

REINHOLD ENVIRONMENTAL Ltd.



2018 APC & Wastewater Round Table & Expo Presentation

July 23 & 24, 2018 in Lexington, KY / Hosted by East Kentucky Power Coop

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wastewater 101

overview of physical and
chemical treatment technologies

July 23, 2018

Reinhold Environmental Conference

ready for the resource revolution



coal fired-power plant waste streams

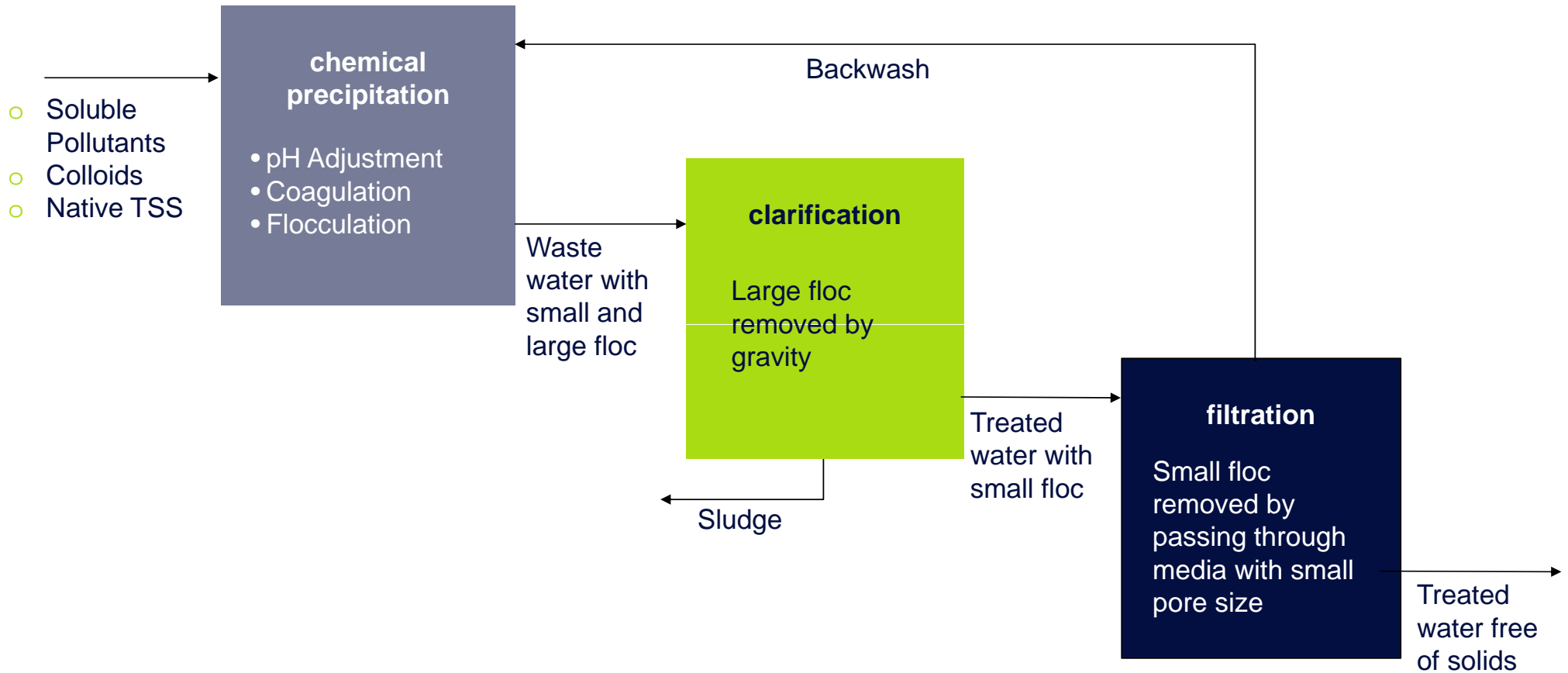


- FGD scrubber blowdown
- Cooling tower blowdown
- Coal pile runoff
- Landfill leachate
- Miscellaneous plant drains
- Outage wash water

coal fired-power plant waste streams

Waste stream	Characteristics	Treatment	Challenges
FGD Scrubber Blowdown	<ul style="list-style-type: none"> • High solids • Metals • Corrosive • Abrasive 	<ul style="list-style-type: none"> • Phys-Chem • Biological • ZLD 	<ul style="list-style-type: none"> • Low effluent limits • Materials of construction • Solids handling
Cooling Tower Blowdown	<ul style="list-style-type: none"> • High flow rate • Low solids 	<ul style="list-style-type: none"> • None (usually) 	<ul style="list-style-type: none"> • None
Coal Pile Runoff	<ul style="list-style-type: none"> • Low pH • Iron and manganese 	<ul style="list-style-type: none"> • Clarification • Filtration (if required) 	<ul style="list-style-type: none"> • Manganese
Landfill Leachate	<ul style="list-style-type: none"> • Metals • Selenium 	<ul style="list-style-type: none"> • Clarification • Filtration (if required) • Biological (if required) 	<ul style="list-style-type: none"> • Selenium
Miscellaneous Plant Drains	<ul style="list-style-type: none"> • Highly variable 	<ul style="list-style-type: none"> • Clarification • Filtration (if required) 	<ul style="list-style-type: none"> • Variable flow rate and characteristics
Outage Wash Water	<ul style="list-style-type: none"> • Highly variable (especially flow) 	<ul style="list-style-type: none"> • Clarification • Filtration (if required) 	<ul style="list-style-type: none"> • Variable flow rate

basic steps



coagulation

By inorganic coagulants:

- Charge Neutralization
 - Fe^{3+} , Fe^{2+} , Al^{3+}
- Self Precipitation as Hydroxide
- Adsorb Particles and Enhance Settling

By organic coagulants:

- Charge Neutralization and Destabilization

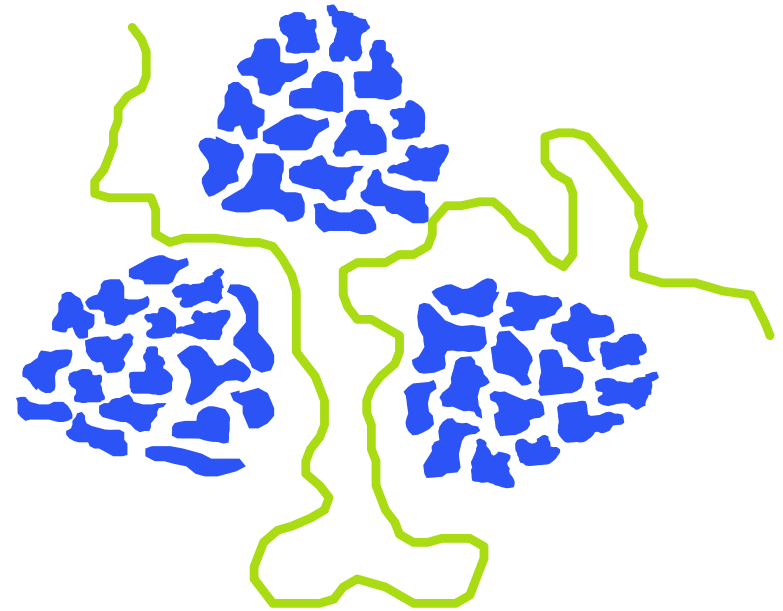


flocculation

Bridging mechanism between neutralized colloidal particles:

- Particle-to-particle contact
- Inter-particle bridging
- Enmeshment

High molecular weight water soluble polymers



optimization of coagulation

- Selection of optimum coagulant(s)
- Proper coagulant dosage
- Coagulation pH (pre-acidification or supplemental alkalinity)
- Order of addition of coagulant & other chemicals
- Mixing energy / retention times
- Selection of optimum flocculant or polymer
- Optimum flocculation (retention / mixing)

metals removal - an ever-increasing market

- Is the metal soluble or already precipitated – usually use lime or caustic high-pH process
- Alternative precipitation/treatment processes:
(sulfide, organosulfides and other organic complexes), and in some cases biological processes
- **PAY ATTENTION TO VALENCE OR OXIDATION STATE – VERY IMPORTANT IN DETERMINING:**
 1. What process is best to remove the metal most efficiently.
 2. To what extent the metal can be removed.

metals control technologies: water issues

- Capability- how low can it go
- Wastewater chemistry
- Residuals: volume, TCLP, segregation
- Analytical: ppm, ppb, ppt
- Potential side effects of approach
- Ease of use and control
- Cost
 - Chemical
 - Equipment (capital and operating)
 - Residuals disposal

national summary

causes of impairment in assessed rivers and streams

<u>Cause of Impairment Group</u>	<u>Miles Threatened or Impaired</u>
<u>Pathogens</u>	141,699
<u>Sediment</u>	107,650
<u>Nutrients</u>	101,395
<u>Organic Enrichment/Oxygen Depletion</u>	83,530
<u>Habitat Alterations</u>	82,510
<u>Polychlorinated Biphenyls (PCBs)</u>	72,888
<u>Metals (other than Mercury)</u>	64,781
<u>Flow Alteration(s)</u>	56,813
<u>Mercury</u>	46,922
<u>Temperature</u>	46,799
<u>Cause Unknown</u>	35,394
<u>Salinity/Total Dissolved Solids/Chlorides/Sulfates</u>	32,492
<u>Cause Unknown - Impaired Biota</u>	30,991
<u>pH/Acidity/Caustic Conditions</u>	28,343
<u>Turbidity</u>	27,021



Source: US EPA

the power industry and mercury (Hg)

mercury discharge regulations

Driven by concern over the neurotoxicity of Hg to humans and the tendency of Hg to accumulate in the food chain

EPA Clean Air Mercury Rule (CAMR)

- Permanently caps and reduces Hg emissions from coal-fired power plants (responsible for 40% of US Hg emissions)
- 2009: Hg monitoring required
- 2010: Phase 1 - emissions cap at 38 tons
- 2018: Phase 2 – emissions cap at 15 tons

Great Lakes Initiative (EPA Regions 2, 3 and 5)

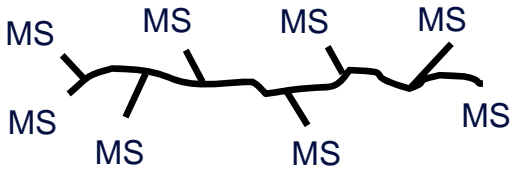
- Limits Hg in lakes and streams to 1.3 ng/l

Ohio River Valley Water Sanitation Commission

- Limits Hg discharge to 12 ng/l

advanced metals removal

Organosulfides (like SUEZ's MetClear* MR2405) = organic-S based polymers with functional sites to attract soluble metals, forms insoluble complex



- Much lower solubility than metal hydroxide (pH adjustment only)
- Captures those metals that hydroxide precipitation can't quite get
- Ppb and ppt levels Hg reached as part of **a total treatment program**
 - ***With and without coagulant and/or flocculant (system dependent)***

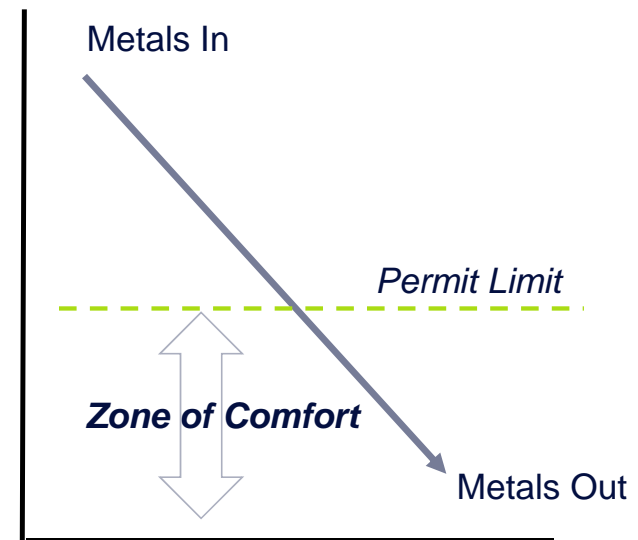
mercury control technologies: air

- **Flue gas desulfurization (FGD) processes**
 - Lime based, already in-place at many power plants to control SO_x emissions
 - Transfers airborne Hg contaminants to wastewater
- **Specialty catalysts**
 - Oxidize Hg⁰ to water soluble Hg⁺²
 - Transfers Hg to wastewater
- **Adsorption processes**
 - Activated carbon, specialty adsorbents

options for enhanced metals removal

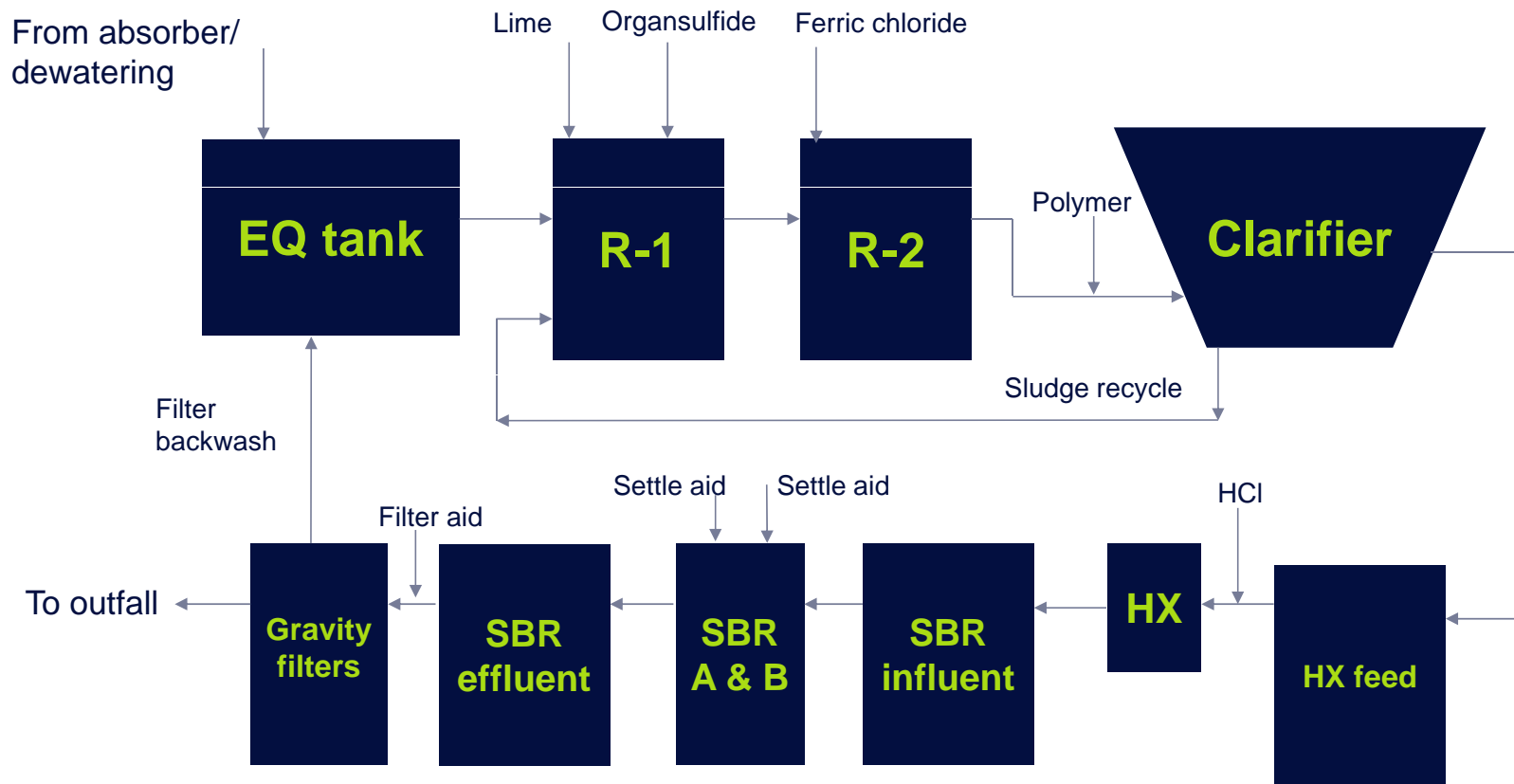
- **Optimization of water pH***
- **Use coagulants**
 - KlarAid* from SUEZ¹
- **Use of organosulfide based precipitant**
 - MetClear* from SUEZ¹
- **Use of flocculant**
 - PolyFloc* or Novus* portfolio from SUEZ¹
- **Primary solids separation**
- **Post clarification filtration¹**

¹Varies, as required

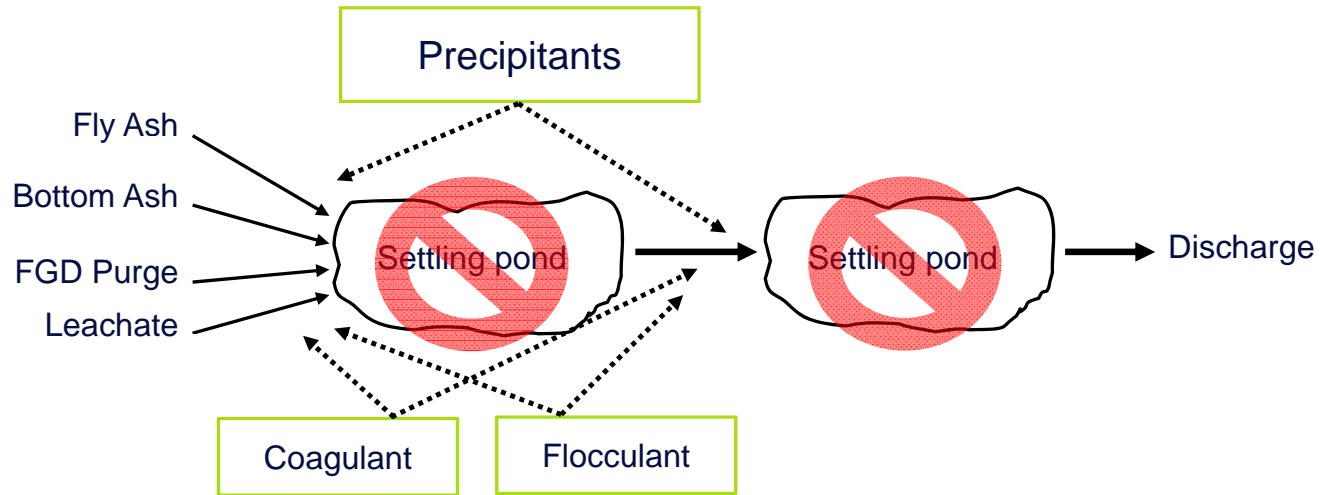


* Trademark of SUEZ; may be registered in one or more countries

FGD scrubber WWTP with nitrogen removal



settling ponds



Settling ponds that are not lined are going away!

other ww treatment example

Cooling water blowdown to pond

- **Issue:** High TSS issues at outfall with TSS linked to Cu
 - **Inlet:** 100-400 ppm TSS; Cu 200 -300 ppb
- **Solution:** 3 prong approach
 - Organosulfide (MR2405) + KlarAid coagulant + PolyFloc flocculant
- **Results:** TSS @ 15 ppm; Cu @ 19 ppb TARGET = < 30 ppm TSS & < 30 ppb Cu
- **Benefits:**
 - Met new more stringent NPDES permit of 30 ppb Cu
 - Savings of +\$120K per quarter vs past chemical use and labor savings to deal with prior program

other ww treatment example 2

Issue: FGD solids balance issues affecting system solids inventory

System: FGD thickener and associated sludge dewatering circuit

Solution: Implementation of a mass balance program using system data on solids balance + plant operational data to understand the relationships of operations on solids generation/removal.

Results: Better mass balance control to allow plant to manage solids blowdown and overall improved thickener /dewatering operation.

Benefits:

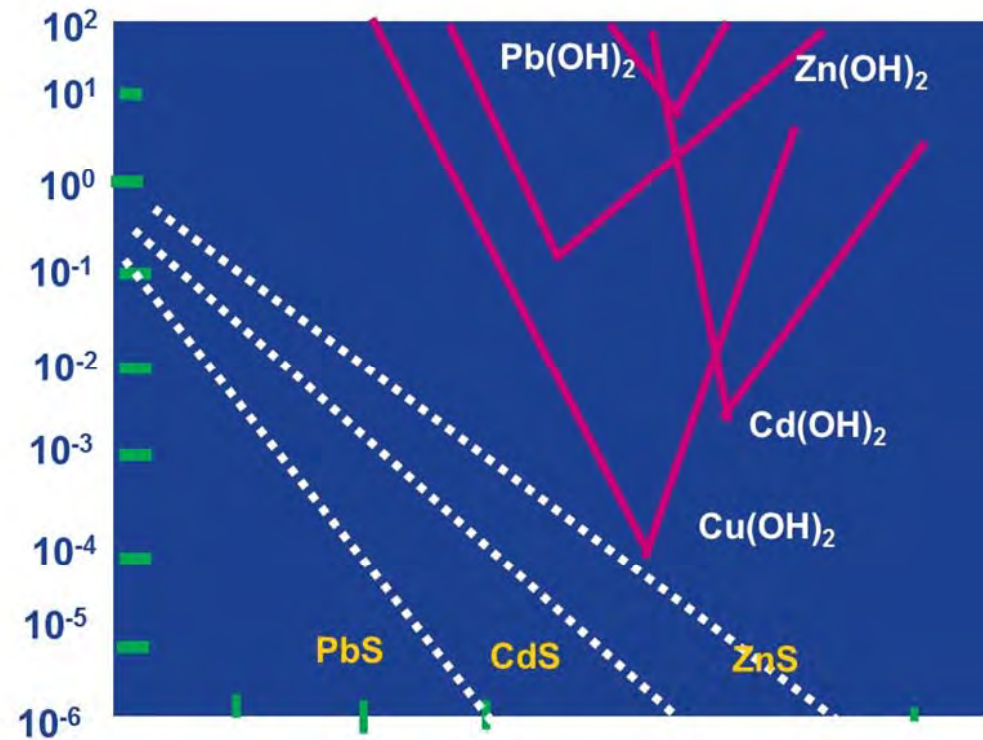
- Avg. FGD solids removal per lb polymer used increased 22% (better capture and efficiency of the polymer)
- Realized savings of >\$500,000 last 3 years

importance of pH

- Metal Hydroxide Solubility
 - Different for each metal
 - Alkaline pHs
 - Use of lime, caustic, or magnesium hydroxide



- Goals: Maximize Metal Hydroxide Removal Efficiency

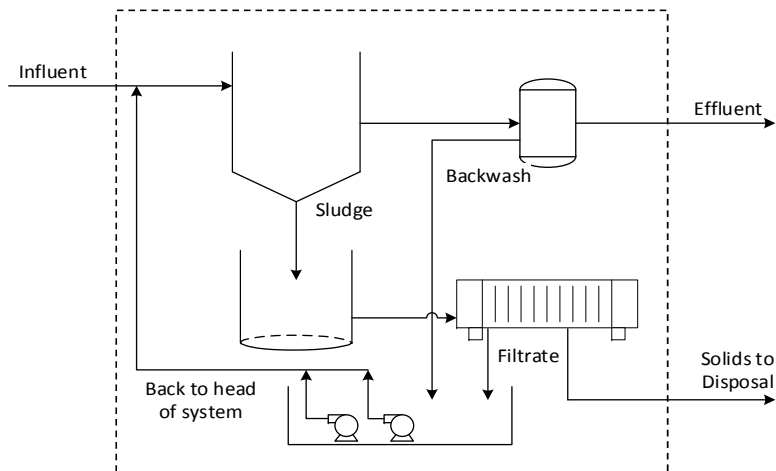


clarification vs. filtration

Clarification

Generates a sludge suitable for dewatering. The filtrate from dewatering generally goes back to the head of the system.

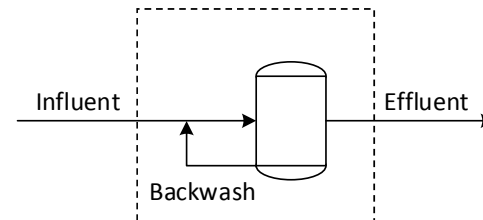
with clarification



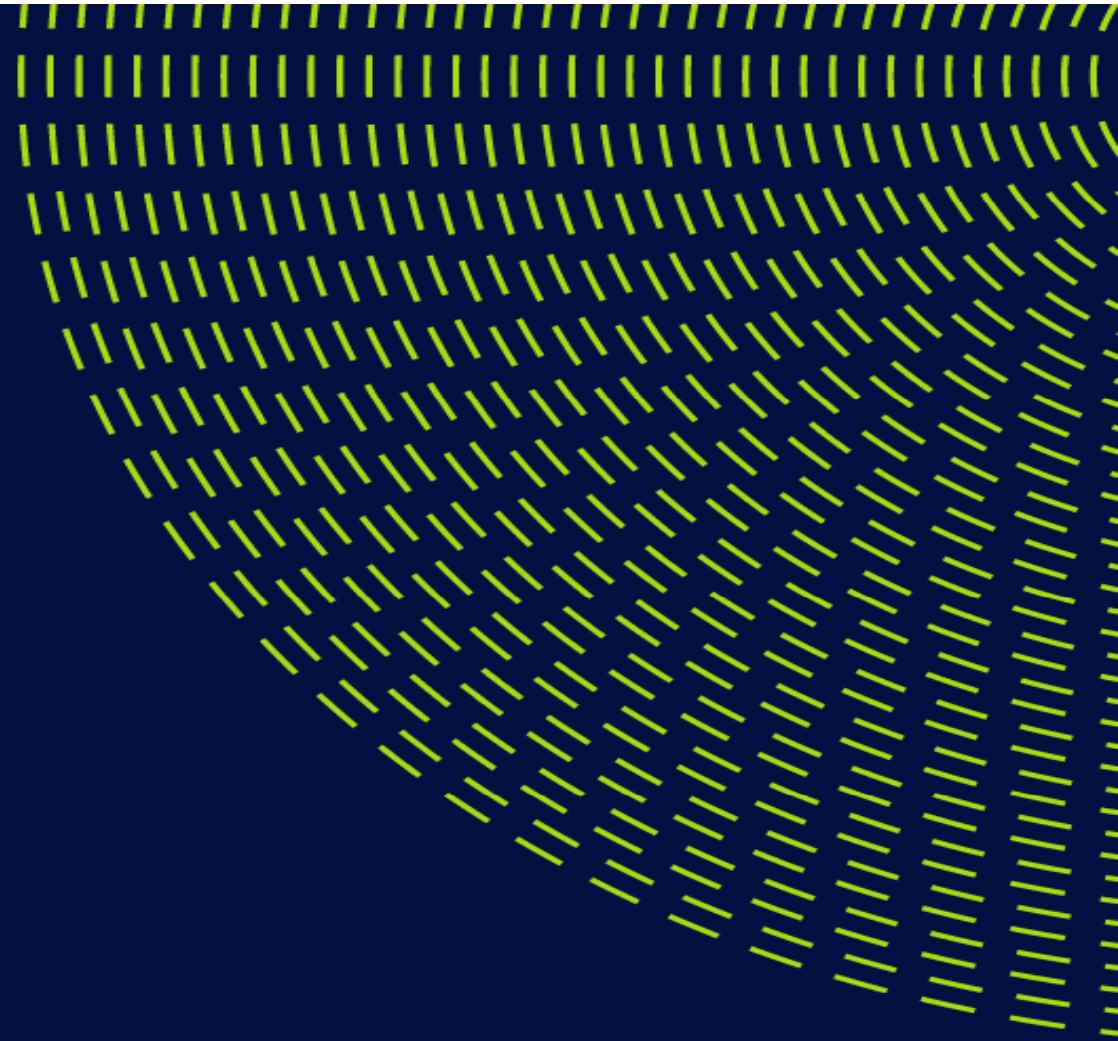
Filtration

The backwash from filtration is generally not suitable for dewatering. Thus it usually goes back to the head of the system (upstream of the clarifier)

without clarification



basics of clarification



basics of clarification

clarifier design is based on the settling velocity of the particles

Settling velocity is dependent on:

- Particle size
- Particle density
- Water temperature

basics of clarification

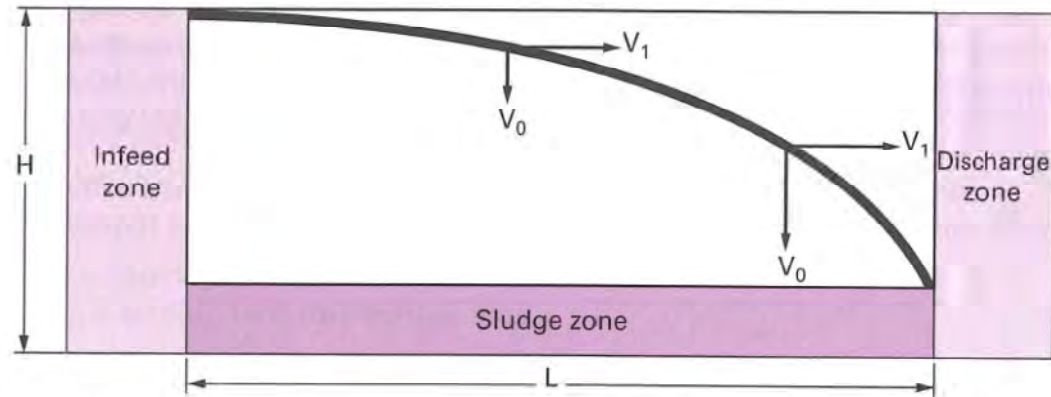


Figure 13. Schematic diagram of a horizontal flow sedimentation application (flocculated particles)

Courtesy of *The Degremont Water Treatment Handbook (7th ed.)*

- Design is such that the slowest settling particles can be captured
- The settling velocity of these particles sets the allowable rise rate

basics of clarification

Table 1
Sedimentation time for various particles according to STOKES law (see § 3.1.)

Particle diameter		Type of particle	Sedimentation time for 1 m of water	Specific surface area $m^2 \cdot m^{-3}$	
mm	μm				
10	10^4	Gravel	1 second	$6 \cdot 10^2$	Settleable suspended solids
1	10^3	Sand	10 seconds	$6 \cdot 10^3$	
10^{-1}	10^2	Fine sand	2 minutes	$6 \cdot 10^4$	
10^{-2}	10	Silt	2 hours	$6 \cdot 10^5$	
10^{-2}	10	Protozoa cysts	20 hours	$6 \cdot 10^5$	Colloids
10^{-3}	1	Clay	2 days	$6 \cdot 10^6$	
10^{-3}	1	Bacteria	8 days	$6 \cdot 10^6$	
10^{-4}	10^{-1}	Colloid	2 years	$6 \cdot 10^7$	
10^{-5}	10^{-2}	Colloid	20 years	$6 \cdot 10^8$	

Courtesy of *The Degremont Water Treatment Handbook (7th ed.)*

basics of clarification

Rise Rate – Expressed as flow per unit area such as

- gpm/ft²
- m³/hr/m²; or simply
- m/hr

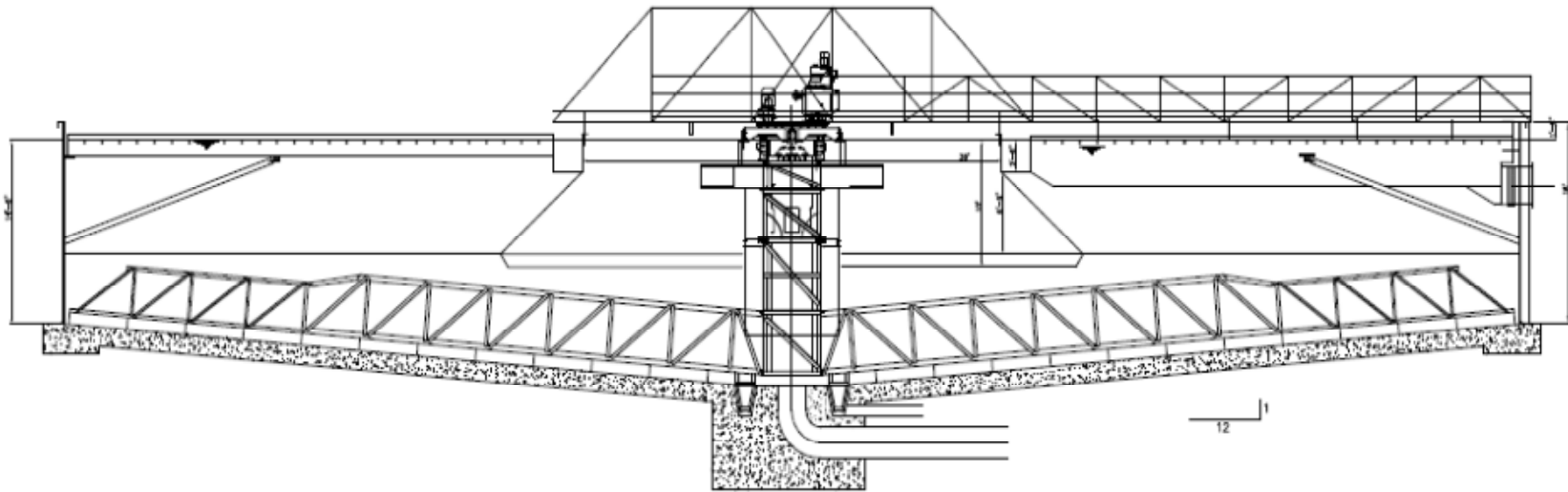
Conventional Clarifier – 0.5 gpm/ft² or 1 m/hr

Specialty clarifiers improve on this by increasing settling velocity

- Inclined plates (lamella)
- Solids contact
 - External recirculation
 - Internal recirculation
 - Filtration through sludge blanket
- Dissolved air flotation
- Ballast

conventional clarifier

- Inlet in the center
- No special tricks to get floc to settle faster
- Launderers usually at the perimeter
- Floor – Concrete. Walls can be concrete or steel



inclined plate separation (lamella clarifier)

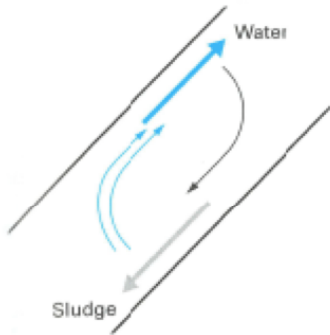


Figure 28. Current separation in a lamellar clarification unit

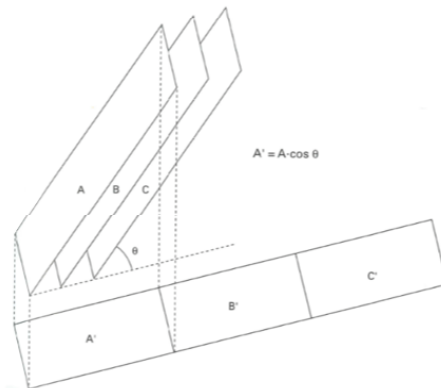
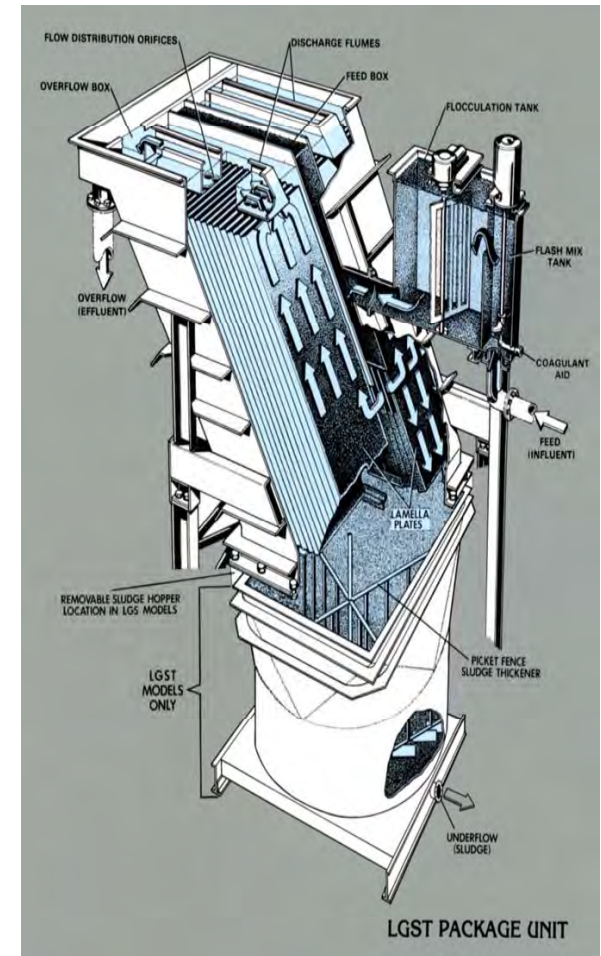


Figure 21. Lamellar plate sedimentation: cumulative effect of the unit surface areas

Courtesy of The Degremont Water Treatment Handbook (7th ed.)

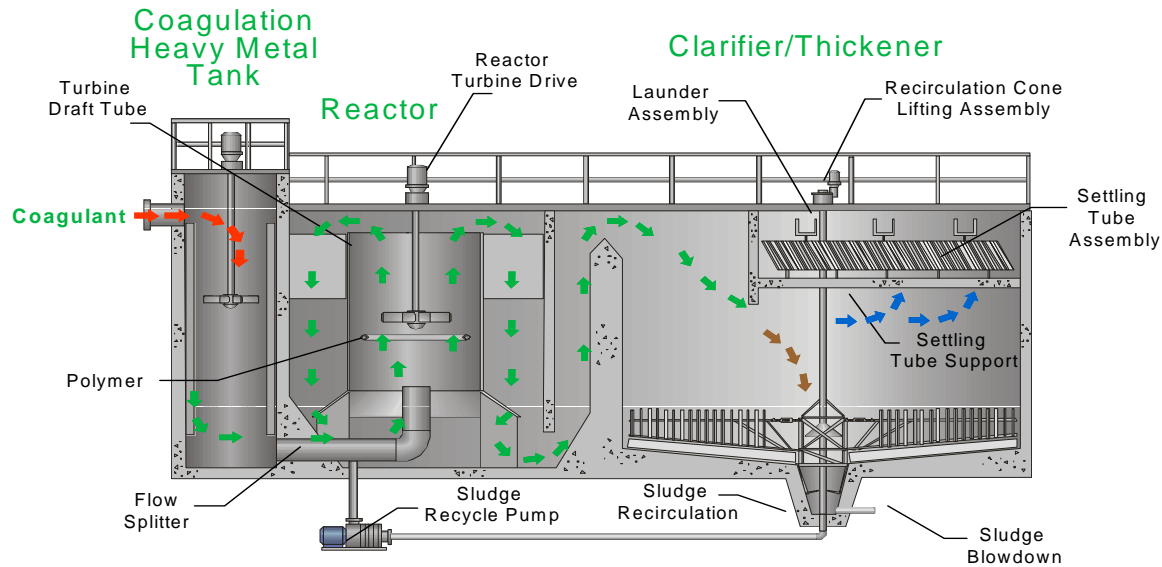
- Short settling distance before a particle 'hits the wall'
- Upward fluid velocity approaches zero at the wall
- Useful for capturing smaller, slower settling particles
- Can allow a clarifier to operate at a higher rise rate



Courtesy of Parkson Corporation

external solids recirculation

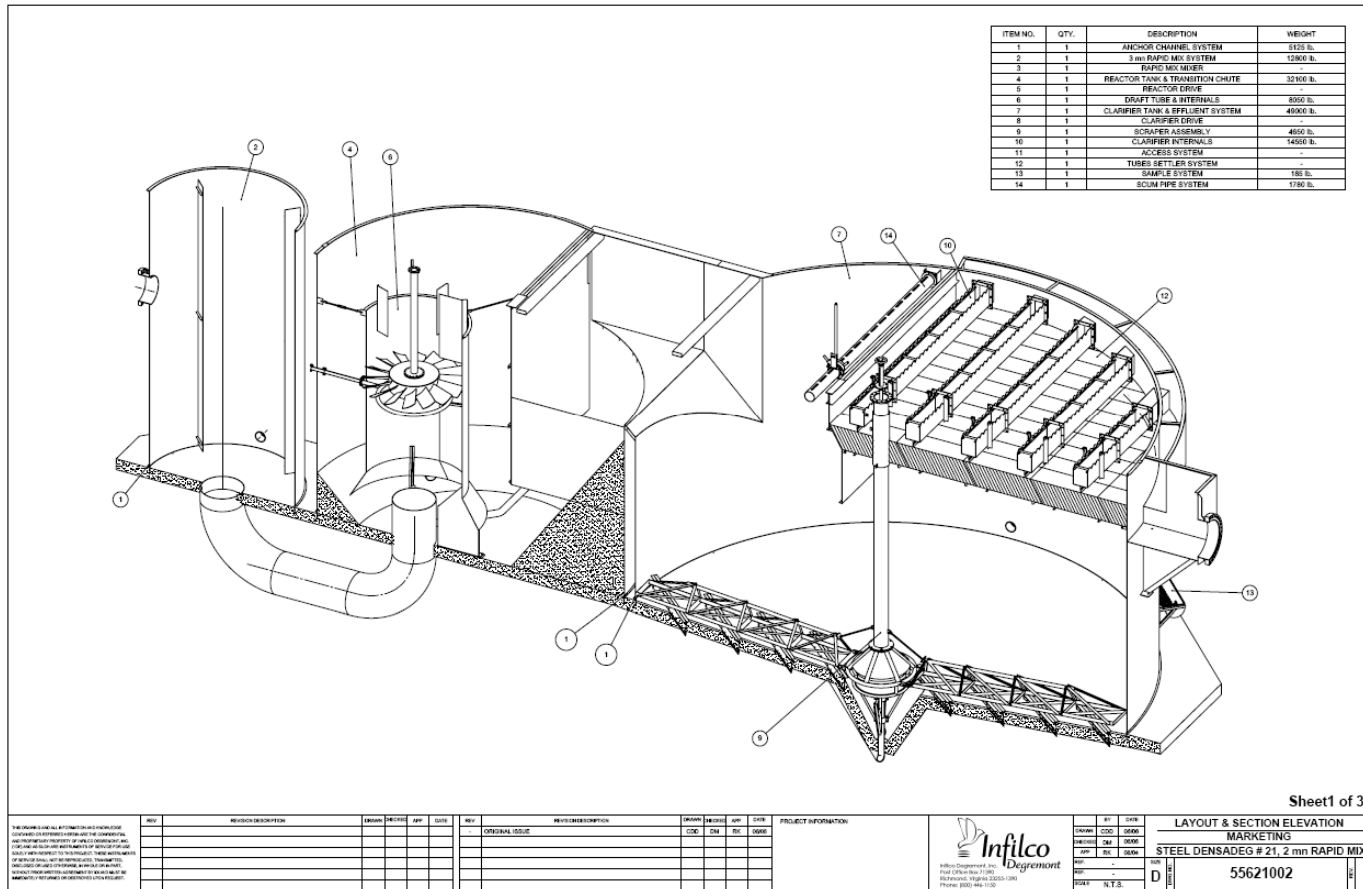
DensaDeg* clarifier thickener



- Rapid mix of coagulant and polymer addition
- Internal solids recirculation within reactor
- External sludge recycle back to reactor
- High solids concentration sweep up small floc particles
- Dense solids/clarified water separation up flow through tube settlers

Trademark of SUEZ; may be registered in one or more countries

DensaDeg clarifier / thickener



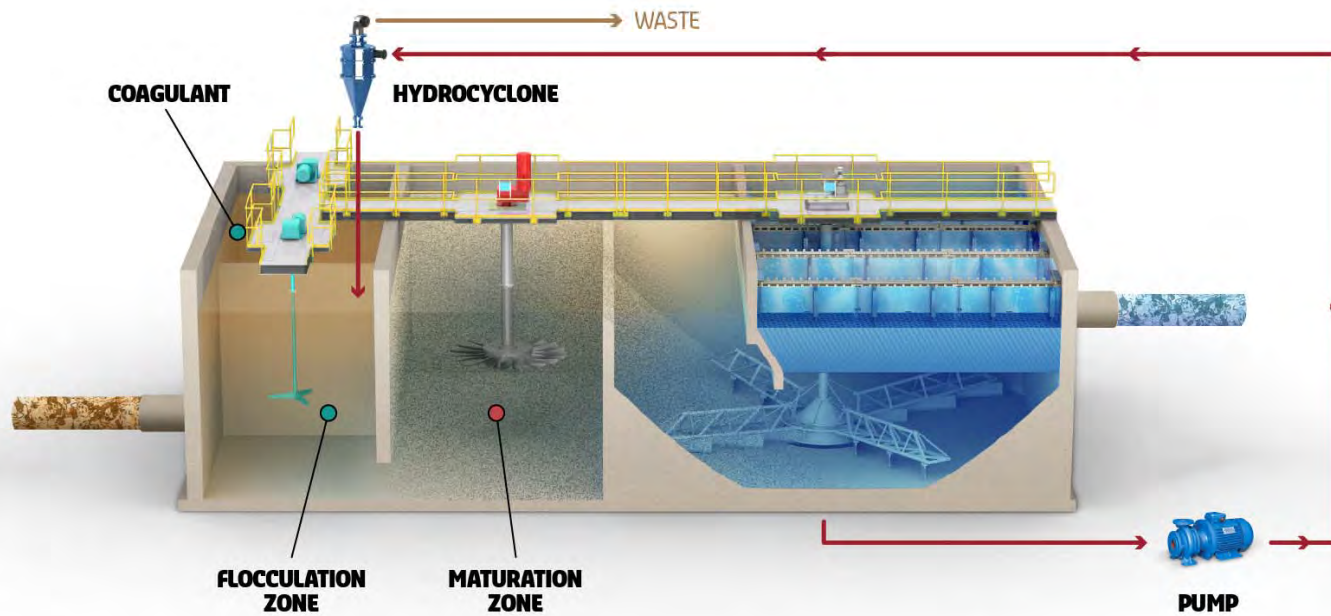
DensaDeg XRC

- High rate settling clarifier process combining solids contact, ballast addition and solids recirculation to provide enhanced, high rate settling of solids.
- Ballast is added to well-formed floc to increase particle density and precipitation.
- Multi-stage Process:
 - Coagulation/Flocculation
 - Maturation
 - Settling/Clarification
- Pros
 - Very high loading rates >20 gpm/ft²
 - Can be small shop fabricated units
- Cons
 - Limited to lower TSS loading/lighter floc

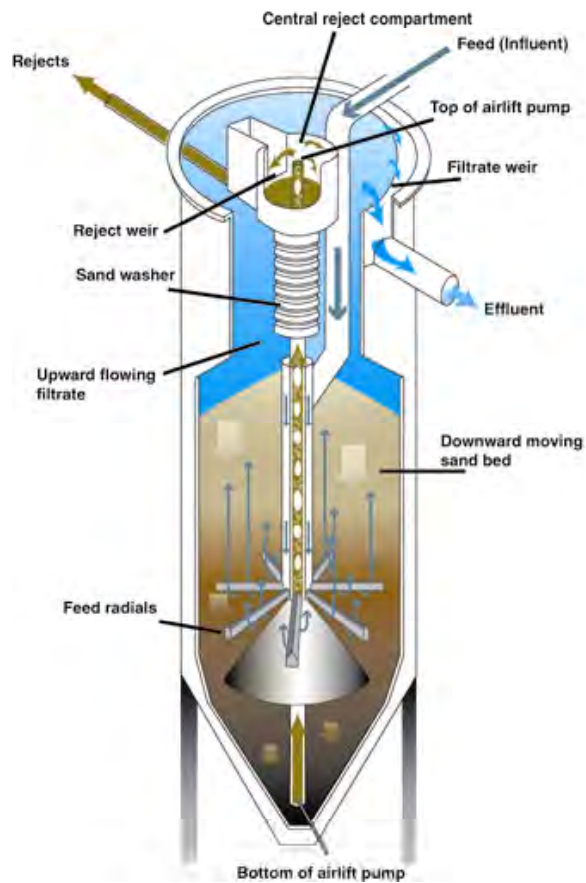
DensaDeg XRC



DENSADEG XRC™
EXTREME-RATE CLARIFIER



continuous backwash filter



Features

- Better depth filtration
- Constant headloss
- Continuous backwash
- Low mechanical & hydraulic energy requirements
- No redundancy required
- No costly ancillary support
- Consistent filtrate quality
- No underdrains/screens
- California Title 22 Approved

Filtrafast*

The media

- Polymeric fibers and beads
- Lower density than sand minimizes energy used for backwash
- Porosity adjusted by the flow to achieve required water quality

SUEZ has selected and qualified the best media to reach optimum filtration and backwash performances with extended media life. A qualification process has been implemented to continuously guarantee quality.

Trademark of SUEZ; may be registered in one or more countries

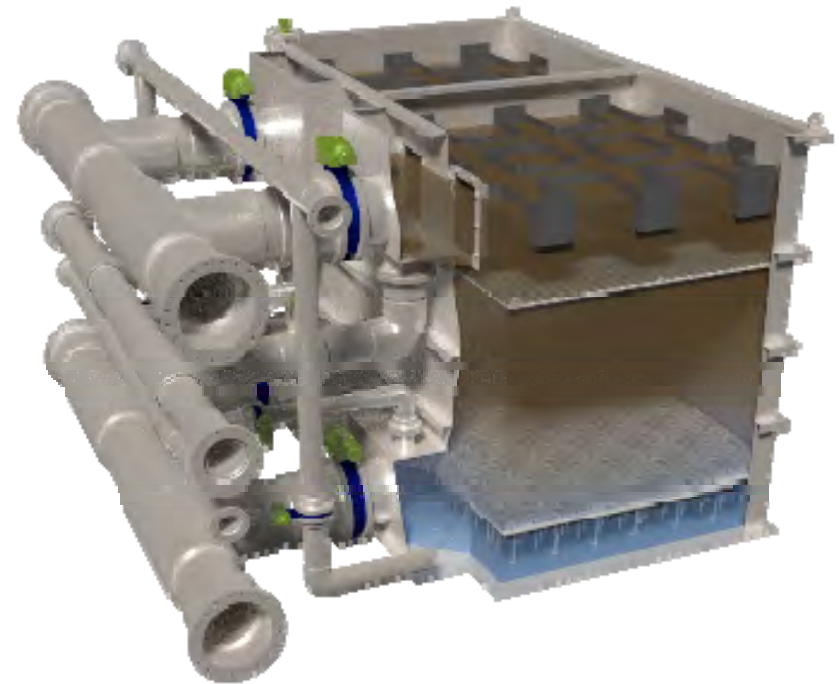


Filtrafast

In filtration mode, the Filtrafast behaves like a traditional gravity filter

- Raw water enters the filter through the top and then flows downward.
- The hydraulic load compresses the media and creates an ideal medium porosity to retain solids and turbidity.
- Solids and turbidity are captured by the media and the filtrate then exits through the nozzles at the bottom of the filter.

Achieving extreme filtration rates without any mechanical device



sludge underflow

- Factors that affect solids content
 - Type of solids
 - Type of clarifier
 - Operations (to some extent)
- Heavy solids
 - Softening sludge (Calcium Carbonate)
 - FGD sludge (Calcium Sulfate)
 - Ash
- Lighter solids
 - Raw water turbidity (silt)
 - Metal hydroxides (ferric, magnesium, aluminum, etc.)

clarifier under flow

	Heavy Solids	Lighter Solids
Conventional Clarifier	2 - 4%	0.2 – 0.5%
Lamella Clarifier	NA	0.2 – 0.5%
DensaDeg	10 - 20%	2 - 4%
Accelator	3 - 5%	0.2 – 0.5%
DensaDeg XRC	NA	0.1 – 0.3%

clarifier sludge flow rate

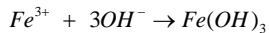
- Calculate dry solids
 - Native TSS
 - Coagulant Solids
 - Other significant solids (softening or FGD)
- Summarize the contents of the sludge in terms of percent
 - This will be important to determining the wet sludge solids
 - It will also be important in estimating final cake solids percent
- Divide by solids content percent to get wet solids
- Divide by density to get flow rate
 - Necessary to size blowdown pumps
 - Necessary to size sludge holding tank

solids generation calcs - examples

Therefore, the sludge produced is :

$$\frac{45 \text{ mg/L} \times 325 \text{ gal/min} \times 2.2 \text{ lbs/kg} \times 3.785 \text{ L/gal} \times 1440 \text{ min/day}}{1,000,000 \text{ mg/kg}}$$

= 175 lbs/day TSS Sludge produced



$$25 \text{ mg/L FeCl}_3 \times \frac{55}{161.5} = 17 \text{ mg/L Fe}^{3+}$$

$$8.5 \text{ mg/L Fe}^{3+} / 55 \frac{\text{mg}}{\text{mmole}} = 0.15 \text{ mmole/L Fe}^{3+}$$

$$0.15 \text{ mmole/L} \times 106 \frac{\text{mg}}{\text{mmole}} Fe(OH)_3 = 16 \frac{\text{mg}}{\text{L}} Fe(OH)_3 \text{ Precipitated}$$

$$\frac{16 \text{ mg/L} \times 325 \text{ gal/min} \times 2.2 \text{ lbs/kg} \times 3.785 \text{ L/gal} \times 1440 \text{ min/day}}{1,000,000 \text{ mg/kg}}$$

= 62 lbs/day Fe(OH)₃ produced

Compound	Composition (%)	Amount of Solids Produced (lb/d)
Fe(OH) ₃	26	62
TSS Sludge	74	175
Total	100.0	237

$$\frac{237 \text{ lbs/day} \times 1,000,000 \text{ mg/kg}}{10,000 \text{ mg/L} \times 2.2 \text{ lbs/kg} \times 3.785 \text{ L/gal} \times 1,440 \text{ min/day}} = 2.0 \text{ gpm or 2,800 GPD}$$

This system only had:

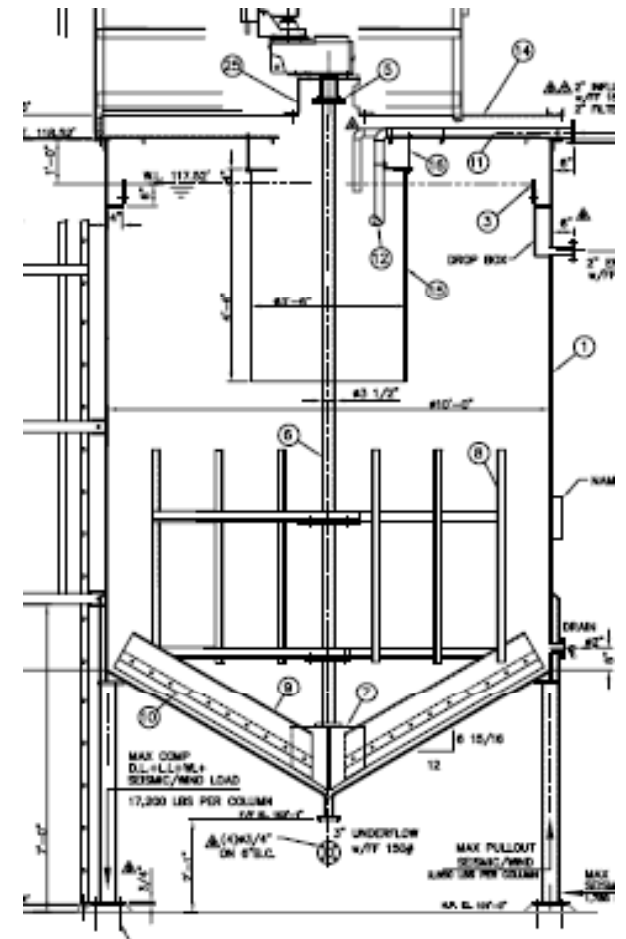
- TSS Sludge; and
- Coagulant Sludge

sludge thickener vs sludge holding

- The sludge needs to be stored until it is dewatered.
 - Bottom of the DensaDeg (rare case)
 - Sludge Holding Tank
 - Gravity Thickener
- Sludge holding tank
 - Just a tank and a mixer
 - Calculate the working volume (remove heel and freeboard)
 - Residence time is working volume divided by sludge flow rate
 - Residence time customer determined (8 hours, 48 hrs, etc.)
 - Usually sized as largest shop fab tank (12' dia by 24' ht)

gravity thickeners

- Simply a conventional clarifier with a picket-fence style rake
- Loading based on dry solids/ft²-day
- Sludge blowdown from the clarifier enters into the center
- Supernatant is forced over the weir
- If loaded too high, sludge level will climb and eventually go over the weir
- If loaded too low, sludge will not have time to thicken
- Also serves as sludge storage

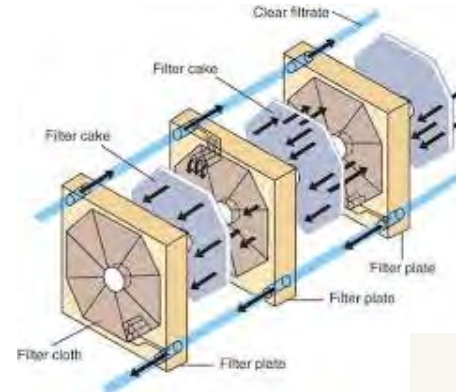


types of filter presses

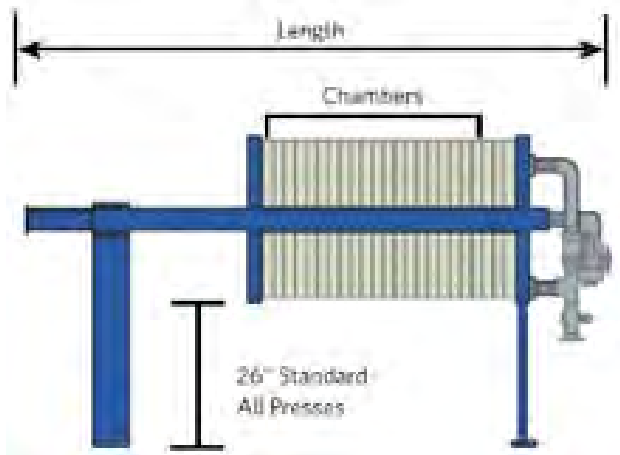
- Plate-and-Frame
 - Batch process
 - Best for smaller applications
- Belt Press
 - Continuous process
 - Messy and maintenance heavy
 - Lower achievable solids percent
 - More economical for large sludge volume applications
- Centrifuge
- Divide by density to get flow rate
 - Don't use these very often in industrial

Plate-And-Frame

- Wet sludge must have high enough solids content (>2% open to debate)
- Wet sludge forced in through the center
- Water passes through the filter cloths
- Solids are caught in the chambers
- Filtrate drains by gravity
- When max pressure is reached, cycle is ended and sludge must be dumped
- Usually on mezzanine
- Core blow at end of cycle
- Capacity is the amount of volume between the plates over the whole press – expressed in cubic feet



example press sizing chart



1200 mm	Volume (ft ³)	50.0	125.0
	Volume (L)	1416.0	3540.0
Height 74.5" (1892 mm)	Length (in)	217.0	356.0
Width 60.0" (1524 mm)	Length (mm)	5512.0	9042.0
1500 mm	Volume (ft ³)	130.0	270.0
	Volume (L)	3682.0	7646.0
Height 95.7" (2432 mm)	Length (in)	311.0	500.0
Width 74.9" (1903 mm)	Length (mm)	7950.0	12,700.0
1.5 x 2.0 M	Volume (ft ³)	275.0	350.0
	Volume (L)	7788.0	9912.0
Height 136.6" (3470 mm)	Length (in)	430.0	507.0
Width 79.0" (2007 mm)	Length (mm)	10,922.0	14,097.0
2.0 x 2.0 M	Volume (ft ³)	300.0	600.0
	Volume (L)	8496.0	16,992.0
Height 106.0" (2692 mm)	Length (in)	405.0	562.0
Width 137.0" (3480 mm)	Length (mm)	10,287.0	14,275.0

filter press feed pumps

- Flow rate sized to fill press in five minutes (quick fill)
- Pressure slowly builds as chambers fill
- Usually use progressive cavity pumps (seepex)
- AOD pumps have advantages
 - Lower capital cost
 - Fed with 100 psi air, will naturally top off at press psi rating
 - Air use does translate to energy cost
- Usually specified at 2 x 100% per press
- This is a costly part of the dewatering

filter press cake solids

- Remember the composition of the dry solids we calculated?
- Achievable cake solids is dependent on that
 - Native TSS is not so good
 - Metal hydroxides are even worse
 - Softening solids are easy (calcium carbonate)
 - FGD sludge (calcium sulfate) and ash are easy
- Some rough estimates
 - Raw water (TSS plus ferric hydroxide): 25–30%
 - Wastewater with mostly metals: 20-25%
 - Softening (mostly calcium): 45-55% (or even higher)
 - Softening (high magnesium): 40-50%
 - FGD sludge: 45-55% (or even higher)

belt filter presses

- The sludge is continuously squeezed between two belts
- Sludge dryness is not as high as plate and frame
- Sizing is based on belt width
- Usually requires dewatering polymer
- Also requires belt wash pump
- Economical for really high sludge generation rate
- Messy and maintenance heavy



wrap up

- Dryness is dependent on the sludge characteristics and the dewatering technology
 - Filter Press on river water clarification - ~30% solids
 - Filter Press on Softening or FGD sludge - ~40 - 50%
 - Belt Press on Softening or FGD sludge - ~30 – 35%
- One basic requirement is to pass 'paint filter' test
- Sludge is always non-hazardous (pass TCLP)
- Usually there is a sump to pump the water back to the head of the system
- Sludge dewatering system are almost always oversized
 - Max TSS
 - Max flow
 - Assume only one shift

thank you