TDS RELATED LEACHING POTENTIALS OF COAL SPOIL AND REFUSE FROM TN AND VA

Zenah W. Orndorff, W. Lee Daniels, Carl Zipper, Matt Eick

Virginia Polytechnic Institute and State University
Surface coal mining in the central Appalachian coalfields generates large quantities of overburden waste rock (spoil) which is removed to access coal seams.
Diverse coal spoil and refuse materials are commonly disposed of into highwall backfills and river valleys (valley fills).

Over the past decade, concerns have emerged over the biological effects of elevated TDS emissions from backfills and valley fills to surface water.
By understanding the leaching potential of diverse spoil and refuse materials, VFs may be designed to minimize environmental impacts.
SPOIL AND REFUSE SAMPLES FROM TENNESSEE
OBJECTIVE

To characterize the potential leaching behavior of 5 mine spoil and 4 refuse materials, in terms of:

- pH
- EC
- Major cation and anion composition
METHODS

BULK SAMPLES (2 5-gal buckets) were each:

- Spread out to air-dry.
- Passed through a 1.25 cm (0.5”) sieve.
- Coarse fraction was crushed to <1.25 cm.
- All material was thoroughly re-blended.
- Subsamples (1200 cm$^3$, with mass recorded) were collected (cone and quarter) for column leaching and to determine pore volume (within columns).
- Subsamples were collected and crushed as appropriate for basic characterization including saturated paste pH/EC, Peroxide Potential Acidity (PPA), and Acid-Base Accounting.
COLUMN SETUP

- Sample volume: 1200 cm$^3$
- Inside diameter = 7.5 cm
- Height of spoil = ~ 27 cm
- Inside bottom of column:
  - 5 cm (2") sand
  - Whatman #1 filter
  - 0.1 mm nylon mesh
  - perforated plastic disc
- PVC pipe nipple and Tygon tubing for drainage
METHODS

- Each spoil material was run in triplicate (3 columns/material)
- Unsaturated: samples initially moistened to maximum water holding, then any amount added = amount drained.
- Saturated: samples initially slowly saturated, maintained with ~1cm of leaching solution above the sand layer.
- Leaching solution: synthetic acid rain with pH=4.6
  Contains very low amounts of CaSO$_4$, K$_2$SO$_4$, Mg$_2$SO$_4$, NaCl, NaNO$_3$, NH$_4$NO$_3$, (NH$_4$)$_2$SO$_4$, H$_2$SO$_4$, HNO$_3$, H$_3$PO$_4$
  (Recipe from Halvorson and Gentry, 1990)
- Simulated rainfall was applied 2x/week (Mon/Thurs)
- Each rainfall event = 125 ml (~2.5 cm; 1”)
- Leachate (~125 ml) collected after ~24 hrs (Tues/Fri).
- Samples analyzed for: pH, EC, several cations, bicarbonate, sulfate, and chloride
<table>
<thead>
<tr>
<th></th>
<th>Saturated paste</th>
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<tbody>
<tr>
<td></td>
<td>pH</td>
<td>EC (uS/cm)</td>
<td>PPA</td>
<td>Total-S %</td>
<td>MPA</td>
<td>CCE</td>
<td>NNP</td>
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<td>SPOIL</td>
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<td>-0.6</td>
<td>0.15</td>
<td>4.61</td>
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- Range from acidic (4.68) to alkaline (7.80)
- Moderate soluble salt content
- Not predicted to be acid forming by PPA or NNP
## BULK SAMPLE CHARACTERIZATION - REFUSE

<table>
<thead>
<tr>
<th>REFUSE</th>
<th>Saturated paste</th>
<th>pH</th>
<th>EC (uS/cm)</th>
<th>PPA</th>
<th>Total-S %</th>
<th>MPA</th>
<th>CCE</th>
<th>NNP</th>
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<tbody>
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</tbody>
</table>

- Alkaline
- Moderate soluble salt content
- 3 samples predicted to be acid forming by PPA
- None predicted to be acid forming by NNP
pH: UNSATURATED SPOIL

pH equilibrated within 10 – 20 leach events (3+ pore volumes)

pH equilibrated ~ 6.9 – 8.2
**pH: SATURATED VS UNSATURATED SPOIL**

Unsaturated pH > Saturated pH
pH: REFUSE

Unsaturated pH (2.6 – 7.6) < Saturated pH (6.9 – 8.2)

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<td>TNR1</td>
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<td>69.7</td>
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<td>TNR2</td>
<td>1.09</td>
<td>75.8</td>
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<td>1.22</td>
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EC: UNSATURATED SPOIL
EC: SATURATED VS UNSATURATED SPOIL

The diagram illustrates the electrical conductivity (EC) over time for different spoil conditions. The EC values are measured in uS/cm and range from 3500 to 500. The graph compares the EC for TN3 and TN5 spoil, both in saturated and unsaturated conditions. The data shows a decrease in EC over time, with the unsaturated spoil generally having a lower EC value compared to the saturated spoil. A horizontal line indicates a baseline EC of 500 uS/cm.
EC: REFUSE

Unsaturated EC > Saturated EC

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EC (μS/cm) - log scale

Leach #
SPOIL:
Most ions exhibited release curves similar to EC.
SPOIL: Bicarbonate was the only major ion that increased over time (for most samples).
SPOIL: Bicarbonate release was higher under saturation.
REFUSE
Most major ions exhibited release curves similar to EC.
TRACE/MINOR ELEMENTS: REFUSE vs SPOIL

Overall release is greater from refuse than from spoils.
Note shift to bicarbonate over time; similar for TN2, TN3, and TN5.
Minimal bicarbonate shift?
SPOIL (TN3) UNSATURATED vs SATURATED

TN3, L-1: 1527 mg/L TDS

TN3, L-39: 271 mg/L TDS

TN3, L-1: 1206 mg/L TDS

TN3, L-39: 294 mg/L TDS

**UNSATURATED**

- Ca
- Mg
- Na
- Al
- K
- Fe
- other cations
- sulfate
- chloride
- bicarbonate

**SATURATED**
Continued sulfate release due to S oxidation.
Saturation limits S oxidation
Summary

• For most spoil and refuse samples (saturated and unsaturated) TDS elution declined rapidly over the first several leach events (approximately 2 – 3 pore volumes), then declined slowly and steadily over the remainder of the study.

• For spoil materials, saturation appeared to affect the pattern of TDS release, but not the overall release of TDS over the study period.

• For 3 of 4 refuse materials, saturation significantly decreased TDS release after the first 6 – 8 leach events.
Summary

• All 5 spoil samples equilibrated to EC < 500 uS/cm within 5 to 20 leach cycles (approximately 2 – 7 pore volumes).

• Unsaturated refuse samples maintained EC > 500 uS/cm over the course of the study.

Under saturated conditions, 3 refuse samples equilibrated to EC < 500 uS/cm (within 14 – 18 leach cycles).
Summary

• Cation composition was dominated by Ca and Mg, with lesser amounts of Al, K, Na and Fe.

• Anion composition was dominated by sulfate and bicarbonate, with lesser amounts of chloride.

• Mass release for most elements reflected declining EC levels (exceptions included bicarbonate and some trace metals).

• For most spoil samples, sulfate was initially the dominant anion, but over time bicarbonate became the dominant anion.
Acknowledgements

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