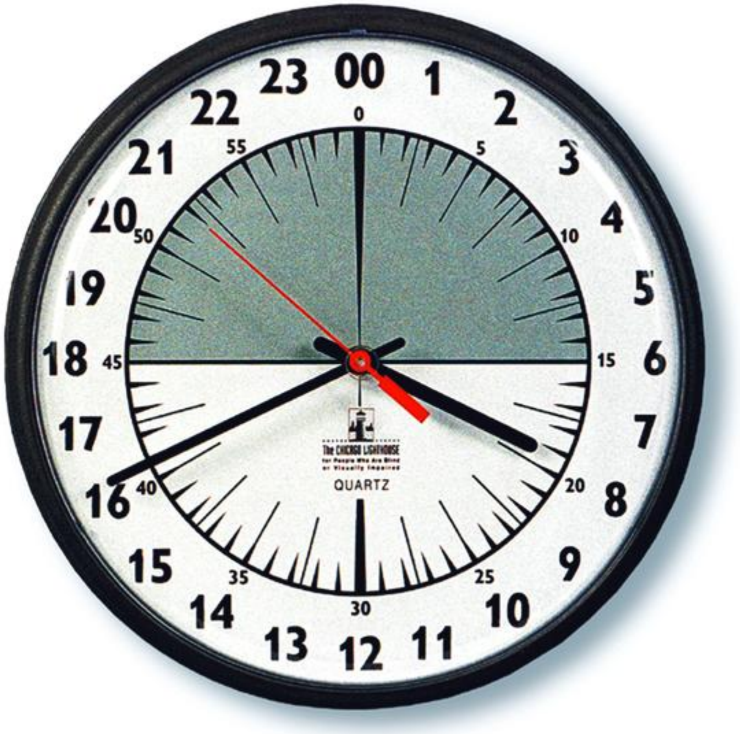
Determine gallons of metal salt solution needed per day.

#sol’n ÷ 8.34 # ÷ 1.350 SG

$$\frac{2{,}696 \text{ \#'s sol'n}}{\text{day}} \times \frac{1 \text{ gallon}}{8.34 \text{ \#'s}} \times \frac{1 \text{ SG sol'n}}{1.350} = \frac{239 \text{ gal. sol'n}}{\text{day}}$$

Step 11.

Determine gallons of solution needed per hour.



gal sol’n/day ÷ 24 hours/day

$$\frac{239 \text{ gal sol'n}}{\text{day}} \times \frac{1 \text{ day}}{24 \text{ hours}} = \frac{9.98 \text{ gal sol'n}}{\text{hour}}$$

Step 12.

Determine milliliters of solution needed per minute.

gal sol'n/hour x 3,780 mL/gal ÷ 60 min/hour

9.98 gal sol'n	x	3,780 mL	x	1 hour	=	628 mL sol'n
hour		1 gallon		60 minutes		minute

Inputs

Metal Salt Additon for Phosphorus Removal Based on % Solution

The following calculator gives a theoretical amount of chemical to add to remove a desired amount of phosphorus.

Molar Ratio	
Chemical	Metal : P
Alum	0.87 : 1
Ferric Chloride	1.8 : 1
Ferrous Chloride	2.7 : 1
Ferrous Sulfate	2.7: 1

Bill of Lading

Bill of Lading

Flow	2.000	MGD
Influent P	8.0	mg/L
Influent BOD	200	mg/L
% solution	35.0	%
Metal : P ratio	1.8	Molar Ratio
Specific gravity	1.350	SG
#mol metal : #mol Compound	1	Ratio
Molecular Weight	162.20	grams/mol

Chemical	Formula	# mol metal / # mol Coumpound	Molecular Weight
Alum	$Al_2(SO_4)3 \cdot 14H_2O$	2	594.42
Ferric Chloride	$FeCl_3$	1	162.20
Ferrous Chloride	$FeCl_2 \cdot 4\ H_2O$	1	198.82
Ferrous Sulfate	$FeSO_4$	1	151.91

Step 1. *Determine the amount of influent phosphorus in pounds.*

2.00 MG / day x 8.0 mg P / Liter x 8.34 L • #s / gallon • MG = 133 #s P / day

Step 2. *Determine the amount of influent BOD in pounds.*

2.00 MG / day x 200 mg BOD / Liter x 8.34 L • #s / gallon • MG = 3,336 #s BOD / day

Step 3. *Determine the amount of P needed for biological assimilation in pounds. 100 #s BOD : 10 #s N : 1 #s P*

3,336 #s BOD / day x 1 # P / 100 #s BOD = 33 #s P / day

Step 4. *Determine the amount of P to be chemically removed in pounds per day.*

133 #s P / day - 33 #s P assim / day = 100 #s P to chemically remove / day

Step 5. *Determine the amount of # mol P to be chemically removed per day.*

100 #s P to chemically remov / day x 1.00 # mol P / 30.97 # P = 3.23 # mol P to remove / day

Step 6. *Determine # mol metal needed to remove P based on ratio of metal to P.*

3.23 # mol P to remove / day x 1.8 # mol metal / 1.0 # mol P = 5.82 # mol metal / day

Step 7. *Determine the # mol of solution needed / day.*

5.82 # mol metal / day x 1 # mol metal compound / 1 # mol metal = 5.82 # mol metal compound / day

Step 8. *Determine the #s of solution @ 100% needed / day.*

5.82 # mol metal compound / day x 162.20 # compound / 1.0 # mol metal compound = 943 #s compound @ 100 % / day

Step 9. *Determine the #s of solution @ bill of lading % needed / day.*

943 #s compound @ 100% / day x 100 # sol'n / 35.0 # compound = 2,696 #s sol'n / day

Step 10. *Determine gallons of metal salt solution needed per day.*

2,696 #s sol'n / day x 1 gallon / 8.34 #s x 1 SG sol'n / 1.350 = 239 gal. sol'n / day

Step 11. *Determine gallons of sol'n needed / hour.*

239 gal sol'n / day x 1 day / 24 hours = 9.98 gal sol'n / hour

Step 12. *Determine milliliters of metal salt sol'n needed per minute.*

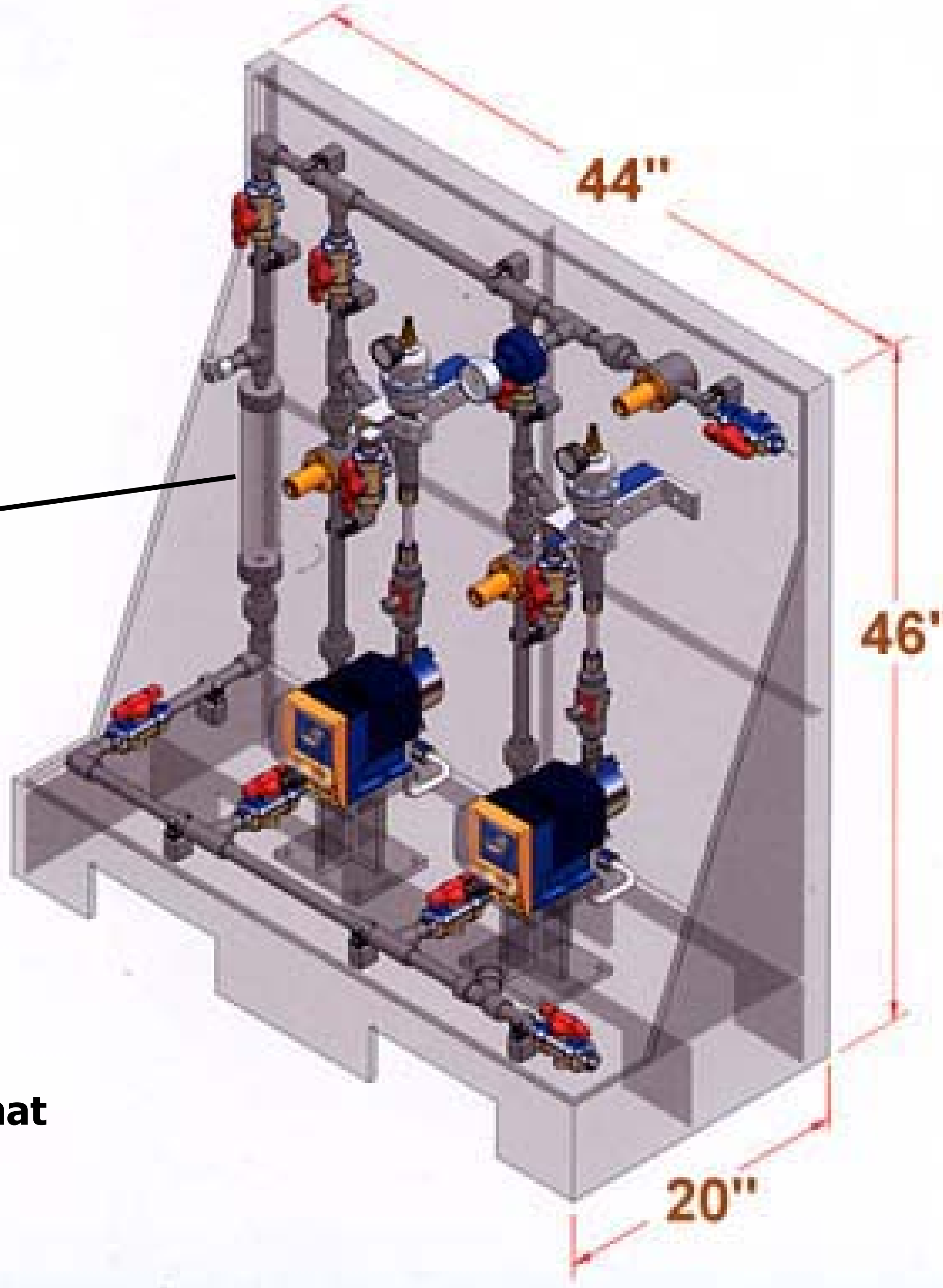
9.98 gal sol'n / hour x 3,780 mL / 1 gallon x 1 hour / 60 minutes = 628 mL sol'n / minute

Outputs

DONOHUE AND ASSOCIATES
3311 WEEDEN CREEK RD
SHEBOYGAN, WI 53081
920-208-0402

Typical chemical feed skid.

Calibration column



Example of equipment shown in is NOT intended to infer any endorsement of that equipment.

Metal Salt MSDS Review




- **Exposure Controls**
  - Protective eyeglasses or chemical safety goggles.
  - Appropriate protective clothing to prevent skin contact.
  - Use a NIOSH approved respirator when necessary.

Any Questions?

References

Information for this training module was derived from the following sources:

- Operation of Wastewater Treatment Plants Volume 1 and 2, Office of Water Programs CSU Sacramento
- Advanced Waste Treatment, Office of Water Programs CSU Sacramento
- Wastewater Engineering, Treatment and Reuse, Metcalf and Eddy
- Activated Sludge Microbiology Problems and Their Control, Michael Richard, Ph.D.
- Operator’s Pocket Guide to Activated Sludge Part I and II, Stevens, Thompson, and Runyan