Tailings Treatment and Nano-particles

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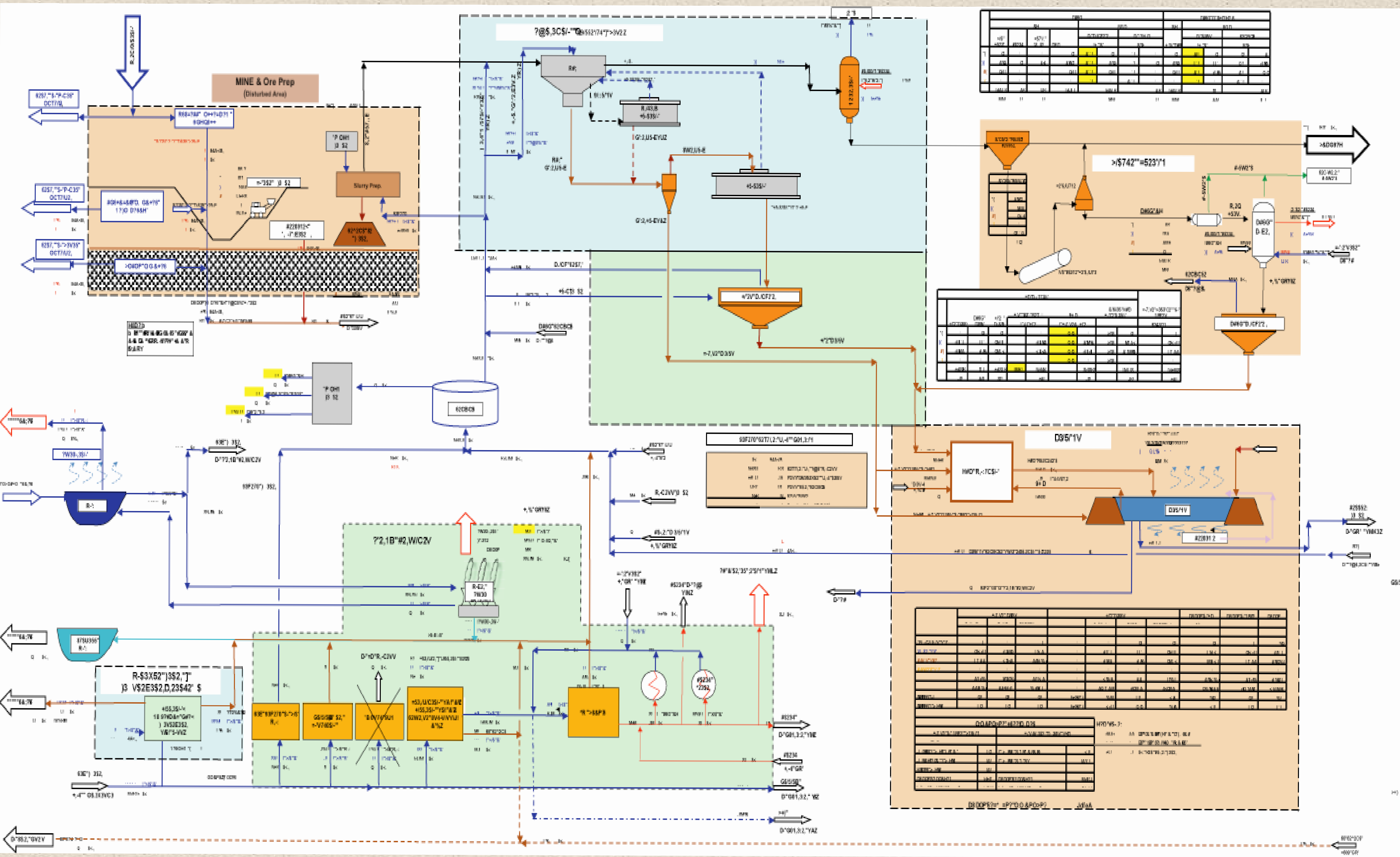
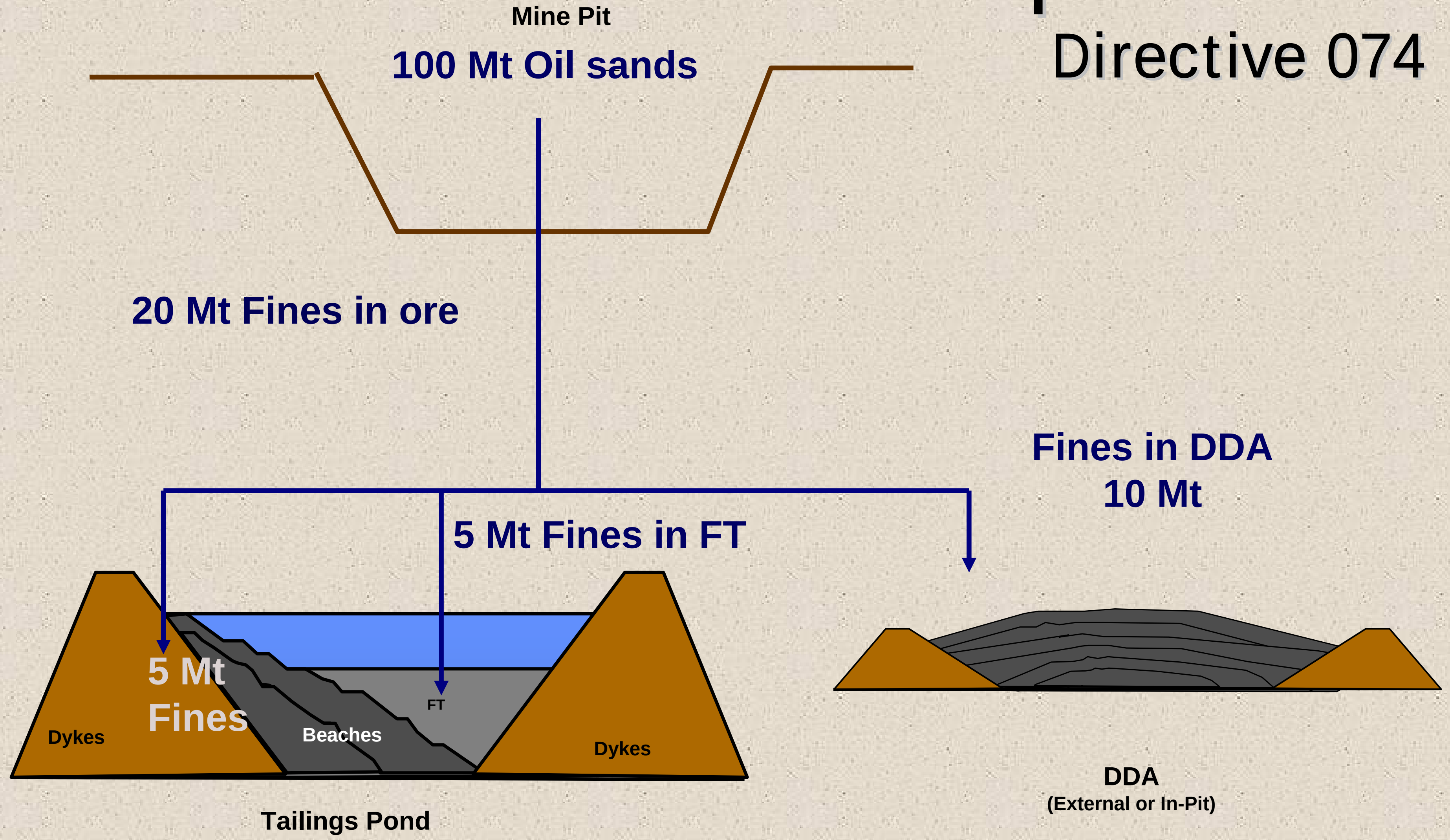
Mining Oil Sands : Complex material balances



What are fluid tailings

Current Regulatory Requirement

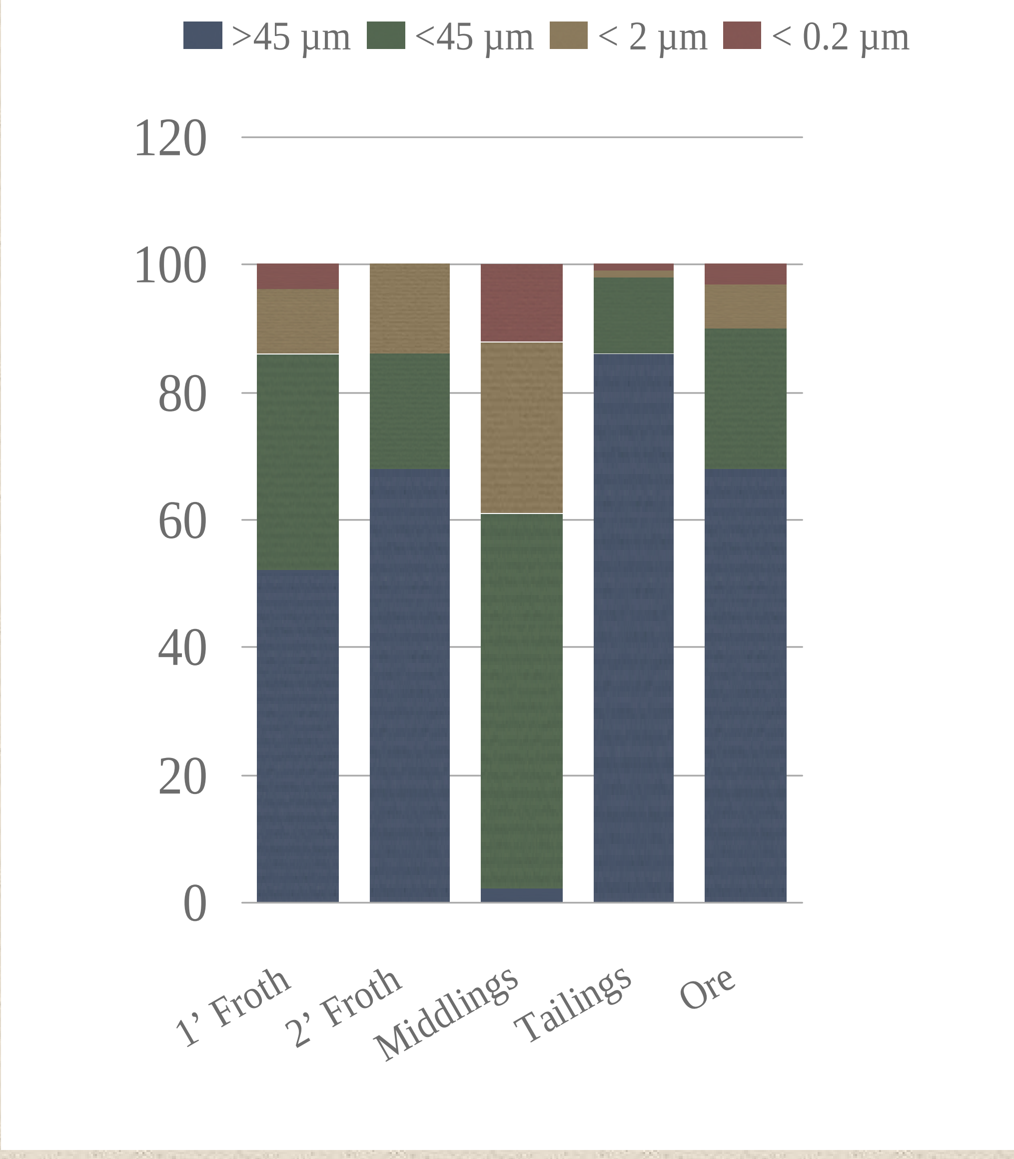
Directive 074



What are Fluid Tailings

- Heterodispersed colloidal (0.001 - 1 µm) and suspended (1-100 µm) particles.
- Hydrophilic clays, metal oxides, organic acids - negatively charged “problems” that require cation/ proton manipulation
- Hydration shells that create “weak gels” - these gels must be broken to solve our tailings problems

Particle Size Distribution



- About 3% of total tailings stream are particles < 0.2 µm
- median particle size for smallest fraction is 0.14 µm this includes primary froth, middlings and fine tailings streams

The smallest fines = the largest problem

QuickTime™ and a
decompressor
are needed to see this picture.

- Very mobile with high charge:mass & surface:mass ratio
- Reactive surface that attracts organics, heavy metals etc.
- Sticks to bitumen preventing coalescence & recovery
- Reactive edge 7-17 Å – easily bridged by cations or bigger organic molecules

Some basics on physical property

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Desirable strength

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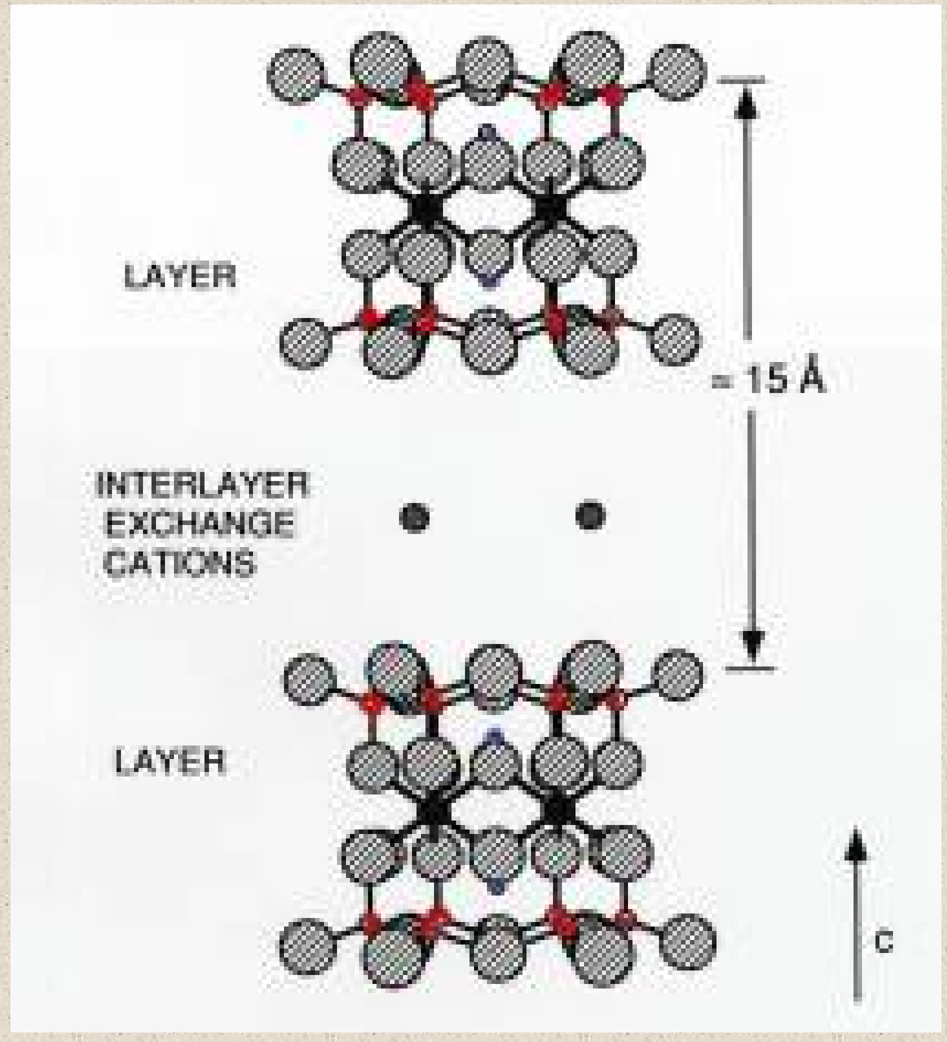
Clays



- Typically < 2 μm particles
- Nano-scale interactions cause the problems
- Multivalent ions increase gel tendency

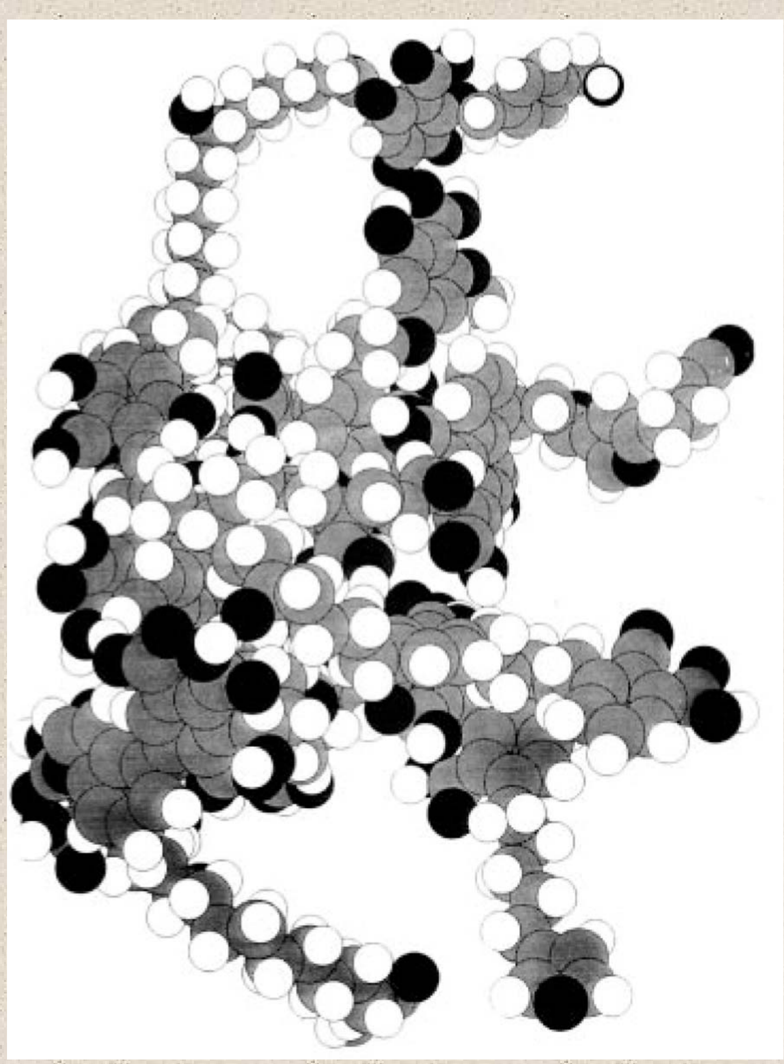
MFT as a gel

QuickTime™ and a
decompressor
are needed to see this picture.

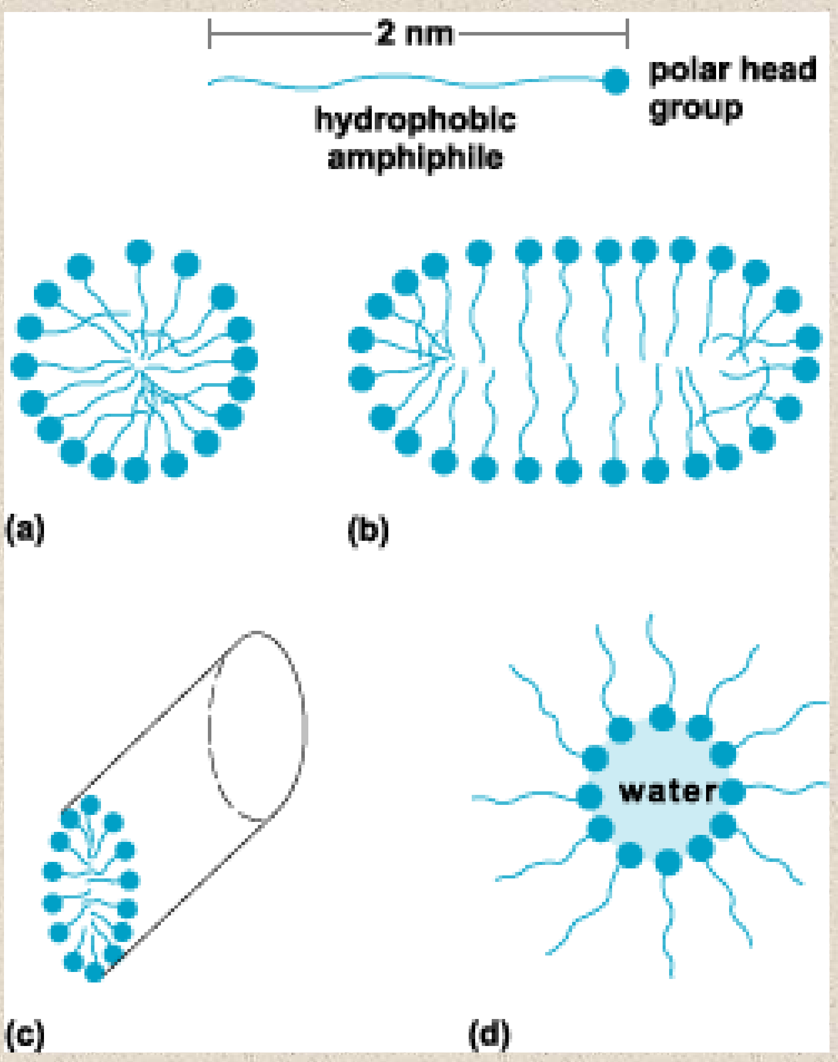
Other factors influencing the gel: Humic material

- Originates from soil and surface run-off (pit moss, muskeg
- Average size ~ 2 nm
- Humic-cation complexes from <3 - >450 nm
- Dilute solutions mobilize metal ions
- Concentrated solutions can precipitate Fe &Al
- Humate attracted to ultra-fine clays - cross bridging at edges.

A model of humic acid & stabilized colloid

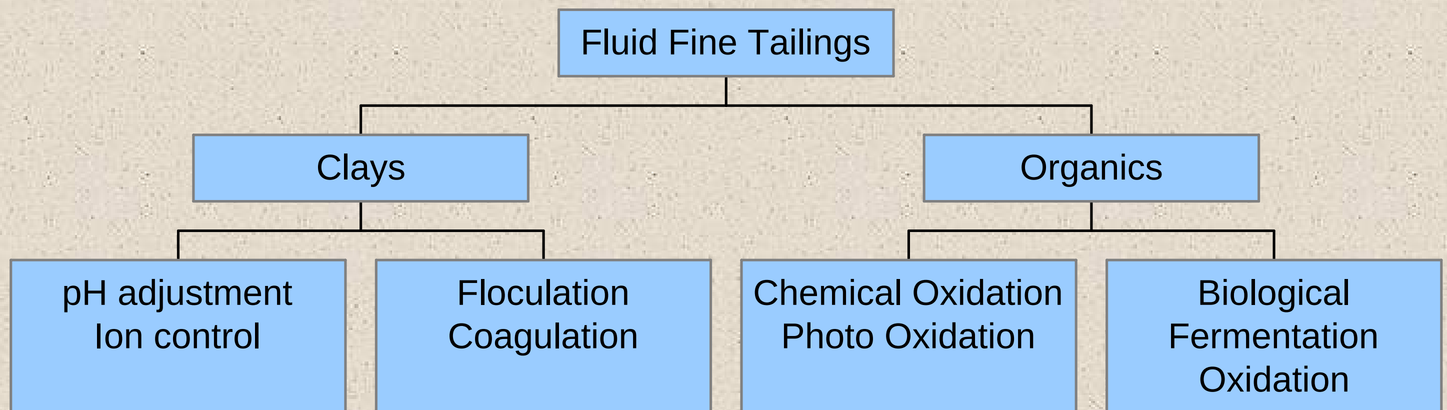


Emulsions and micelles

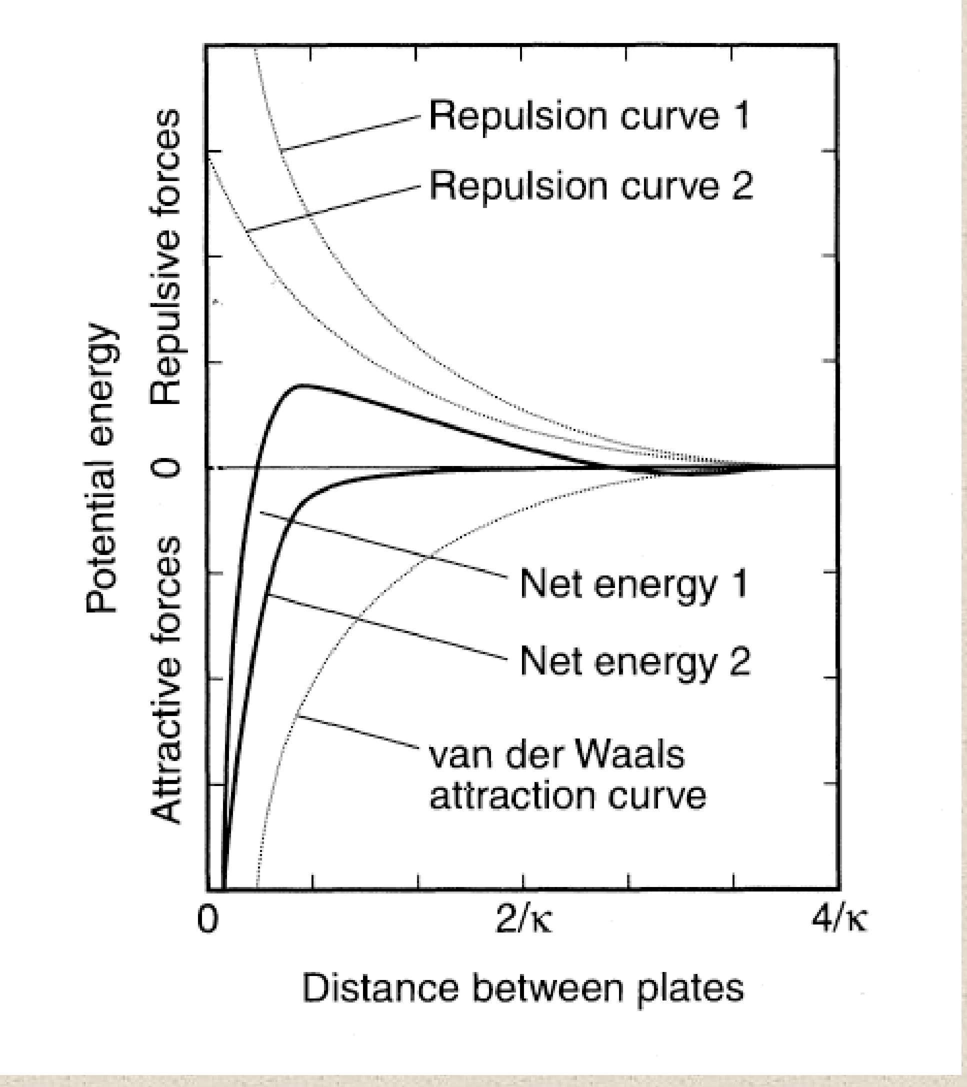


- High shear in process
- Very stable
- High pH beneficial
- High charge:mass ratio, surface:volume
- Made of or attract toxics
- Exact physical forms not investigated

Treatment

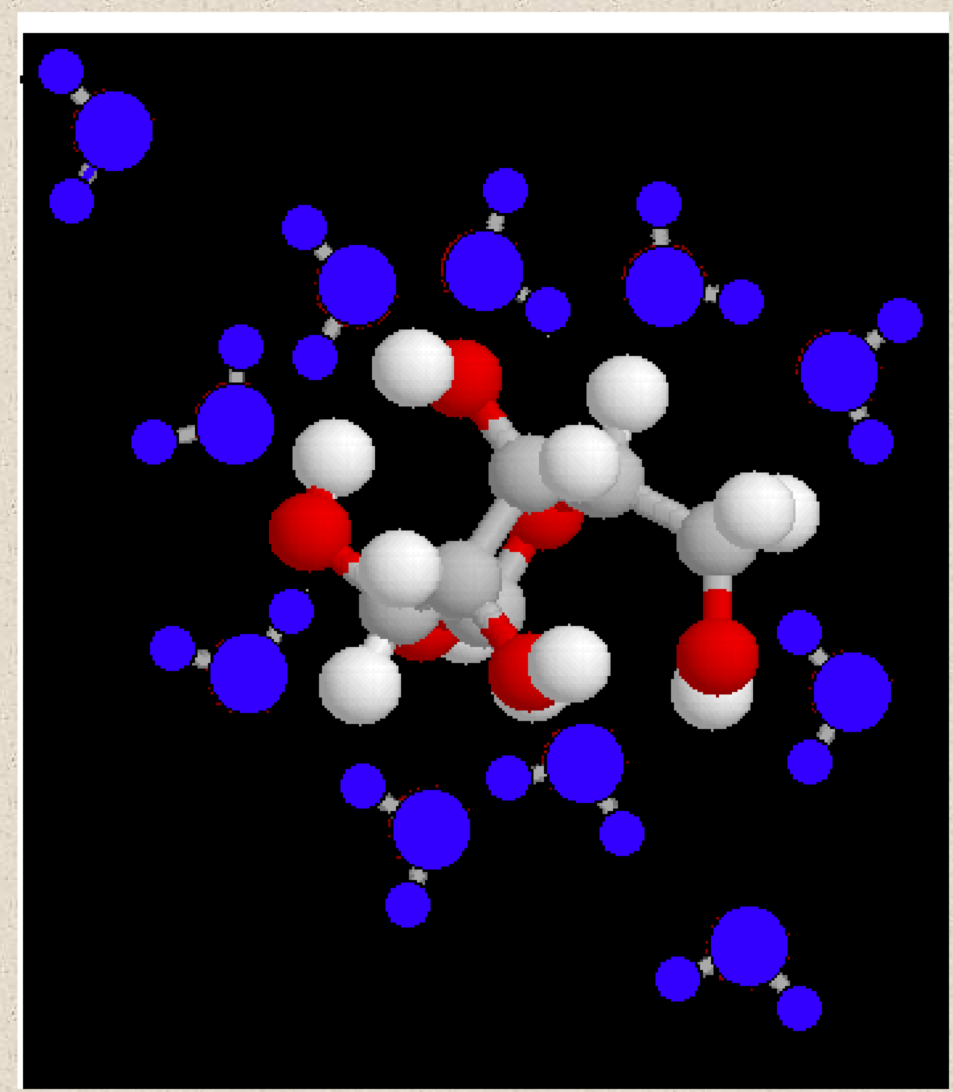

Fluid Fine Tailings
Clays
Organics
pH adjustment
Ion control
Floculation
Coagulation
Chemical Oxidation
Photo Oxidation
Biological
Fermentation
Oxidation

Overcoming repulsive forces



- Classical treatment is to create the conditions that destabilize particles changing from 1 to 2 so flocculation will occur

Previous pH control of tailings



- pH alters clay particle behavior
- pH < 5 clays coagulate
- pH > 8 clays form dispersive gels
- Divalent and polyvalent cations important in breaking gel behavior (0.008 mol/L)

Polymers

- Large polyacrylamides
  - Capture fines in cross-bridged structures
  - Changes surface charge of clays & ultrafines
  - Easily digested by Pseudomonas sp.
- Inorganic gels: Fe, Al, Si, phosphates
  - Holds water, fillers, bridging
  - Complexation and cross-bridging
- Exopolysaccharides – microbial in MFT
  - Role depends on size and charge

Advanced Oxidation & other nano

- Photo catalyzed Oxidation
  - Titanium Oxide
  - Ferritin
  - Zinc Oxide
- O_3 pre-treatment
  - Break the rings and long carbon chains of NA
  - Aid biotransformation
- Zero Vallent Ions
  - nZV Iron

Biotreatment

- Explore the use of engineered, microbially-mediated wastewater treatment technologies to significantly accelerate oilsands tailings consolidation and improve quality of water produced from the treatment processes for reuse or discharge.

Key elements considered

- pH adjustment by means of biological reactions and bioaugmentation to accelerate reactor start-up;
- Addition of primary substrate and nutrients to facilitate enhanced biotransformation;
- Use of organic coagulants to improve tailings consolidation and reuse water quality.

Single reactor & enhancement tests

- Determine best primary conditions for rapid start and continued microbial activity:
  - Initial pH and primary substrate adjustment to start up (e.g. CO_2 injection, other acids)
  - Potential substrates: Organic acids (formic, acetic, oxalic, citric etc.), starches (barley, oat flours) that metabolize into acids
  - Can organic acids produced from anaerobic fermentation maintain appropriate pH in system?

Our focus - biological treatment

- Can engineered biological reactors accelerate microbial oxidation of polycyclic aromatic and acyclic hydrocarbons in tailings water?
  - What is the best reactor design?
  - What is the potential to produce biofilm exo-polysaccharides substances (EPS)

Determine Engineering Reactor Types and Biological Processes

- Reactor with combined suspended growth and attached growth vs. reactor with single type of growth pattern
- Single reactor with both anaerobic and aerobic processes vs. reactors in series, each with one process only
- Reactors with low operational cost vs. reactors with high treatment efficiency

Potential Engineering Reactor Types

- Anaerobic-Aerobic Fluidized Bed Reactors
- Expanded Up-flow Anaerobic Sludge Blanket Reactor plus Aerobic Reactor
- Sequencing Batch Reactors
- Aerobic Granular Activated Sludge Reactor
- Enhanced Wetland

Determine reactor design parameters

- Reactor volume
- Organic loading rate
- Microbial concentration
- Primary substrate and its concentration
- Nutrients and their concentrations
- Means to handle high inorganic solids concentration in the reactors

Engineering the Bio-treatment

- Study the interactions in the mixed microbial communities for accelerated microbial transformations.
  - Microbiological techniques (test natural & existing engineered cultures)
  - Molecular techniques (PCR and DGGE)
  - Microsensor techniques (pH, O_2, CH_4, H_2S, SO_4^{2-}, NO_3^-, Redox)
- Several other researcher have isolated predominant bacterial species
  - May not be appropriate for engineered reactors due to chemical conditions of the micro-environments.

Consolidation behavior

- Study the interactions between organic coagulants/polymers and clay particles/inorganic ions.
- Examine mineralogy of clay, nano-particle mix before and after bio-treatment
- Exploit additional polymer/ flocculent treatments to enhance post-treatment settling.

Post (or pre) bio-treatment storage

- Study the effects of gas bubbles (methane) in the matrix of tailings and biofilm EPS, with a focus on their impacts on the microbial activities and tailings consolidation.
  - Laser and video imaging techniques


End