Twenty-five Years of Mine Waste Characterisation in Western Australia:

Overview of Testwork Approaches

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Outline

A. Static Testing
   • S Forms
   • Bulk-ANC, CO3-ANC, pH-buffering
   • NAG
   • mineralogy

B. Kinetic Testing
   • columns (cf. humidity-cells)
   • oxygen-consumption cells
Generics

- Prescriptive (?) Compendia for Geochem Testing
  - MEND (2009) (= "Bill's Tome"!)
  - GARD Guide, AMIRA (2002), and others
  - originators may not intend these to be prescriptive, but can easily be perceived as prescriptive by regulators, consultants, etc.

- But, in undertaking a characterisation programme:
  - always "horses for courses"
  - personal preferences of individual practitioners
  - professional judgement
Static-testing (1)

• **S Forms**
  - Total-S (Leco)
  - SO4-S-[Na2CO3]
  - Cr(II)-Reducible-S when needed
  - mineralogy selective samples

• **ANC (= NP)**
  - Bulk-ANC
    - use -2mm (nominal) crushings (cf. pulps, AMIRA [2002])
  - CO3-C
  - pH-buffering curves selective samples
    - autotitrations and pH5-soak tests
Static-testing (2)

- **NAG**
  - Single-addition
  - Multiple-addition when needed

- (in)consistency between NAPP and NAG values
  - useful prompt for things being not what thought to be initially (?)
  - rarely strive for accurately "matching" NAPP and NAG values
    - any "mismatch" generally enough in itself to "corrected" direction for valid interpretation
Kinetic-testing (1): Weathering-Columns

- **AMIRA (2002)**

- setup similar to AMIRA (2002), but modified operating protocol:
  - control of sample-bed temperature, and higher V/M ratio

- used for estimating:
  - rates of sulphide-oxidation, acid-consumption, and solute-elution

- suited to both coarse- and fine-textured materials, due to **aggressive drying conditions** (i.e. rates limited by high relative-saturations rare even for tailings)

But:

- variation in seasonal-T can confound interpretation

- drying to residual-moistures, and remaining at these for days, is at variance with moisture/suction regimes *in situ*
Kinetic-testing (2): Weathering-Columns
Kinetic-testing (3): Weathering-Columns

(defining thermal "boundary conditions" for kinetic testing)
Kinetic-testing (4): Weathering-Columns

Intermittent (cf. Continuous) Operation of Flood-Lamps
Kinetic-testing (5): Weathering-Columns

Variation in Temperature and Moisture Regimes During Peak-Summer Period (residual-moistures/suctions attained during drying-stage)

(NLS = near-lamp-side; FLS = far-lamp-side; Ep = pan-evaporation)

80W-lamps, and pulsed-6hrs-on-cycle during nighttime for 5-Days. Ep c. 5-6 mm/day.

Diurnal-range in temperature for a maximum-ambient-air-T of c. 30-35 oC, even as residual-moistures/suctions are approached.

flush with DW (ponded infiltration)
Kinetic-testing (6): Weathering-Columns

gamma of applied heat loads → lateral variation in drying
Kinetic-testing (7): Weathering-Columns

Flushing under ponded conditions of infiltration. Formation of "surface-clay-skin" ➔ limitation of oxidation by O2 diffusion (i.e. limiting relative-saturation)
Kinetic-testing (8): Weathering-Columns

Breakup "surface-clay-skin" by chipping when not too sticky
Kinetic-testing (9): Weathering-Columns

chipping breaks connectivity of capillary-pores to surface

formation of "mulch-layer"
Kinetic-testing (10): Weathering-Columns

evaporative-drying continues via capillary-flow below, and vapour diffusion through mulch-layer: all acting under transient diurnal-T gradients

Moist sample-bed with interconnected pores in tact. Evaporative drying via (net) upward capillary flow to interface with mulch-layer.

Dry-n-dusty mulch-layer through which (net) vapour diffusion is upward.
Kinetic-testing (11): Weathering-Columns

Desiccated state prior to flushing ➔ marked **matric-suction gradients** initially (= sorptivity phase of infiltration into dry soil).
Variation in Sulphide-Oxidation Rates for Weathering-Columns

(day* corresponds to c. 3 days per week when moisture regime is within the LLWR; SORs based on rates of SO4 elution from columns)

See Lapakko (2003) for related Seasonal-T swings for SORs in humidity-cell testing
Kinetic-testing (12): Oxygen-consumption Cells

use weathering-columns to measure OCR directly
use flood-lamps to dewater "sludge" immediately after flushing to a "middling-moisture", then keep in an incubator
Kinetic-testing (14)

- AMIRA (2002) weathering-columns corresponds to dewatering under non-isothermal conditions

  - need to define thermal boundary conditions to assist interpretation

    e.g. seasonal-T trends masking intrinsic-weathering trends

  - are effects associated with drying to residual-moistures/suctions important practically, or inconsequential?

- Above rendered redundant where use incubators after dewatering to relative-saturations less than 80-85 % (nominal)

  - remain within **Least-Limiting-Water Range (LLWR)**
Sulphide-Oxidation within Least-Limiting-Water Range (LLWR) (Arid-Zone Weathering)

• Long-held concept in soil-science and agronomy

Moisture limits on plant-growth:

• “wet-end”: $\theta_v > 80-90 \% \text{ of } \phi \Rightarrow \text{O}_2\text{-limited}$
• “middling”: $\Rightarrow \text{optimal}$
• “dry-end”: $\Psi_t > 10-20 \text{ bars (nominal)} \Rightarrow \text{H}_2\text{O}-\text{limited}$

Moisture limits on sulphide-oxidation:

• “wet-end”: $\theta_v > 80-90 \% \text{ of } \phi \Rightarrow \text{O}_2\text{-limited}$
• “middling”: $\Rightarrow \text{optimal}$
• “dry-end”: $\Psi_t > 10+ \text{ bars (nominal)} \Rightarrow \text{H}_2\text{O}-\text{limited}$
Seasonal Variations in Desaturation and Unsaturated-Flow Dynamics During Weekly-Weathering-Cycles (GCA8644)

(drying to residual-moistures/suctions)

- flushing step and subsequent ambient drying
- ambient drying during daytime, and operation of flood-lamps intermittently during nighttime

Winter-Drying Dynamics:
Residual moistures attained by Day-6/7, but high relative-saturations initially until flood-lamps operated

Summer-Drying Dynamics:
Residual moistures attained by Day-4, but relative-saturations rapidly drop before flood-lamps operated

Gravimetric-Water Content (% w/w)

Day No.

period that sample-beds are within LLWR is taken as 3 days for each weathering-cycle irrespective of time of year
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