Paste Backfill: Influence on Mine Water Quality

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Sponsored by MEND3/MAC

Definition of tailings paste

- "A dense, viscous mixture of tailings and water that, unlike slurries, does not segregate [except when being transported]"

  (Verburg, 2002)
- Essentially 'thickened' tailings
- Consistency of wet concrete
- With or without additives such as Portland cement

Purpose - Economics

- Use of existing waste (tailings) for structural stability in underground mines
- Enhances ability to remove ore pillars
- Added costs of cement and pumping

Potential Environmental Benefits

- Reduction in volume of tailings requiring surface disposal
- Reduction in potential for tailings to oxidize or leach
  - Little free water available for leachate generation
  - Ground water preferentially flows around backfill, not through it
  - Less available oxygen
  - Addition of cement provides extra NP
  - Potential for flooding at closure (reduced sulphide oxidation)

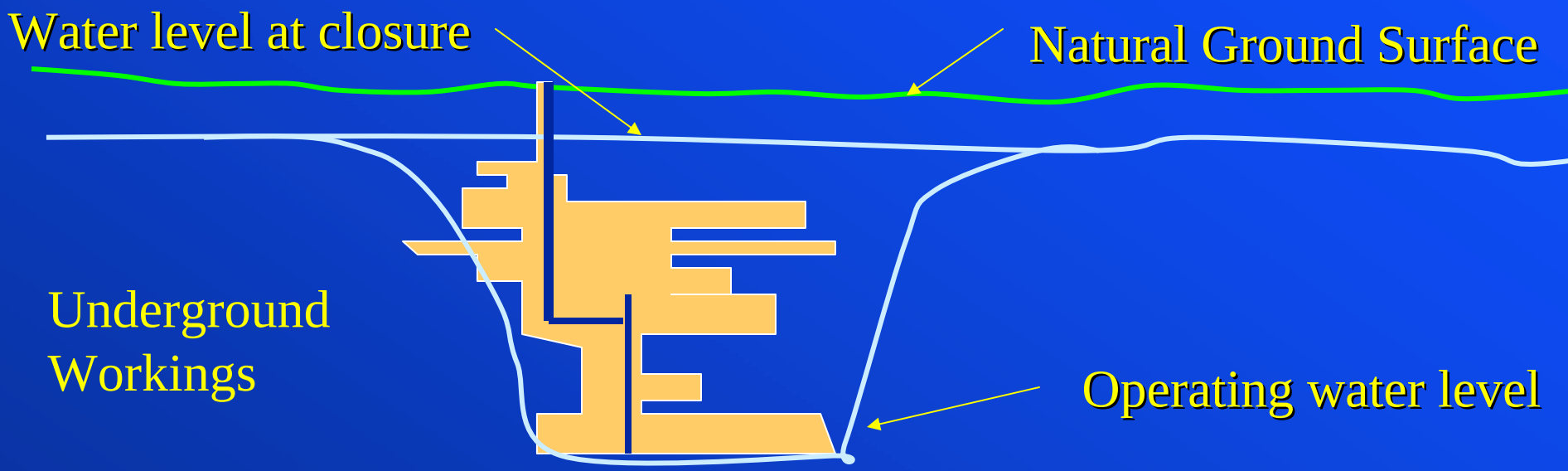
Importance of Geochemistry

- Conditions underground may allow reactions of tailings minerals or binders, producing ARD or soluble contaminants
- Addition of cement provides an alkaline environment, but for how long?

Importance of Geochemistry

- Reactions can reduce the long term strength of the paste
  - Reduced mining efficiencies/safety
  - Potential subsidence at closure
  - Changes to ground water flow patterns

Underground Mine

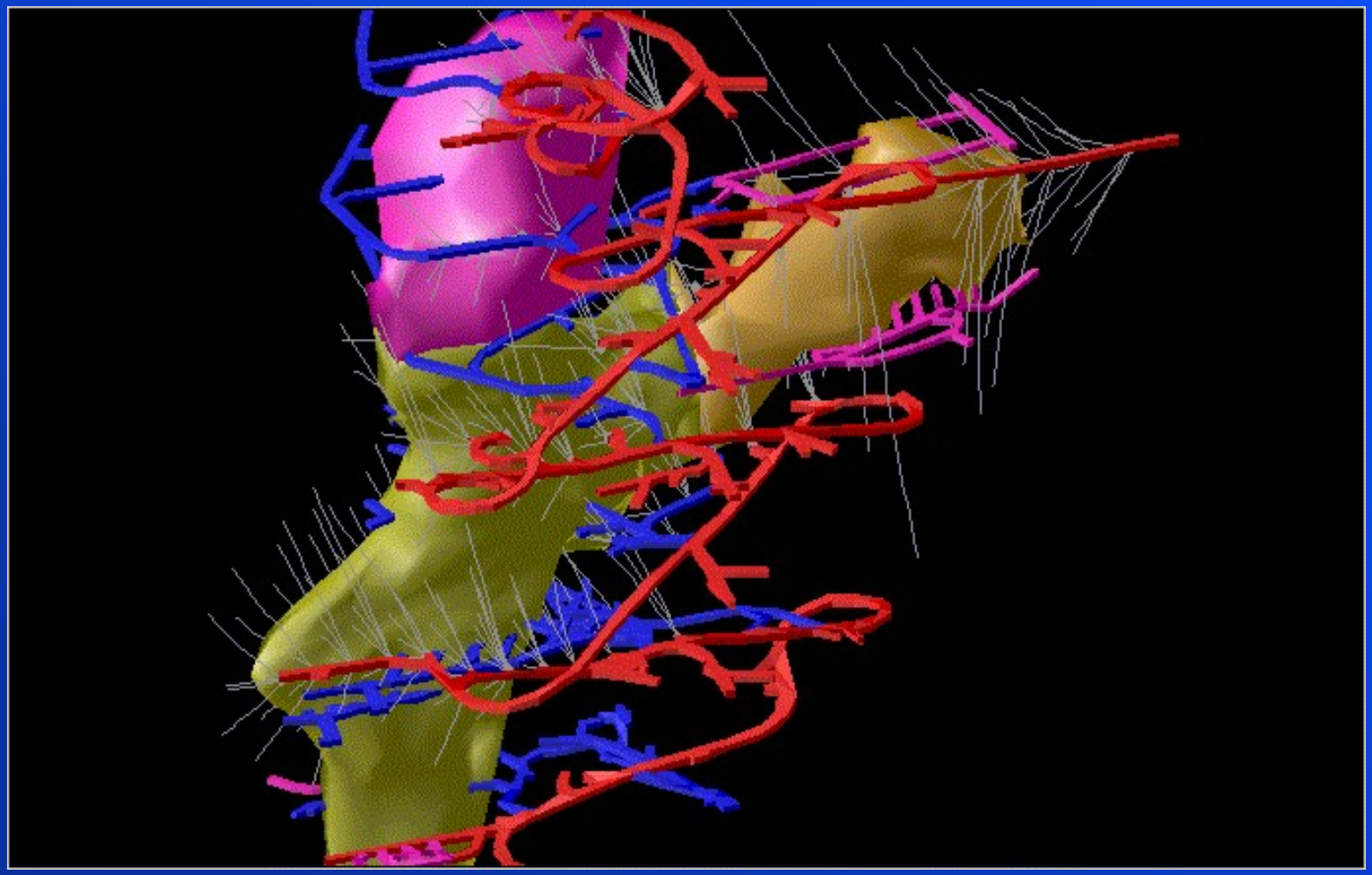


- Floods at closure
- No immediate ground water discharge
- Potential for a contaminant plume, albeit moving slowly
- "Out of sight, out of mind"

Sidehill Mine

- Portion of mine flooded at closure, releasing stored oxidation products
- Portion of mine remains drained, continued production of oxidation products
- Potential for uncontrolled surface discharges

Drill holes



So is the influence of paste backfill on mine water quality being studied?

- Contacted 37 underground mines to date

Paste Backfill

- 16 use or propose paste backfill
- 11 use cement additives varying from 2 to 6.5%
- 5 use no additives

- Of these, only 4 appear to be doing water quality predictions

Other Backfills

- 15 underground operations use unthickened tailings, waste rock or aggregate mixed with cement
- Cement content varies from 2 to 10%
- Appears only 1 is doing water quality predictions

Surface Paste Applications

- 7 mines are using paste tailings on the surface
- 6 are doing water quality predictions

Extreme Alkalinity

- Backfill of 4 to 8% cement added to inert river aggregate
- Stope monitoring: pH 12.4
  Diss. Sb 5.0 mg/L

  despite acid generating waste rock that reached pH 4 in humidity cells within 5 weeks

Extreme Acidity

Mine A	MA-F	MA-Y	MA-R
	Fresh Paste	Yellow Paste	Red Paste
Paste pH	7.91	2.93	2.33
Fe sulfides	11.81	6.5	4.08
S Total	14	12.4	11.9
SO4	1.02	14.45	21.4
CO2	5.32	1.21	0.29
S2-	13.66	7.56	4.77
SAP	426.88	236.98	148.96
CNP	120.64	27.44	6.58
CNNP	-306.24	-209.54	-142.38
CNP/SAP	0.28	0.12	0.04

Bernier and Li, 2003

Paste Characterization

- Static (ABA) analysis
- Chemical analysis (metals)
- Mineralogical analysis
- Short term leach tests (SWEP, leach extraction)
- Long term kinetic tests

Kinetic Test Methods (cemented paste)

- Cubes
- Intact concrete test cylinders
- Crushed
- Mass and surface reaction

  (reported both as mg/kg/week and mg/cm^2)

Key Findings

- Paste can still be very reactive
- Surface areas are critical
  - Surface spalling (SRK – Crandon)
  - Weathering rind (Bertrand, SRK)
- Preferential leaching of neutralizing minerals under both subaerial and submerged conditions (Venburg, 2000)

Mine Water Quality Predictions

- Few published predictions with underground paste
- New or recently proposed mines
- Varying approaches and assumptions
  - Cured paste backfill considered likely to act as a hydraulic barrier to groundwater flow (formation of more stable minerals, reduced opportunity for ingress of solutions)
  - Interaction between mine water and paste expected to be limited to diffusion-controlled exchange of chemicals.

Water Quality Predictions

- Approaches and assumptions (cont'd)
  - Release of contaminants expected limited by the rate at which oxygen could be transported into the backfilled stopes.
  - Potential for oxygen ingress and sulphide oxidation balanced against presence of neutralizing minerals.
  - Oxygen ingress limited by diffusion
  - Oxygen freely available to stope walls
- Minimal field validation (limited time frame)

Key Factors for Mine Water Prediction

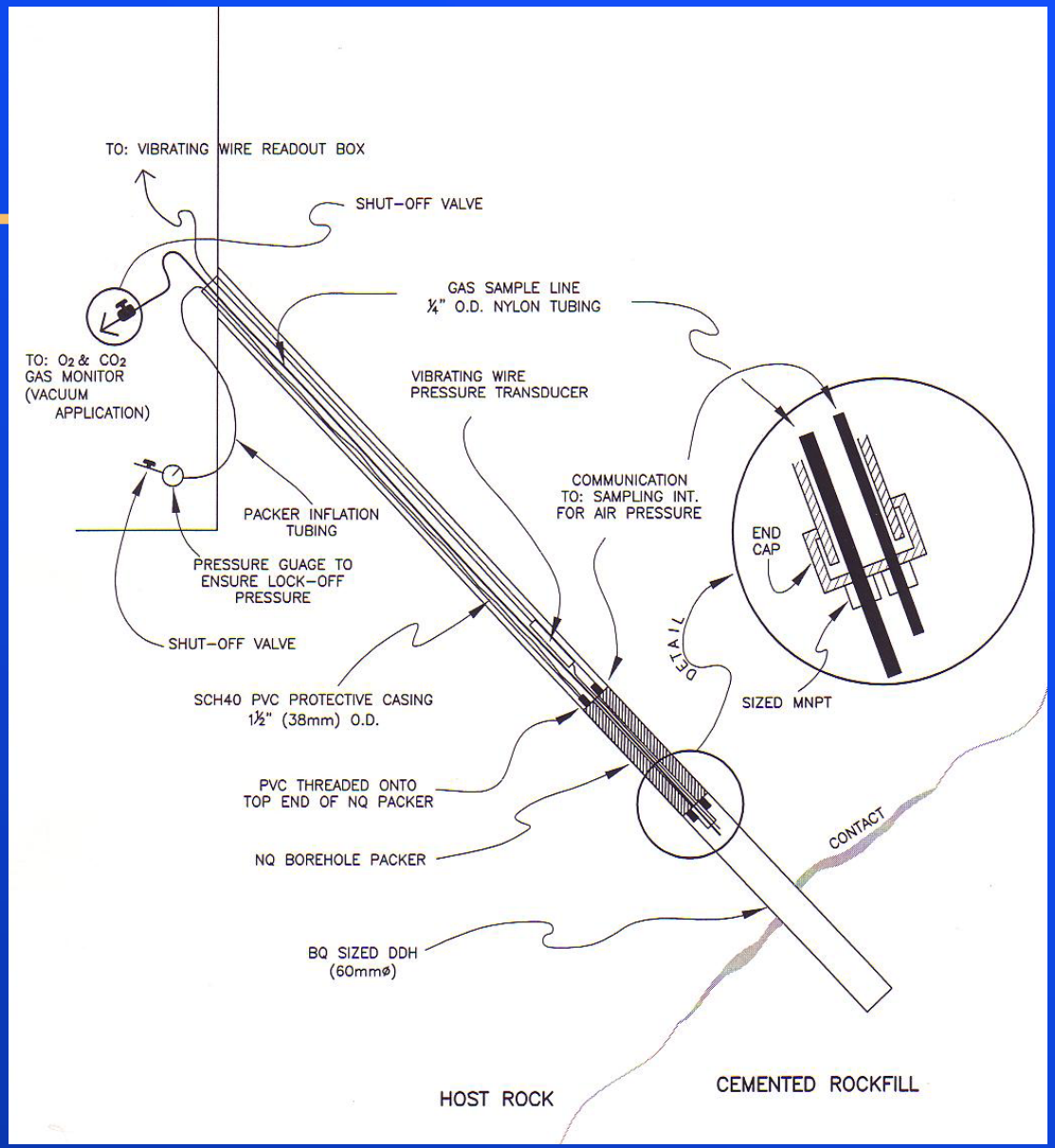
- Cement chemistry (or other additives)
- Oxygen availability/ Available reactive surface area
- Hydrogeology (flushing of soluble products)
- Paste breakdown (and subsequent enhancement of oxygen access/flushing)

Oxygen availability

- Limited to diffusion?
- What surface areas are exposed?
  - Internal gaps in paste mass
  - Gaps against underground walls
  - Gaps between successive paste campaigns
  - Links between stopes
  - Exploration and underground drillholes

Gas Sampling

- Operating mine
- Active ventilation
- Ram-placed backfill
- 4 to 8% cement
- Partially isolated stope
- Reactive sulphides in stope wall



Gas Sampling Results

Sampling Interval Length (m)	Contact Sampled	O_2 (%)	CO_2 (ppm)
9.70	Both	17.9	0
5.20	Backfill only	19.0	0
3.90	Hangingwall	20.6	100
7.11	Footwall	20.2	0

Preliminary Conclusions

- Given costs and problems associated with poor mine water quality, need to better understand the underground scale and time effects.
- Use of paste backfill appears to be beneficial to the mine operation, but…
- The influence of paste backfill on short and long term mine water quality needs to be better understood.

Information Gaps identified to date

- Oxygen availability underground (Stope and Mine Scale)
- Reactive Surface Areas
- Hydrogeology/flushing
- Cement chemistry (and other additives)
  - rates of dissolution of cement NP (loss due to flushing versus acid neutralization)
  - thermodynamic database

Information Gaps identified to date

- Monitoring of stope water quality evolution – alkaline to acid
- Long term monitoring to confirm predictions

(some data compiled by mines, but little published or publicly available)