The Formation of High-Density Sludge when Treating Mine Drainage

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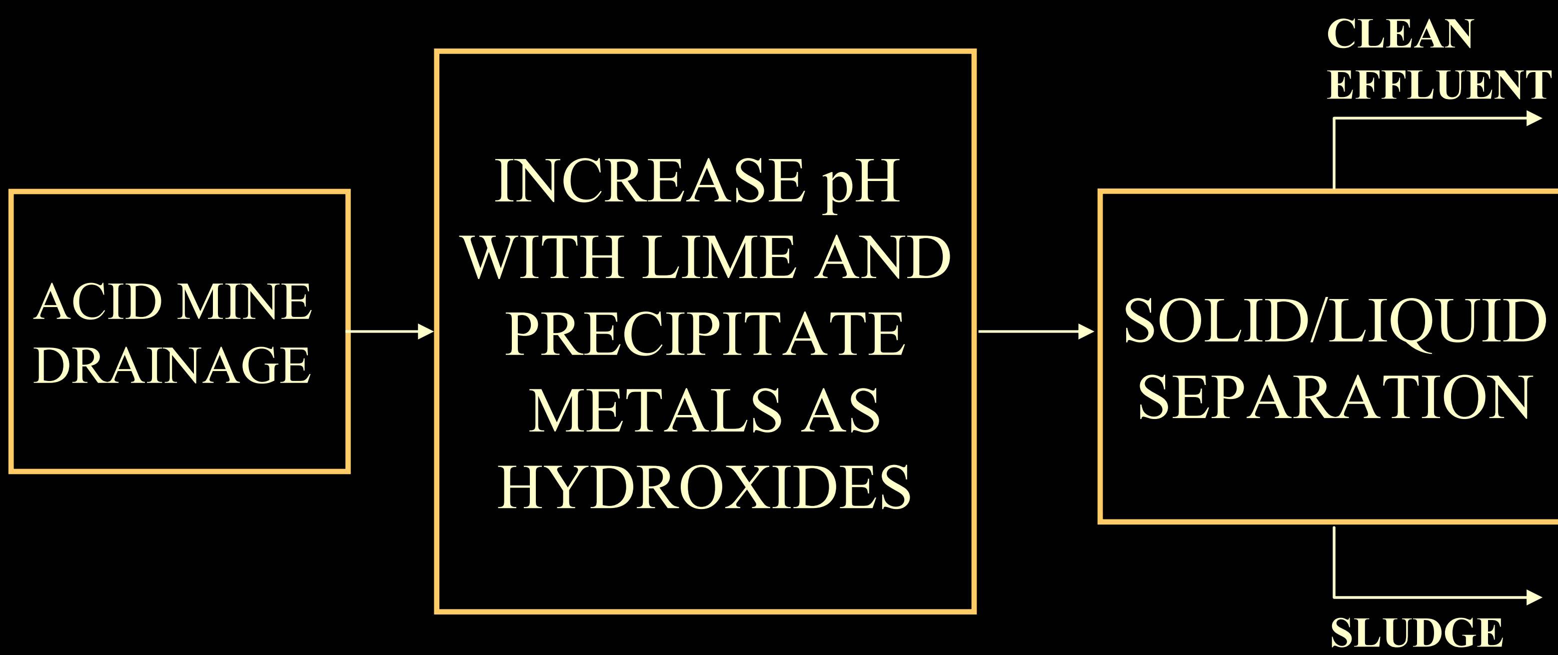
Factors Affecting Sludge Density

1. Raw water quality
2. Process design
3. Reagents (alkali and flocculant)
4. Process operating parameters
5. Process equipment

AMD Metal Concentrations

- Fe and Cu densify well if contained in sufficient concentrations
- Al, Zn, Mn, and Ni do not densify as easily
- With less than 100 mg/L total metals, difficult to attain 15% solids
- With more than 200 mg/L Fe or Cu, more than 20% solids expected with HDS process

Lime Treatment Processes



Neutralisation Chemistry

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

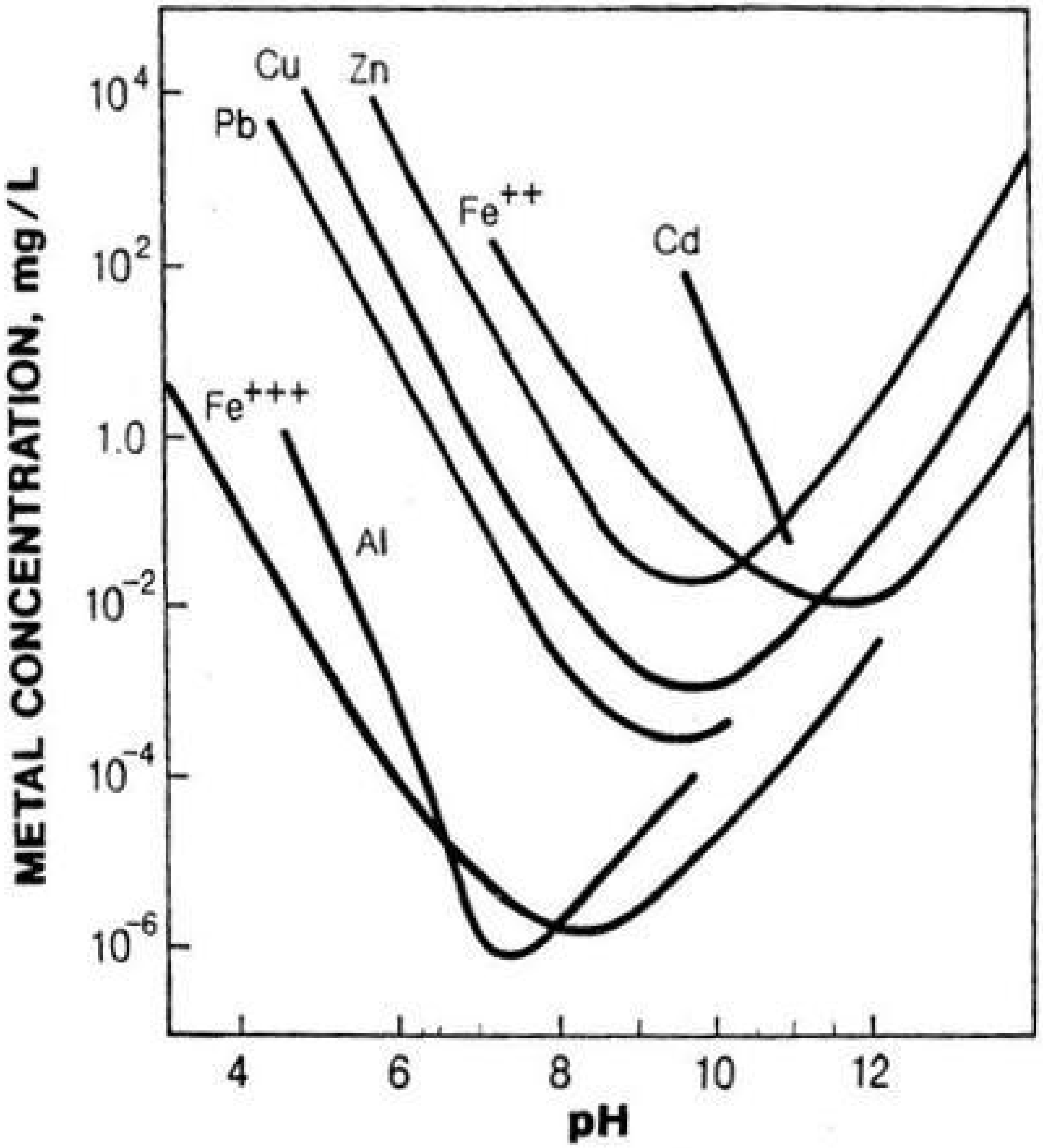
$$Fe^{2+} + 2OH^- \Rightarrow Fe(OH)_2$$

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

$$Zn^{2+} + 2OH^- \Rightarrow Zn(OH)_2$$

$$Me^{x+} + xOH^- \Rightarrow Me(OH)_x$$

Metal Precipitation



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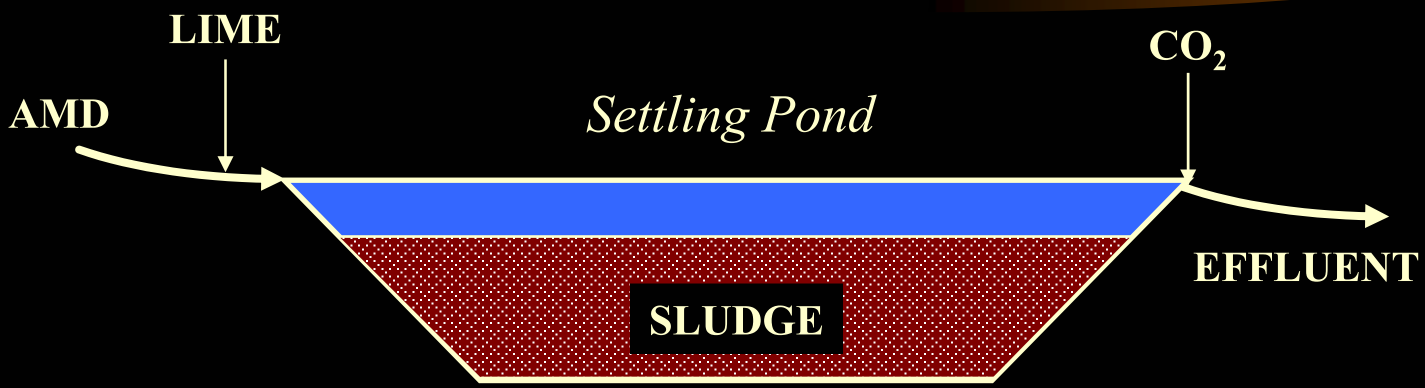
Lime Treatment Processes

- Settling Ponds/Pit Treatment
- Conventional lime neutralisation
- High-density sludge treatment systems

Settling Ponds



- Low capital costs and simple to operate
- Low sludge density – less than 5% solids
- Sludge must be periodically dredged ($)

Aerial Photo of Pond Treatment System

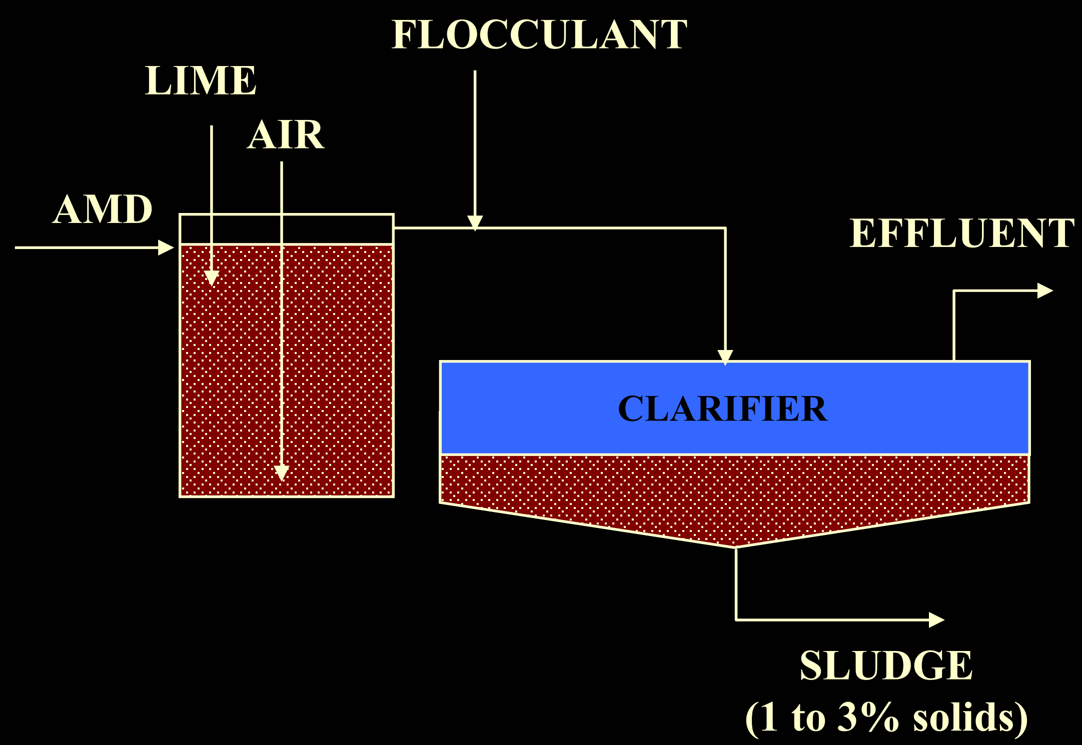
Falconbridge Limited, Kidd Mining Division

Raglan Pit Treatment System

Increasing Density in Pond Systems

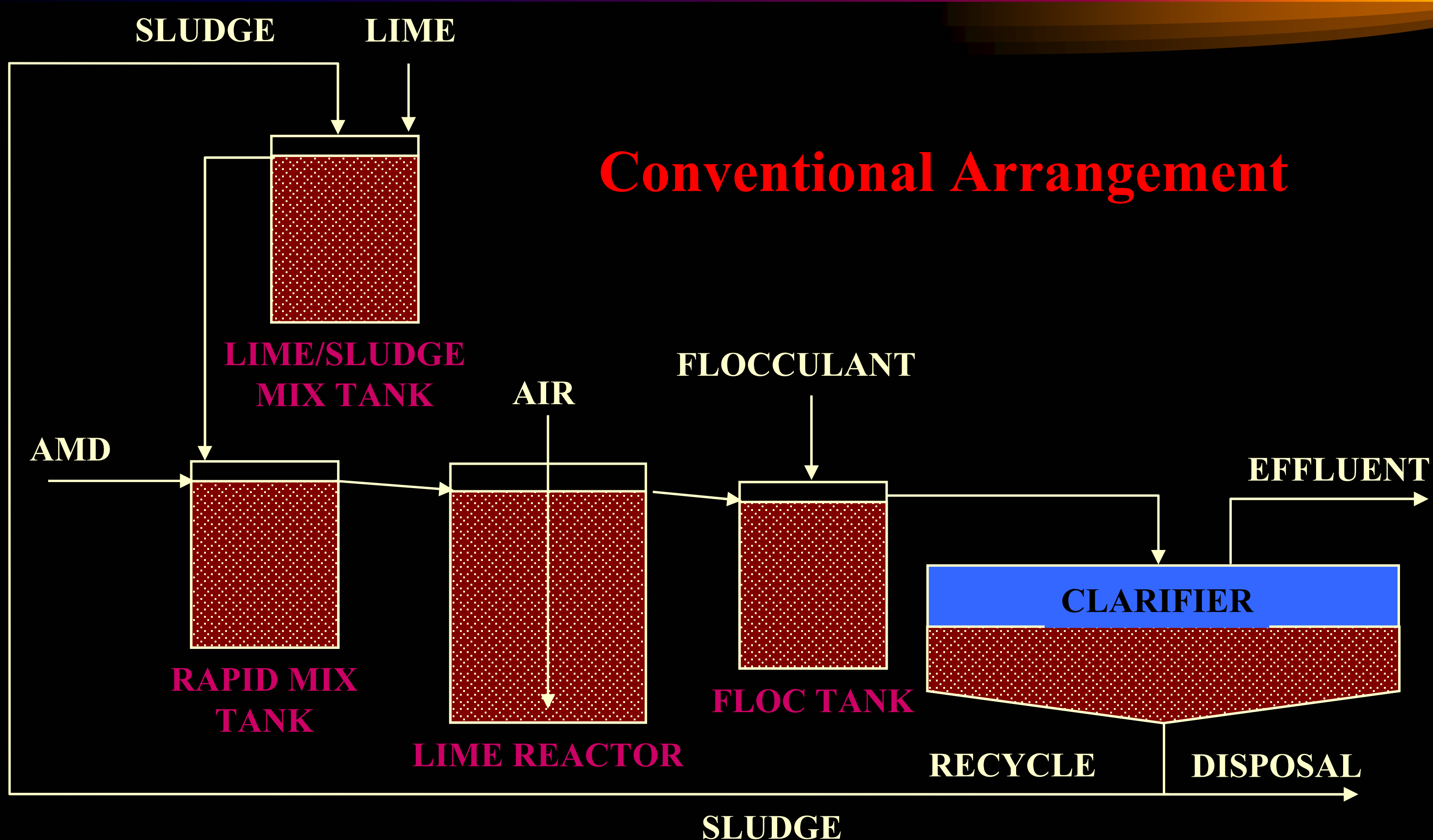
- Possible in some cases to recycle sludge with a dredge or submersible pump
- Recycling will:
  - Increase lime efficiency
  - Increase sludge density
  - Improve settling and treatment efficiency

Conventional Treatment



- Though simple to operate, scaling and low sludge density have rendered this process obsolete
- Easy to convert to an HDS process and minimize these disadvantages

High-Density Sludge Process



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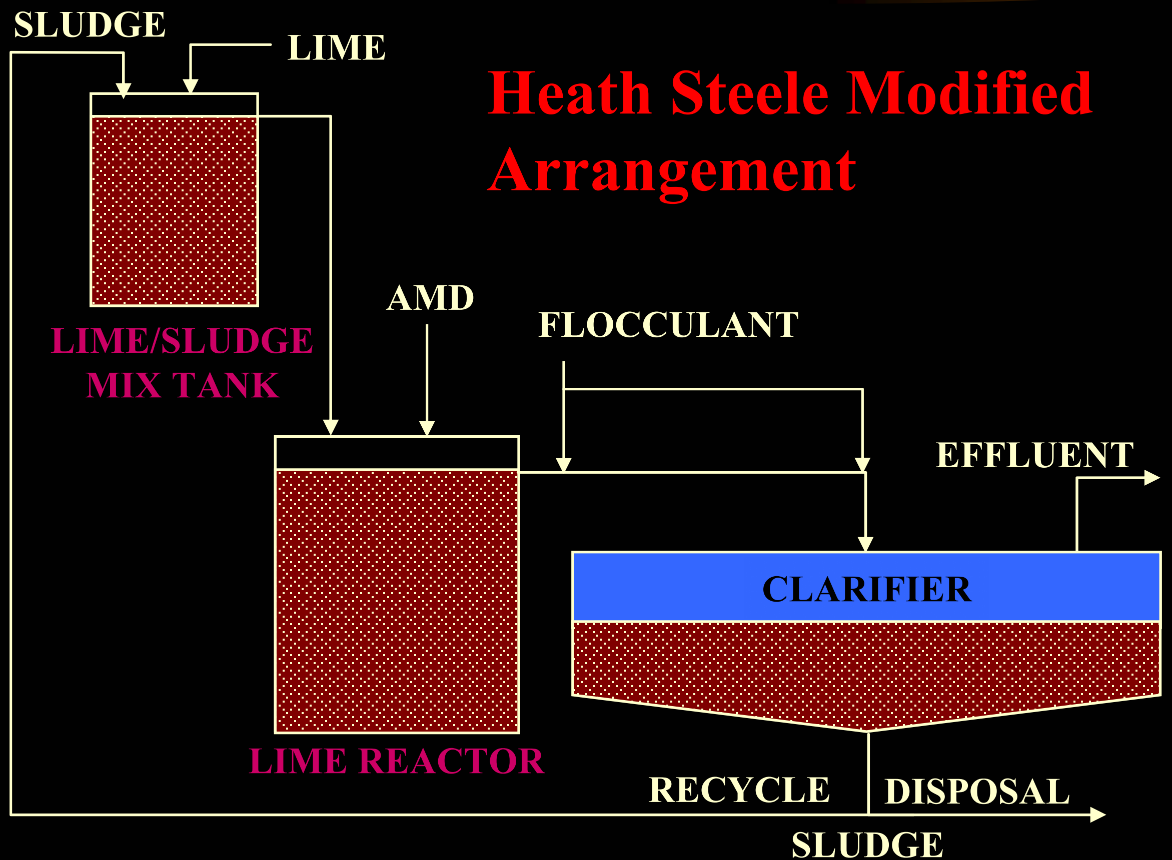
High-Density Sludge Process



Heath Steele Modified Arrangement

Heath Steele Treatment Plant

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High-Density Sludge Process

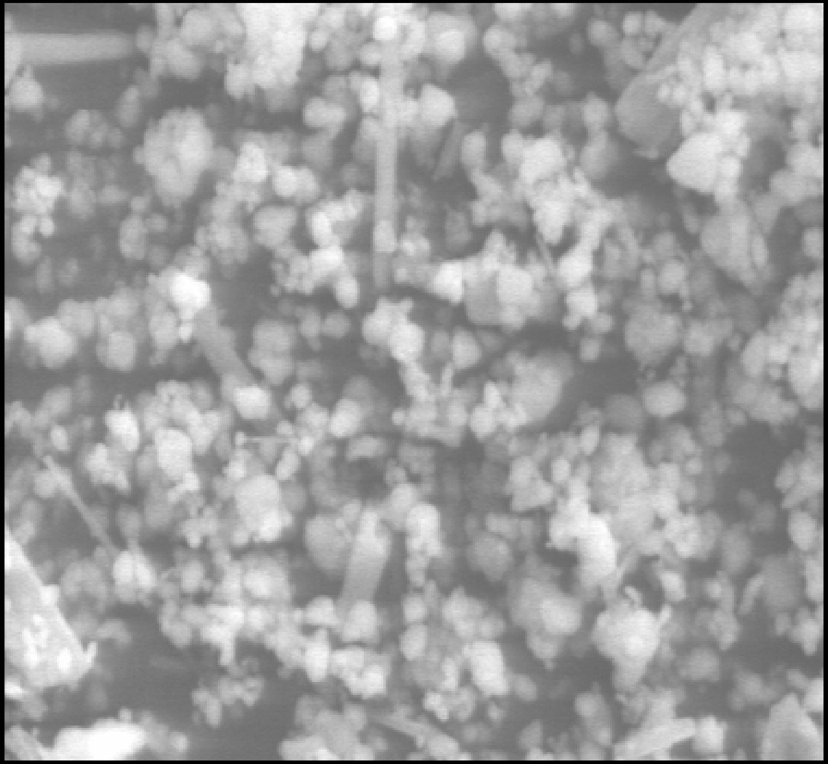
ADVANTAGES

- Low sludge volumes
- Good lime efficiency
- Decreased scaling in reactor and launders

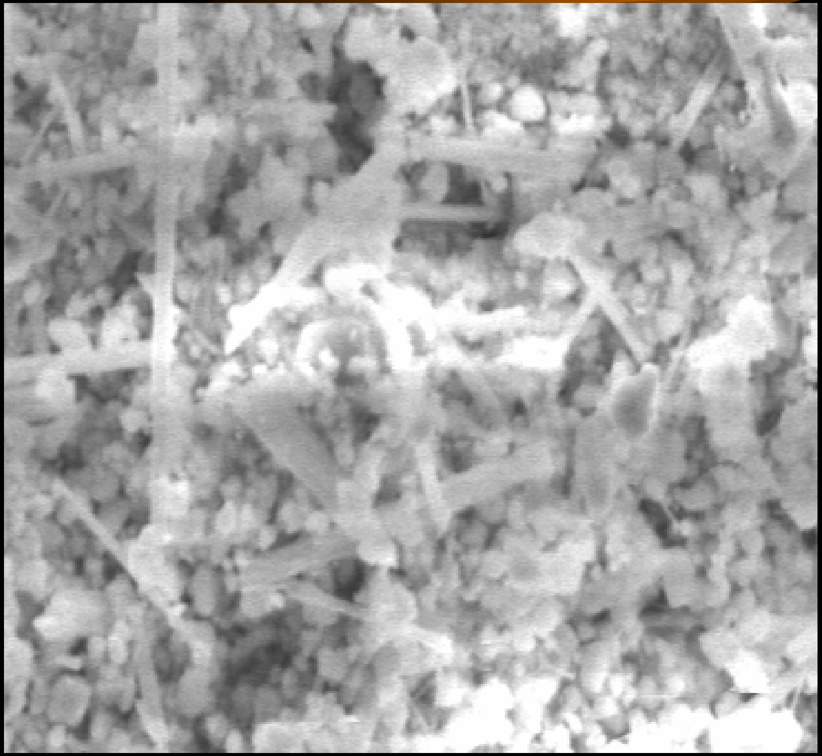
DISADVANTAGES

- Possible sludge viscosity
- Viscosity/scaling problems in Lime/Sludge Mix Tank

Sludge and Lime/Sludge Mix



Sludge Solids

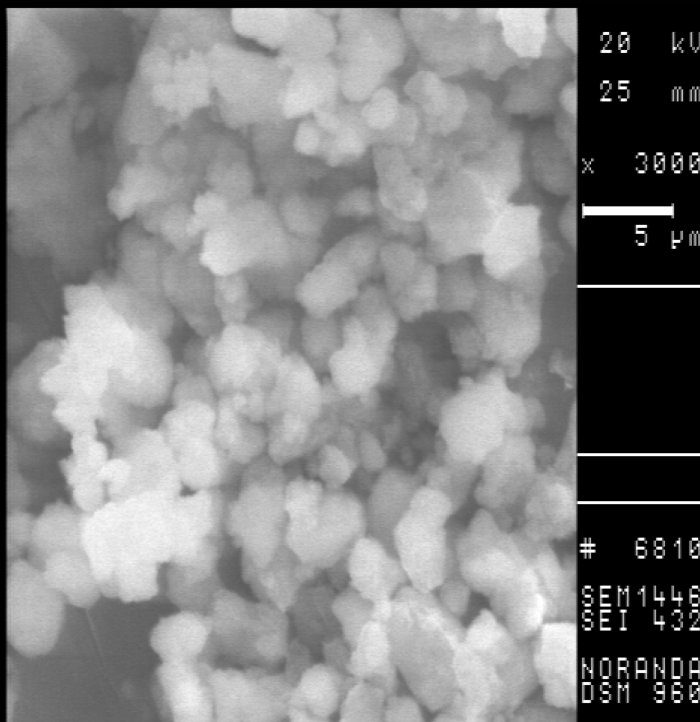


Lime/Sludge Mix

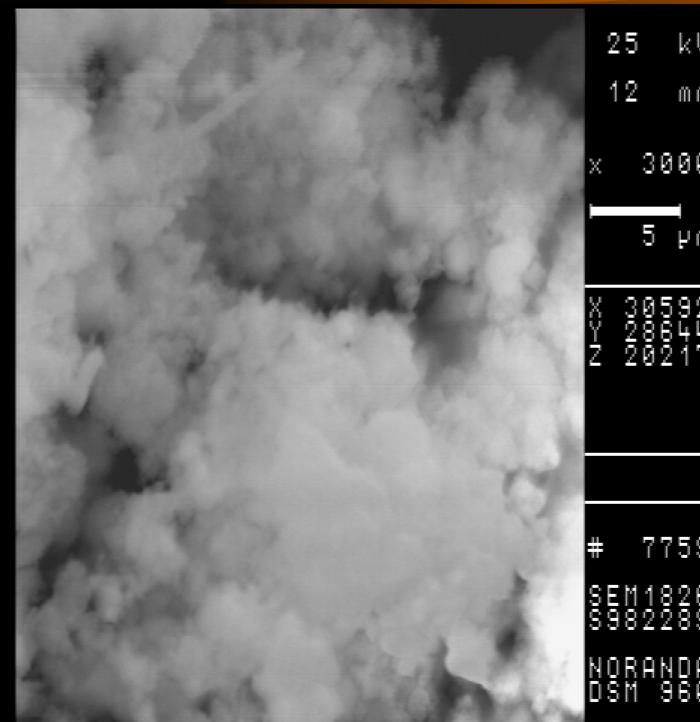
HDS Process - Densification

- HDS is formed as:
  - the sludge is coated with lime particles in the Lime/Sludge Mix Tank
  - forces precipitation reactions to occur on surface of particles
  - increases particle size, settling and densification

Sludge Micrographs

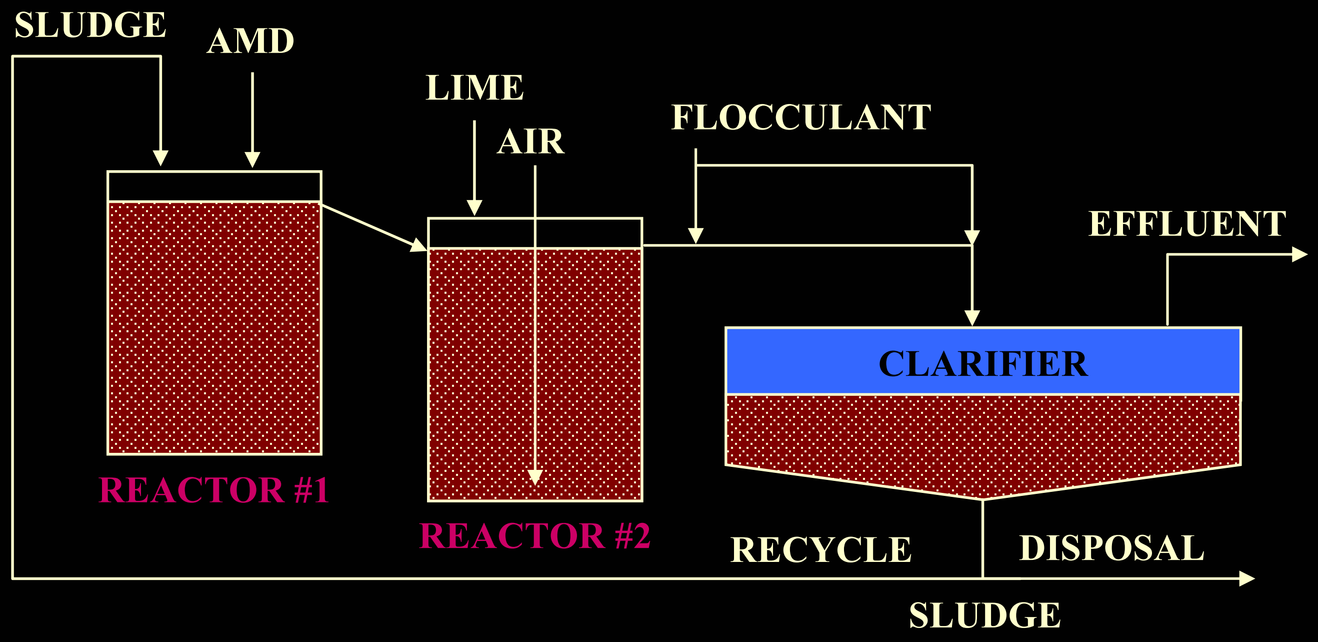


High Density Sludge
(ball-bearings)



Low Density Sludge
(cotton balls)

Geco Process



Geco Process

ADVANTAGES

- Low sludge volumes
- Excellent lime efficiency
- Decreased scaling in reactor and launders
- No troublesome Lime/Sludge Mix Tank

DISADVANTAGES

- Possible sludge viscosity

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Geco Process - Densification

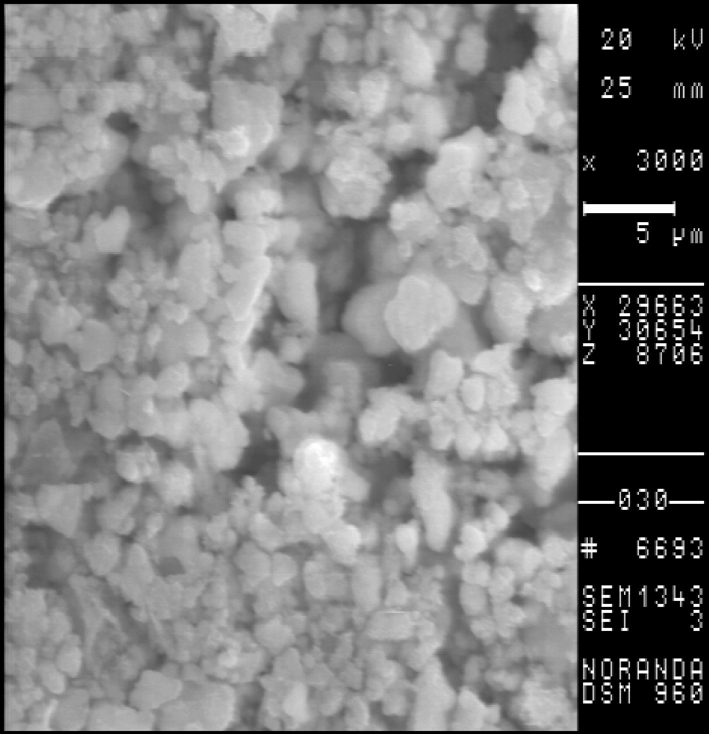
- Produces HDS due to
  - Partial dissolution of sludge when in direct contact with AMD
  - Causes a pH increase and precipitation of metals in first reactor
  - This occurs on surface of existing particles thus causes the particles to increase in size

Comparing Geco and HDS

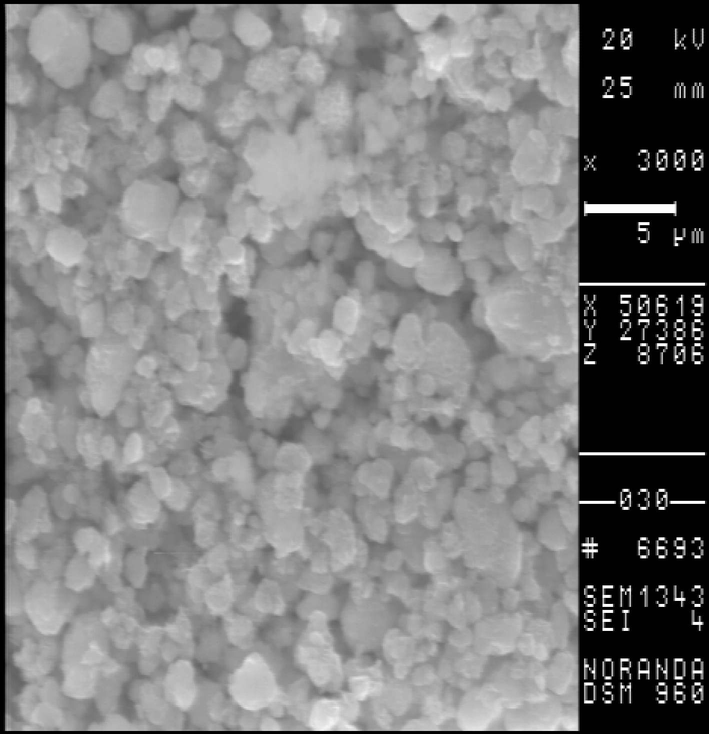
- Large-scale pilot program conducted at Heath Steele in 1996
  - Operated both processes in repeated tests and analysed all liquids and solids extensively
  - Detailed review and interpretation of all data for Master's thesis
  - Compared for effluent quality, sludge density, sludge stability, and lime consumption

Comparing Geco and HDS

Test 4 (Geco)



Test 5 (HDS)



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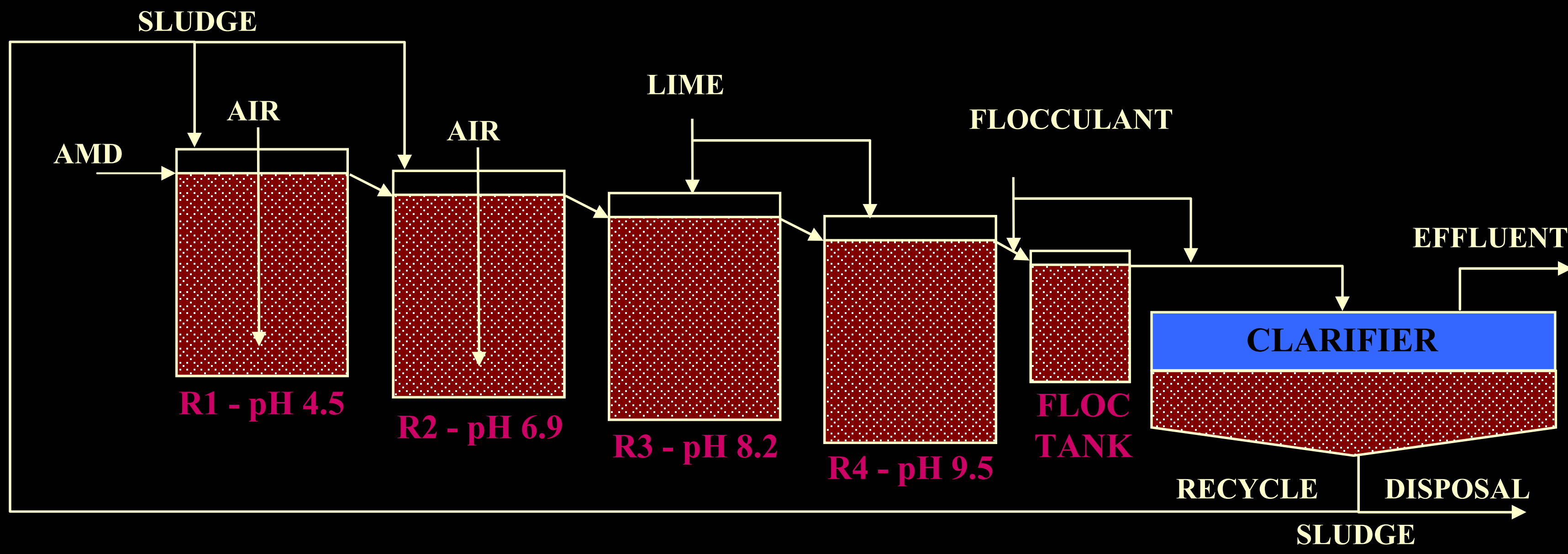
Comparing Geco and HDS

- Conclusions
  - Geco process produced a slightly better effluent quality
  - HDS Process created a higher density sludge (27% vs. 25%)
  - Geco formed less solids, thus compensating on the sludge density
  - HDS Process formed a more stable sludge
  - Geco Process consumed less lime

Other Processes

- Tetra Process
  - Has both direct sludge contact with AMD and a Lime/Sludge Mix Tank
- Staged-Neutralisation Process
  - Requires many large reactors – capital-intensive
  - Not yet applied but potentially excellent

Staged-Neutralisation Process



Reagents

- Alkali used for forming HDS:

quicklime>hydrated lime>caustic

- Flocculant (polymer)
  - Some polymers are better at densification
  - Overdosing the flocculant will decrease the density

Process Operation

- Need:
  - Good pH control
  - Ferrous iron oxidation
  - Sufficient solids for the desired reactions to occur

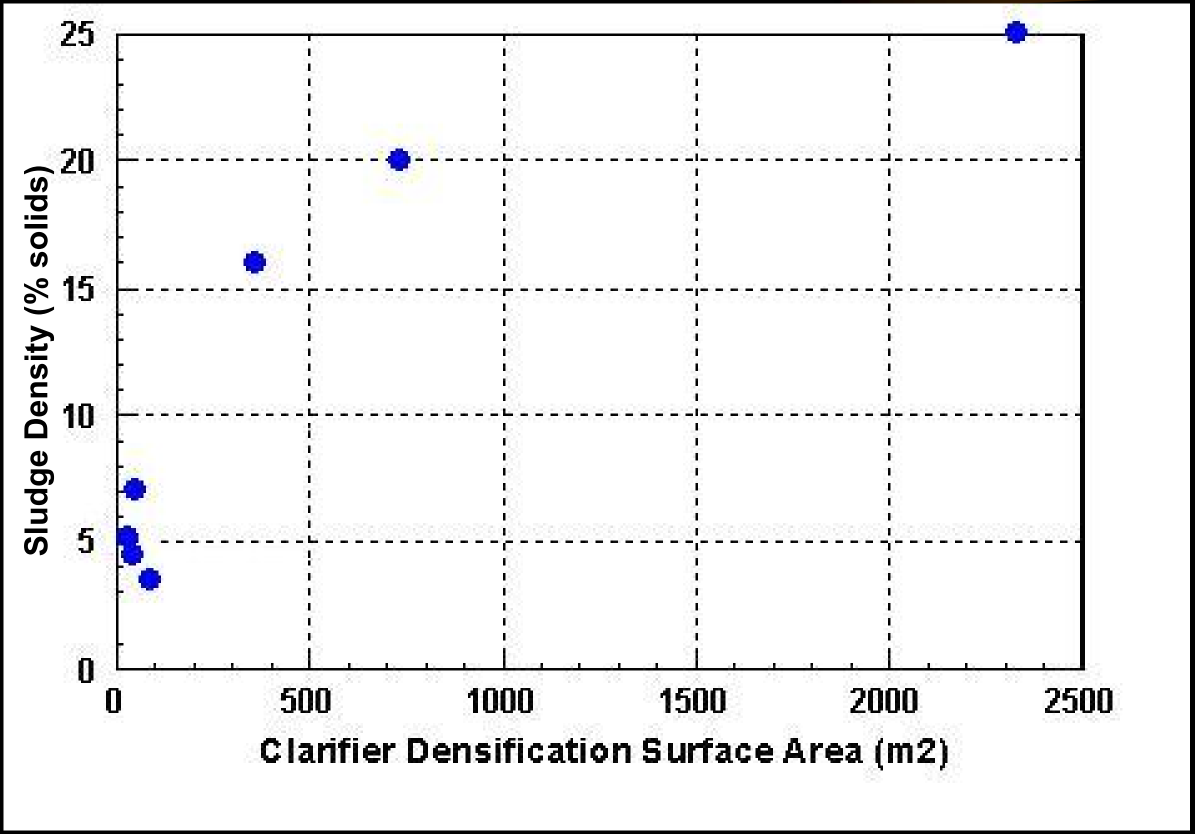
Operation – Recycle Ratio

- Published 20:1 or 25:1 ratio of recycled solids to formed solids
  - (mass of solids recycled per unit time):(mass of solids formed per unit time)
- Experience: only need sufficient solids in the neutralisation reactor to force the desired reactions
  - 10 g/L often enough
  - More than 25 g/L detrimental to effluent quality

Process Equipment

- Reactors
  - Minimum retention time 20 minutes
  - 45 minute retention recommended
- Clarifier
  - For clarification, 1 m/hr rise rate a minimum
  - The larger, the better (both for effluent and for sludge)

Sludge Density - Clarifier Size



Sludge Storage

- Long term settling, sludges increase 1.5 to 3 times original solid content
- Freeze-thaw helps quick densification
- Densification greater in drainage ponds than underwater
- Density increase similar with pressure filtration

Sludge Density - Conclusions

- Affected primarily by raw water chemistry and process design
- Sludge density is formed by precipitating solids on the surface of existing particles
- Larger clarifiers improve sludge density
- Process operating parameters and choice of reagents critical


Thank you
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