Physical Equipment Treatment Technologies 101

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Outline

* Proposed Effluent Limitation Guidelines (ELG)
* Physical Treatment Technologies
  * TSS Removal
  * Heavy Metals Removal
  * Solids Dewatering
* Pros / Cons of Treatment Technologies
* Conclusions

Background

* Current ELGs last updated in 1982
* Waste streams in current rule:
  * Low volume wastewater
  * Fly / Bottom ash transport wastewater
  * Once through cooling water
  * Cooling tower blow down
  * Coal pile runoff
  * Metal cleaning wastes

Background

Limits in Current ELGs

Pollutant	Maximum (ppm)	30-day Average (ppm)
126 priority pollutants[1]	Zero discharge	Zero discharge
Chromium[1]	0.2 mg/L	0.2 mg/L
Copper[2]	1.0 mg/L	1.0 mg/L
Free Available Chlorine	0.5 mg/L	0.2 mg/L
Iron[2]	1.0 mg/L	1.0 mg/L
Oil and grease	20 mg/L	15 mg/L
pH, standard units	6 – 9	6 - 9
PCBs	Zero discharge	Zero discharge
Total residual chlorine	0.20 mg/L	-
Total suspended solids (TSS)[3]	100 mg/L	30 mg/L
Zinc[1]	1.0 mg/L	1.0 mg/L

1 – applies to cooling tower blow down
2 – applies to metal cleaning wastes
3 – 50 mg/L instantaneous maximum for coal pile runoff

Proposed Limits

- EPA proposed new guidelines on April 19
- Impacted waste streams from:
  - Flue gas desulfurization systems
  - Fly ash sluice water
  - Bottom ash sluice water
  - Flue gas mercury control systems
  - Gasification processes
  - Combustion residual leachate
- Timing for compliance
  - Permit cycle beginning July 1, 2017

Proposed Limits

Limits Applicable to FGD Wastewaters

Pollutant	Maximum, any 1-day	30-day Average
Arsenic, total	8 ug/L (ppb)	6 ug/L (ppb)
Mercury, total	242 ng/L (ppt)	119 ng/L (ppt)
Nitrate/nitrite, as N	0.17 mg/L (ppm)	0.13 mg/L (ppm)
Oil and grease	20 mg/L (ppm)	15 mg/L (ppm)
pH, standard units	6 – 9	6 - 9
Selenium, total	16 ug/L (ppb)	10 ug/L (ppb)
Total suspended solids (TSS)	100 mg/L (ppm)	30 mg/L (ppm)

ppm – parts per million
ppb – parts per billion
ppt – parts per trillion

Limits for other wastewater sources very similar to FGD wastewater.

Typical FGD Wastewater

Typical FGD Wastewater Characteristics[1]

Pollutant	Minimum	Maximum
Arsenic, total	58 ug/L (ppb)	5,070 ug/L (ppb)
Mercury, total	7,500 ng/L (ppt)	872,000 ng/L (ppt)
Nitrate/nitrite, as N	1 mg/L (ppm)	270 mg/L (ppm)
Selenium, total	40 ug/L (ppb)	21,700 ug/L (ppb)
Total suspended solids (TSS)	5,000 mg/L (ppm)	170,000 mg/L (ppm)

ppm – parts per million
ppb – parts per billion
ppt – parts per trillion

1 – Data from several sources including:

- EPA 821-R-09-008, Steam Electric Power Generating, Point Source Category: Final Detailed Study Report
- EPRI 1012549, Treatment Technology Summary for Critical Pollutants of Concern in Power Plant Wastewaters

Reductions Required

Typical Reductions Required

Pollutant	Minimum, %	Maximum, %
Arsenic, total	89.6%	99.8%
Mercury, total	98.4%	99.9%
Nitrate/nitrite, as N	87%	99.9%
Selenium, total	75%	99.9%
Total suspended solids (TSS)	99.4%	99.9%

Proposed Limits

- No discharge allowed:
  - Fly ash sluice water
  - Bottom ash sluice water
  - Flue gas mercury control systems
- Similar to FGD wastewater quality:
  - Combustion residual leachate
- More stringent than FGD wastewater quality:
  - Gasification processes

Key Containment Sources

* Total Suspended Solids
  * Conveyor/plant wash-down
  * Boiler fly ash and bottom ash
  * Transport wastewater – bottom or fly ash
* Heavy Metals
  * Fly and bottom ash transport
  * Flue gas desulfurization systems
  * Boiler chemical cleaning wastes
  * Coal pile runoff pond decant
  * Ash landfill leachate collection system

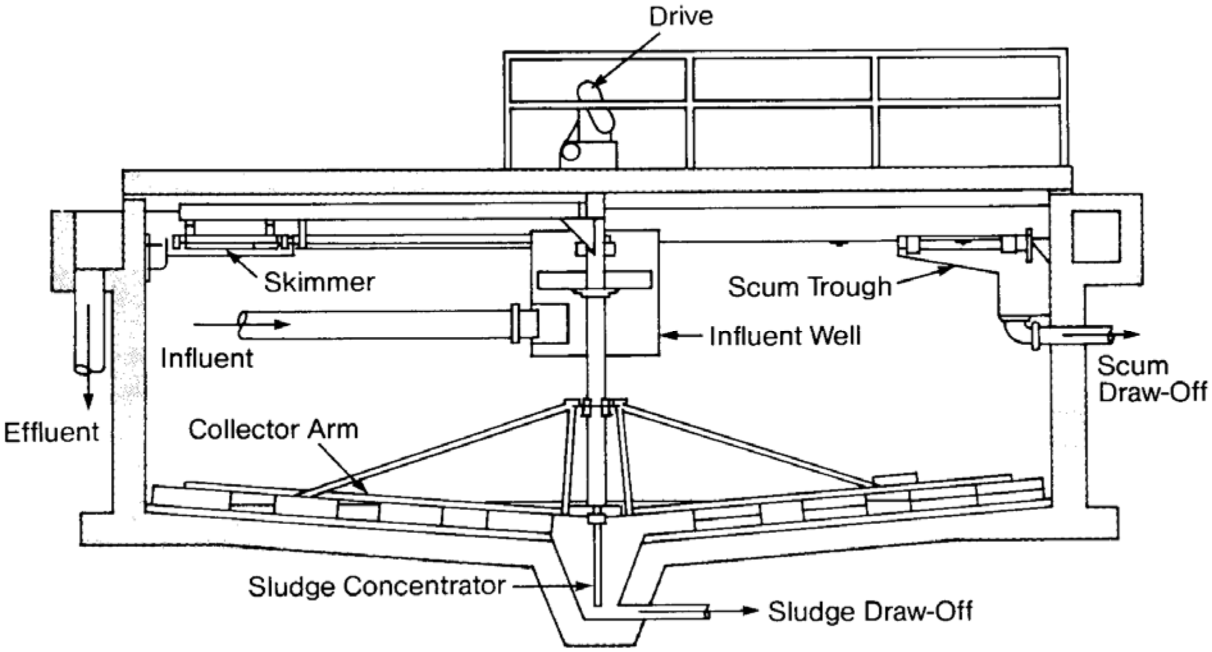
Physical/Chemical Treatment Options

- Total Suspended Solids Removal
  - Conventional Clarification
  - High Rate Clarification
  - Conventional Filtration
  - Dissolved Air Flotation

Conventional Clarification

* Clarification relies on gravity settling for water/suspended solids separation.
* Chemicals can be added to the influent well to enhance settling
* Designs are based on surface and solids loading rates

Conventional Clarification



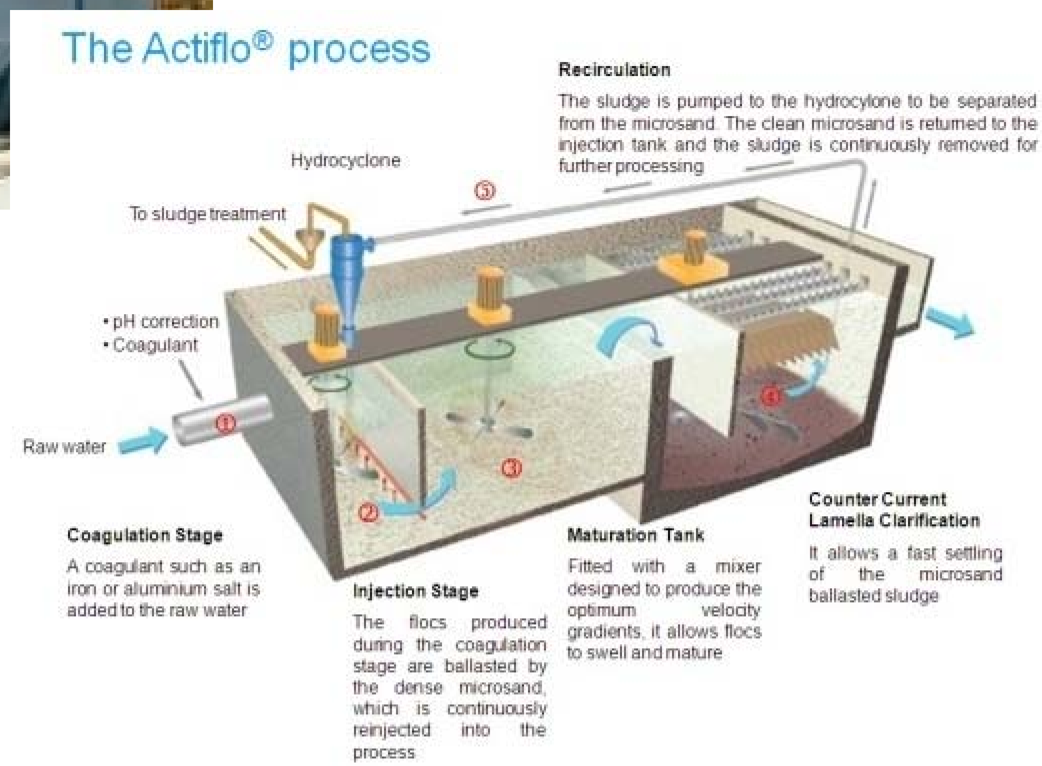
Conventional Clarification Advantages and Disadvantages

* Advantages
  * Proven technology
  * Simple operation
  * Low cost equipment and power usage
* Disadvantages
  * Large footprint
  * Does not handle large fluctuations in flow well

High Rate Clarification

* Utilizes micro-sand: enhances flocculation and lamella plate settling
* Rapid Mix Zone: polymer and micro-sand are added in a high energy mixing environment
* Maturation Zone: low energy mixing for floc development
* Settling Tank: micro-sand floc settles out quickly, lamella settlers further clarify water

High Rate Clarification



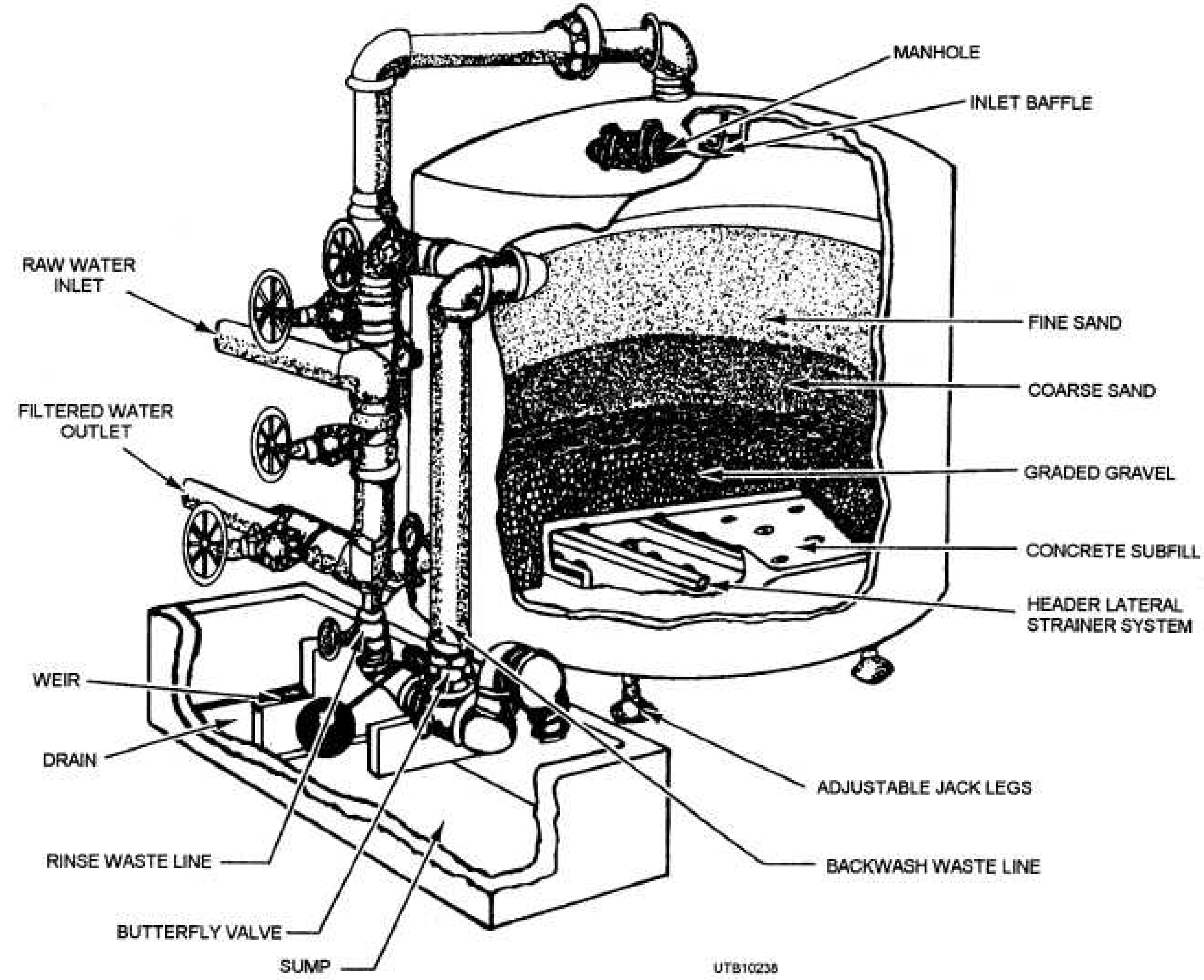
High Rate Clarification Advantages and Disadvantages

- Advantages
  - Very high loading rates reduce area required (small footprint)
  - Use of microsand allows clarifier to absorb varying influent quality
  - Some heavy metals removal is possible
- Disadvantages
  - Proprietary systems (increases capital cost)
  - High power use
  - Microsand must be replenished/replaced on a regular basis.

Conventional Filtration

* Process of removing particulate material those accumulation on the surface or throughout the depth of the filter.
* Filters require occasional backwashing
* Backwash supply and waste water storage required
* Vessels can utilize single or multiple types of media
* Common media includes
  * Sand
  * Anthracite coal
  * Granular activated carbon

Conventional Filtration



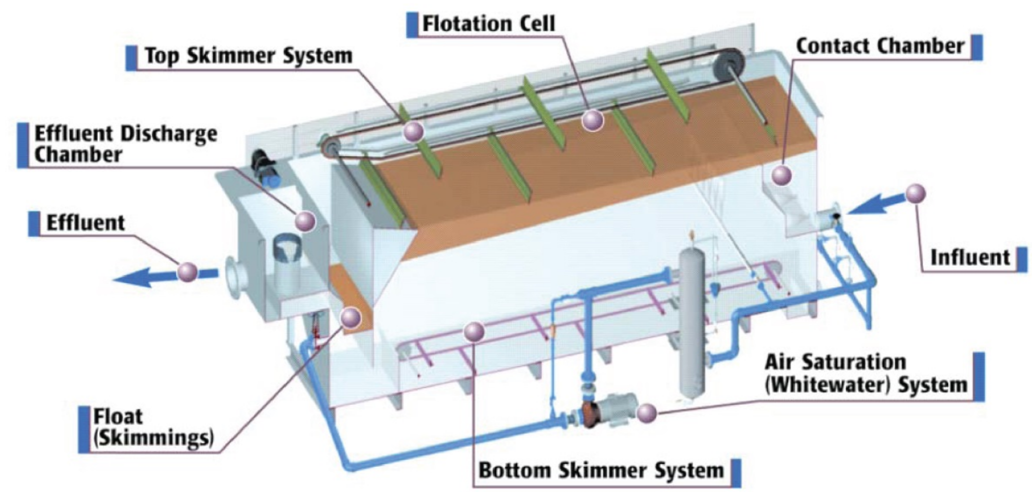
Conventional Filtration Advantages and Disadvantages

- Advantages
  - Most common form of TSS removal
  - Relative simple operation
  - Relative small footprint
  - Low capital and operation cost
- Disadvantages
  - Backwash supply and waste water storage required
  - Require occasional media addition
  - High headloss is possible depending on media size

Dissolved Air Floatation

* Solids are separated by floating the floc to the water surface through the use of dissolved air bubbles
* The “float” is scraped from the top of the reactor
* Settle solids are removed from the bottom of the tank

Dissolved Air Floatation



Dissolved Air Floatation Advantages and Disadvantages

* Advantages
  * Proven technology
  * Small footprint
  * Produces a concentrated waste stream
* Disadvantages
  * High capital cost
  * Complex system to operate
  * High power consumption

Physical/Chemical Treatment Options

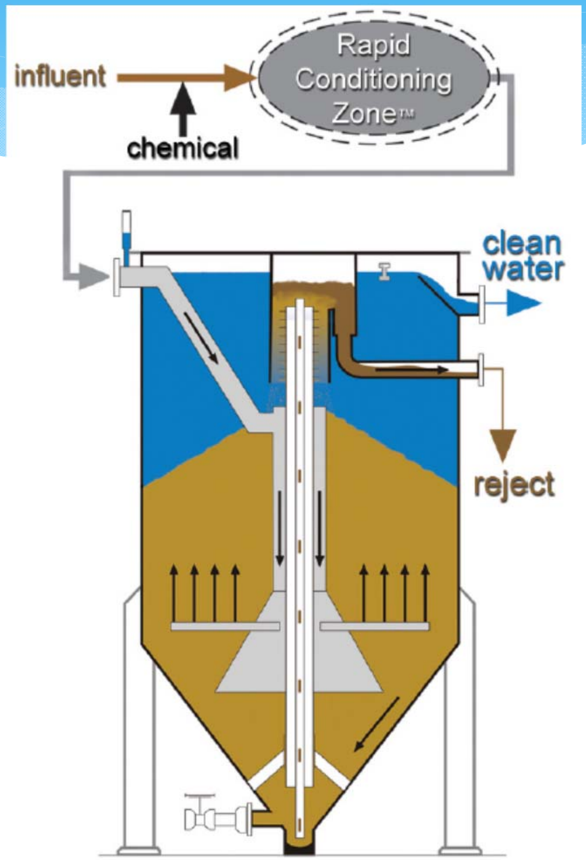
* Metals Removal
  * Iron Adsorption
  * Metal Hydroxide Precipitation
  * Iron Co-precipitation
  * Metal Sulfide Precipitation
  * Ion Exchange
  * Reverse Osmosis
  * Thermal Evaporation

Iron Adsorption

* Metal adsorption onto hydrous ferric oxide (HFO) coated sand
* Continuous up-flow sand filtration
* Feed ferric sulfate to coat sand
* Metals adsorbed onto coating
* Coating scoured off and removed

Iron Adsorption

- Figure showing typical up-flow sand filter
- An air lift pump moves sand from bottom of bed to top
- Coating is scoured from sand at the top
- Sand is returned to bed and recoated



Iron Adsorption Advantages

- Advantages:
  - Various metals removed
  - Small footprint
  - No moving parts
  - Low volume of waste generated
  - Low cost
  - Minimal operator involvement
  - Some removal of TSS

Source: Blue Water Technologies

Iron Adsorption Disadvantages

- Disadvantages:
  - Chlorides inhibit mercury adsorption
  - Not a replacement for bulk TSS removal
  - Concentrated waste stream
  - Unable to achieve discharge limits by itself
    - Could be used in combination with other processes
    - Polishing step
  - Unable to treat for nitrates

Iron Adsorption Results

Reductions Observed in Pilot Testing

Pollutant	Inlet	Outlet	Removal, %
Aluminum, total	1,740 ug/L (ppb)	16 ug/L (ppb)	99%
Arsenic, total	5 ug/L (ppb)	2 ug/L (ppb)	60%
Chromium (+6), total	6 ug/L (ppb)	0.5 ug/L (ppb)	92%
Copper, total	0.84 ug/L (ppb)	0.7 ug/L (ppb)	17%
Lead, total	3.6 ug/L (ppb)	3.2 ug/L (ppb)	11%
Mercury, total	29 ng/L (ppt)	3 ng/L (ppt)	90%
Selenium, total	24 ug/L (ppb)	15 ug/L (ppb)	38%

Metal Hydroxide Precipitation

* Various metal hydroxides are insoluble
* Precipitation by feeding lime or sodium hydroxide
* High quantities of lime feed required
* Large volume of sludge generated
* Removal down to low ppm levels possible
* Removal not adequate to meet ELG limits
* Not recommended

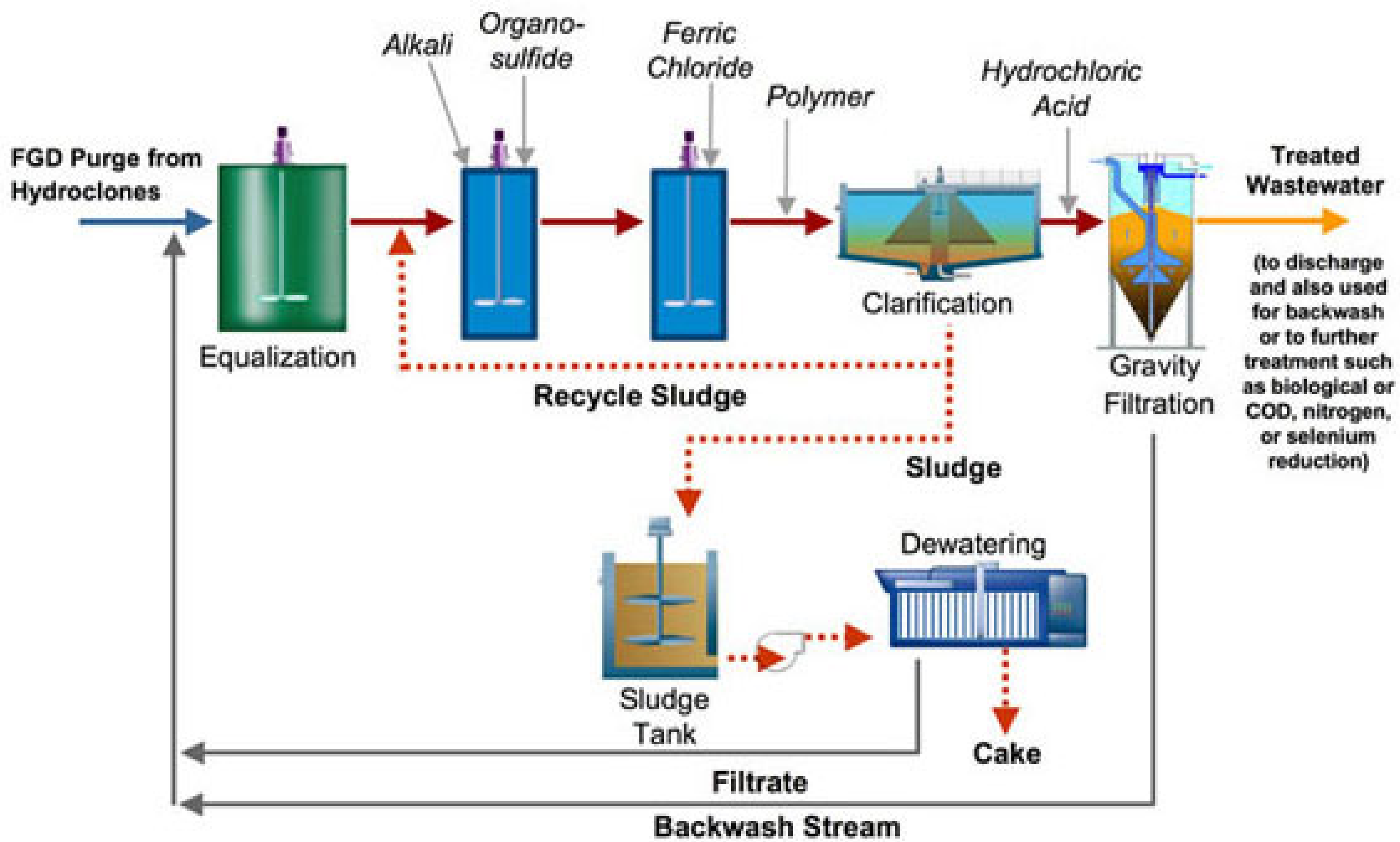
Iron Co-Precipitation

* Various metals will co-precipitate when ferric hydroxide precipitates from solution
* Ferric chloride or Ferric sulfate feed
* Hydroxide feed
* High quantities of chemical feeds required
* Large volumes of sludge generated
* Removal to low ppm – high ppb levels
* Removal not adequate to meet ELG limits
* Not recommended

Metal Sulfide Precipitation

* Solubilities of metal sulfides are significantly lower than metal hydroxides
* Organo or inorganic sulfide feed
* Removal to ppb or sub-ppb levels
* Removal close to proposed ELG limits
* Preferred method
* May need subsequent polishing step(s)

Metal Sulfide Precipitation



Source: Siemens

Metal Sulfide Precipitation Advantages and Disadvantages

* Advantages:
  * Provides for significant concentration reductions – close to ELG limits
  * Metal sulfide sludges are stable
* Disadvantages:
  * Large volume of waste sludge generated
  * Large footprint required
  * High capital and operating costs
  * Heavy operator involvement
  * Doesn’t address nitrates/nitrites

Metal Sulfide Precipitation Results

Observed Typical Reductions[1]

Pollutant	Inlet	Outlet	Removal, %
Arsenic, total	1,590 ug/L (ppb)	10 ug/L (ppb)	99.3%
Mercury, total	243,000 ng/L (ppt)	10,000 ng/L (ppt)	96%
Nitrate/nitrite, as N	54.5 mg/L (ppm)	36.5 mg/L (ppm)	33%
Selenium, total	2,130 ug/L (ppb)	83.6 ug/L (ppb)	96%
Total suspended solids (TSS)	7,320 mg/L (ppm)	17.5 mg/L (ppm)	99%

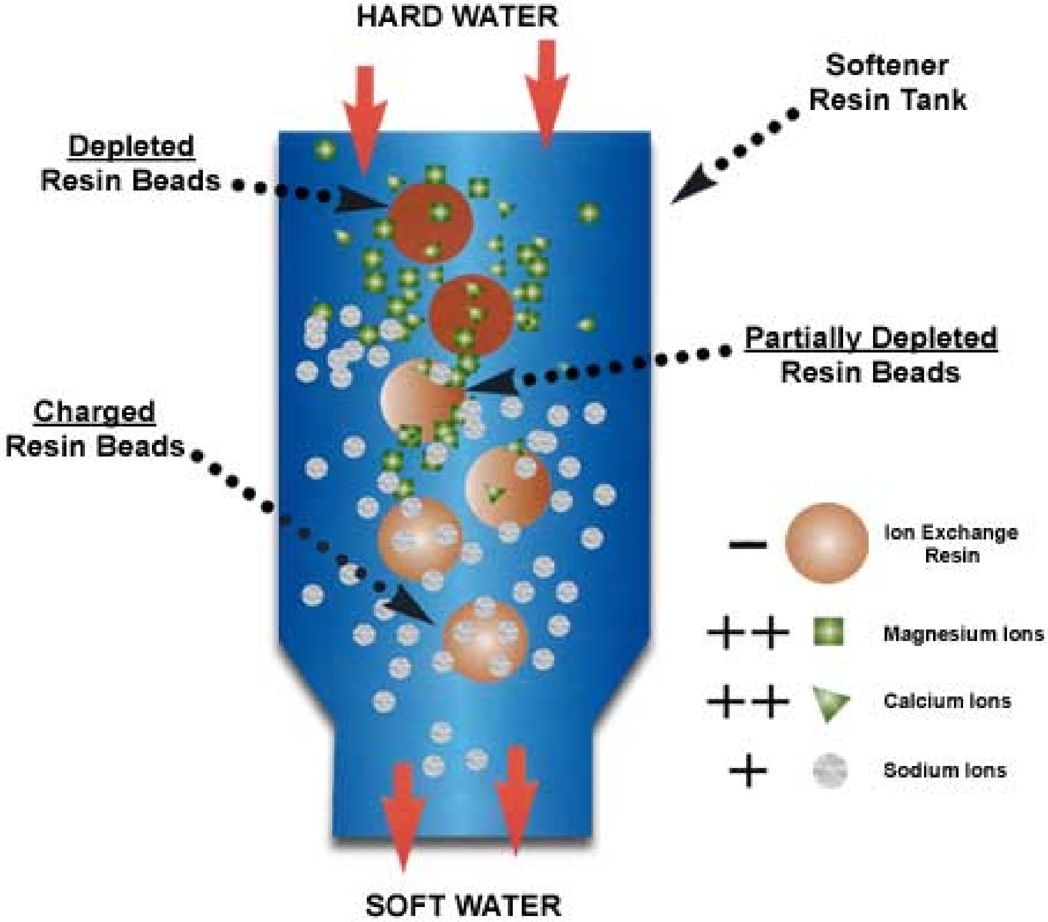
1 – for systems treating FGD wastewaters; data taken from

- EPA 821-R-09-008, Steam Electric Power Generating, Point Source Category: Final Detailed Study Report

Ion Exchange

* Resins that are capable of exchanging particular ions with ions in a solution
* Applications include the removal of
  * Heavy metals
  * Nitrogen
  * Hardness (Ca and Mg)

Ion Exchange



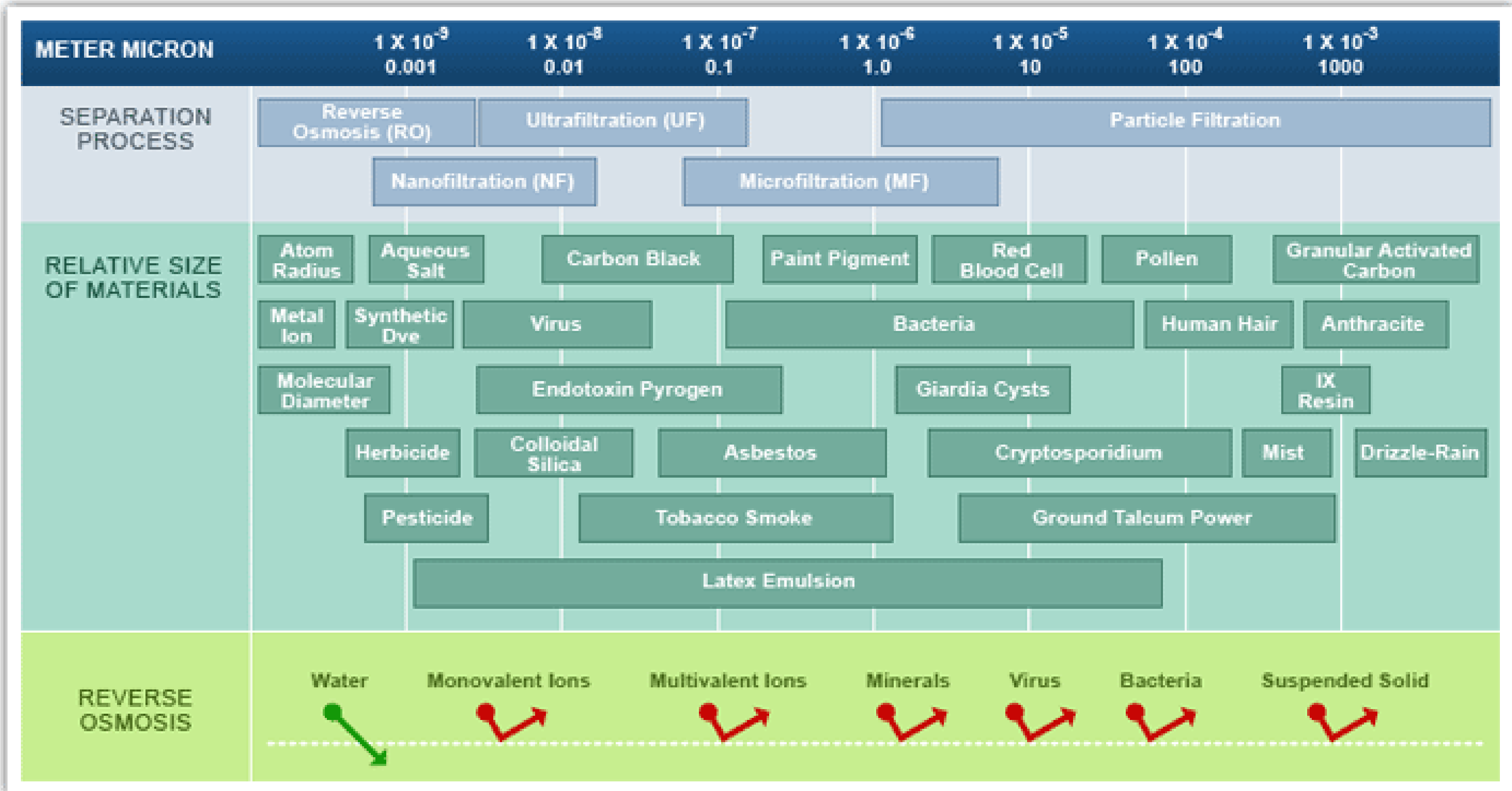
Ion Exchange
Advantages and Disadvantages

* Advantages
  * Proven technology
  * Effect for heavy metal removal
  * Inexpensive equipment costs
* Disadvantages
  * High resin capital and regeneration or disposal costs
  * Not effect for organics removal
  * Resin fouling (iron, calcium sulfate, organic matter, bacterial contamination)

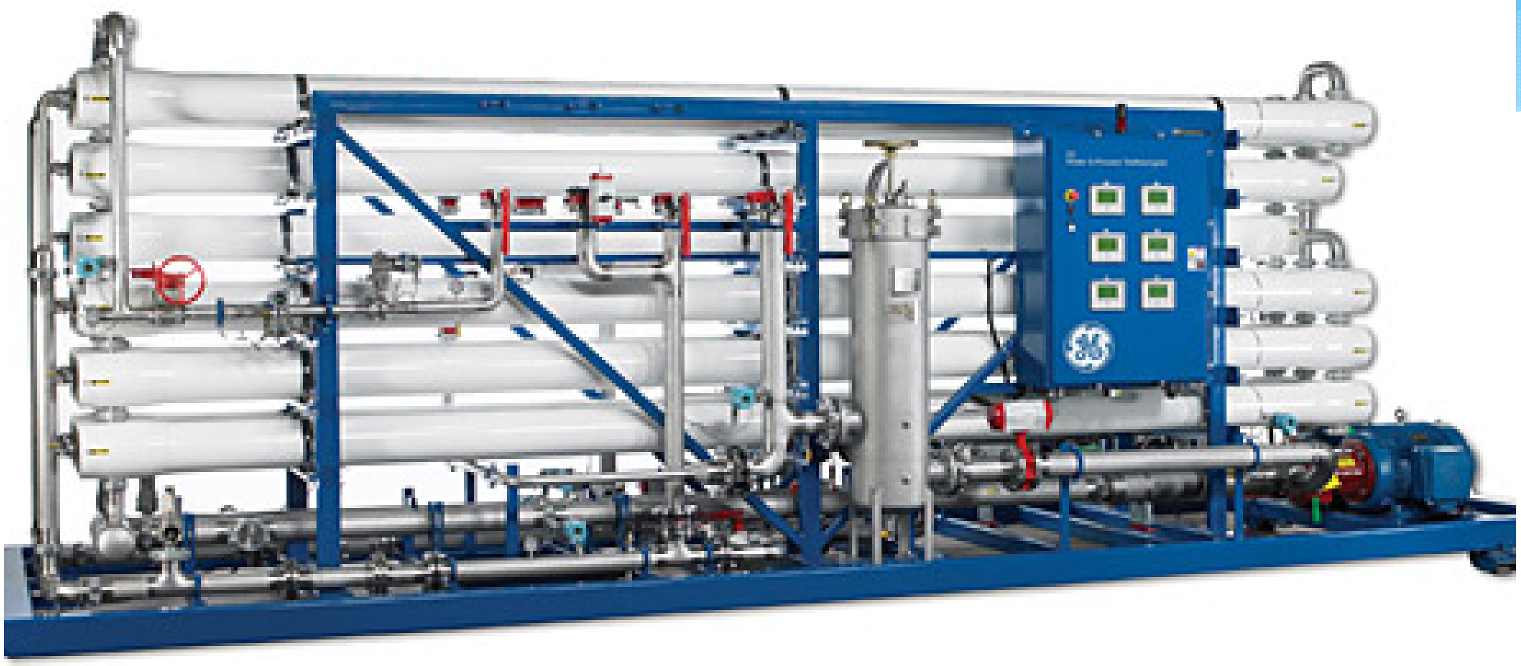
Reverse Osmosis

* Osmosis – solvent naturally moves from an area of low solute conc through a membrane to an area of high solute conc. Creates osmotic pressure.
* RO - External pressure is used to overcome osmotic pressure and reverse flow of solute.
* Solute is retained on the pressurized side and pure solvent is allowed to pass through.

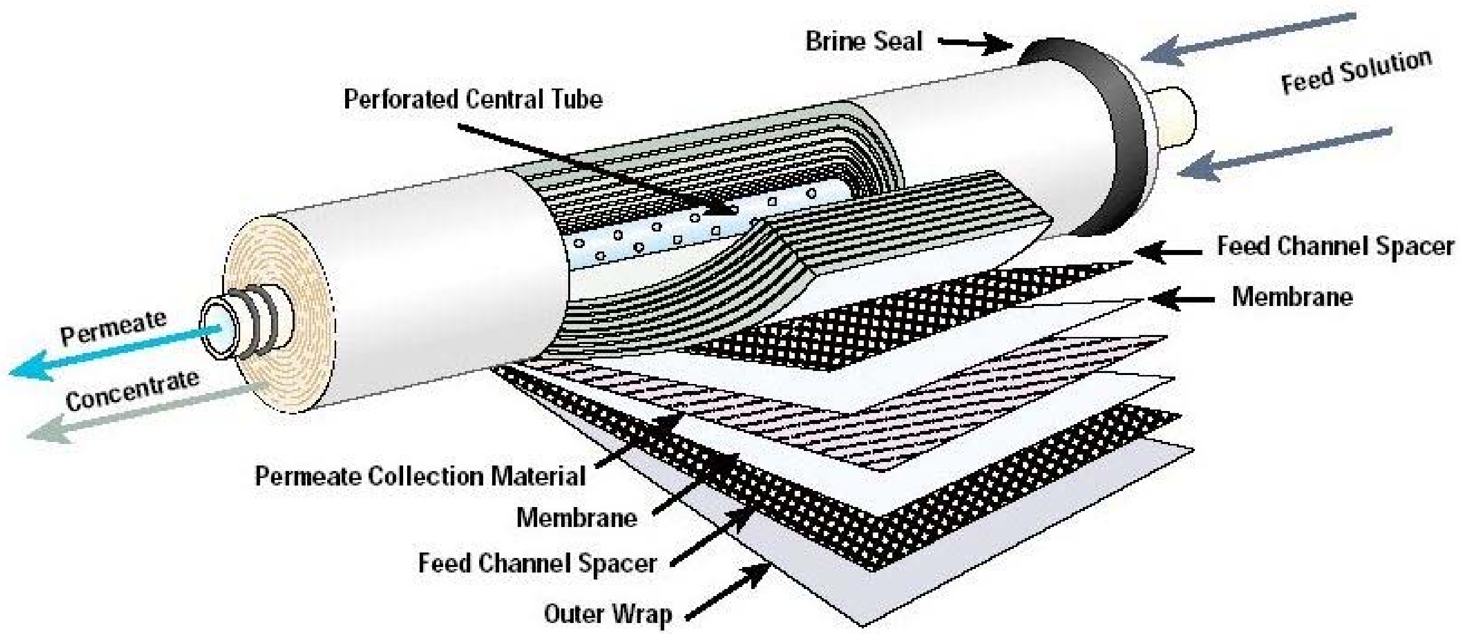
Reverse Osmosis



Reverse Osmosis



Reverse Osmosis



Reverse Osmosis Advantages and Disadvantages

- Advantages:
  - No future permitting issues if regulations change, again
  - Recovery of high purity condensate for reuse in facility
- Disadvantages:
  - High capital cost
  - High operating cost
  - Significant electrical consumption
  - High maintenance cost
  - Brine disposal is required (deep well, thermal evaporation, local POTW)

Thermal Evaporative

* Evaporative Systems
  * Evaporation ponds
  * Spray dryers
  * Falling film evaporators
    * Thermal or mechanical vapor compression

Thermal Evaporative Advantages and Disadvantages

- Advantages:
  - No liquid waste to discharge
  - No future permitting issues if regulations change, again
  - Recovery of high purity condensate for reuse in facility
- Disadvantages:
  - High capital cost
  - High operating cost
  - Significant electrical consumption
  - High maintenance cost
  - Dedicated operating staff

Physical/Chemical Treatment Options Continued

- Solids Dewatering
  - Drying Beds
  - Belt Filter Press
  - Plate and Frame Filter Press
  - Centrifuge

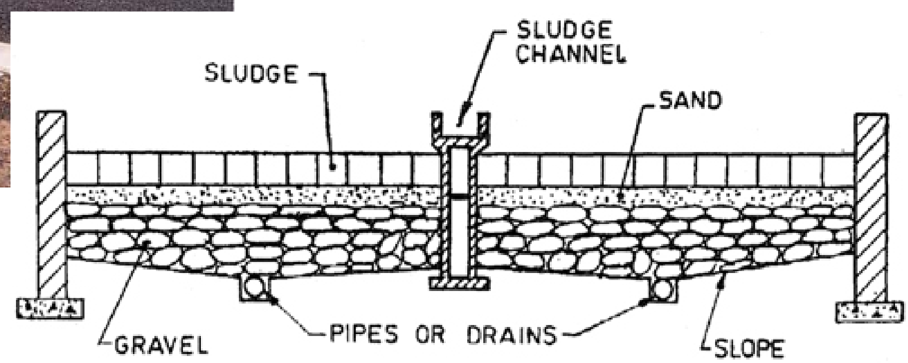
Solids Dewatering

* Drying Beds
* Belt Filter Press
* Plate and Frame Filter Press
* Centrifuge
* Dewatering Box

Drying Beds

* Equipment
  * Feed Piping
  * Filtration bed
  * Underdrain System
* Feed Piping
  * Allowing operations staff to select and distribute sludge to drying beds
* Filtration Bed
  * Typically sand/gravel media to allow drainage through the sludge and prevent the underdrain pipe from clogging.
* Underdrain System
  * Series of perforated pipes/laterals used to collect sludge drying bed drainage

Drying Beds



Drying Beds
Advantages and Disadvantages

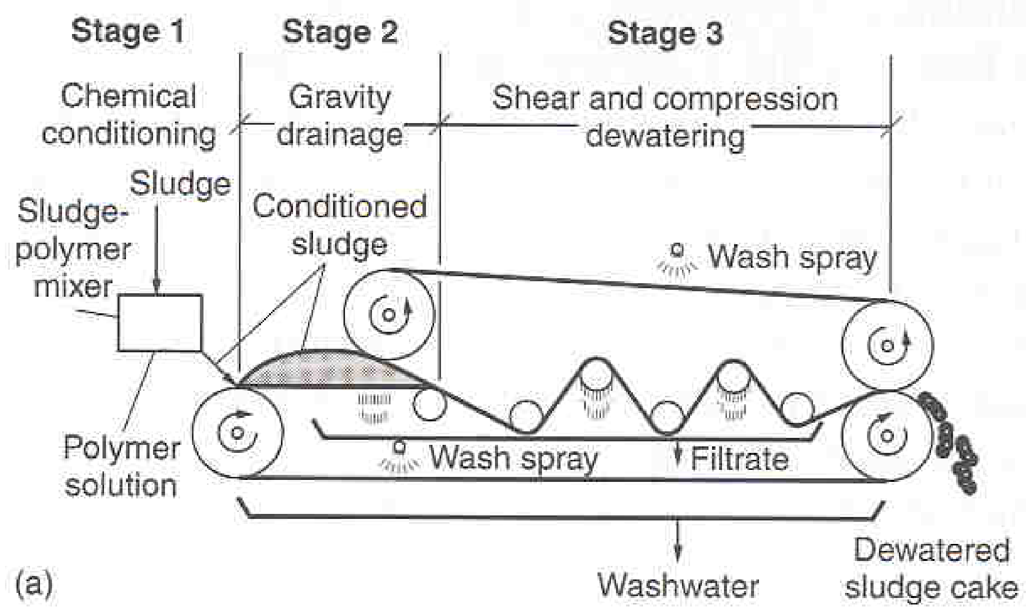
* Advantages
  * Low O&M requirements
  * Low capital costs
  * Can handle variable loadings
  * Can produce very dry solids with extend time
* Disadvantages
  * Large land area required
  * Solids removal equipment and contracting
  * Work best in dry climates, covers required for wet areas

Belt Filter Press

- Equipment
  - Polymer preconditioning
  - Gravity Section
  - Pressure Section
- Polymer Preconditioning
  - Added to destabilize interaction between water and solids
- Gravity Section
  - Drainage occurs and the sludge is allowed to thicken as it travels on a porous belt.
- Pressure Section
  - Mechanical pressure is applied to the perforated belt, squeezing water out of the sludge through the porous belt

Belt Filter Press

- Discharge Solids Conc: 15-25%



Belt Filter Press
Advantages and Disadvantages

* Advantages
  * Proven technology
  * Lower capital cost
  * Maintenance can be preformed by plant staff
* Disadvantages
  * Large footprint requirement
  * Cake 3 to 5% les than a centrifuge
  * Poor solids capture

Plate and Frame Filter Press

* Equipment
  * Skeleton
  * Filter Pack
* Skeleton
  * Holds the filer packs together against pressure (100 psi is typical)
* Filter Pack
  * Actual liquid/solid separation
  * Series of filter elements that form chambers
  * Process – slurry is pumped under pressure into the filter pack, liquid passes through the filter pack leaving solids behind

Plate and Frame Filter Press

20-30%

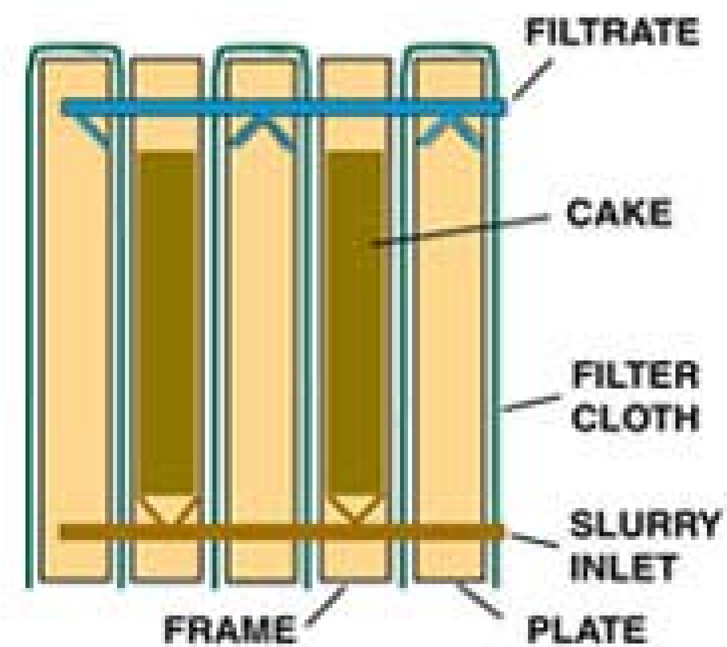


Plate and Frame Filter Press Advantages and Disadvantages

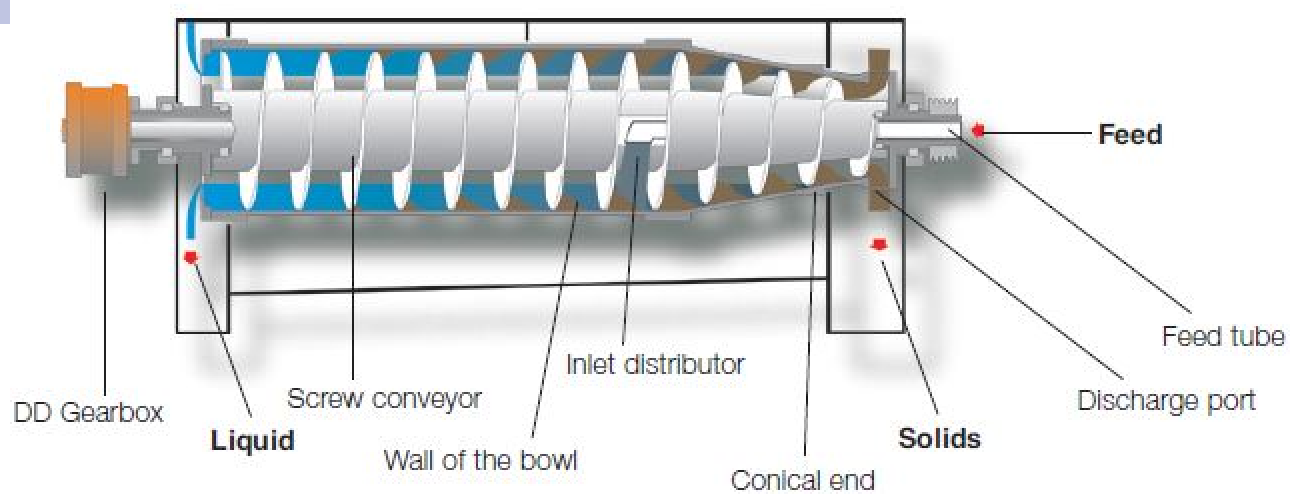
* Advantages
  * Proven technology
  * Produces high solids concentrations
  * Clean operation
* Disadvantages
  * High capital cost
  * Large footprint requirement
  * Typically run in batch processes

Centrifuge

* Equipment
  * Polymer preconditioning
  * Bowl
  * Screw
  * Drives
* Polymer Preconditiong
  * Added to destabilize interaction between water and solids
* Bowl
  * Sludge particles are pressed against the bowl and dewatering through centrifugal force (2,500-3,500 rpm)
* Screw
  * Moves dewater sludge to the centrifuge discharge
* Drives
  * Responsible for the bowl and screw rotation

Centrifuge


G2


Feed
Feed tube
Discharge port
Inlet distributor
DD Gearbox
Screw conveyor
Liquid
Wall of the bowl
Solids
Conical end

Centrifuges
Advantages and Disadvantages

* Advantages
  * Proven technology
  * Recent advances in backdrive technology reduces HP requirement/use
  * Small footprint
  * Clean operation
* Disadvantages
  * High energy and chemical usage
  * High capital cost
  * Skilled mechanical staff required
  * Centrate management

Dewatering Box

* Equipment
  * Polymer preconditioning
  * Bowl
  * Screw
  * Drives
* Polymer Preconditiong
  * Added to destabilize interaction between water and solids
* Bowl
  * Sludge particles are pressed against the bowl and dewatering through centrifugal force (2,500-3,500 rpm)
* Screw
  * Moves dewater sludge to the centrifuge discharge
* Drives
  * Responsible for the bowl and screw rotation

Conclusions

* Many options for treatment of:
  * Total suspended solids
  * Heavy metals
  * Solids dewatering
* May not get to proposed ELG limitations with a single treatment systemo
* Wastewater treatment may need to consist of multiple stages of treatment to address different constituents
* Evaluate plant specifics to determine best approach

Questions?

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