10th ICARDIMWA2015
10th International Conference on Acid Rock Drainage
& IMWA ANNUAL CONFERENCE

Geochemical Characteristics of Oil Sand Tailings and Bitumen Upgrading By-Products, Alberta, Canada

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Acknowledgements

- Study undertaken by Suncor Energy Inc.
- Geochemical analyses by Maxxam Analytics.
- Mineralogy by the University of British Columbia and University of Saskatchewan.

Oil Sands Production in Alberta, Canada

- Alberta has the third largest oil reserve in the world (170 billion barrels).
- Most oil occurs in association with three oil sand deposits.
- Bitumen is obtained by surface mining and in-situ extraction.

Image credit Alberta Government http://oilsands.alberta.ca/reclamation.html

Bitumen Extraction from Mined Oil Sands

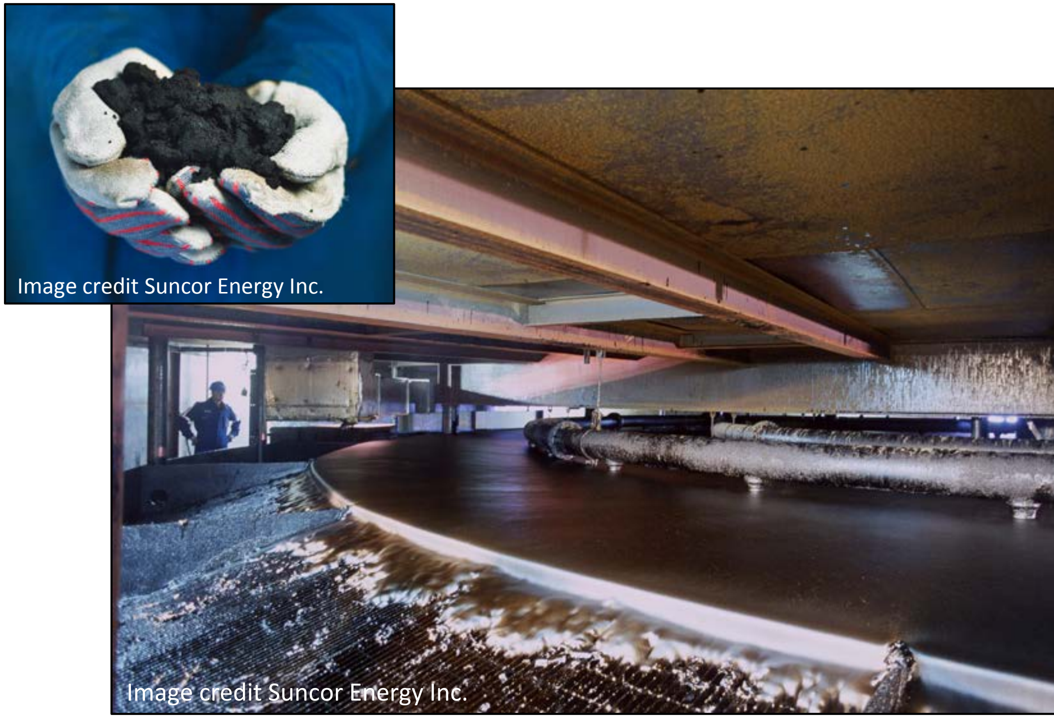


Image credit Suncor Energy Inc.

Image credit Suncor Energy Inc.

- Bitumen
- Bitumen froth
  - → Froth treatment tailings (FTT)
- Coarse & fine tailings

Mined oil sands are crushed and bitumen is extracted using a process of gravity separation and flotation.

Oil Sands Tailings

Suncor Tailings Pond 1 in 2002

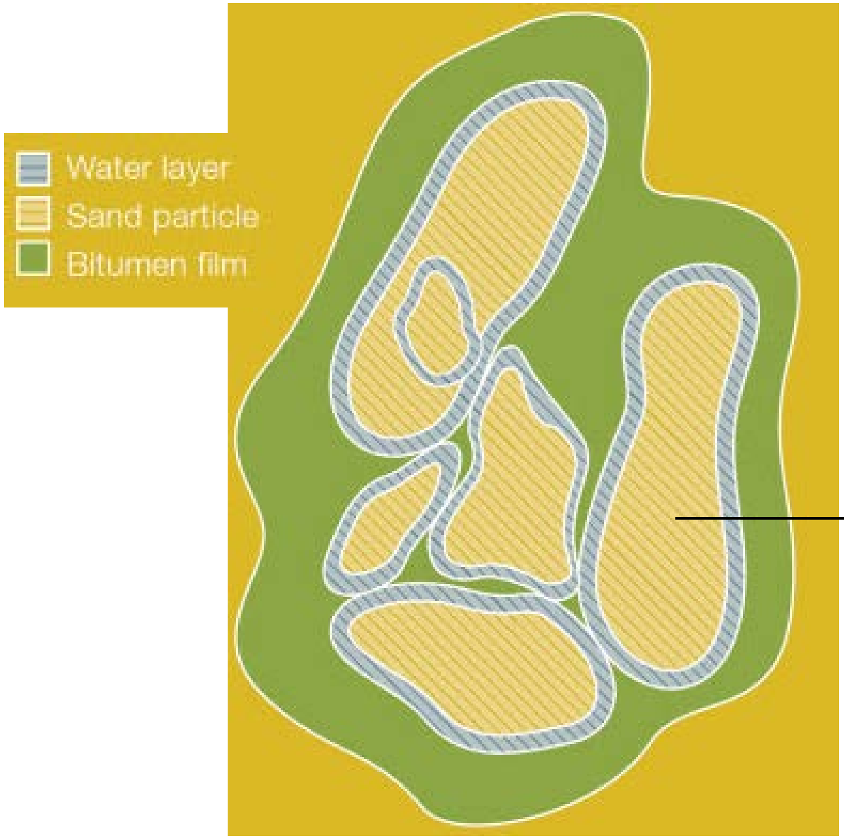
Dried MFT

- Fine tailings are deposited into ponds where they settle to form mature fine tailings (MFT) containing about 30 to 40 wt.% solids.
- MFT is mixed with polymer and dried in thin lifts to become dried MFT.

Bitumen Upgrading By-Products

- Bitumen is upgraded to lighter hydrocarbon products through a process of reductive coking.
- Some coke is utilized for heat generation resulting in bottom & fly coke ash.

Overview of ARD Potential



An oil sands particle

- Quartz
- Kaolinite
- Mica
- Microcline
- Clinochlore
- Albite
- **Pyrite**
- Siderite
- Calcite
- Ankerite
- Ti oxides
- Zircon
- Tourmaline

Image credit Alberta Government
http://www.energy.gov.ab.ca/oilsands/793.asp

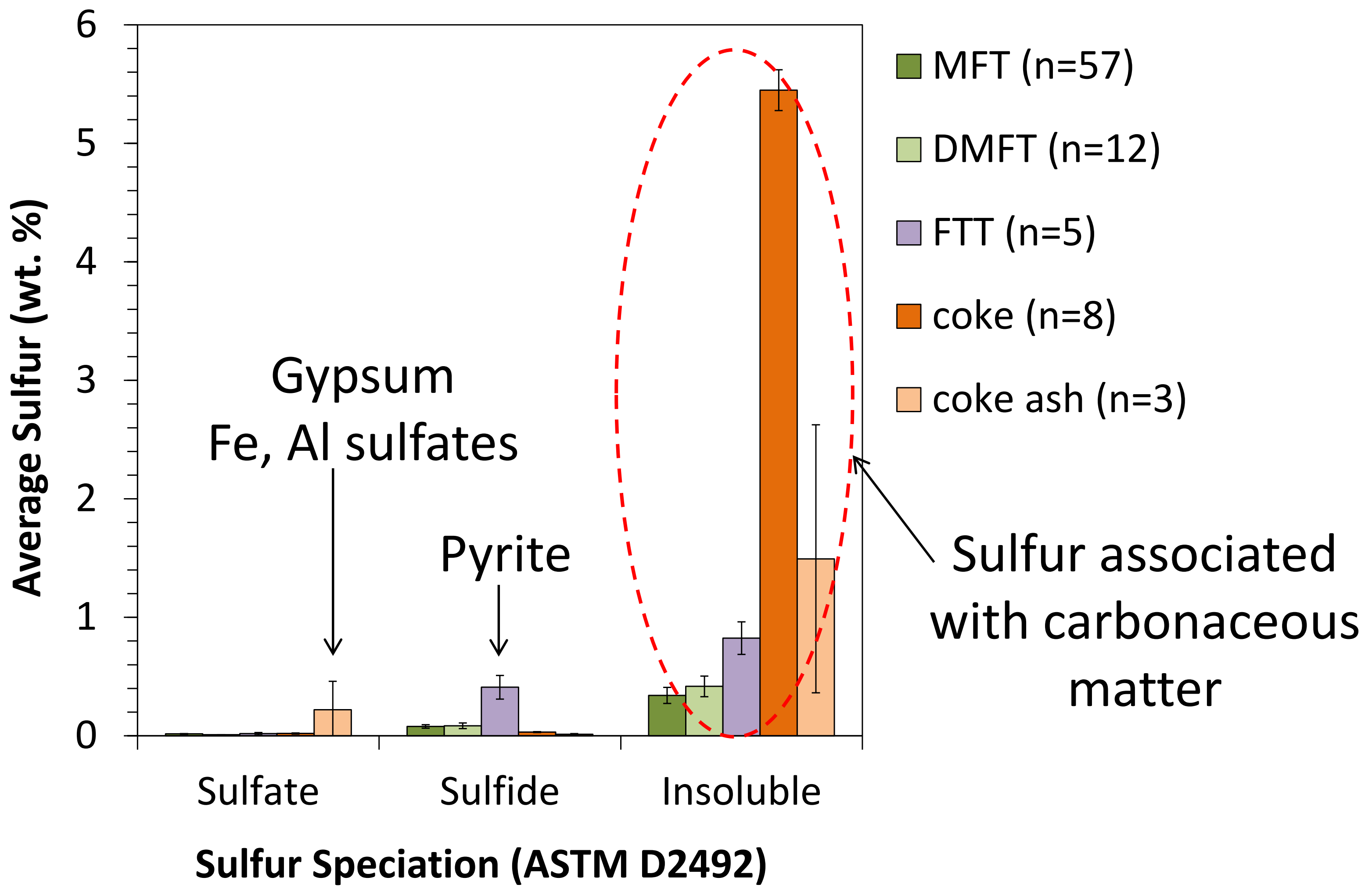
Study Objective

To geochemically characterize the metal leaching & acid rock drainage (ML/ARD) potential of oil sand tailings (FTT, MFT, dried MFT) and bitumen upgrading by-products (coke & coke ash) from the McMurray Formation.

Approach

- Used methodologies typically applied to coal & metal mine wastes.
- Included:
  - Mineralogy (XRD, μ-XRD)
  - Element composition (XRF, four-acid digestion)
  - Sulfur speciation (ASTM D2492)
  - Total inorganic carbon (by difference)
  - Acid-base accounting (including siderite-corrected Sobek NP)
  - Net acid generation (NAG) with & without Dean Stark extraction to remove residual bitumen
  - Humidity cell testing (minimum of 20 weeks)

Acid Potential



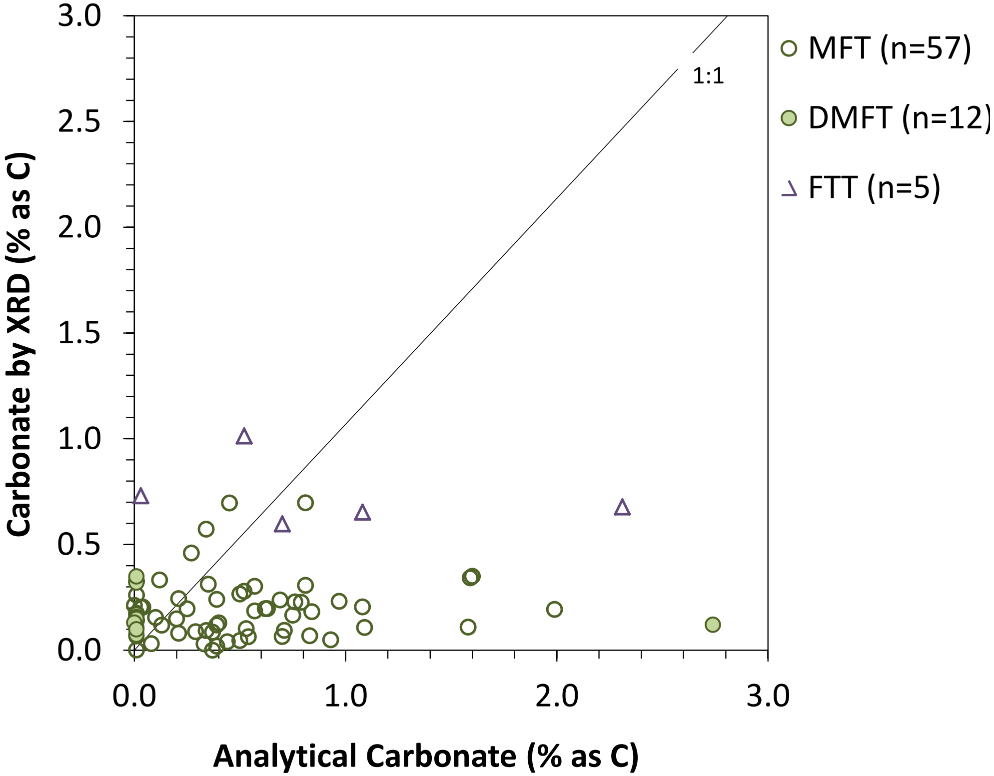
Error bars indicate 95% confidence interval.

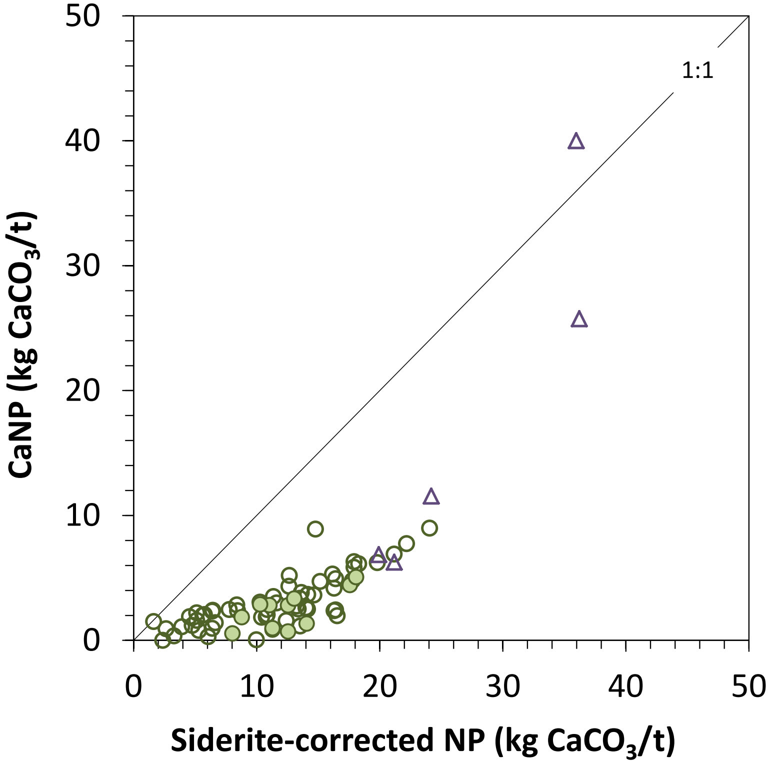
Acid Neutralization Potential

- Primarily associated with calcite & ankerite dissolution.
- Three determinations:
  - Inorganic C determined as the difference between total C and residual C
  - NP associated with Ca & Mg in calcite & ankerite (CaNP) from QXRD[1]
  - Sobek NP with siderite-correction[2]

[1] Day, S.J. (2009) Estimation of calcium and magnesium carbonate neutralization potential for refined acid-base accounting using electron microprobe and X-ray diffraction. 8th International Conference on Acid Rock Drainage (ICARD), Skelleftea, Sweden, June 22-26.
[2] Skousen, J. (1997) Neutralization potential of overburden samples containing siderite. Journal of Environmental Quality. 26(3): 673-681.

Acid Neutralization Potential

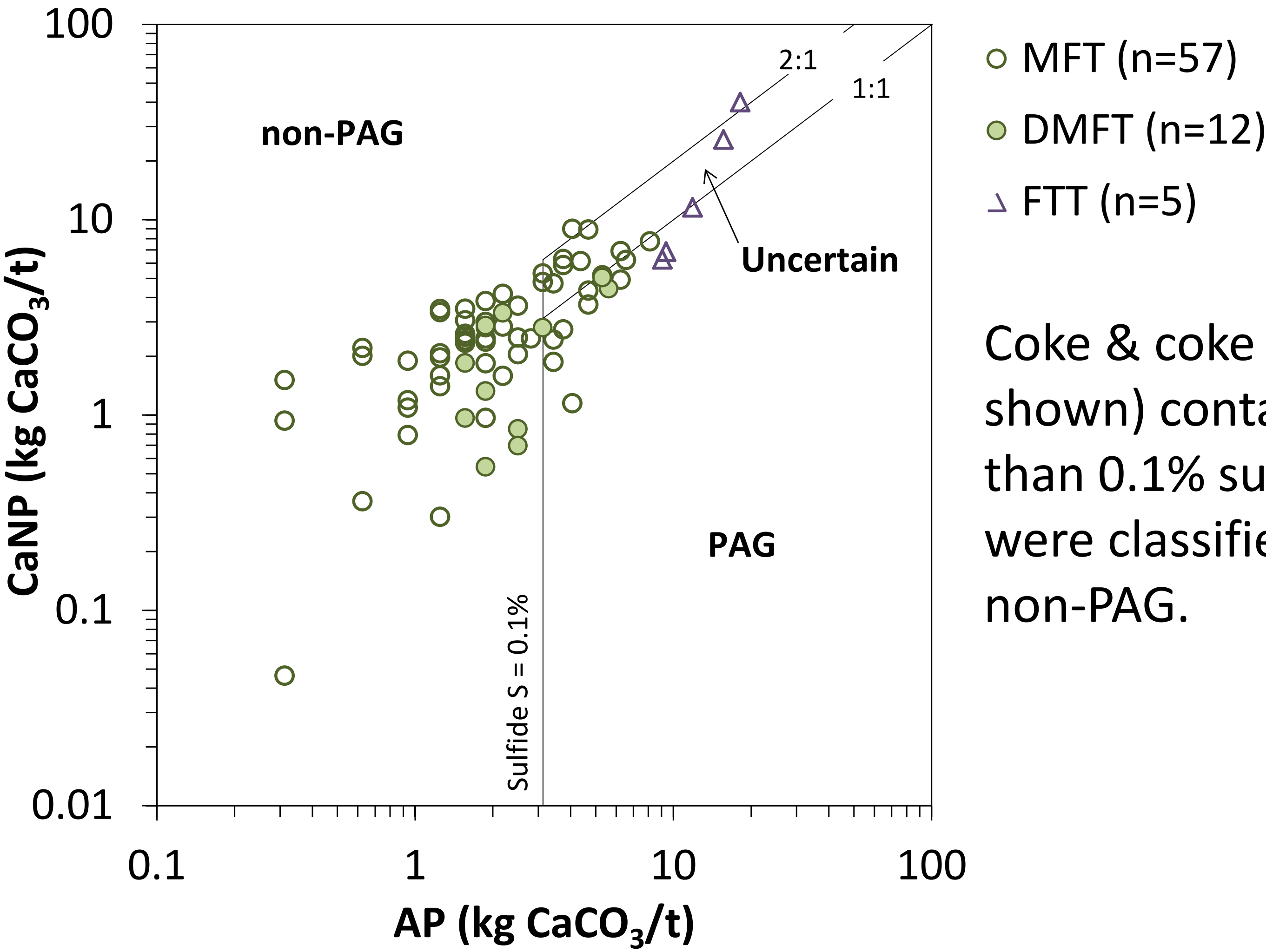




Poor relationship likely attributable to high organic C content & hydrophobicity

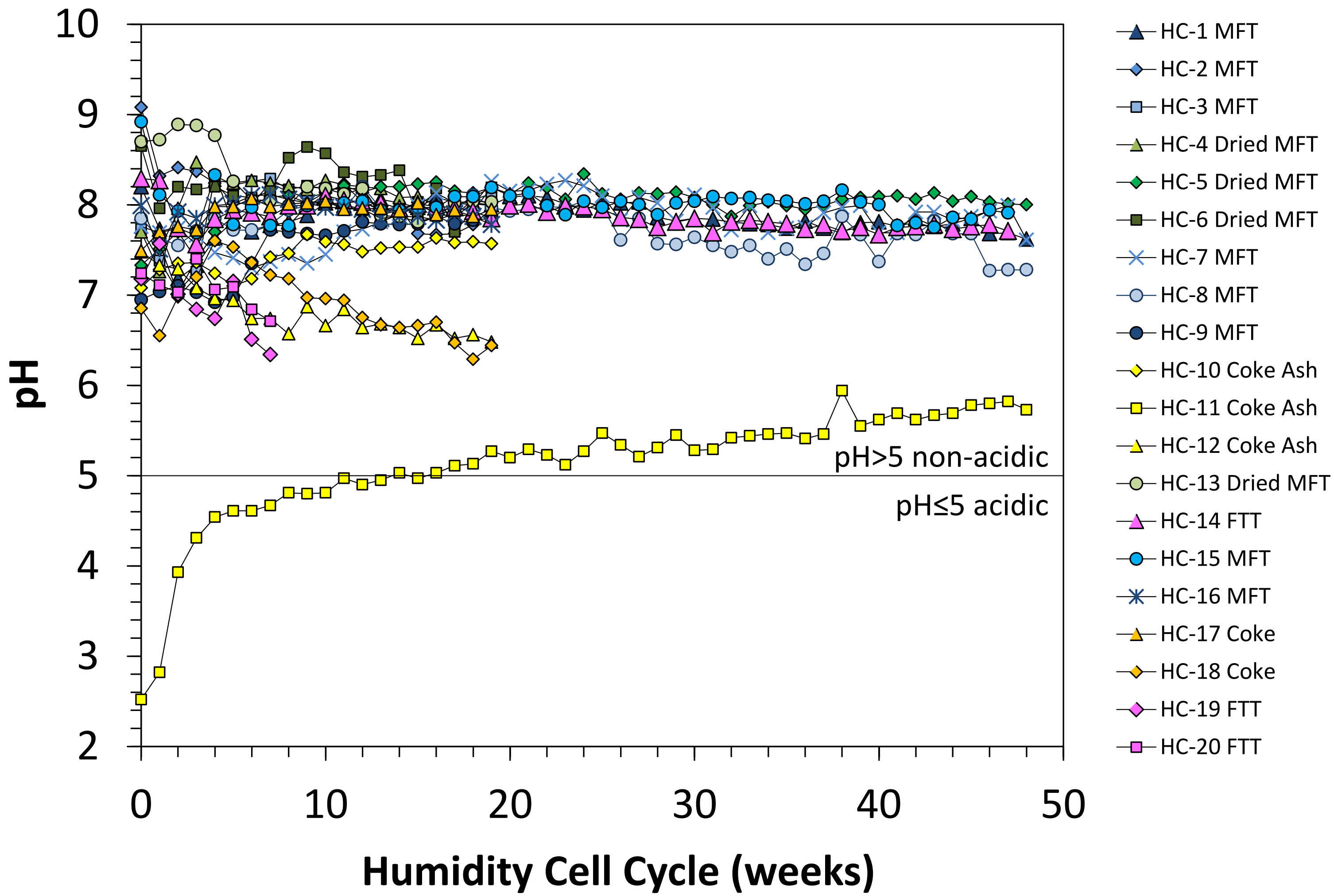
More consistent relationship but differences observed

Acid Rock Drainage Potential



Coke & coke ash (not shown) contained less than 0.1% sulfide & were classified as non-PAG.

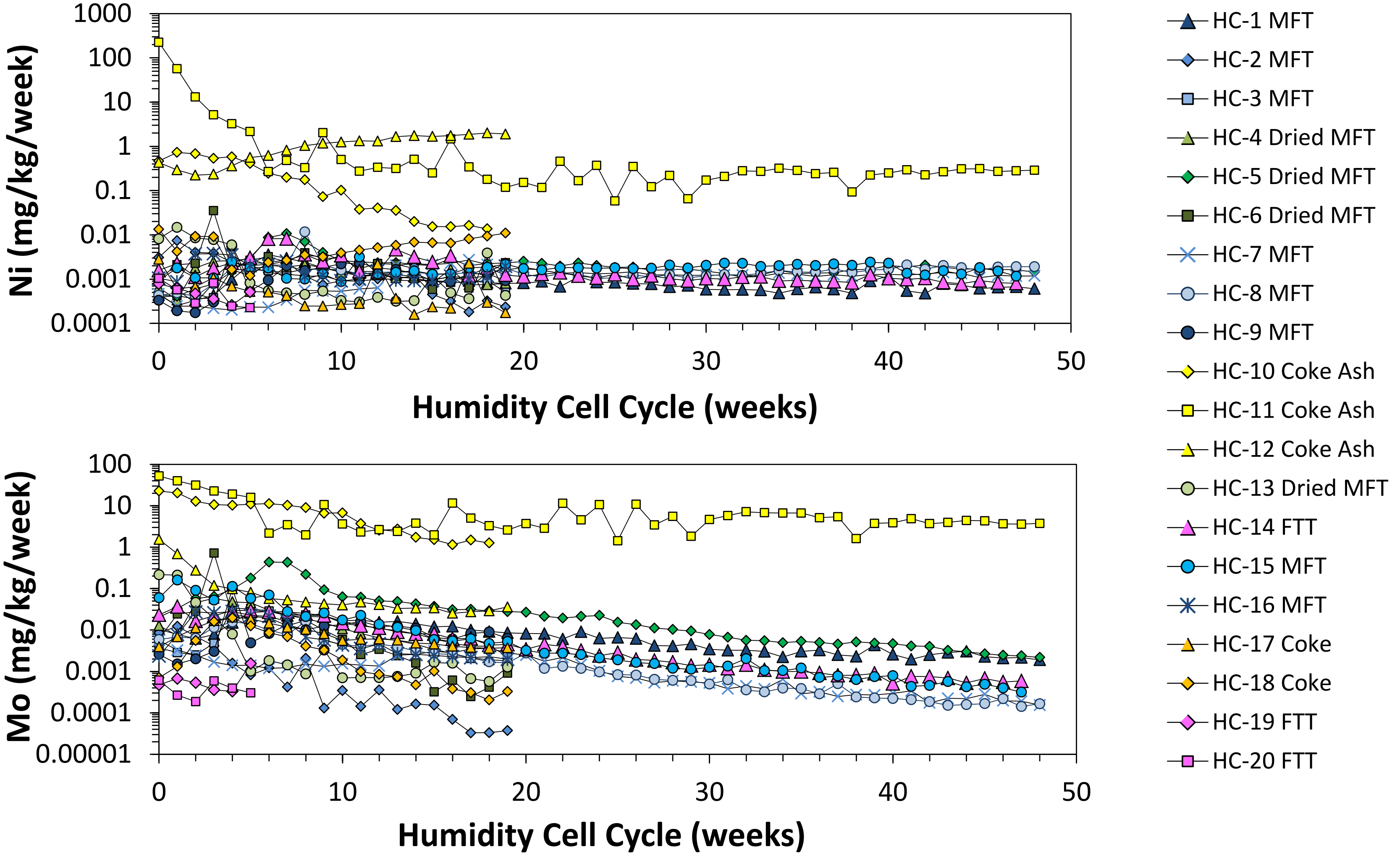
Acid Rock Drainage Potential



Trace Element Leaching Potential

- Tailings bulk composition showed enrichment of Co, Mo, Ni, Se & U in comparison to global average values for sandstone.
- Coke & coke ash bulk composition showed elevated V, Ni & Mo in comparison to tailings.

Trace Element Leaching Potential



Summary of ML/ARD Potential

- Tailings, coke & coke ash had low ML/ARD potential due to low sulfide content.
- FTT is a possible exception.
  - Classified as potentially acid-generating by static test methods.
  - No acidity observed in humidity cell tests.
- Generally low metal mobility under neutral to alkaline pH.
- Greater element leaching from coke ash due to soluble sulfates & oxide phases.

Application of ML/ARD Potential Methods to Oil Sands

- Sample hydrophobicity requires dispersants & sonification to allow regeants to properly react with samples.
- Quantitative XRD may be an alternative to wet chemistry methods for inorganic C determination.
- Application of siderite-corrected Sobek NP to oil sands tailings requires further investigation.

Application of ML/ARD Potential Methods to Oil Sands

- Application of humidity cell rates to site conditions requires careful consideration of:
  - Sample hydrophobicity
  - Scaling
  - Likely limited oxygen diffusion due to high organic C & moisture content.