# *Scaling Geochemical Loads in Mine Drainage Chemistry Modelling*

## from humidity cell leachate to mine-site drainage chemistry

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        - Geochemical concentrations
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        - Geochemical concentrations
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# Kinetic Experiments

Humidity cells; *from ASTM D5744*

Column experiments

Typical field bin set-up

**Derivation of loading rate in mg/kg/wk**

# Geochemical Loads

**Geochemical load = HC Loading Rate x Time x Mass of Rock Dump**

↳ $$Drainage\ Concentration = \frac{Geochemical\ Load}{Seepage\ Volume}$$

- Upscaling to full mine rock facility tonnage generally leads to unrealistically high predicted drainage concentrations

- Scaling factors are commonly applied to account for discrepancies in small-scale vs mine-scale conditions

# Scaling Factors

**For example:**

- **Temperature**
  - *Pyrite oxidation and carbonate solubility are temperature dependent*
- **Water contact or water-rock ratio**
  - *Development of preferential flow paths will isolate reactive particle surfaces within the waste facility*
- **Grain size**
  - *Standardized humidity cell samples have a $P_{80}$ of -6.4mm → higher proportion of reactive surface area compared to dump materials*

**Adjusted Geochemical Load =**

**HC Loading Rate x Time x Mass of Rock Dump x $SF_1$ x $SF_2$ …**

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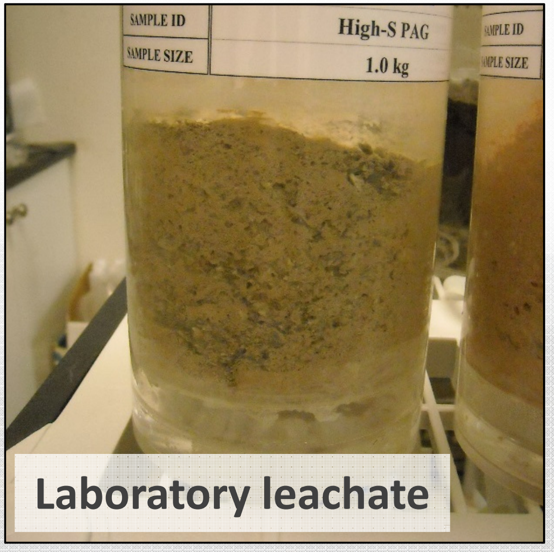
# Approach




Laboratory leachate

Upscaling using scaling factors

uncertainty

Full-scale mine drainage

*Known:*

- Leaching rates (mg/kg/wk)

***If** known:*

- Drainage chemistry (mg/L)
- Waste dump tonnage
- Waste dump composition
- Seepage flow rates

**Empirical bulk scaling factor can be derived: $SF_{bulk} = SF_1 \times SF_2 \times \ldots \times SF_x$**

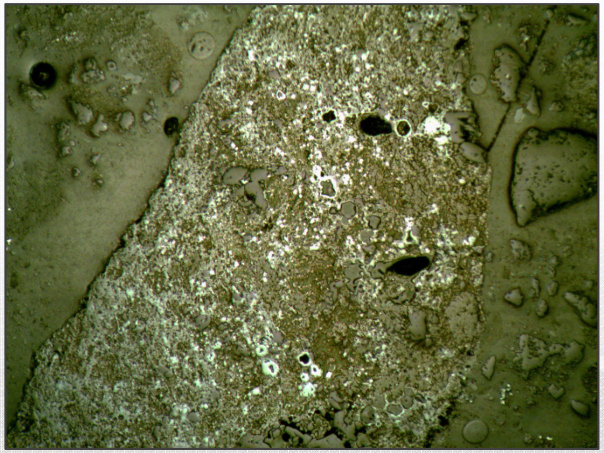
# Study sites

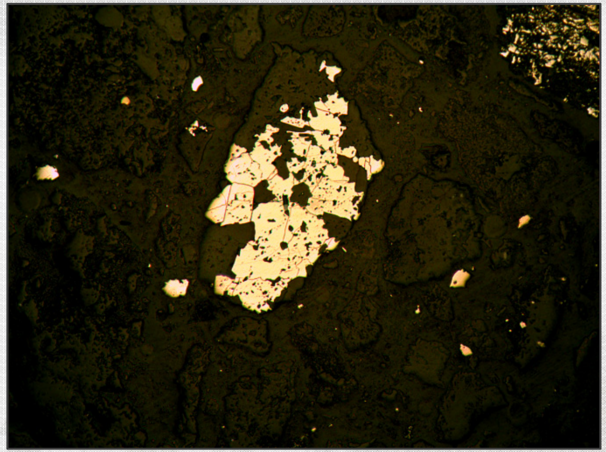
- One site releases acidic drainage, the other has neutral drainage
- Both sites are located in semi-arid environments

| | | Site A (acidic) | | Site B (neutral) |
|---|---|---|---|---|
| *Material Type* | | *Oxide* | *Sulphide* | *Diorite* |
| **Total S** | *%* | 0.82 | 2.9 | 0.22 |
| **Sulphide S** | *%* | 0.020 | 2.5 | 0.030 |
| **NP** | *kg CaCO3/t* | -1.0 | -1.1 | 88 |
| **NPR** | | <0 | <0 | 40 |
| **WRSA tonnage** | *Mt* | 57 | 38 | 2.7 |
| **WRSA footprint** | *ha* | 91 | | 9.9 |
| **Mean precipitation** | *mm/yr* | 510 | | 310 |
| **Mean temperature** | °C | 12.3 | | 6.3 |

# Site A – geology

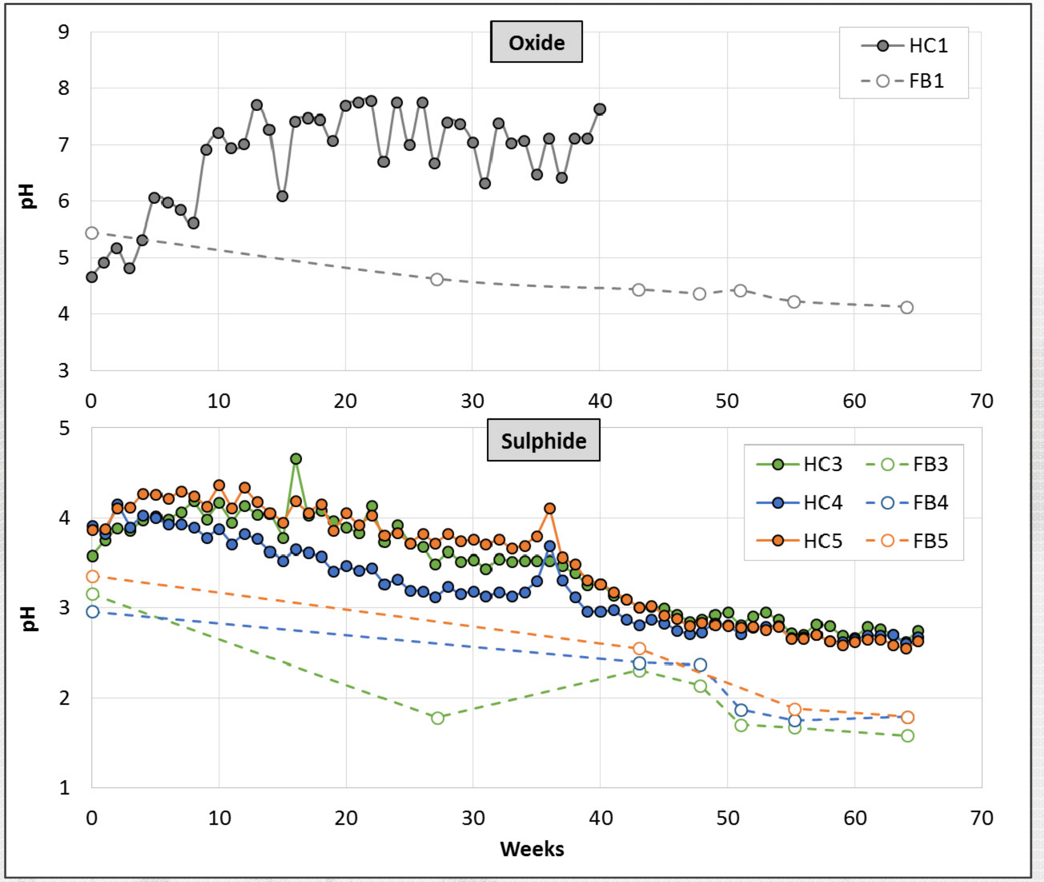
- Porphyry-gold deposit hosted in a highly altered intermediate to felsic volcanic system
  - Primarily latite flows and volcaniclastic sediments
- Environmentally, two main waste rock categories were defined:
  1. Oxide
     - (low sulphide S, strongly weathered to Fe-oxyhydroxide and sulphate assemblage)
  2. Sulphide
     - (high sulphide S, mostly pyrite with minor Zn- & Cu-sulphides, as well as hydrothermal alunite)





*FOV = 0.75 mm*

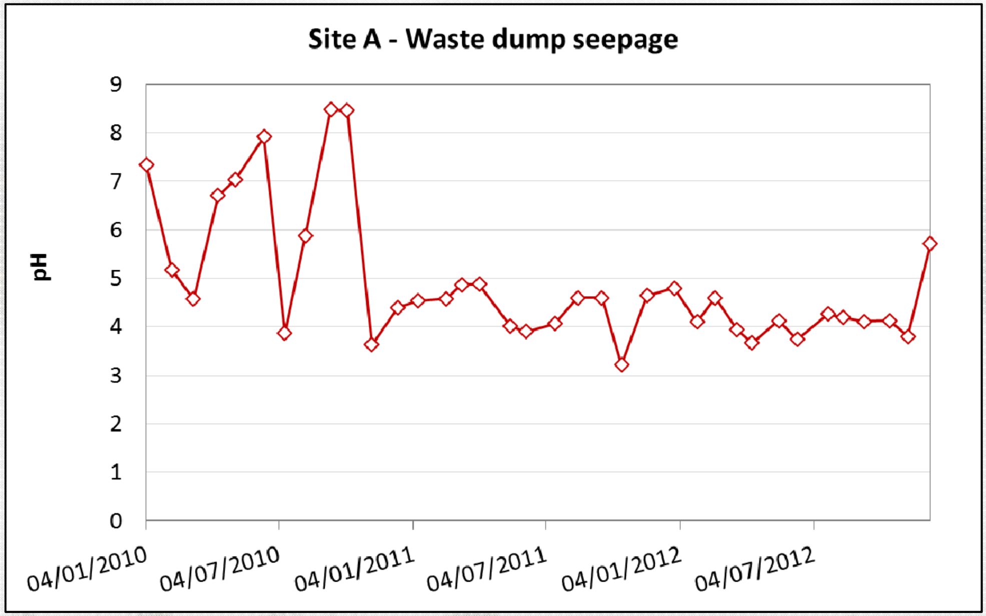
# Site A – kinetic test pH

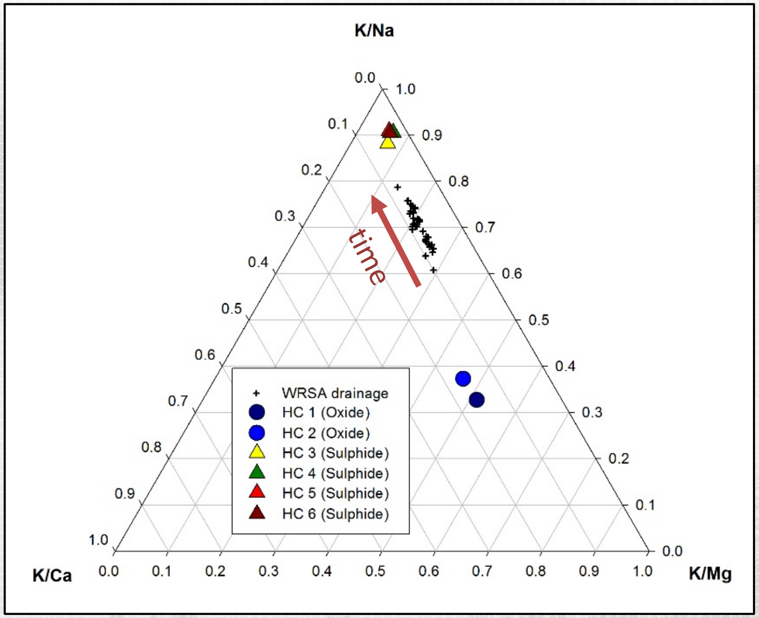



- pH values are variable depending on scale, water-rock ratio, and waste rock material
  - Higher in humidity cell leachates
- Stored acidity and mineral re-precipitation likely contributes to the low pH values in field bin leachates

# Site A – site drainage

- Waste dump drainage initially circum-neutral, turning acidic over time
  - ➢ Increasing influence of Sulphide waste rock



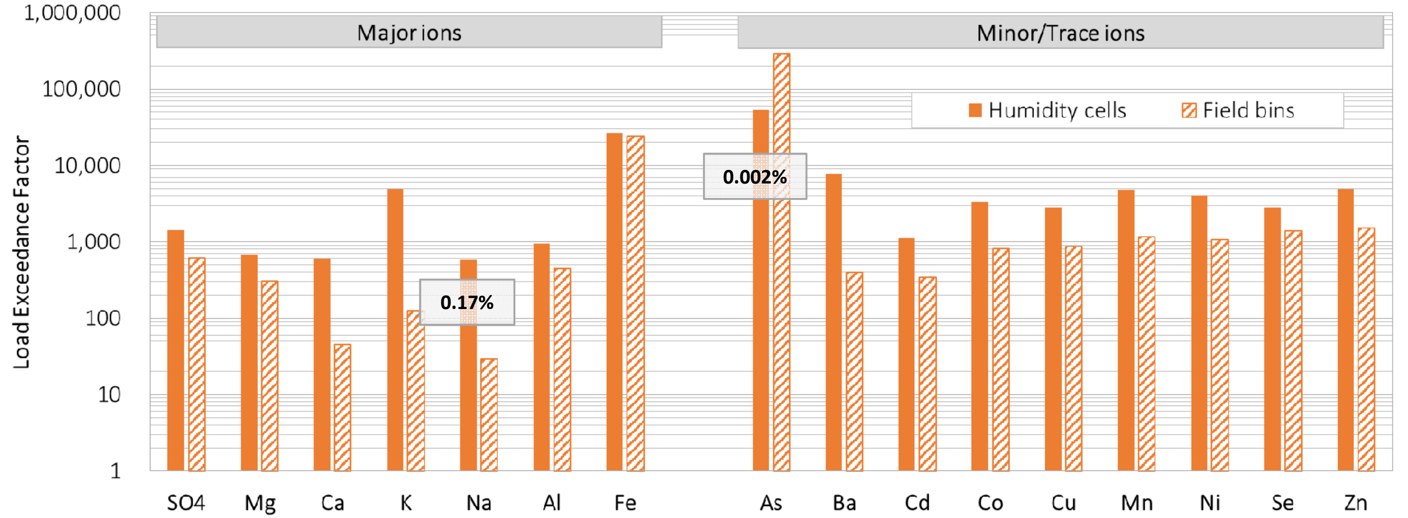



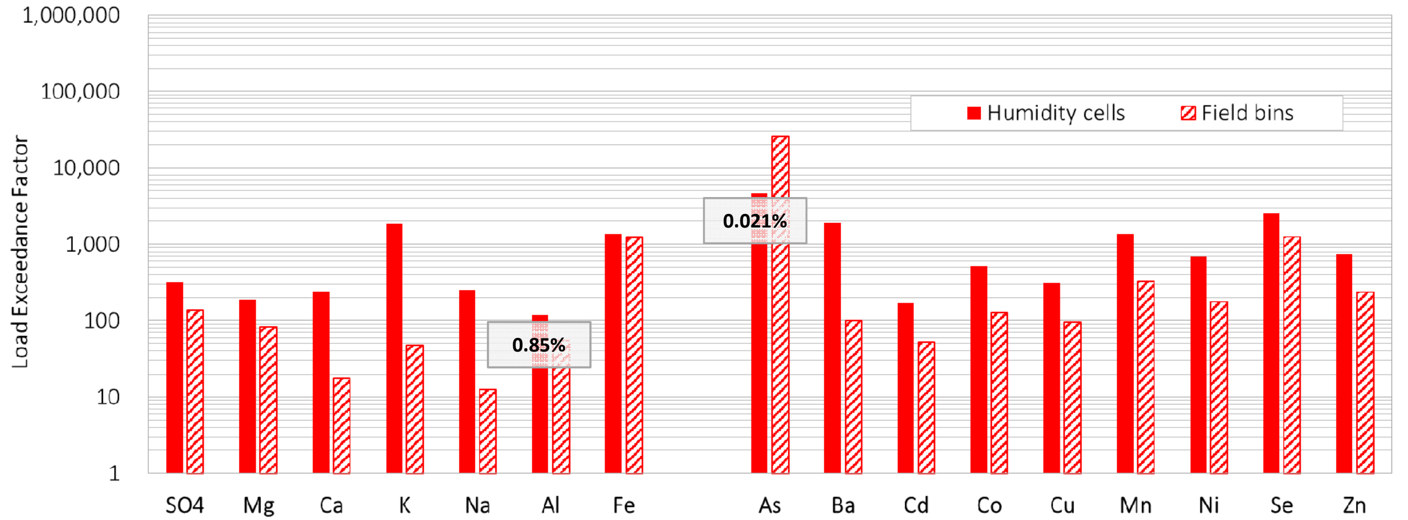
# Site A – *loading assumptions*

- **Best estimate:**
  - Waste dump drainage loads were calculated based on average chemistry and average flow rates into seepage collection pond
- **Conservative case:**
  - Waste dump drainage loads were calculated based on worst observed chemistry and average flow rates into seepage collection pond

- **Loads from kinetic tests were then normalized to mine drainage loads to obtain *exceedance factor***
  - ➢ ***Inverse of empirical bulk scaling factor***

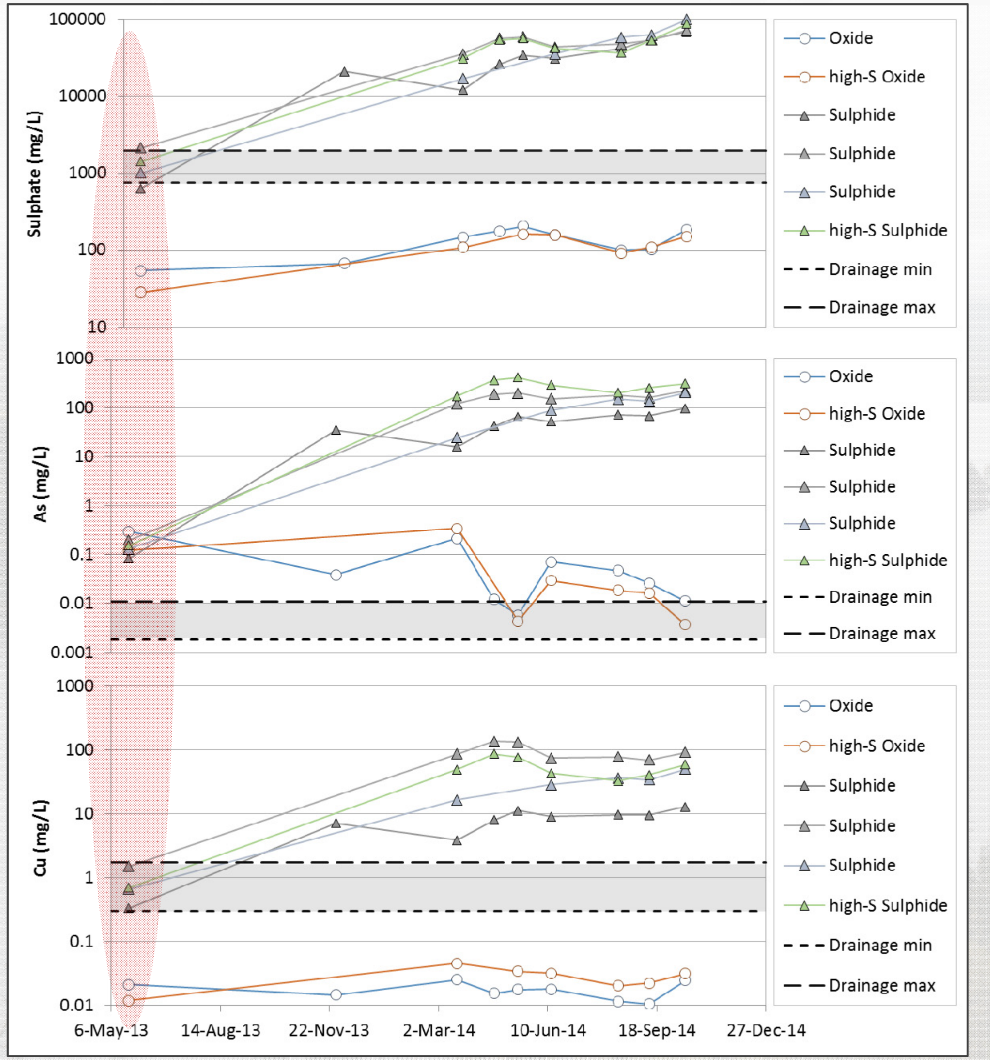
# Site A – exceedance factors



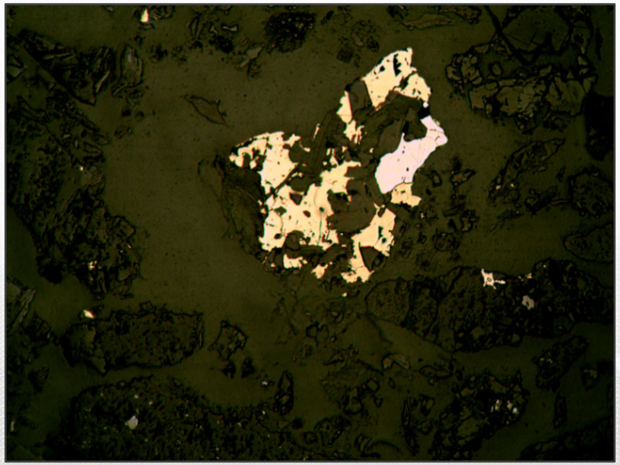
# Site A – concentrations

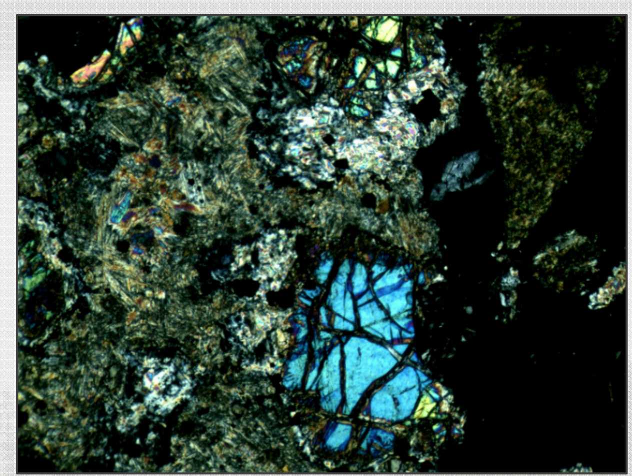
- Concentrations in leachates from Sulphide field bins are in the range of waste dump drainage for the initial sampling cycle (pH>3)
- Arsenic is generally higher in all field bin leachates → different redox conditions and attenuation mechanisms in dump?
- Data shows signature of both Oxide and Sulphide waste rock on drainage chemistry



# Site B – geology

- Porphyry-copper deposit hosted in a primarily mafic volcanic complex comprising volcanic and plutonic rocks
- Excess neutralization is available and all mine rock storage facilities have released neutral drainage for ~20 years
- Pyrite is the main sulphide mineral observed; minor Cu-sulphides

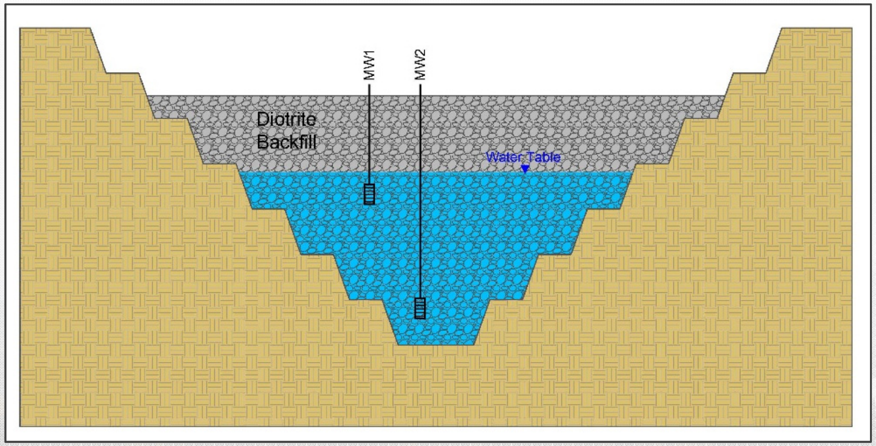




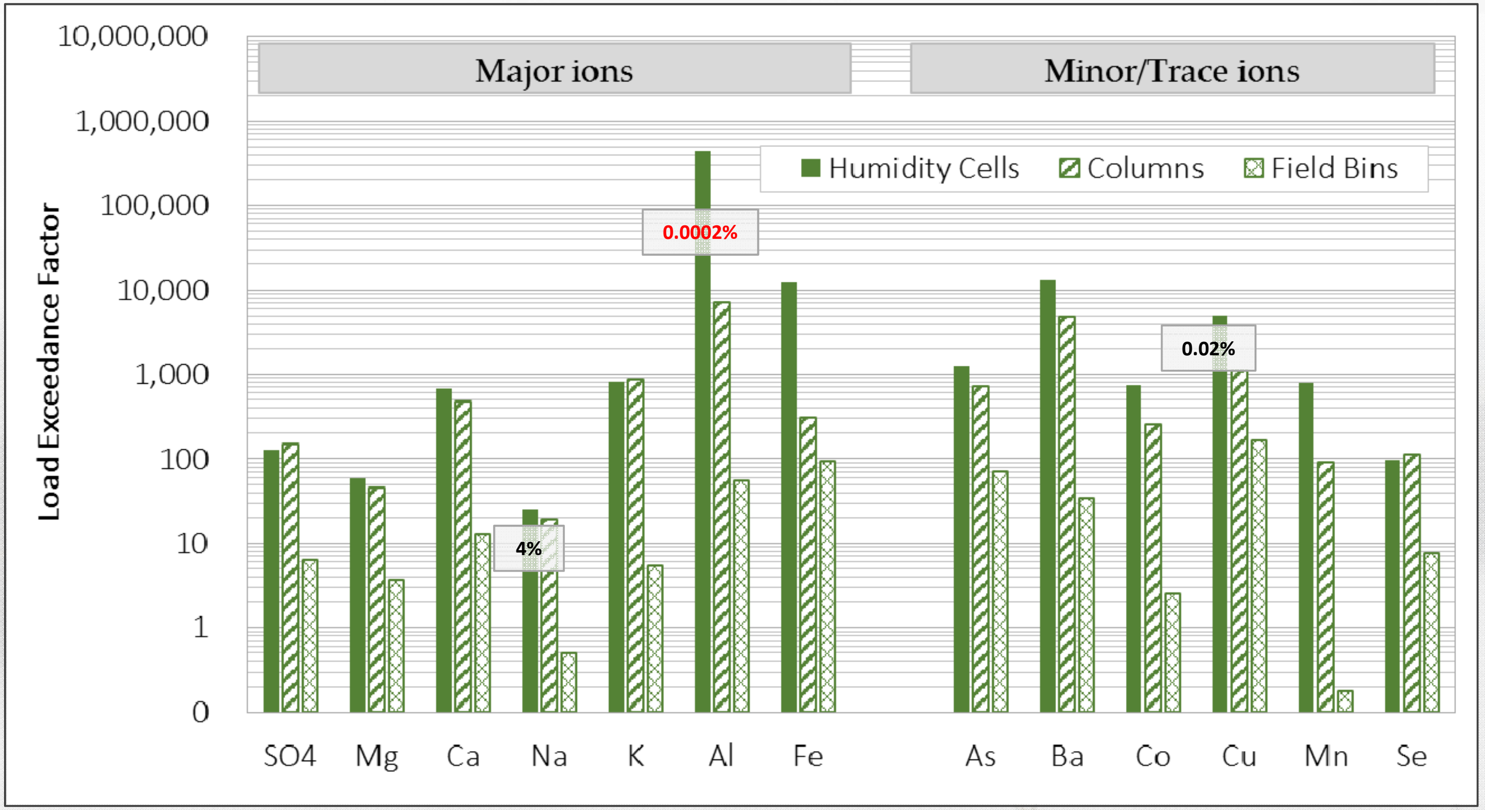
*FOV = 0.75 mm*

# *Site B – loading assumptions*

- Waste material (mostly diorite) backfilled into open pit
- Water samples were collected from monitoring wells at ~17 and 40m below the waste rock surface
  - Water table at around 12m below surface
- Infiltration was used for flow calculations
- Only rock mass in unsaturated zone was considered for loading calculations




# *Site B – exceedance factors*

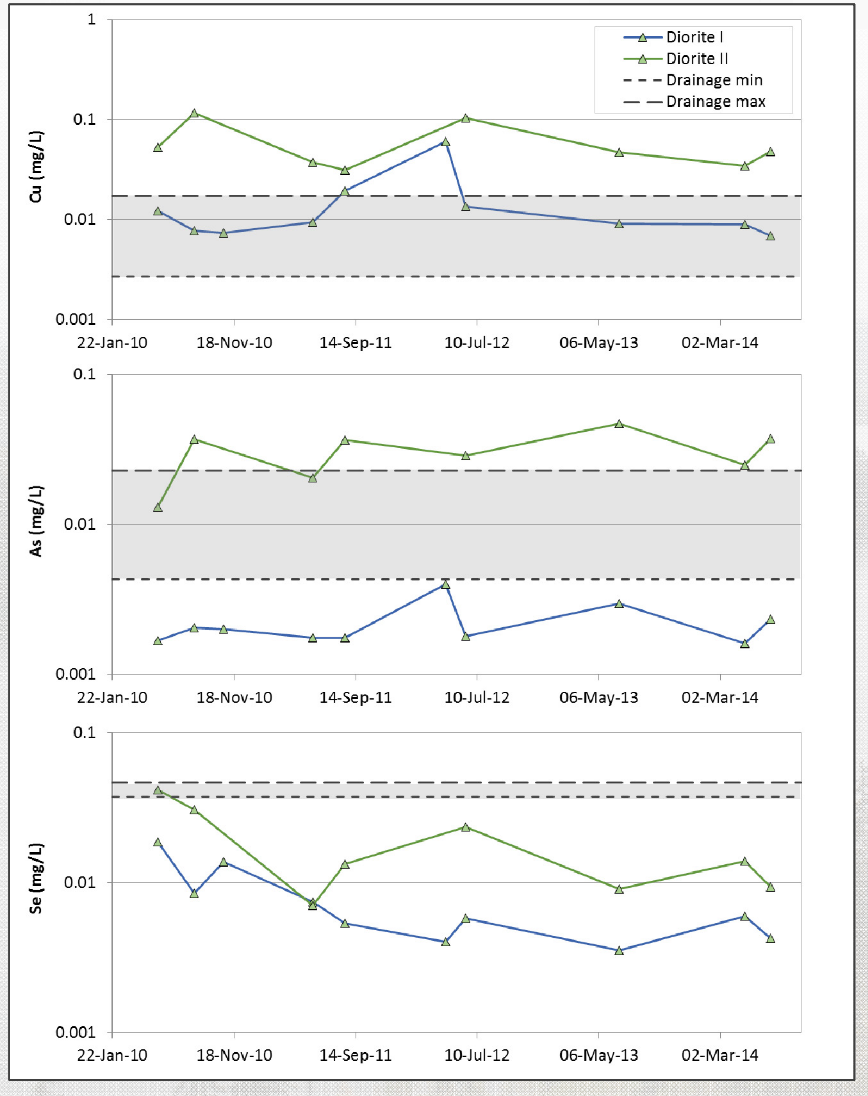



- Difference in Al and Fe exceedance factors between humidity cells and columns shows that solubility controls become important at small scales

# Site B – concentrations

- Concentrations in field bin leachates are generally within the same order of magnitude as waste dump drainage

- Geochemistry in both monitoring wells is relatively consistent suggesting that either:
  - Equilibrium conditions have been reached at shallow depths
  - Degree of waste dump saturation is sufficient to inhibit oxidation of rock



# Conclusions

- **Bulk scaling factors were calculated to generally fall below 1% at the study sites (semi-arid conditions)**
  - ***ranging from 0.002 to 0.17% (median = 0.03%) in acidic drainage and 0.00023% to 4% (median = 0.13%) in neutral drainage***

- **These values are generally lower than previously reported in similar studies;**

- **For both sites, several species appear to be solubility-controlled at relatively small scales (field bin ~200 kg);**

- **An openly available database compiling empirically-derived bulk scaling factors would increase the confidence in upscaling exercises used for drainage chemistry prediction modelling.**