Sullivan Fatalities Incident
Technical Investigations & Findings

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Overview

- Fundamental processes driving gas transport in waste rock piles
- Evidence for these processes in Sullivan No. 1 Shaft Dump

Conclusions

- No. 1 Shaft Dump
- Other sites
Geochemical Processes

- **Geochemistry**

  - $O_2$
  - Heat
  - $MeS_x$
  - $Me, H_2SO_4$
  - $CO_2$
  - $CO_3$
  - Heat
Physical Processes

- **Gas flows in response to differences in:**
  - Temperature
  - Pressure
  - Composition

- **Rate of gas flow is constrained by:**
  - Permeability
**Physical Processes**

- **Temperature**

![Graph showing oxygen concentration over time with arrows indicating temperature changes in Winter and Summer.](source: SRK 1998)
Physical Processes

**Pressure**

Sustained pressure differences measured below a soil cover after sharp change in barometric pressure

(Source: Hockley et al 2003)
Physical Processes

- **Gas composition**

Oxygen and carbon dioxide measured in rapidly oxidizing but neutral waste rock.

(Source: Hockley et al 2000)
**Physical Processes**

- **Gas permeabilities \((s^{-2})\) measured in covered waste rock in wet and dry conditions**

<table>
<thead>
<tr>
<th>Cover</th>
<th>August 2001</th>
<th>May 2001</th>
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<tr>
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<tr>
<td>Cover 3</td>
<td>2 x 10^{-15}</td>
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</tbody>
</table>

(Source: Hockley et al 2003)
**Coupled Processes**

- **Combinations of physical and chemical effects leads to very complex effects**
- **Best studied with help of models**

(Source: Lefebvre et al 2001a,b)
Which effects are discernible in Sullivan No. 1 Shaft Dump monitoring data?

Modeling: Rene Lefebvre & Balkicem Lahmira

Numerical Grid

- Base is tilted 8 degrees with respect to horizontal
  (The orientation of the gravity acceleration vector in the simulator takes into account this tilting)
- Non Active Top Boundary Layer
- 1 m Thick Till Top Material
- Waste Rock
- Impermeable Base
- Toe Drain Fill Material

Grid elements are all 1 m thick
Grid element lengths are adapted to better reproduce surface slopes

Vertical (Y) exaggeration of 2
Sullivan No. 1 Shaft Dump

- **Geochemistry**
  - Oxidized and visible sulphides (up to 5%)
  - Calcite in waste rock and in till cover
  - Leachate pH 3-4.5
  - Sulphate, zinc, iron
Sullivan No. 1 Shaft Dump

**Temperature**

Depth (m)

Borehole 1A
Sullivan No. 1 Shaft Dump

- Temperature driven inflow - dry cover

**Pneumatic Potential (Pa) and Flow Paths**

Low Atmospheric Temperature - Dry Cover

- Outflow
- Inflow

Conditions after 5 years (near steady state)

2X Vertical Exaggeration

Marker Spacing 100 days

Elevation (m)

Horizontal Distance (m)
Sullivan No. 1 Shaft Dump

- Temperature driven outflow - dry cover

Pneumatic Potential (Pa) and Flow Paths

High Atmospheric Temperature - Dry Cover

Marker Spacing 100 days

Conditions after 5 years (near steady state)

2X Vertical Exaggeration
Sullivan No. 1 Shaft Dump

- Temperature driven outflow - dry cover
Sullivan No. 1 Shaft Dump

- **Temperature driven outflow - wet cover**

Pneumatic Potential (Pa) and Flow Paths

High Atmospheric Temperature - Wet Cover

Marker Spacing 100 days

Outflow

Inflow

Conditions after 5 years (near steady state)

2X Vertical Exaggeration

Horizontal Distance (m)

Elevation (m)
Sullivan No. 1 Shaft Dump

- Temperature driven outflow - wet cover

![Diagram showing Pneumatic Potential (Pa) and Flow Paths with high atmospheric temperature and wet cover.](image-url)
Sullivan No. 1 Shaft Dump

### Pressure

| Air pressure (Pa): 84530 84960 85390 85820 86250 86680 87110 87540 87970 88400 |

The graph shows the pressure variation over time for Borehole 1A.
Sullivan No. 1 Shaft Dump

**Pressure**

Air pressure (Pa): 84530 84960 85390 85820 86250 86680 87110 87540 87970 88400

Borehole 3A
Sullivan No. 1 Shaft Dump

- **Pressure**
  - Model response to 2 kPa pressure drop

After 5 min
After 10 min
After 20 min
Sullivan No. 1 Shaft Dump

- Oxygen

```
+-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+
|     |     |     |     |     |     |     |     |     |     |
| 0   | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   |
|-----+-----+-----+-----+-----+-----+-----+-----+-----+-----|
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<table>
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<th>Borehole 1A</th>
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Depth (m)
Sullivan No. 1 Shaft Dump

$\text{CO}_2$
Sullivan No. 1 Shaft Dump

- Gas composition effect on density

- 21% O₂
  - 79% N₂
  - 28.96 g/mol

- 2% O₂
  - 28.48 g/mol

- 5% CO₂
  - 29.00 g/mol
Conclusions to date

- Oxygen depleted by sulphide oxidation reactions within dump
- Dominant effect controlling direction of airflow was temperature
- Barometric effect is much less influential
- Carbon dioxide production compensates for oxygen depletion and counteracts gas composition effect
Technical panel recommends that all individuals responsible for safety at mine sites should be aware of the hazards associated with waste dump gases.

Risk factors include but are not limited to:

- Sulphide minerals (w or w/o carbonate minerals)
- Dump temperatures that are within range of atmospheric temperature changes
- Sharp drops in barometric pressure
- Factors that serve to concentrate air flows
- Factors that restrict dispersion of gases
Questions