


Challenges and Common Mistakes to Avoid when Designing Mine Water Treatment Plants

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2025 BC MEND ML/ARD Workshop

Main Challenges – Water Treatment Plants (WTP)

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With over 30 years of experience including operation, many designs, optimisation/troubleshooting projects and reviews...

- Design Criteria
- Challenges in new types of mines
- Process
- Plant Hydraulics, Reactors, Reagents
- Equipment selection
- Process design engineer
- Quick hits

Design Criteria

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- Most critical problem on new mines:

STARTING TOO LATE

- Design Criteria – you need to know what you're dealing with
  - Flows – hydrology, hydrogeology, metallurgy, water balance
  - Raw water quality – geochemistry, metallurgy, mass balance
  - Treated water quality – permitting (don't just promise anything), receiver studies

- So many steps, some of these (Geochem) take months but they need to happen before getting the mine permitted.
  - Absolutely needs to be included in pre-feasibility, feasibility level too late – the water will cause delays
- Understanding that it's not that simple and it's an essential/integral part of mining (also becoming more expensive)

Design Criteria – Critical Minerals

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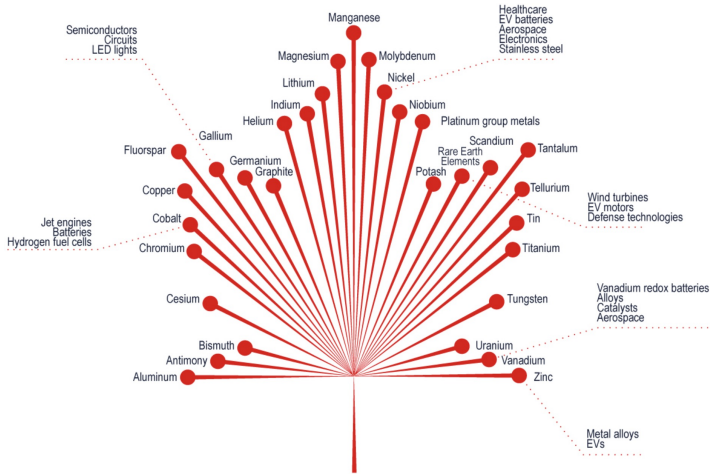
- Benchmarking is a large part of well-known mines
  - Sulphide mines (Cu, Zn, Ni, Pb, ..) will have oxidation, sulphate, maybe acid
  - Fe and diamond mines have suspended solids
  - Gold mines may have acid, generally N-species due to CN (NH_3, NO_3, NO_2…)
  - …
- Not much benchmarking for
  - Hard-rock lithium, graphite, and rare earths, for example
- Need more time and more studies
  - Geochemistry is new
  - Concentrator processes innovative, tailings porewater chemistry unknown
    - Need to run met trials longer, ensure water recycle and representativity of tailings water
    - May need to pilot treatment systems



Design Criteria – Hopeful Engineering

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- New mine, or closing mine, need to establish the flows and water qualities
  - As always, late in the process, and owner must minimise costs
- Natural human tendency to view optimistically and to want to please client
  - ZERO DISCHARGE! …in a wet climate…
  - Water covers or soil covers will be 100% effective!
  - We won't need treatment!
  - At PFS level: "I'm sure a $5M WTP will work when we get there…"
  - Using a 1 in 20-year design flood (1:100 is way too expensive, unrealistic)
- Regulators asking for unrealistic limits
  - Trend in some provinces, targeting receiver water quality for end-of-pipe permits
  - Juniors just want a permit, accept anything
- It takes courage to face the truth. The sooner the better.

  It takes more courage to tell your client!

Panic Plant

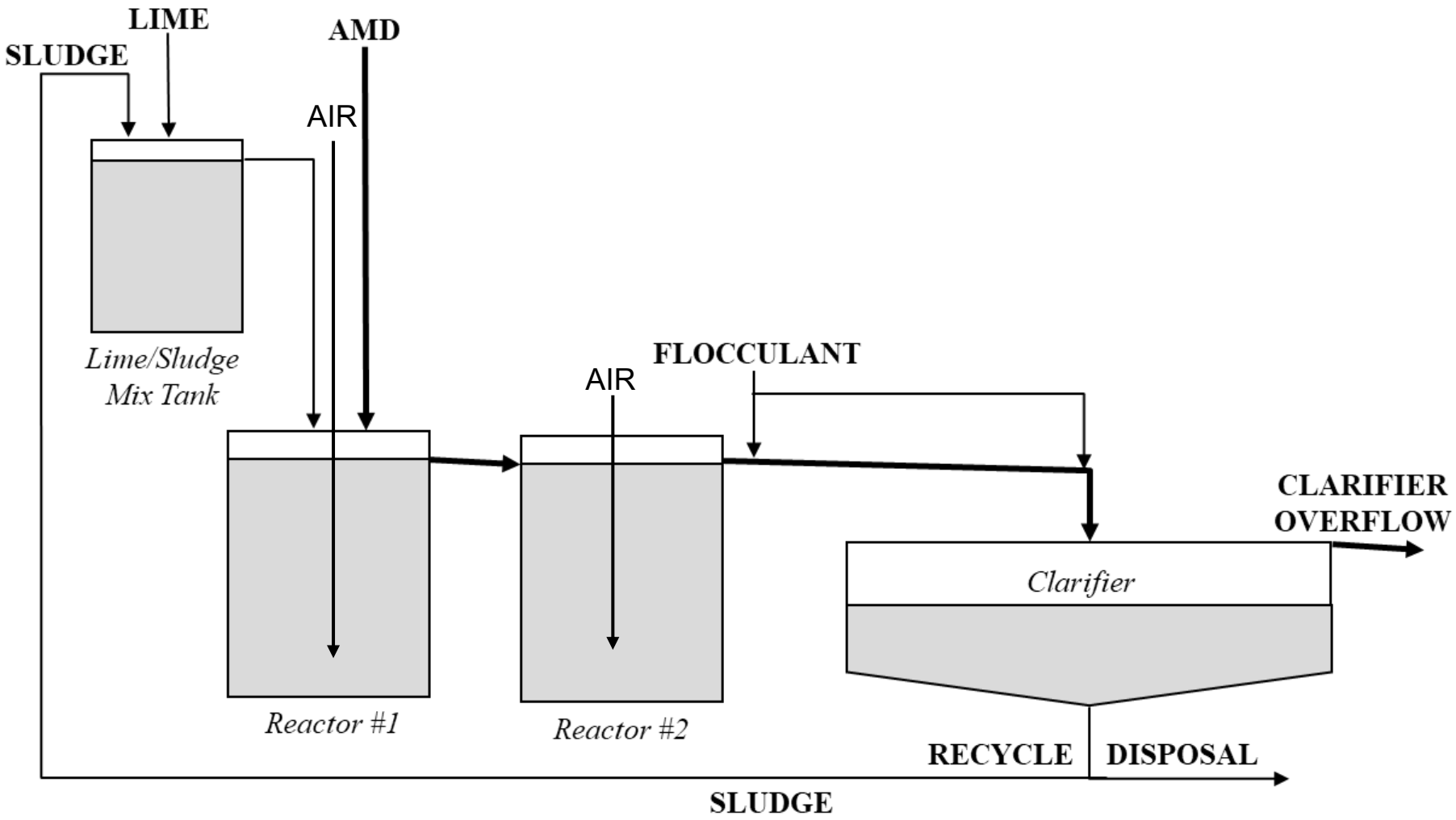
- Due to leaving water last or to Hopeful Engineering, urgent works needed to treat water
- Accelerated design and delivery
  - Inadequate design criteria
  - Use concentrator engineers
  - Higher capital costs for contingency
  - Higer than-needed operating costs
  - Wrong reagents
- Straight to Suppliers, they can only sell what they provide – not fit-for-purpose
  - Will always have solution
  - Guarantees can always be disputed
- Worst Case:

  Does not meet needs – non-compliance!

The HDS Process – For ARD or Sulphate

The HDS Process is the current standard in lime treatment:

- higher sludge density,
- better lime efficiency,
- improved metal removal,
- better solid/liquid separation, and
- improved removal of sulphate



Micro-Physical Basis of the HDS process

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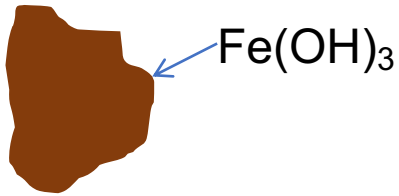
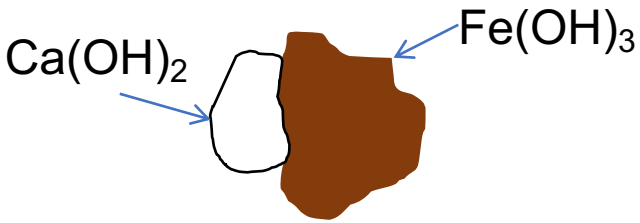
1. Solids in sludge:



2. In Lime/Sludge Mix Tank (coagulation of lime with solids from sludge) :

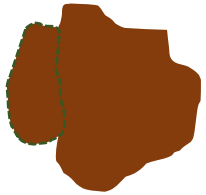


3. In neutralisation reactor (dissolution of lime and precipitation of metals):

$Ca(OH)_2 \rightarrow Ca^{2+} + 2OH^-$

$Fe^{3+} + 3OH^- \rightarrow Fe(OH)_3$

4. New solids with particle growth:



Note: Same principle for gypsum, but much slower reaction

$$Ca^{2+} + SO_4^{2-} \Rightarrow CaSO_4 \cdot 2H_2O$$

The HDS Process – NOT For All

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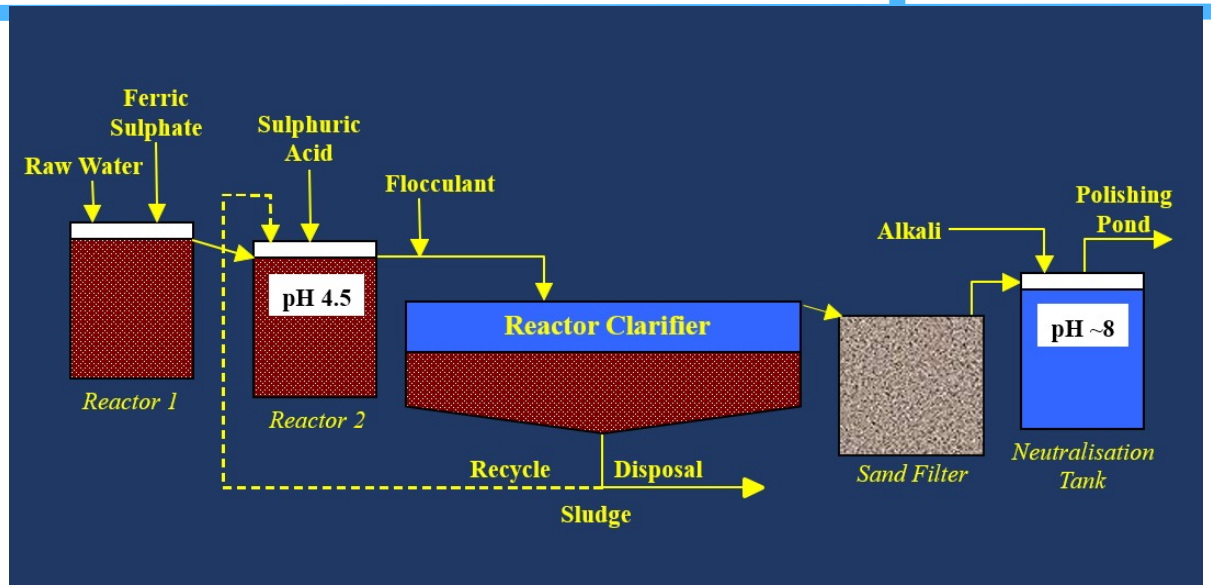
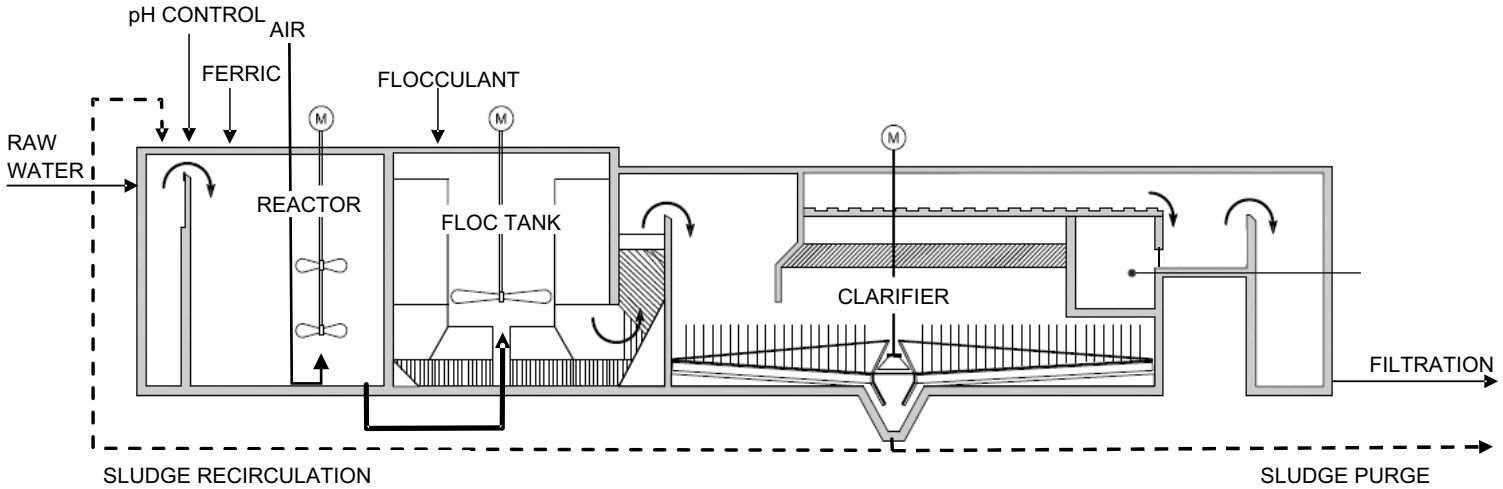
Mo and As removal are co-precipitation processes

- No Lime/Sludge Mix Tank!!
- Does not make any sense chemically
- Causes more harm than good



TSS removal and other non-scaling processes are best with lamella clarifiers

- Won't make high density anyhow.
- Better CAPEX and OPEX



Confusing Coagulation and Flocculation

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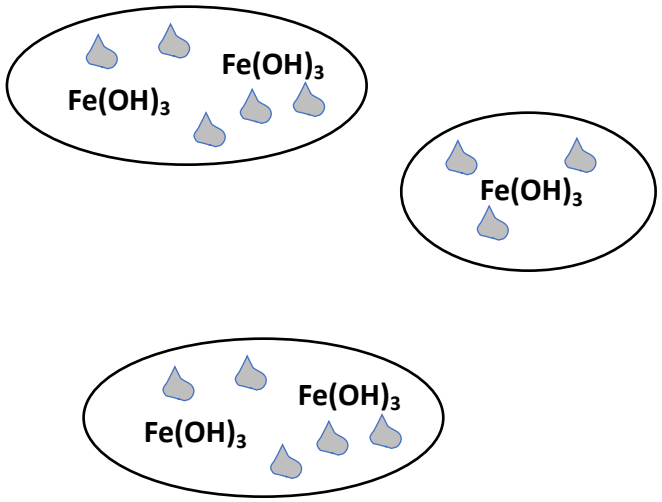
Colloidal Suspended Solids

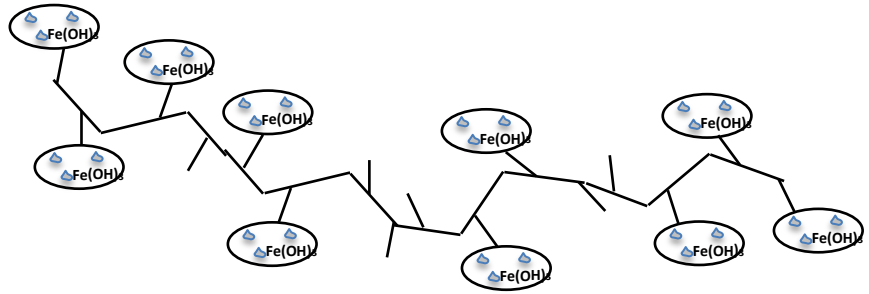
VERY SMALL COLLOIDAL PARTICLES THAT WON'T SETTLE

Coagulated Solids



WITH A COAGULANT, THE PARTICLES MEET AND FORM LARGER PARTICLES

Flocculated Solids

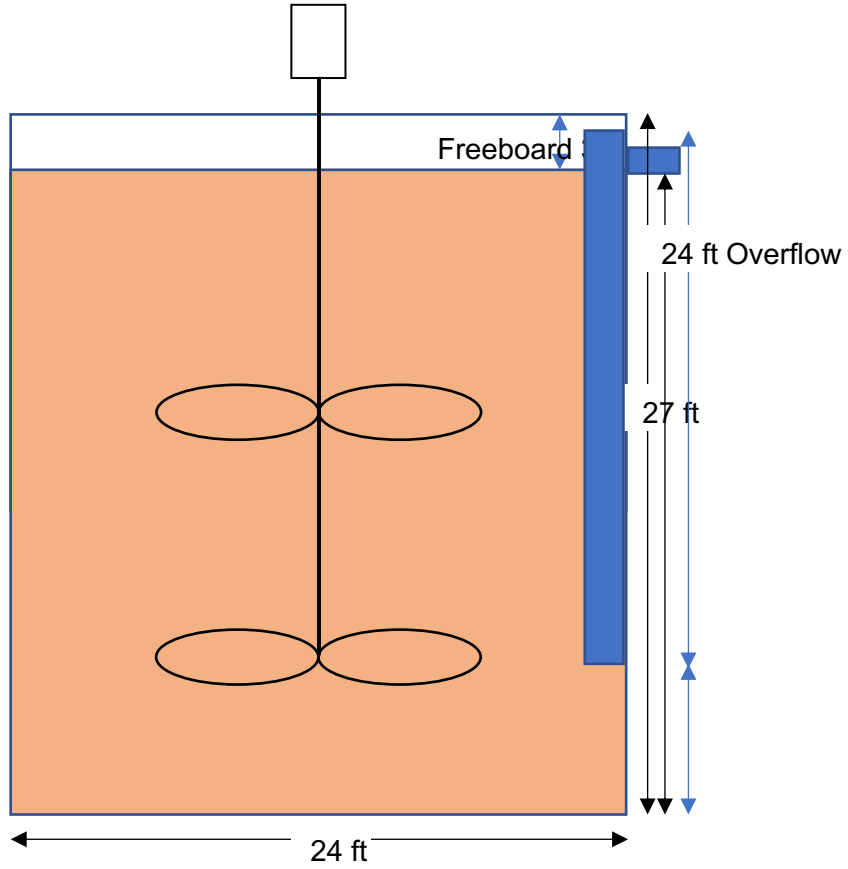


FLOCCULANTS ARE LONG POLYMER CHAINS WITH CHARGED "LIGANDS" THAT ATTRACT PARTICLES TO MAKE A HEAVY "FLOC" THAT SETTLES QUICKLY

In pond treatment for example, going straight to floc can do more harm than good

Reactor Design

- Near square - H/D ratio of 0.8 to 1.2 preferred for agitation efficiency
- Use a riser (or upcomer)
  - Starts at one third from bottom
  - Sized to carry solids
  - Place pH probe in riser
- Feed all inputs on surface
  - Prevent short-circuiting
- Ensure sufficient retention time
  - Gypsum precipitation slow



Lime/Sludge Mix Tanks a whole other animal – see Aubé et al., 2024

Reactor Design - Risers

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Also: Transferring out of reactors using troughs (or launders) reduces maintenance, allows visual verification of flow and colour, and is a good location for sampling

Reactor Feed and pH Probe

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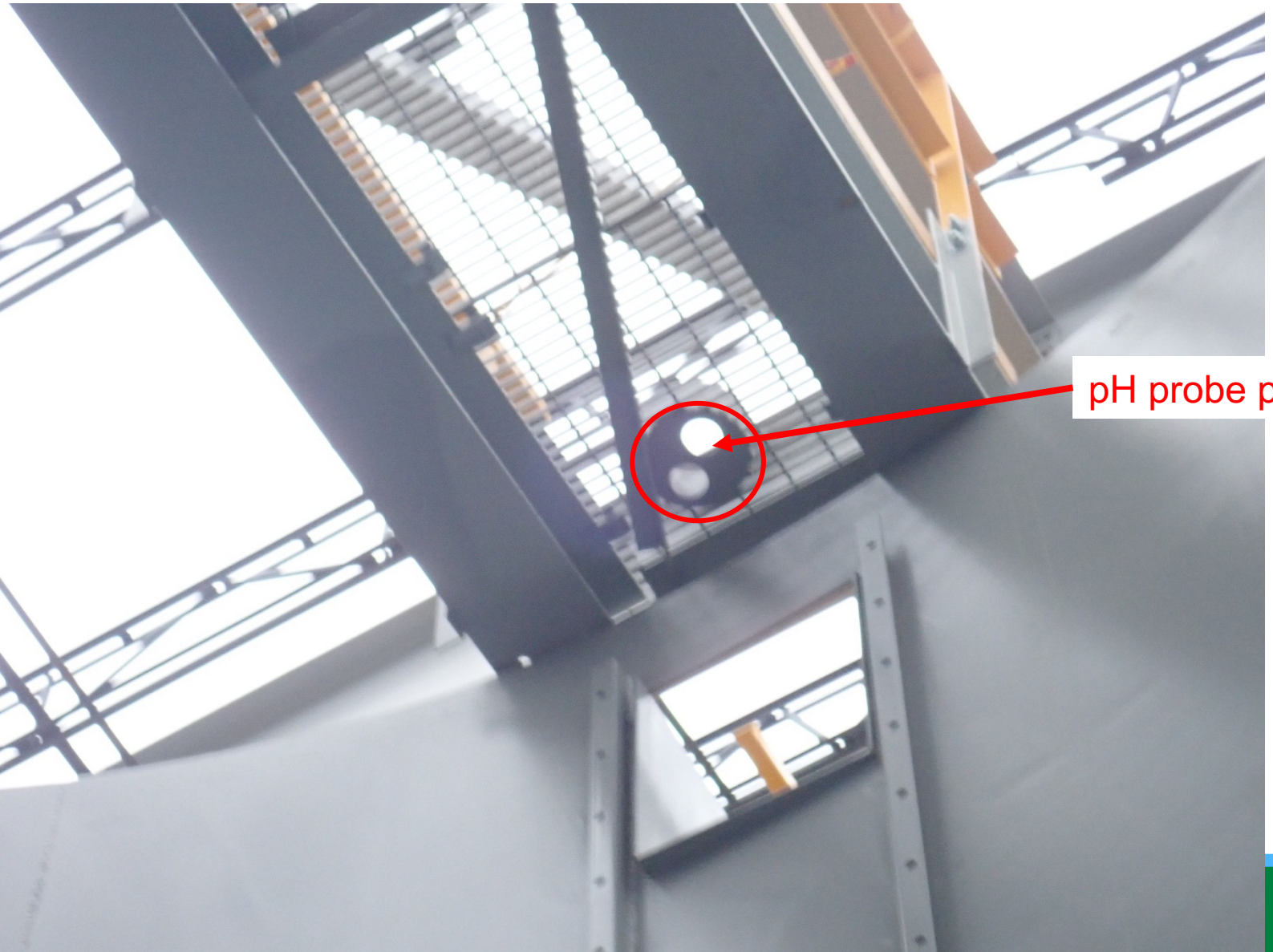

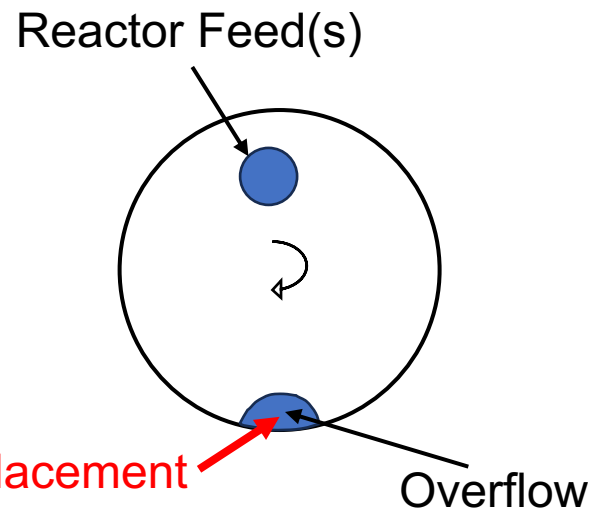

Keep different feeds close when possible and opposite side from overflow

Place pH Probe at outlet – PID loops are a feedback control

Water Treatment Plant Reactor Feeds

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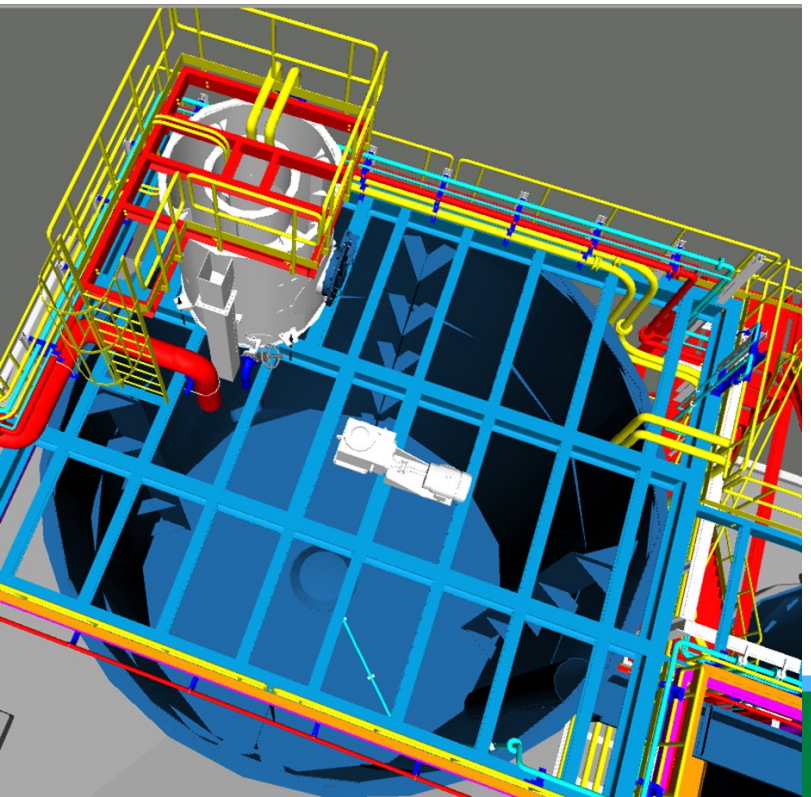
- Inputs to reactors often fed below surface to "avoid splashing"
- Minor splashing is just not an issue – creates no problems
- Feeding below surface causes many issues such as
  - Potential to siphon reactor contents back
  - Complicates maintenance and shutdowns
  - Requires valves, which fail (need power and/or air) or get obstructed
  - Use of check valves also required, but these also cause problems
  - Cannot have visual confirmation of flows

All Inputs to Reactor Surface

Place feeds midway between reactor wall and agitator

Splashing not an issue

Simple, easy, and effective



No risk of siphoning

No issues with power outages

Easy maintenance

Visual confirmation of flow and colour

Piping and Equipment

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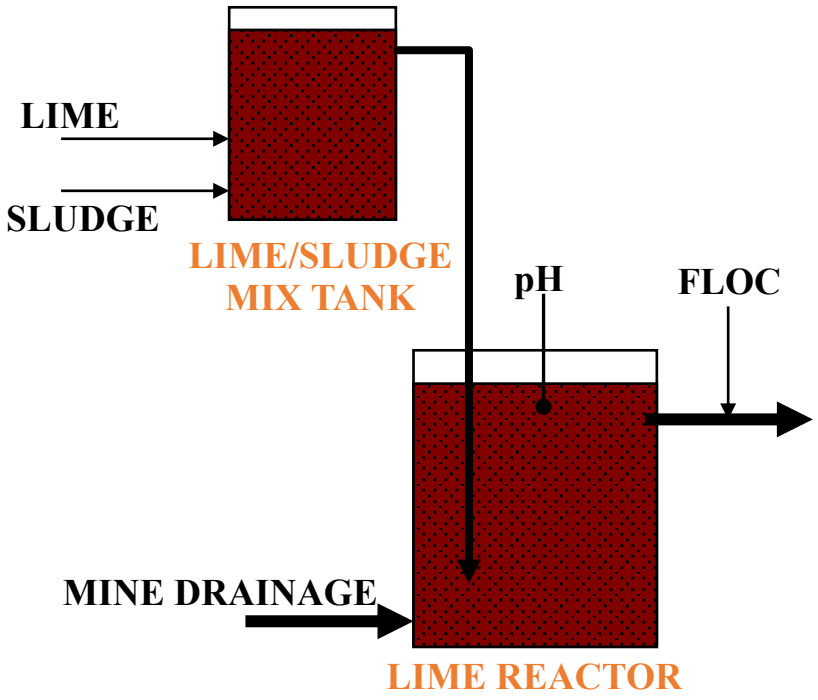
- Slurries (lime and sludge) cause a lot of downtime and maintenance
  - Use positive displacement pumps
  - Minimise valves and obstructions – dedicate lines to pumps
  - Remove 90° elbows – use long radius
- Reagent injection in line to be avoided
  - Drop reagents on top of tank, in open launder, in feed well
  - Ensure complete reaction before measurement (pH Control)
- Keep up with the times
  - “We’ve proven this works for over 40 years”… yes, but with a lot of maintenance and downtime, higher costs then necessary
    - Lime is better dosed with a peristaltic pump
    - Sludge doesn’t need water dilution when using positive displacement pumps

What Not To Do



Injected Sludge, Lime, and Floc lines all risk plugging (worst is Lime/Sludge Mix)

Can’t rinse and drain sludge lines

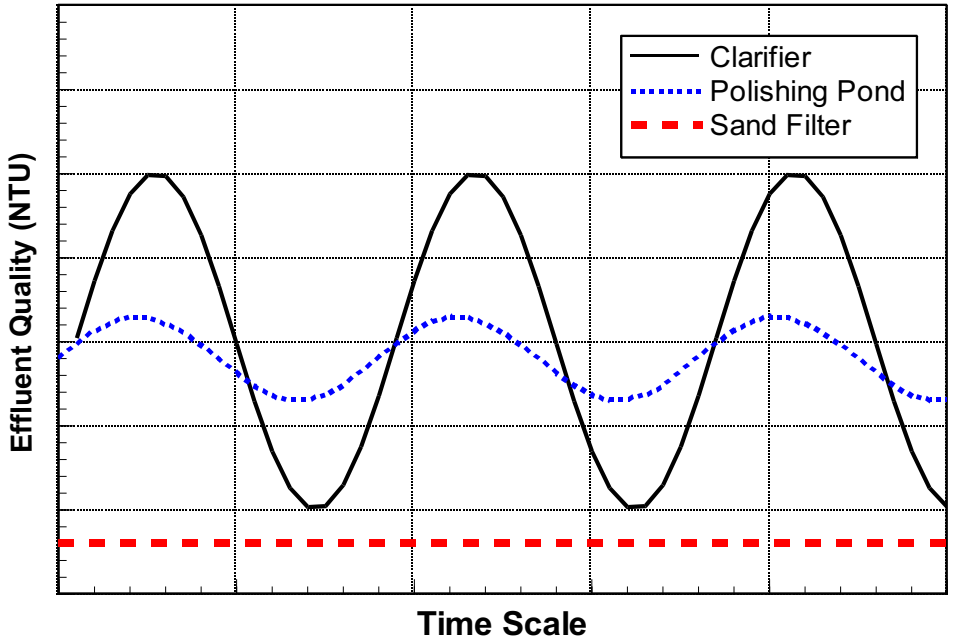
Difficult access, can’t see the feeds

Raw Water feed line needs valves, check valve, lock-out for maintenance, risk of draining back

Probe at surface, pH control difficult due to mixing heterogeneity at surface

Clarification

- Solid-liquid separation most common challenge in mine water
- HDS plants need large conventional clarifier
  - Can't create high-density with small footprint
- Non scaling systems – use lamella
  - Decreased footprint and costs
- Ballasted systems complex
  - They work and are great for a downtown industrial basement WTP
  - In mining, space is not that limited – simplicity, operating cost, and reliability more important
  - Comparatively, create sludge of less 1% solids versus ~10% with lamella
- Filtration helps meet compliance – beware of scaling issues



Process Design

- In the end, it's all about the lead process engineer
- You can't learn mine water treatment process engineering from publications and books
  - At minimum, when spending >$10M, need a senior reviewer
- Municipal and other industrial water treatment not the same
  - Higher flows and less manpower to consider and design for in mining
  - Less scaling issues in municipal, piping often underground
- A good design targets minimal maintenance, maximum reliability
  - "We managed to make it work in the past" is not a valid objective

Quick Hits

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- Everywhere you can, use gravity, not pumps
  - In my 33 years of experience, I have found gravity to be quite reliable
- Remove all focus on percent removal – it's about the final quality
  - 99% effectiveness with 100 mg/L does not meet the 0.5 mg/L limit
  - 50% efficiency with 1 mg/L does
- Full-Scope Treatment Solutions
  - If it seems too good to be true…
- Settling ponds with pumphouse drawing from bottom of the pond!
  - Settling ponds need to overflow, or at least be drawn from surface
  - Note: silt curtains are just a short-term fix

Quick Hits

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- What goes in, must come out
  - Waste rock pile infiltration disappears in modelling (not in reality)
- Site-wide mass balance shows manageable average concentrations
  - Water treatment is not about averages, it's about compliance at extremes
- Giving one water quality to designers, based on history
  - WTP built for 20 years – need to forecast and design for future
- Every site is different, solutions are site-specific
  - "It worked at this site" doesn't mean it'll be the same at another
- Cold winters – design whole WTP indoors
  - Traditional clarifiers work well with ice cover
  - Reactors just need a roof
- Overdosing Flocculant
  - Dosage gets notched up for every upset

Challenges – Main Conclusions

- Mine water management and treatment is integral to mining
- Take the time, don’t underestimate the needs and costs
- Need experienced process engineer, but keep up with the times


THANK YOU