Total Dissolved Solids in Waters from Valley Fills

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With essential contributions by:
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ARIES
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Powell River Project
Problem: Salts (measured as total dissolved solids, \textit{TDS} and specific conductance, \textit{SC}) from coal mining operations area regulatory concern – and a concern to the coal industry.

What are we learning about TDS in mine water discharges? What can industry do to address that problem?
Presentation Outline

• Background: Why do we care about TDS?
• What are we learning about TDS production and release from mine spoils?
• And: What are we learning about TDS control – on the mines.
**Background:**

**TDS: Why care?**

Timpano et al. 2015 JAWRA 51: 240-250.
Background:

... and we have much to learn about the true nature of the TDS problem:

- Causes for taxa losses?
- Seasonal patterns?
- Impacts of taxa losses?
- How to gauge “allowable” impacts,
- etc.

Data: Community metrics in 12 streams of three water-quality types (4 streams per type), over 19 months.

Boehme et al., Ecol. Applic., in review.
We care, because: TDS in mine water is a problem!
So … What do we do about it?

Valley fills are convenient for learning about managing the problem.

We learn about it, understand it – and manage it.
Spoil Characterization Research - Lee Daniels, VT:
TDS release differs dramatically among spoils, but generally declines with time.

SC in mine-spoil leachate:
Data from Lee’s student, Clay Ross, shows spoil placed in large vessels, leached with rainwater, behave similar to the columns – but with higher concentrations emerging after extended dry periods.

Water quality data from UKy plots are also consistent with the column data.

Field plots: each ~1 acre in size, 4 feet in depth. Each with its own water collection drains.

Data in: Daniels, Barton, Skousen et al. 2015. in prep.
Research (Evans et al. 2014): 137 Virginia valley fills, agency data: SC of water discharge over periods extending from ~1 to >20 years.
Black dots are individual Virginia valley fills studied by Evans et al. (2014): 137

Time periods represented
Individual valley fill data:
1 to 21 years
Quality of Waters emerging from Virginia valley fills:

Highly variable.

Evans et al. 2014. JAWRA 50: 1449-1460
Quality of water emerging from many valley fills is changing with time.
Example: SC of waters discharged by one valley fill over 20+ years (Virginia DMME database).

The older the valley fill, the more like it is to exhibit declining SC. On average: the older Virginia fills required ~20 years to reach 500 µS/cm.
Electrical Resistivity Imaging: Water within a valley fill, Response to Artificial Rainfall Application

Red Box: Area of artificial rainfall (pond water, 1.5 to 2 inches total) on a valley-fill cross section

Red & Yellow: moisture has increased.

Green: No detectable change.

Blue: Strong moisture contrast to adjacent red-yellow (no detectable change).

Source: B. Greer, M.S. thesis (E. Hester), VT
**What have we learned?**

- Spoil characterization procedures can predict relative differences between materials in the field - although under some circumstances, columns underpredict actual SC levels.

- Management of both spoil placement and water movement is essential to SC/TDS control.

- Known differences between spoils and valley fills – and known high-TDS practices* that can be changed -- suggest opportunities for improved TDS management – *if we try.*

* Known high-TDS practices:
  - alkaline/acid spoil blending;
  - lack of attention to high-TDS spoil placement;
  - lack of control over water movement into the fill.
Questions:
How to apply what is being learned?
How to build mine-spoil fills for reduced TDS in mine water discharge – on the job?
Two experimental fills are being constructed.

1. Alpha / Paramount, 88 Strip near Duty: Under construction for approx. 3 years.


Similar strategies are being employed for the 2 fills – but with some differences

Waters emerging from experimental fills are monitored.

Conventional fills constructed in similar strata are also monitored for comparison.
Project Goals:

✓ **Reduce TDS** levels coming out of the fill, relative to TDS produced by fills constructed using conventional techniques.

✓ Produce surface-water flows that more closely approximate *pre-mining hydrology* than current fills.

✓ Establish a forest cover that will develop into a **forested ecosystem** resembling those which occur on nearby non-mined areas.

✓ **Control costs** to extent possible, as needed for profitable mining.
Mined Land, as envisioned: Forest and Hydrologic Restoration, Water Quality Protection. Operational prototypes being developed by industry.

Low-TDS mine spoil fill concept

Underlying graphic by Kevin McGuire
### Basic Strategies

Test spoils for TDS, segregate/handle accordingly.

<table>
<thead>
<tr>
<th>Leach No.</th>
<th>Depth</th>
<th>Rock Type</th>
<th>Composition (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>462-520</td>
<td>gray sandstone</td>
<td>100</td>
</tr>
<tr>
<td>2</td>
<td>415-460</td>
<td>gray sandstone, gray shale, gray sandy shale</td>
<td>37, 31, 31</td>
</tr>
<tr>
<td>3</td>
<td>376-408</td>
<td>gray sandstone, gray sandy shale, gray shale</td>
<td>66, 23, 10</td>
</tr>
<tr>
<td>4</td>
<td>290-375</td>
<td>gray shale, gray sandy shale, minor sandstone</td>
<td>83, 15, 2</td>
</tr>
<tr>
<td>5</td>
<td>211-290</td>
<td>gray shale, gray sandstone, gray sandy shale</td>
<td>50, 26, 24</td>
</tr>
<tr>
<td>6</td>
<td>160-211</td>
<td>sandy shale, gray sandstone, brown sandstone</td>
<td>54, 43, 3</td>
</tr>
</tbody>
</table>

- Select for drains
- Also good material

![Graph showing EC (µS/cm) vs Leach No.]
Basic Strategies

Interpret Mine-Spoil Testing Results.

For fill construction: we see 4 main rock types

1. Durable rock, low TDS: for drains
2. Bulk fill: Other low and Intermediate TDS material, unweathered.
3. Weathered spoil and soil materials: Lowest TDS is usually closest to the surface
4. High TDS (often include shales, anything pyritic): to isolate “high and dry.”
Basic Strategies

- Install drains to intercept known groundwater entries, direct waters to daylight along low TDS pathways.
Underdrain construction using selected low-TDS sandstone Paramount fill
Basic Strategies

Minimize flat areas that may enhance water infiltration

Line and/or pitch ditches over fill to minimize water infiltration.

No standing water on fill

Goal:
Reduce Surface Water Influx to Fill

Note: Photo is a conventional mine site. We do not have a photo of proposed practices (not yet applied in a comprehensive manner)

http://pa-eng.com/services_mining.html
Establish surface hydrology to minimize water influx, achieve reclamation goals.

Weathered rocks (+ soil and organics?) at surface and organics?

Physical settling of fines limits compaction at interface 

Unweathered rock - bulk fill

Extra compaction limits permeability at interface if possible

Plant rooting maintains voids near surface - and hydrologic function

Conceptual plan, not yet tried.
FRA: Operational Reclamation with VT Oversight, Age 6
Paramont / 88 Strip Fill Design:

- Build low-TDS rock drains to collect groundwater from abandoned deep-mine seep and old valley fill being covered with new, larger fill.
- Use low-TDS spoils (including weathered material) to build fill.
- Build road down into fill, with weathered spoil base.
- Construct fill as compacted lifts, 25 foot, crowned.
- Contour surface with steep slopes, in effort to prevent seepage into fill.
- Cover with soil/weathered spoil where possible, reclaim with Forest Reclamation Approach.
At Paramount 88 Strip

Barton Hollow fill (experimental) 11/14

Flume for water monitoring at End Fill

Office Fill (conventional)

End Fill (conventional, older)
Paramont 88 Strip Valley Fills: SC, Mean Daily Values

Specific Conductance (μS/cm)

Barton Hollow (Experimental)
Office Fill (Conventional, Young)
End Fill (Conventional, Old)

SC prior to current mining at Barton Hollow
Paramont 88 Strip Valley Fills: Unit Discharge, Mean Daily Values

- Barton Hollow (Experimental, under construction)
- End Fill (Conventional – Old)
Teco, Spring Branch Fill Design:

- Build low-TDS rock drains to collect *all* ground-water (including highwall seeps) for gravity discharge.
- Isolate high TDS spoils “high and dry”.
- Loose dump bulk spoil over drains.
- Contour surface with steep slopes, in effort to prevent seepage into fill.
- Build all channels to prevent seepage into fill.
- Cover with soil/weathered spoil where possible, reclaim with Forest Reclamation Approach.
- Minimize open-spoil areas, to extent possible.
Teco (at Hurley)

Bearwallow (conventional)

Flume at Bearwallow

Spring Branch below flume

Spring Branch (experimental)
Photo: 1/15
Valley Fills at Teco Hurley: SC, Mean Daily Values

Specific Conductance (μS/cm)

- Spring Branch
  (Site clearing)
- Bearwallow
  (Conventional, Young)
Valley Fills at Teco Hurley: Unit Discharge, Mean Daily Values
Water chemistry: Means of all samples to date.
Conclusions

Spoil testing and characterization can differentiate mine spoils based on TDS generation potentials.

Valley fills exhibit significant variation in SC discharge, suggesting opportunities for SC management in mine spoil fill construction.

Two Virginia valley fills are designed to test different SC management strategies; construction of both are underway.
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