REINHOLD ENVIRONMENTAL Ltd.

2015 Wastewater-Ash Round Table Presentation

September 22, 2015, in Charlotte, NC / Hosted by Duke Energy

Physical/Chemical Treatment System Design Considerations

Ralph Cutler

2015

WesTech

Factors Affecting Wastewater Characteristics

- Fuel type/Switching/Blending
- Limestone Quality
- Upstream Flue Gas Treatment
- Scrubber Operation
- Reagent Addition
- Dewatering Options

Factors Affecting FGD Wastewater Treatment Process Selection/Design

- pH
- Temperature
- Residence Time
- Solids Concentration
  - Feed
  - Reactor
  - Underflow

Factors Affecting FGD Wastewater Treatment Process Selection/Design

- Solids Particle Size Distribution
- Constituent Concentration and Speciation
- Plant Operation
  - Base Load
  - Peaking
- Treatment Objectives- Treated Water Quality
  - Downstream Treatment
- Disposal of Dewatered Solids

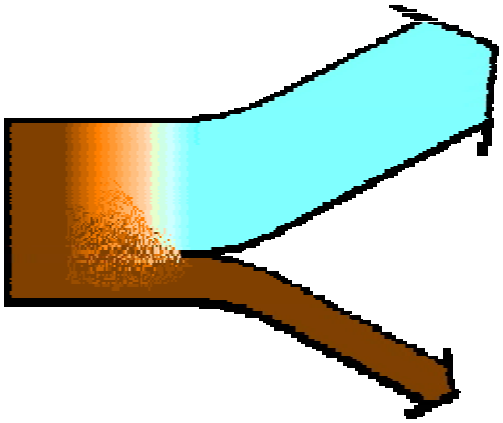
Physical Unit Processes

- Equalization
  - Tank
    - Mixed versus Un-mixed
  - Lined Basin
- Flocculation
- Sedimentation
  - Clarifier versus Thickener
- Gravity Sedimentation includes both Clarifiers and Thickeners

But – What's The Difference ?

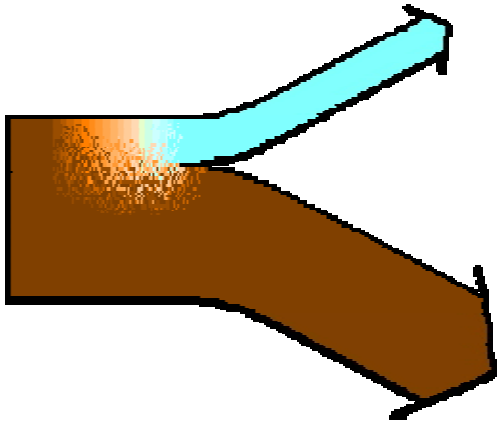
Clarifiers =

Overflow



Thickeners =

Underflow



Physical Unit Processes

- Standard Clarifier
- Flocculating Clarifier
- Solids Contact Clarifier
- Lamella Clarifier
  - Plates versus Tube Settlers
- High Rate Clarification
- Ballasted Flocculation/Sedimentation
- Thickener

Physical Unit Processes

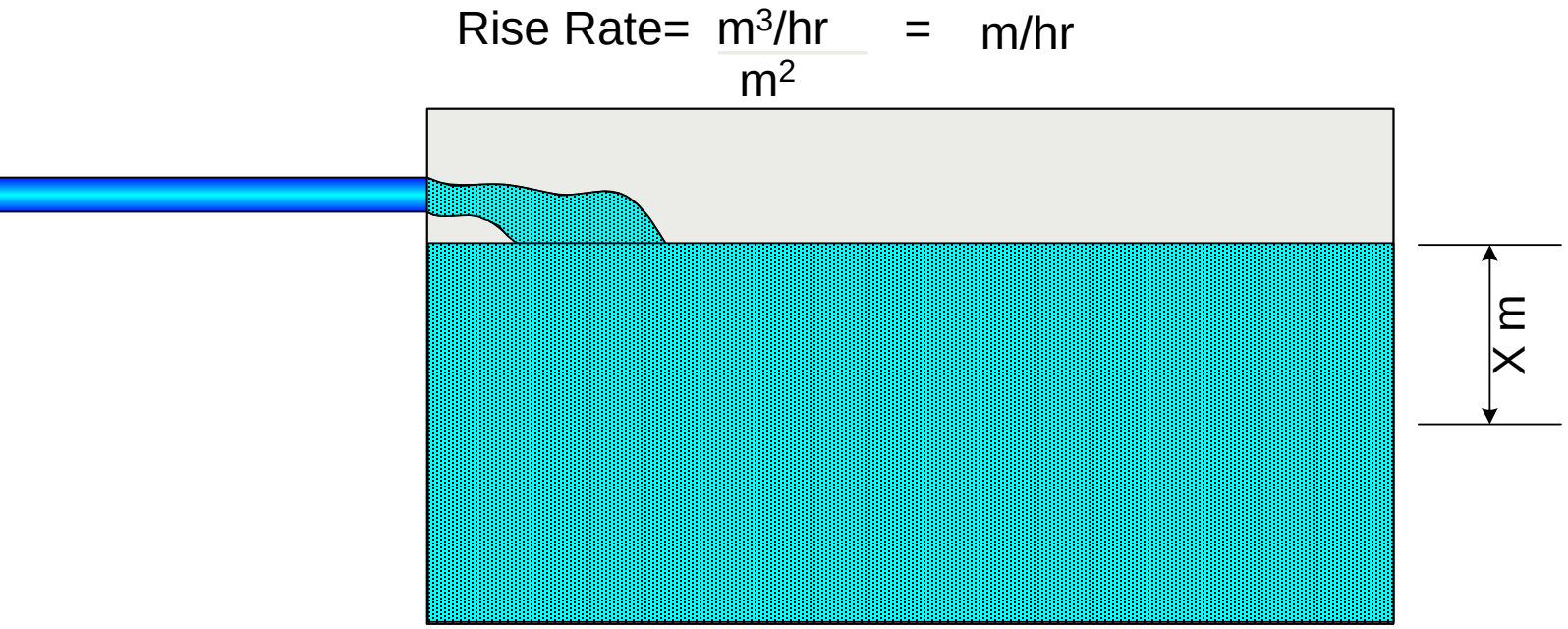
- Clarifier Sizing Criteria

Clarifier Sizing

- The Minimum Diameter is Determined by:
  - Settling Rate/Rise Rate
    - Hydraulic loading
  - Unit Area Requirement
    - Solids loading

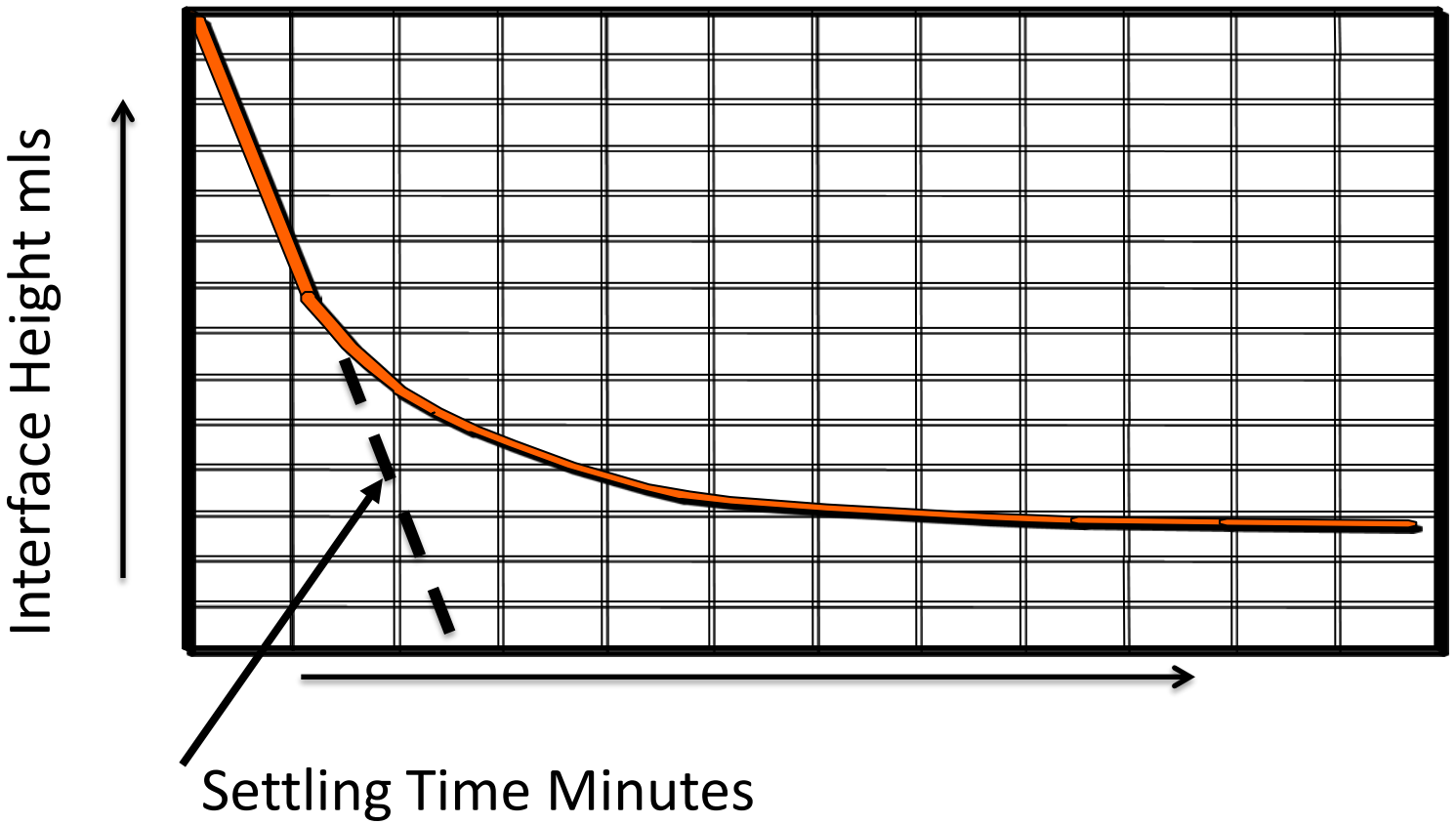
What is Rise Rate

- The upward velocity of effluent in the clarifier/thickener.
- Rise Rate= (Feed Rate-Underflow Rate)/Area



How is Settling Rate Determined?

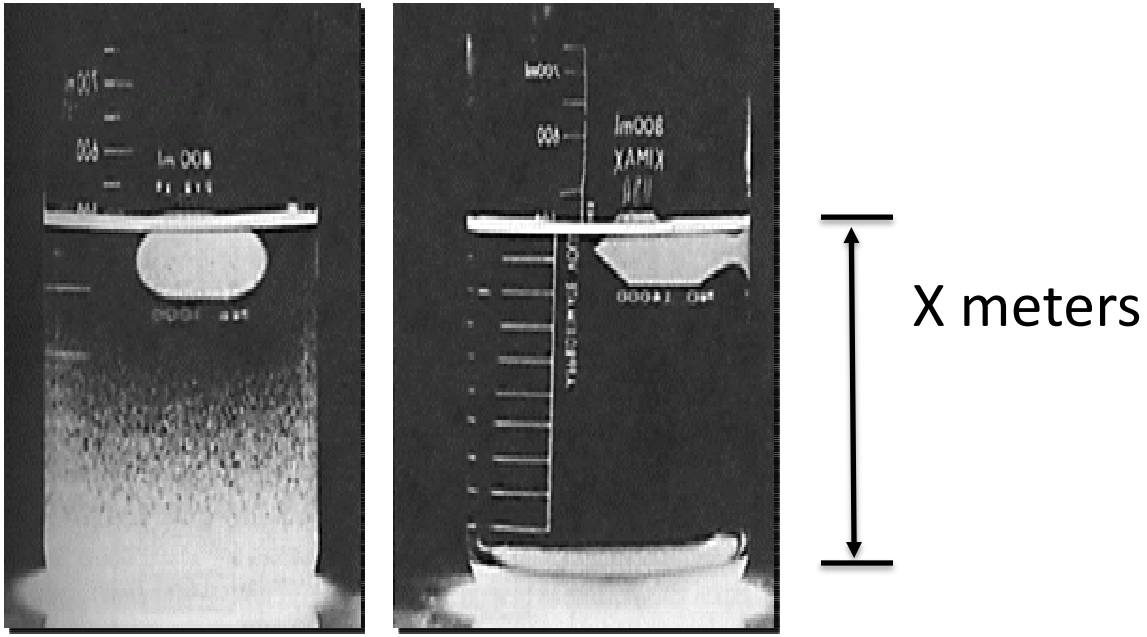
Interface settling using a graduated cylinder



Slope = Bulk Settling Rate , in m/h or gpm/ft^2

How is Settling Rate Determined?

Particulate settling using a beaker and ruler



Bulk Settling Rate = Distance / Time

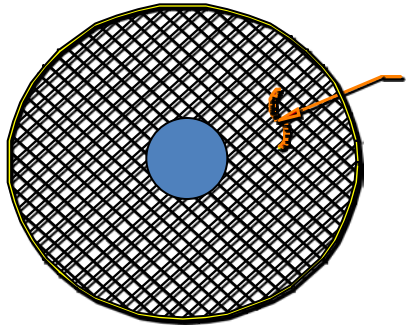
Hydraulic Loading Sizing

Settling Rate * Scale-up Factor $\leq$ Rise Rate

Settling Rate * 0.5 $\leq$ (Feed Rate-Underflow Rate) / Area

Where: Area = surface area of thickener minus feed well area

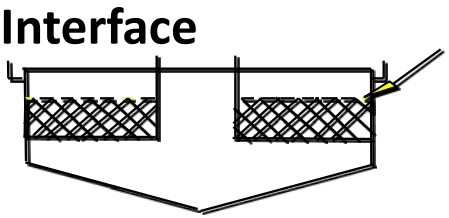
$$\text{Area} \leq \frac{\text{(Feed Rate-Underflow Rate)}}{\text{Settling Rate * 0.5}}$$



Area for Clarification

UNITS

$$m^2 = \frac{m^3/h}{m/h} \quad \text{or} \quad ft^2 = \frac{gpm}{gpm/ft^2}$$



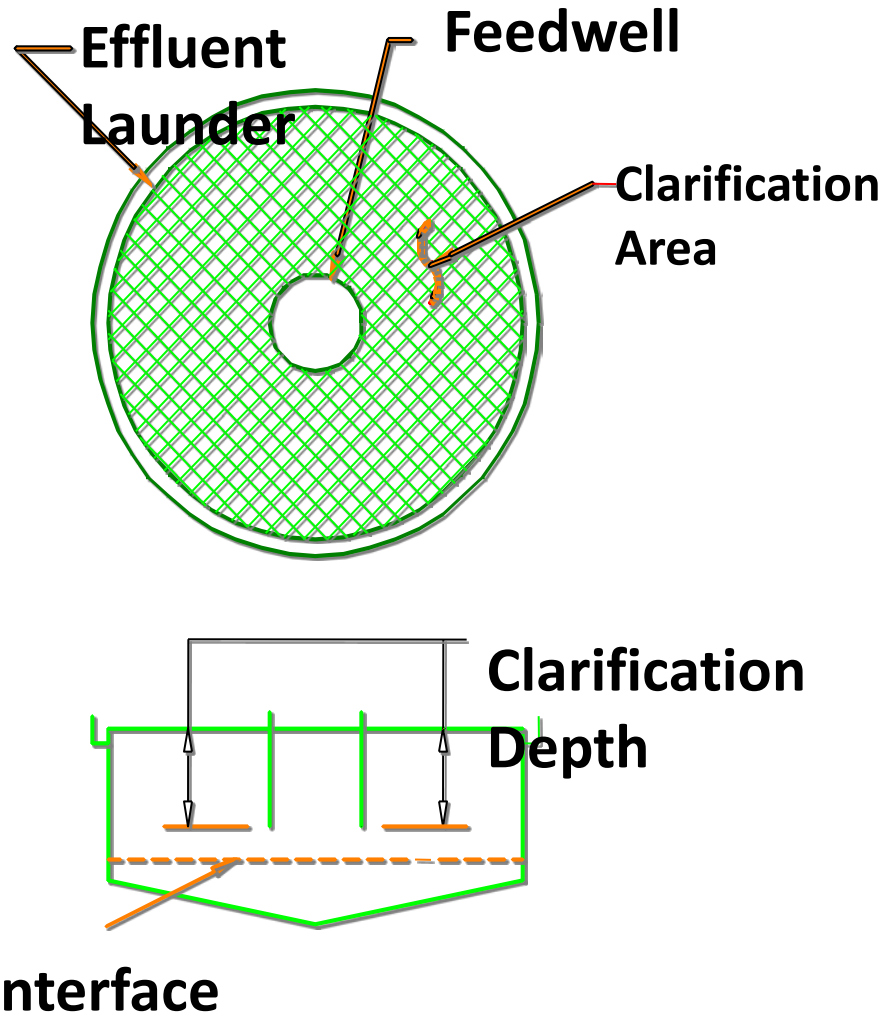
Clarification Area

How is the Clarifier Side Wall Height Fixed?

- The minimum side wall height is determine by:
  - Clarification Time
    - An extra long clarification may dictate an increase in diameter

Clarification Time

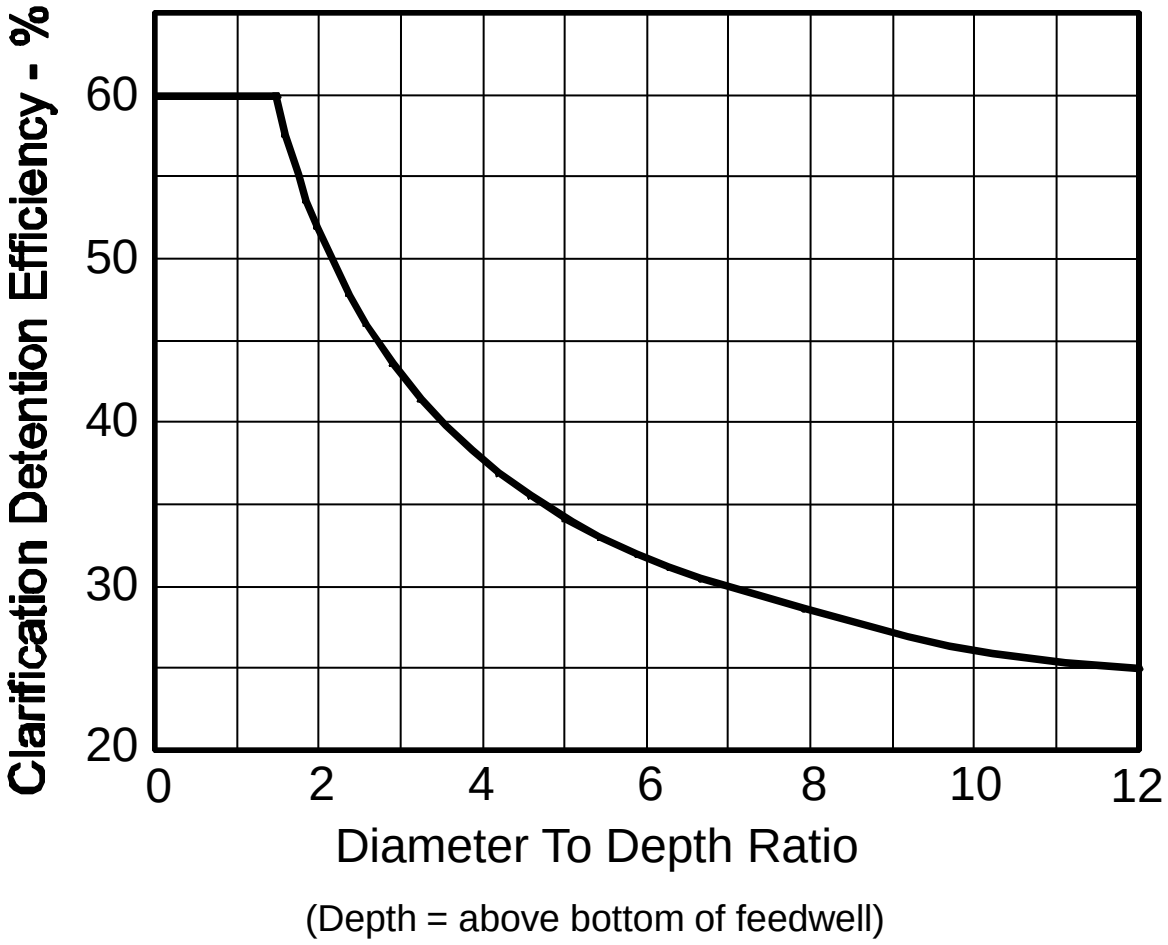
- Some fine solid or flocs remain in suspension
- In “Time” they agglomerate and settle
- This “Time” is the clarification time
- Observed or “Static” time must be scaled up to operating or “Dynamic” time.



Determine Clarification Time Flocculated Solids

Clarification rate somewhat slow, but typical

Clarification Detention Efficiency



- An estimate of short-circuiting within tank
- Used to calculate required full scale detention time
- If static detention time = 30 minutes, and dia./depth = 12, nominal detention time = 30/0.25 = 120 min.
- Use this time to calculate wetted feedwell depth

Feed Solids Limitations

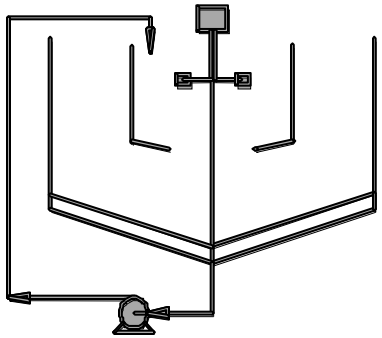
- **Minimum solids required for flocculation**
  - Very dilute suspensions -- difficult / impractical to produce a settleable floc
  - Minimum solids concentration = 300 – 700 mg/L
  - Flocculation improves as solids concentration increases up to a value of at least 0.5 wt.%
  - Upper limit in range of 3.0 wt.% -- At higher concentrations Unit Area may be controlling

Applies to ALL Clarifiers

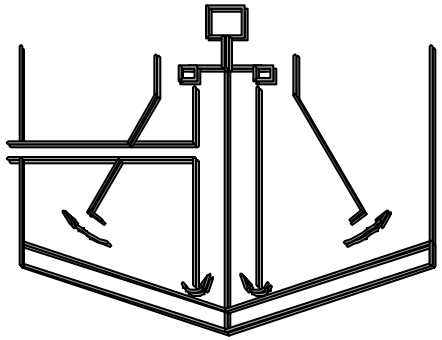
Conventional, Flocculating, Solids Contact

If Solids Concentration Must Be Increased

- Increase solids by external or internal recirculation
- **How to determine?**
  - Bench testing can quickly identify the need for increased solids and the optimum solids concentration



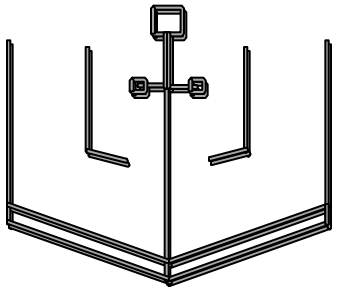
External Recirculation
Underflow Pumping



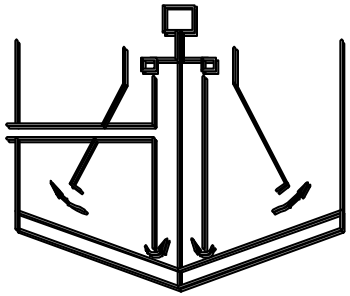
Internal Recirculation
Solids Contact Clarifier
(Draft Tube)

Mechanical Floc Growth

- Flocculation is not always "instantaneous:
  - Gentle mixing and time may be required
  - Liquid phase clears with time
- Observed time to clear must be scaled up to nominal detention time
  - Nominal time = 3 x observed time



Center Flat Blade Impeller Mixer



Solids Contact Clarifier

Sludge / Pulp Blanket?

- Purpose:
  - To provide extra liquid/ solids contact time
  - To provide enhanced flocculation of fines
- Consider use:
  - Following a precipitation reaction
  - When high degree of clarity required
- **A blanket is not always possible nor is it necessary for excellent clarity**

Sedimentation

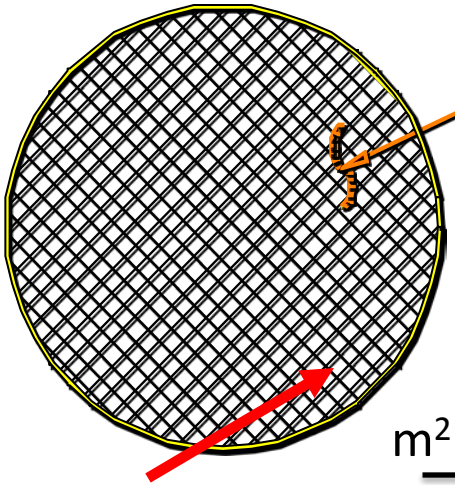
- Thickener Sizing Criteria

How is the Thickener / Clarifier Diameter Fixed?

- The minimum diameter is determined by:
  - Settling rate/ rise rate
    - Hydraulic loading
  - Unit Area Requirement
    - Solids loading

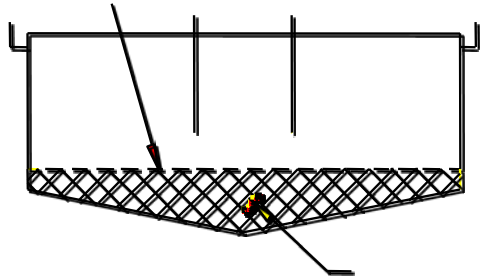
Solids Loading - Thickening

- Solids require time to thicken
- Area of thickener provides the time
- Unit Area = area required for a ton per day of solids to thicken to a given concentration

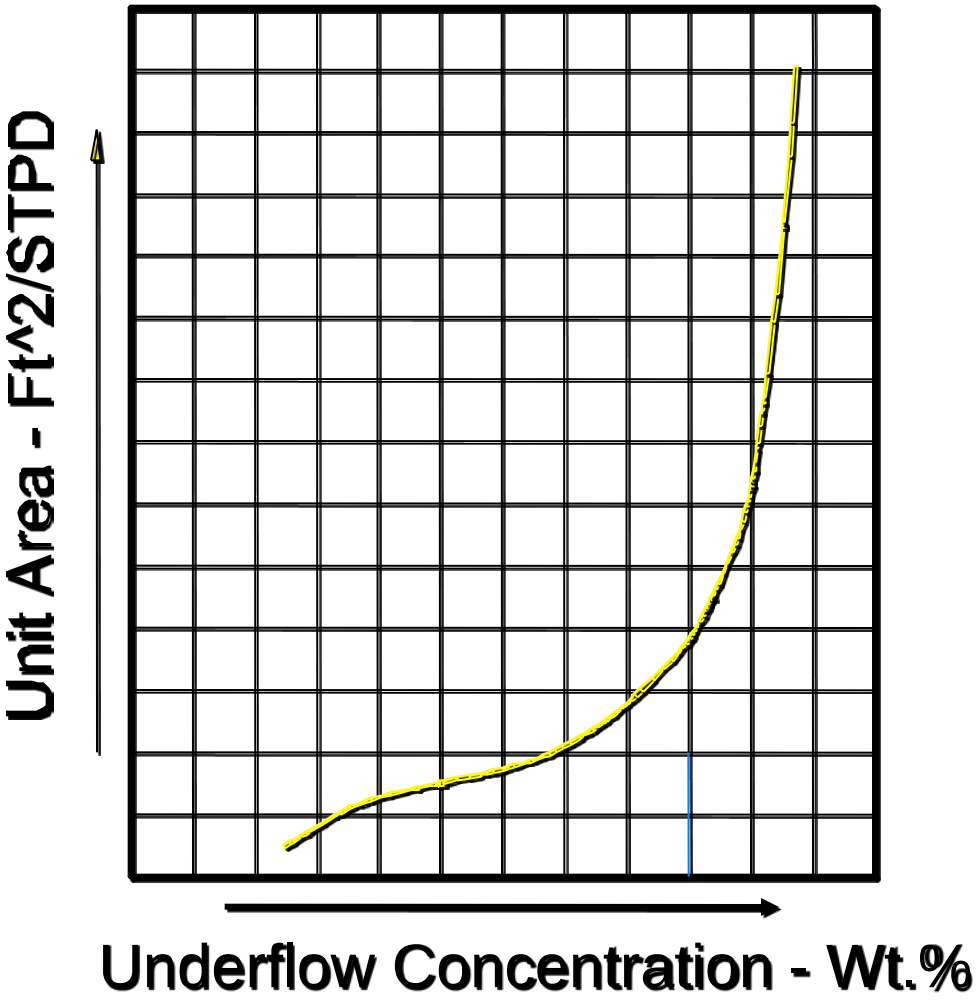


Thickener Area = Unit Area * Solids Rate

$$m^2 = \frac{m^2 * MTPD}{MTPD}$$



Operating Curve



- Typical curve for conventional thickeners
- Different methods of settling test data interpretation give different results

Sedimentation

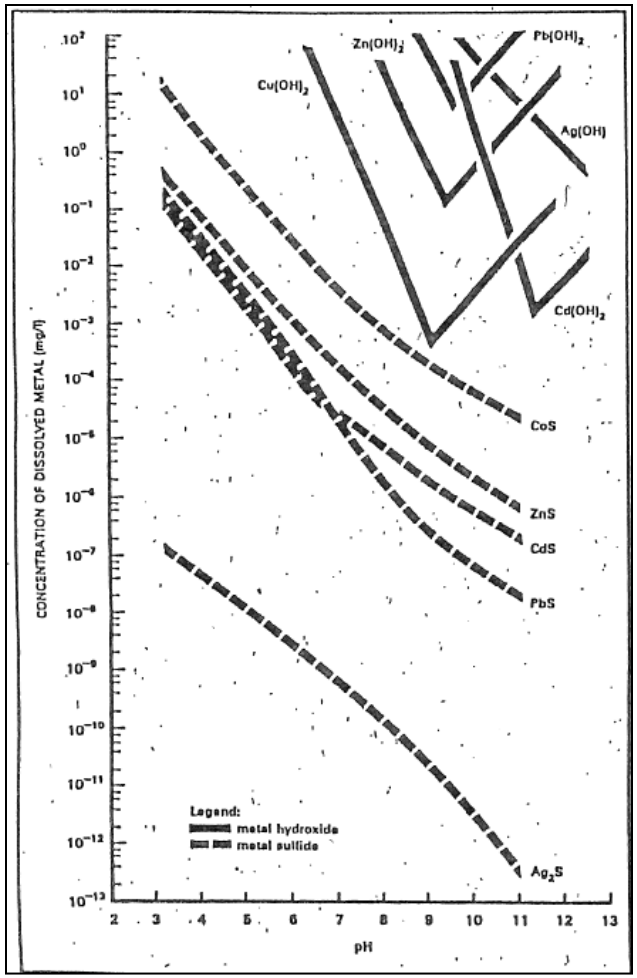
- Flotation
  - Dissolved Air Flotation
  - Induced Air Flotation

Chemical Unit Processes

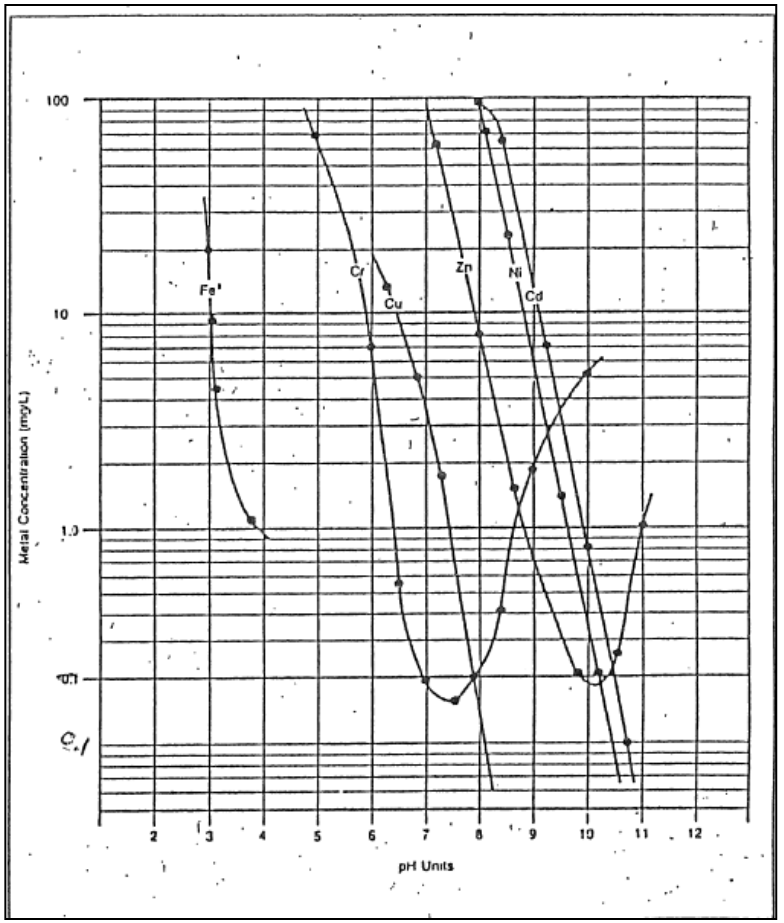
- Precipitation
  - De-supersaturation of Gypsum
  - Cold Lime Softening
  - Metals Removal
    - Metal Hydroxides
    - Metal Sulfides

Solubility of Metals

Metal Sulfide Solubility



Metal Hydroxide Solubility



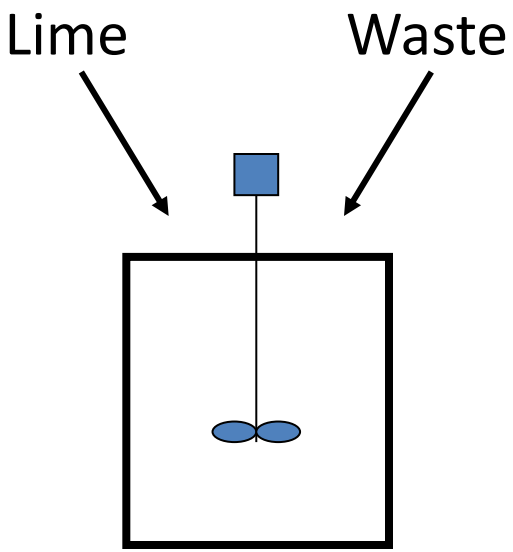
Chemical Unit Processes

- Iron Co-Precipitation
- pH and its effect on solids solubility
- Reactor Design Considerations

Principles of Efficient Precipitation

- Seed the reaction
- Increase the concentration of previously formed solids in the reaction vessel
- Mix one of the reactants with previously formed solids before addition of the second reactant
- Subject formed solids to an elevated pH
- Provide an extended reaction time

1st Approach To Precipitation

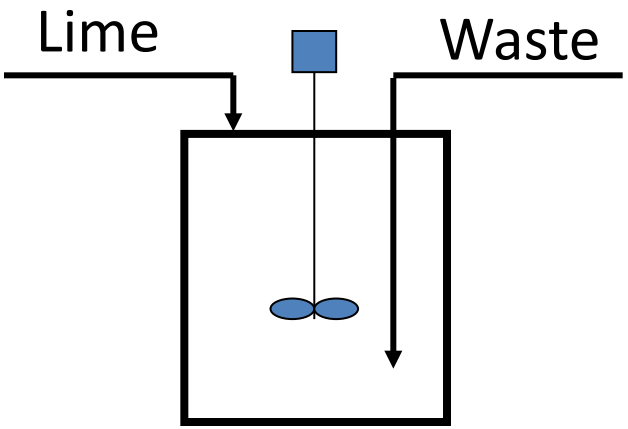


Once Through
Shock Precipitation

Guarantees:

- Maximum number of new particles
- Minimum particle size
- Minimum particle settling rate
- Maximum unit area requirement
- Minimum filtration rate
- Maximum cake moisture content
- Maximum supersaturation

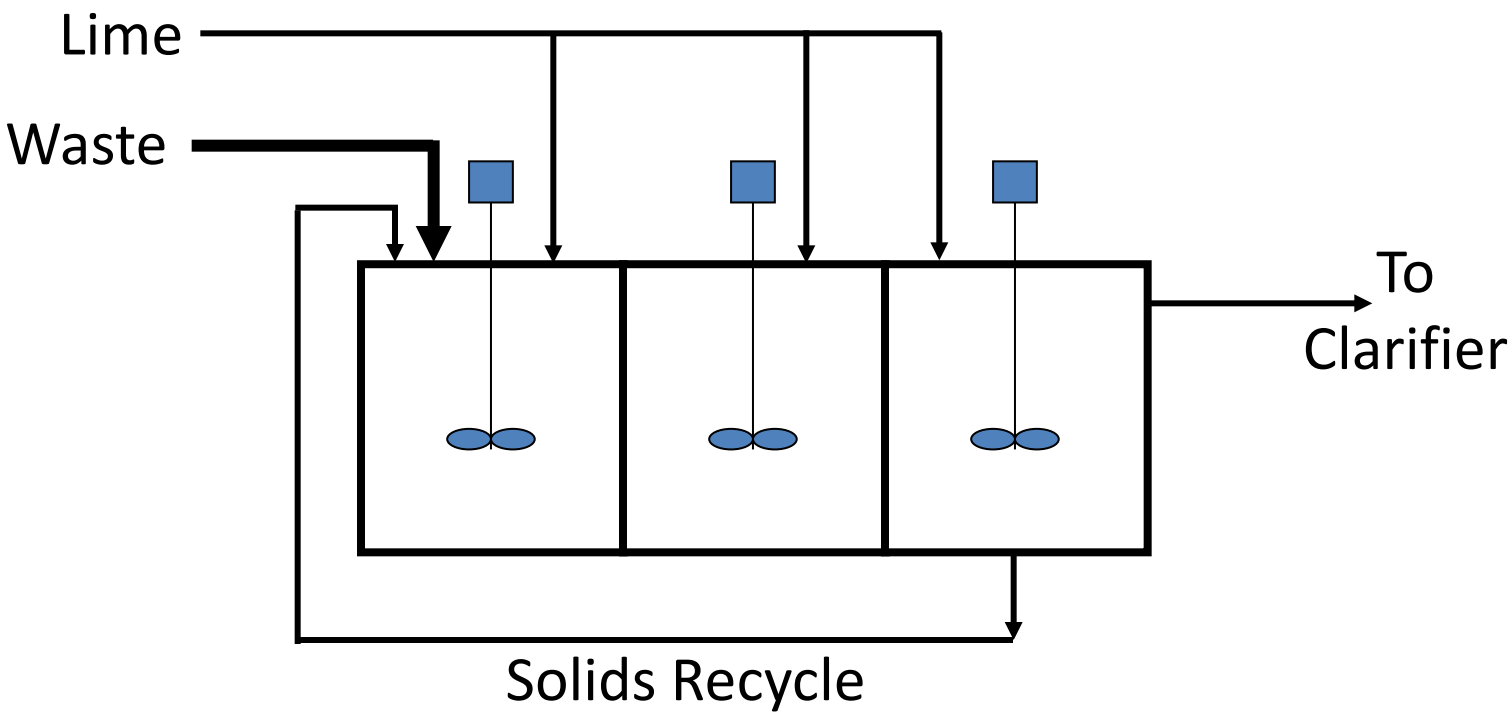
Better Approach To Precipitation



Improves:

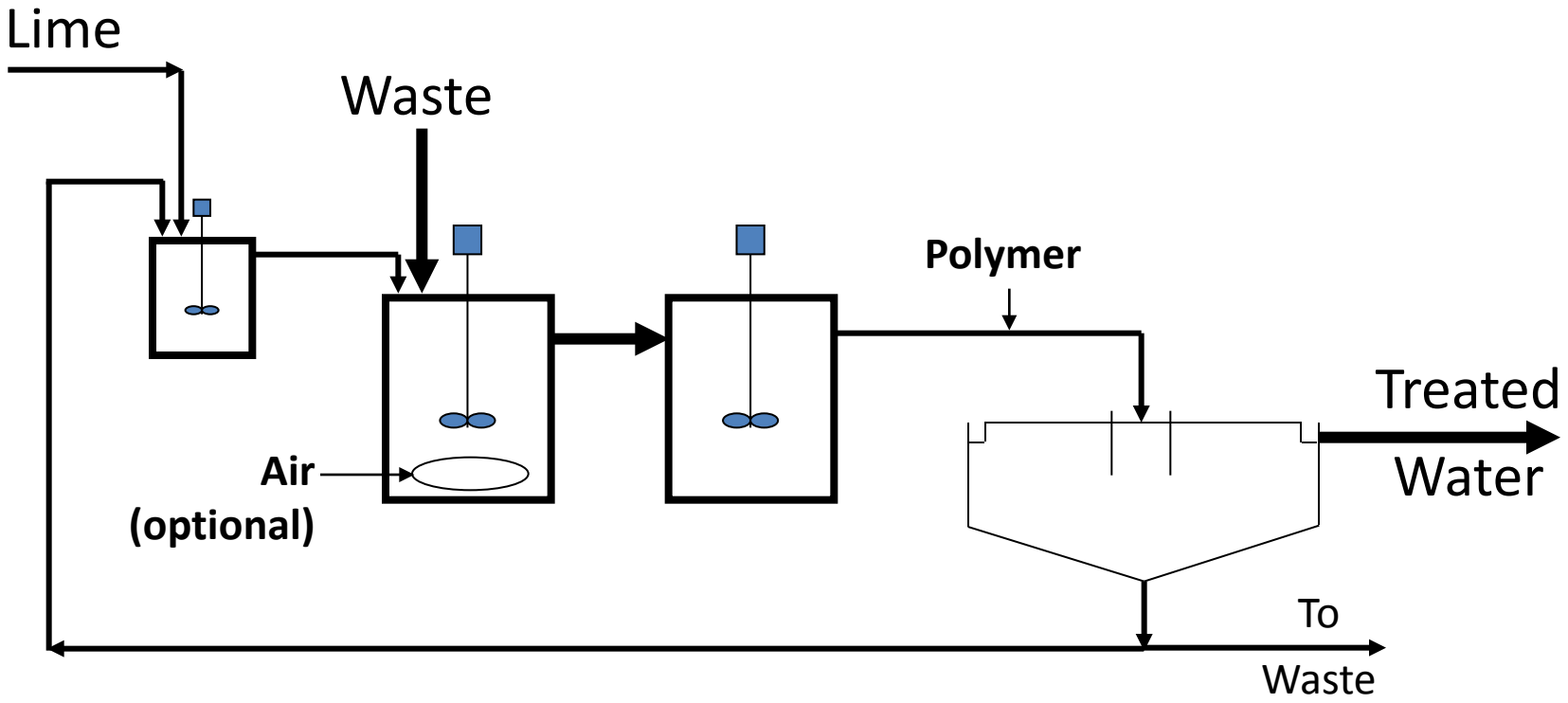
- Particle size
- Desupersaturation
- Scale protection

Better Approach To Precipitation



This approach starts to experience the "Advantage Of A Crowd" by John H. Smith, III

The Basic HDS Flowsheet



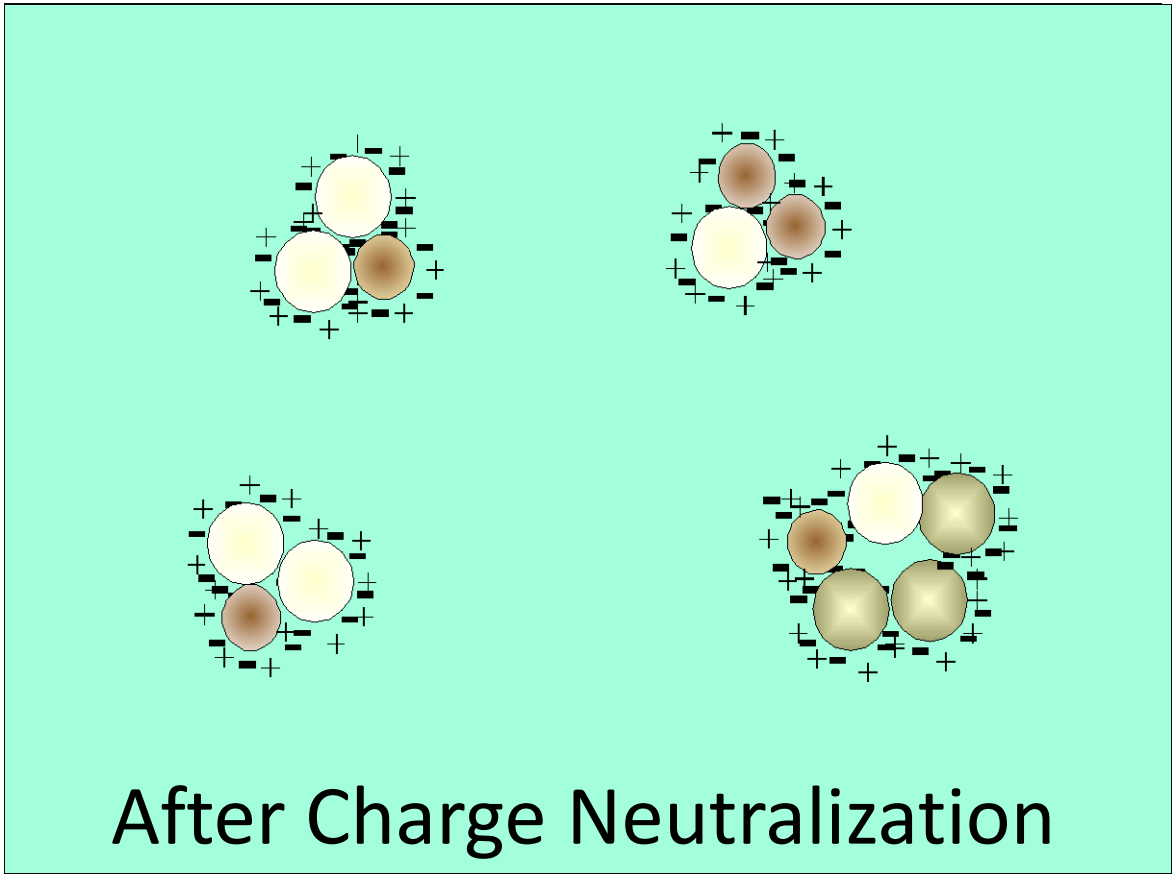
Provides:

- Particle size growth
- Desupersaturation
- Scale protection
- Better lime utilization

Coagulation

- Adding a coagulant to allow agglomeration
  - Coagulants neutralize the negative charge usually associated with naturally occurring particles
  - Usually use cationic multivalent inorganic ions such as Ca^{2+} or Al^{3+}
  - May also be a cationic polymer
  - Flocs form rapidly and reform rapidly after being destroyed by shear

Coagulation After Charge Neutralization



Flocculation

- Anionic
- Nonionic
- Cationic

Flocculation

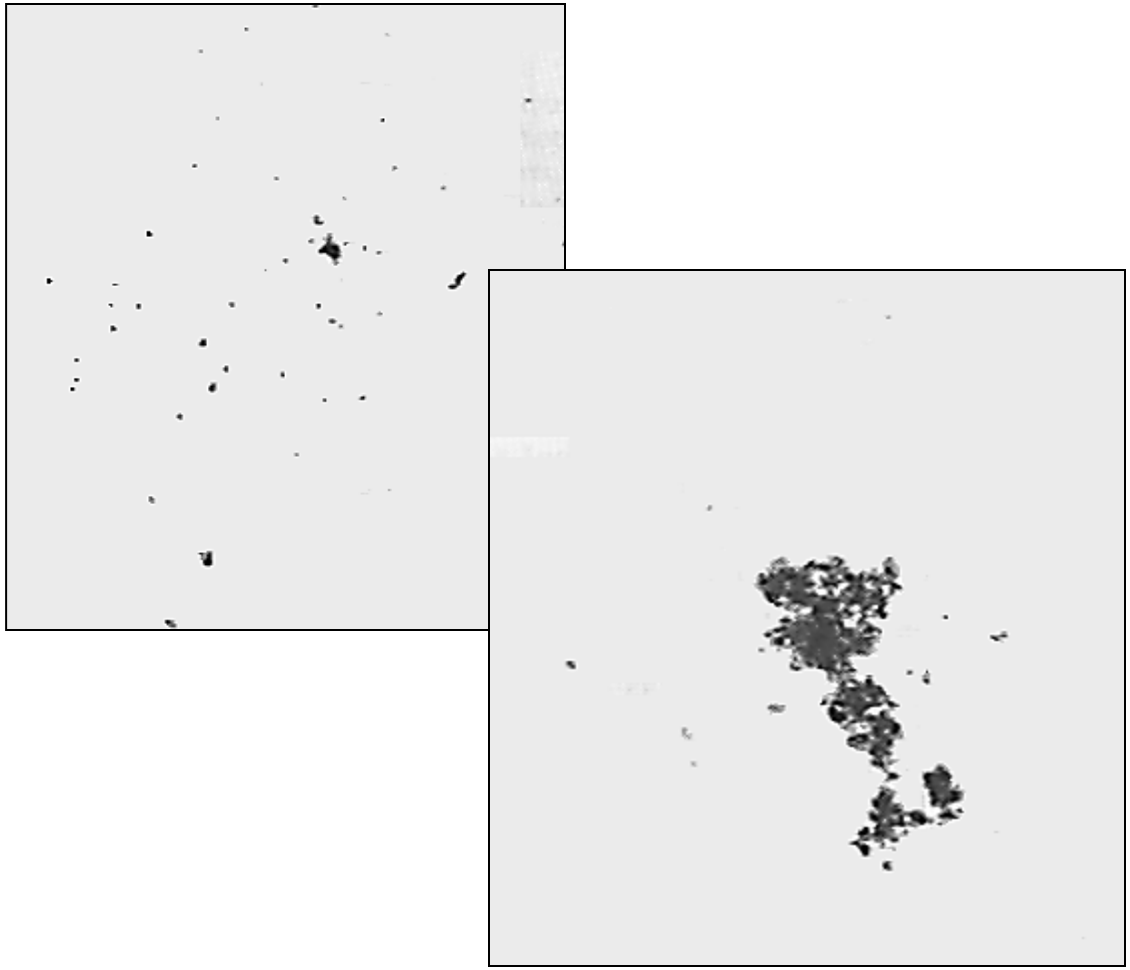
- Adding a long chain polymer
  - May require time for flocs to form
  - Flocs are shear sensitive
    - Never reform as well without the addition of more polymer

NOTE:

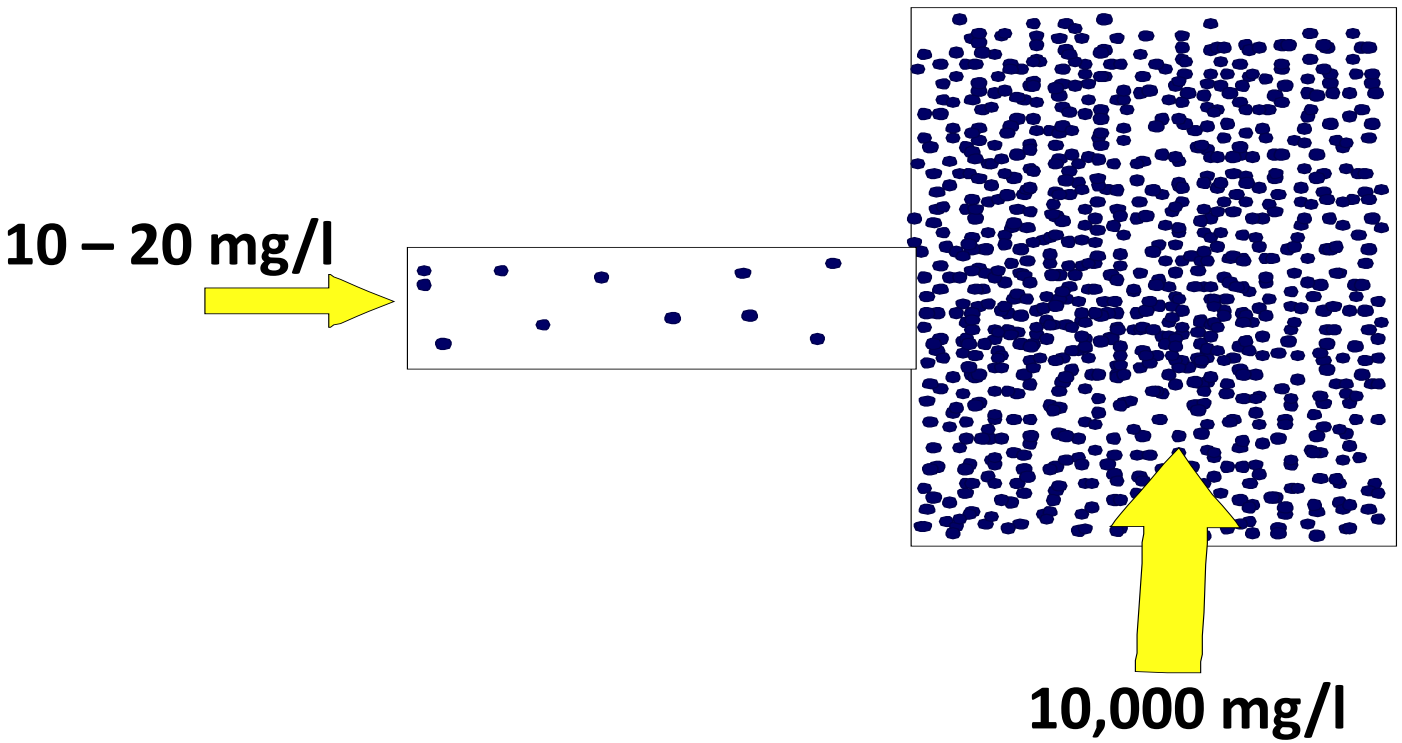
- Medium to small flocs are usually best for clarification
- Flocs which settle too rapidly leave fines in suspension

Flocculation

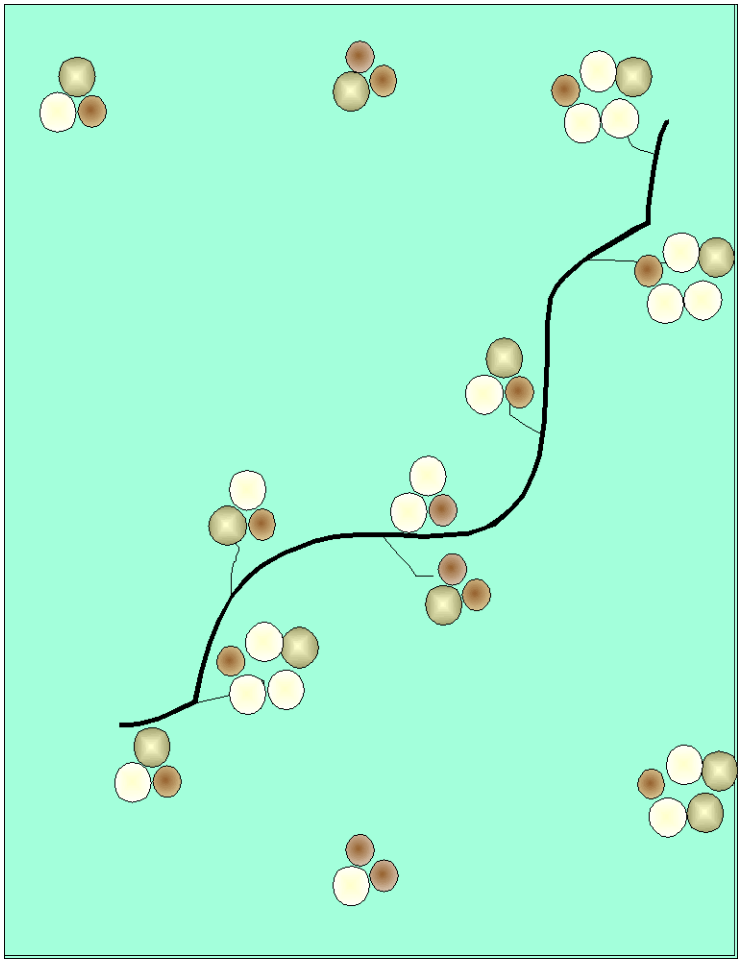
- Little particles into big particles
- Aids both settling rate and clarification



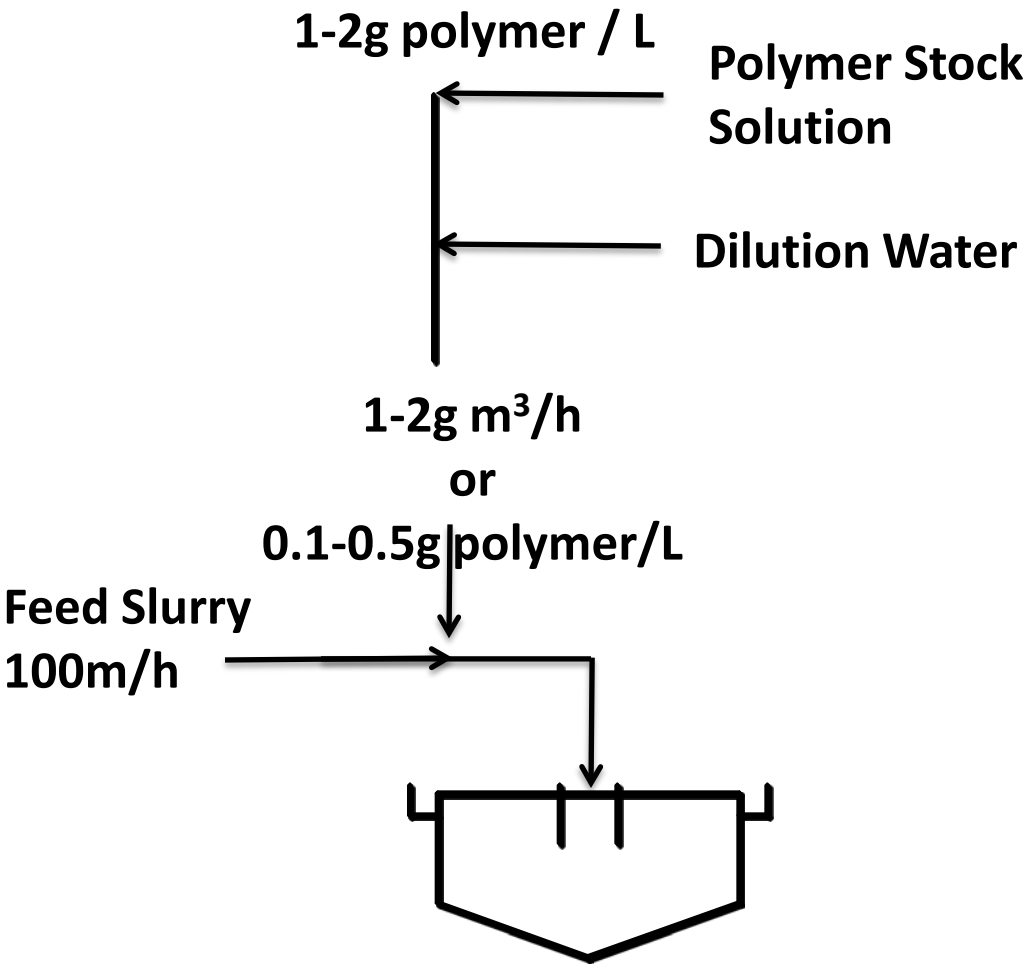
Solids Contact Ration
Mass recirculated / Mass in



Flocculation



Polymer Dilution



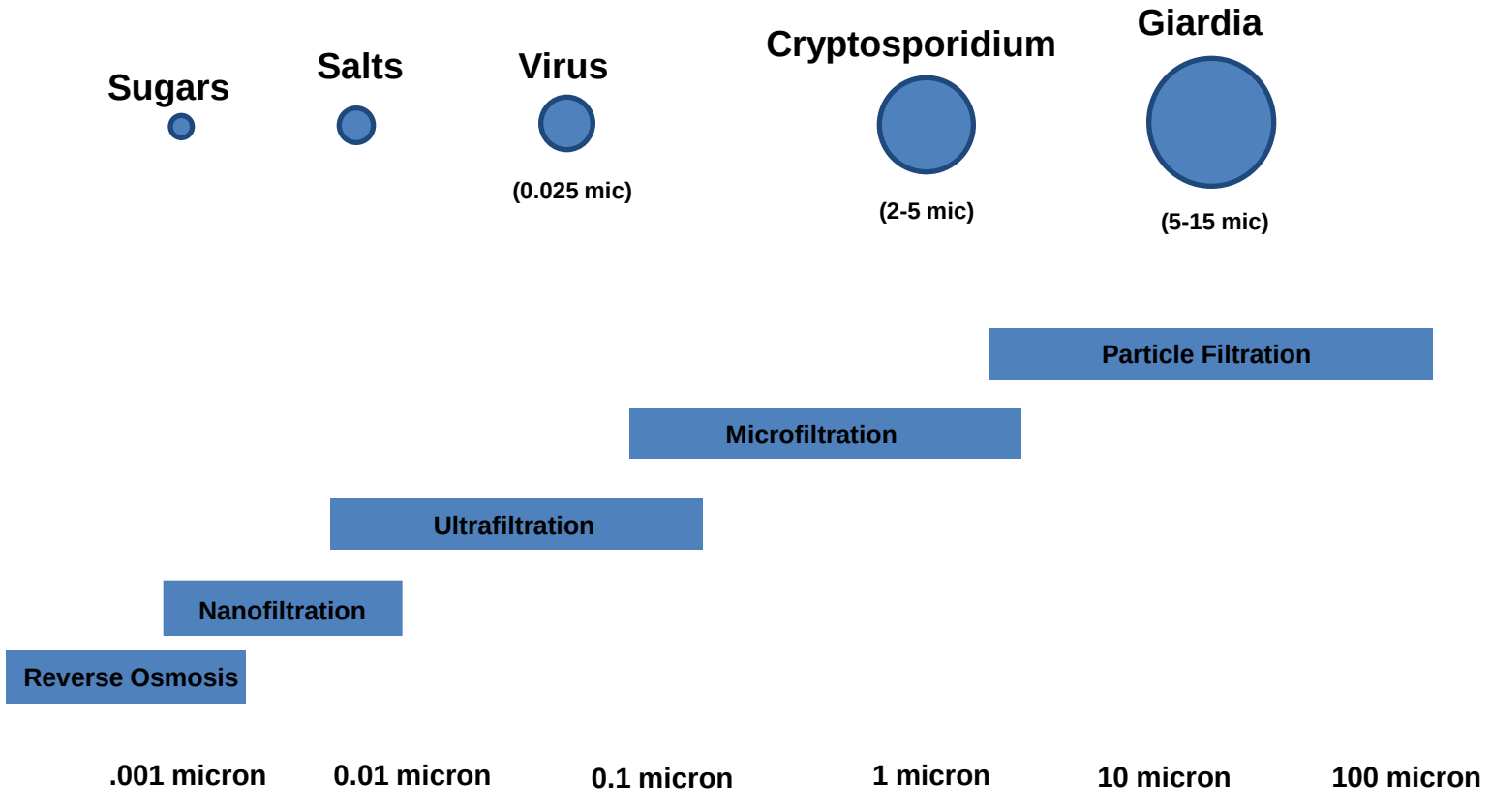
pH Adjustment

- Acid (Hydrochloric vs. Sulfuric)
- Lime (Hydrated vs Quick lime)
- Sodium hydroxide
- Soda ash

Effluent Filtration

- Granular media (super flocculation)
  - Gravity
  - Pressure
- Bag Filtration
- Membrane (barrier)
  - Ultra
  - Nano
  - RO
- Polishing filtration
  - Adsorption media

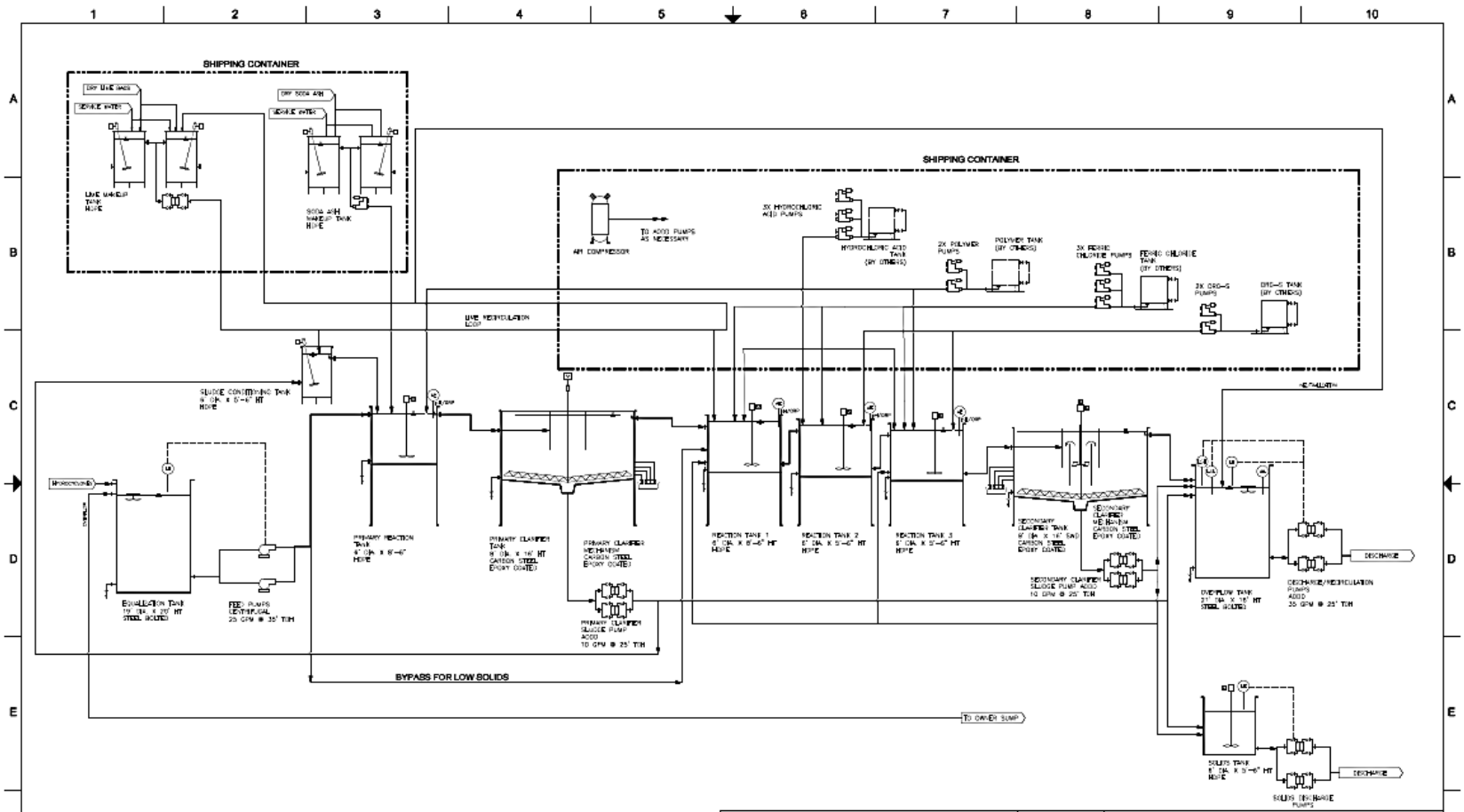
Filtration Spectrum



Solids Dewatering for Disposal

- Equipment options
  - Vacuum Filter
  - Belt Press
  - Plate and Frame Filter Press
  - Centrifuge
- Design for filtrate/pressate return to system
- Design for wash water

Process Flow Diagram



Thank you

WesTech