3.5. MODELING ACIDIC DRAINAGE FROM WASTE ROCK PILES

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MODELING ACIDIC DRAINAGE
FROM WASTE ROCK PILES

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Tracy Delaney
Jason Smolensky

Steffen Robertson & Kirsten (Canada) Inc.

Presented at the Fourth Annual B.C. ARD Symposium, Vancouver B.C., November 7-8, 1996
Objectives

"critical review and discussion of mathematical models of acidic drainage from waste rock piles ..."

"emphasis on engineering models ..."

"reference to ... physical and conceptual modelling"

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Topics covered in Report (and Presentation)

Terminology

*Process-specific models*

*Engineering models*

*Recommendations*
Terminology

"... discussions about modeling are often confused by imprecise or inconsistent terminology"

conceptual vs. physical vs. mathematical models

empirical vs. mechanistic

deterministic vs. stochastic

comprehensive vs. process specific

engineering models

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Process - Specific Models

"models of individual processes,
or groups of coupled processes,
that contribute to, influence or are influenced by
acidic drainage in waste rock"
Process - Specific Models

- Site Geology
  - Mine Planning and Operations
    - Construction of Waste Rock Piles
  - Site Hydrogeology
    - Infiltration and Water Flow within Rock Pile
    - Geochemical Processes
  - Oxygen and Heat Transport within Rock Pile
- Site Meteorology
  - Contaminant Transport within and Discharge from Rock Pile
  - Downstream Impacts

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Process - Specific Models

External processes and variables

- *site geology & mine planning*
  - *site hydrogeology*
  - *site meteorology*
Process - Specific Models

Construction of waste rock piles

- pile geometry
- distribution of material
- mixing of material during construction
- effects on physical characteristics

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Process - Specific Models

Infiltration and water flow within waste rock piles

- infiltration
- unsaturated flow
- channel flow
- saturated flow

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Precipitation
Run-off

More uniform
infiltration

Infiltration

Partially saturated
downward migration

Discrete flow
channels

Highly discretized
outflow

Umbrella effect

ARD MODELLING OF WASTE ROCK PILES

MECHANISMS OF CHANNELING
IN WASTE ROCK

MINISTRY OF ENERGY, MINES
AND PETROLEUM RESOURCES

STEFFEN ROBERTSON AND KIRSTEN
Consulting Engineers

PROJECT NO. S1202P9
DATE SEPT., 1995
APPROVED
FIGURE 3.7
Process - Specific Models

Oxygen and heat transport

- advection
- thermal convection
- air phase diffusion
Process - Specific Models

Geochemical processes

- oxidation of sulphide minerals
- dissolution of carbonates, hydroxides, silicates
- precipitation of oxy-hydroxides
- precipitation and dissolution of sulphates
- co-precipitation, ion exchange, sorption
Process - Specific Models

Contaminant transport within waste rock piles

Downstream impacts

Remediation measures

- covers

- geochemical controls

- collection and treatment

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Engineering Models

"models that are intended to support practical decisions about real systems"
Engineering Models

Empirical models

Equity Silver Technical Committee (1991)

AMD Time - Ziemkiewicz (1994)

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The lime consumption curve used by the technical committee model.
Engineering Models

Semi-empirical models

Morin & Hutt (1994)

QROCK - SRK (1993)

ACIDROCK - Senes (1991)

FIDHELM - ANSTO (1994)

TOUGH AMD - (Gelinas et al. 1994)
## Input Parameters for FIDHELM Simulations

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Values</th>
<th>Type *</th>
</tr>
</thead>
<tbody>
<tr>
<td>ambient temperature (°C)</td>
<td>3</td>
<td>M</td>
</tr>
<tr>
<td>intrinsic air density (kg/m³)</td>
<td>1.2</td>
<td>C</td>
</tr>
<tr>
<td>acceleration due to gravity (m/s²)</td>
<td>9.8</td>
<td>C</td>
</tr>
<tr>
<td>air permeability (m²)</td>
<td>$2.9 \times 10^{-9}$, $10^{-8}$</td>
<td>M</td>
</tr>
<tr>
<td>viscosity of air (kg/(m.s))</td>
<td>$1.9 \times 10^{-5}$</td>
<td>C</td>
</tr>
<tr>
<td>thermal coefficient of volume expansion (K⁻¹)</td>
<td>$3.47 \times 10^{-3}$</td>
<td>C</td>
</tr>
<tr>
<td>oxygen diffusion coefficient of oxygen in air (m²/s)</td>
<td>$2.26 \times 10^{-5}$</td>
<td>C</td>
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<tr>
<td>parameter in particle oxidation model (m³/(kg.s))</td>
<td>$1.354 \times 10^{-9}$</td>
<td>E</td>
</tr>
<tr>
<td>bulk density of solid (kg/m³)</td>
<td>2200</td>
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<tr>
<td>specific heat of solid (m²/(s² .K))</td>
<td>866</td>
<td>E</td>
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<tr>
<td>specific heat of air (m²/(s² .K))</td>
<td>$1.06 \times 10^{-3}$</td>
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<tr>
<td>thermal diffusivity (m²/s)</td>
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<tr>
<td>heat of oxidation reacton per mass of reactant oxidised (J/kg)</td>
<td>$2.2 \times 10^{-7}$</td>
<td>C</td>
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</table>

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<table>
<thead>
<tr>
<th>Parameter</th>
<th>Values</th>
<th>Type *</th>
</tr>
</thead>
<tbody>
<tr>
<td>mass fraction of oxygen in air</td>
<td>0.22</td>
<td>C</td>
</tr>
<tr>
<td>mass of oxygen used per mass of reactant in oxidation reaction</td>
<td>1.746</td>
<td>C</td>
</tr>
<tr>
<td>solid volume fraction</td>
<td>0.763</td>
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<tr>
<td>density of reactant (kg/m$^3$)</td>
<td>118</td>
<td>M</td>
</tr>
<tr>
<td>maximum intrinsic oxidation rate (kg (O$_2$)/m$^3$/s)</td>
<td>$10^{-9}, 10^{-8}, 10^{-7}$</td>
<td>E</td>
</tr>
<tr>
<td>infiltration rate (m/y)</td>
<td>1.134</td>
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<tr>
<td>viscosity of water (kg/m s)</td>
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<td>intrinsic water density (kg/m$^3$)</td>
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<tr>
<td>specific heat of water (m$^2$/s$^2$.K))</td>
<td>$4.184 \times 10^3$</td>
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<tr>
<td>temperature at which micro-organisms cease to be effective as catalysts (°C)</td>
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<td>E</td>
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<tr>
<td>temperature above which the micro-organism catalytic activity diminishes</td>
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<td>tortuosity factor</td>
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<td>radius of pile (m)</td>
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</tr>
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<td>height of pile (m)</td>
<td>6.7</td>
<td>M</td>
</tr>
<tr>
<td>side slope angle of heap (radians)</td>
<td>0.245</td>
<td>M</td>
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</table>

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Conclusions

Process - Specific Models

- surprising number & diversity

- some processes well understood & modeled

- other (important) processes neglected

- current approach is "bottom up"
Conclusions

Engineering Models

- all are at least partly empirical
- empirical models are more transparent
  - poor documentation
- lack of consideration of uncertainty
  - lack of validation
  - "bottom up"

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Recommendations

- limitations of ARD models need to be better communicated to industry and regulators

- strong “bottom up” work should be complimented by a “top down” approach

- appropriate combination of mathematical and physical models needs more attention