BC MEND ML/ARD ANNUAL WORKSHOP

MEM

The science behind success

Humidity Cell Testing: Conventions and practice

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Humidity Cell Testing

- Humidity Cell Tests (HCT) are a commonly employed laboratory test where aerial oxidation of granular, mine sourced materials occurs within a timeframe of months to years.
- The methodology for HCTs is outlined in ASTM D 5744-18 and is accepted by British Columbia Ministry of Energy and Mines and Ministry of Environment, Lands and Parks and European Committee for Standardization amongst others
- Note however that the ASTM method states that the test is not intended to simulate site-specific leaching conditions

Waste Rock

Tailings

Image credit: Geochemic Ltd, Blaenavon, UK

Humidity Cell Testing – Method Summary

- A sample of material is crushed or screened to a particle size less than 6.3 mm (1/4 inch). A representative 1 kg sub-sample of this material is loaded into a cylindrical cell constructed of clear acrylic plastic.
- Cell runs on a weekly Cycle:
  - Days 1-3 → dry air (<10% relative humidity).
  - Days 3-6 → water saturated humid air (>95% relative humidity)
  - Day 7 → dosing with deionised water, sample collection and subsequent analysis
- The weekly cycle is repeated for a minimum of 20 weeks while the sample is held at a constant 25 °C

How common are HCTs?

- Perplexity AI gave an estimate of ~120-200 or roughly 45-75% for how many out of the 266 Canadian mining EIAs explicitly mention HCT data
- *Microsoft Copilot estimated that 120-150 of the 227 Canadian projects, and 140-180 of the 266 Canadian assessments, included HCT data*
- *Chat GPT gave this table:*

Humidity cell testing is included in the majority of mining EIAs that involve any credible risk of acid rock drainage or metal leaching.

A reasonable high-level estimate:

Type of deposit	Likelihood HCT appears in EIA
Sulfide-based (Au, Cu, Ni, VMS, Coal with pyrite)	**80–100%**
Mixed oxide/sulfide	**50–70%**
Oxide-only, low-sulfur	**10–30%**
Reprocessing of old tailings	**70–90%**

Context of this talk: what is the purpose of the HCT test?

Staring point: kinetic tests **can** provide prediction information including:

- (1) the relative rates of acid generation and neutralisation
- (2) the time to ARD onset
- (3) drainage chemistry and the resulting downstream loading for each of the probable geochemical conditions

Sapsford, D.J., Bowell, R.J., Dey, M. and Williams, K.P., 2009. Humidity cell tests for the prediction of acid rock drainage. *Minerals Engineering*, *22*(1), pp.25-36.

Humidity cell tests for the prediction of acid rock drainage

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Question does the HCT provide all this information?

In the time before AI….

The primary objectives of humidity cell tests are to:

- measure reaction rates under specific geochemical conditions; and
- to calculate depletion times for acid generating, acid neutralizing, and metal leaching minerals.

The well-flushed humidity cell procedure clearly does not usually simulate the precipitation and dissolution of secondary weathering products, which often determine drainage chemistry under field conditions.

The well-flushed humidity cell is the recommended kinetic test for predicting primary reaction rates under aerobic weathering conditions.

Measurement of primary mineral weathering requires an action to remove the solubility constraints. Usually this is accomplished with aggressive leaching or flushing that limits secondary mineral precipitation. Measurement of drainage chemistry and primary mineral weathering are often mutually exclusive.

MEND Manual (Price 2009)

Lets ask Chat GPT…real question to ask is where has AI got these ideas from?

Q: What is the purpose of a Humidity Test Cell for Mine-Waste Testing

- **Simulate Weathering Conditions**
  - Mimics natural environmental conditions—drying/wetting cycles, humidity fluctuations, and air exposure that mine waste experiences in the field.
  - Allows researchers to study long-term geochemical reactions in a controlled, accelerated setting.
- **Assess Acid Rock Drainage (ARD) or Metal Leaching Potential**
  - Helps determine whether waste materials will generate **acidic drainage** or release **metals/metalloids** when oxidized.
  - Measures sulfide oxidation rates and secondary mineral formation.
- **Evaluate Water Quality Impacts**
  - Leachates collected from the cell are analyzed for pH, electrical conductivity, sulfate, and dissolved metals.
  - This predicts potential impacts on groundwater and surface water.

Further AI “insights”

- **Test Oxygen and Moisture Effects**
  - Humidity cells operate with controlled air flow and moisture addition, isolating how:
    - **Oxygen supply**
    - **Humidity**
    - **Moisture content**

    influence reaction rates and environmental risk.
- **Standardized, Repeatable Testing**
  - Humidity cells follow recognized protocols (e.g., ASTM D5744).
  - Provides consistent results for regulatory submissions and environmental assessments.

Humans and AI agree can on this point

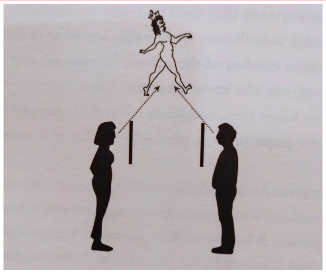
Human decision making vs scientific decision making

- Science alone is not sufficient to explain decisions made by humans
  - Vested interests
  - Commercial aspects
  - Reputation
  - Behavioural phycology
    - Common knowledge and conventions

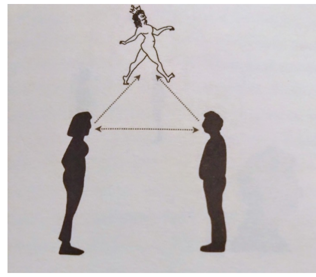
- **Standardized, Repeatable Testing**
  - Humidity cells follow recognized protocols (e.g., ASTM D5744).
  - Provides consistent results for regulatory submissions and environmental assessments.

- We must consider this when looking at “industry practice”
  - When considering kinetic testing in particular humidity test cells we first need to understand the importance of “Common knowledge”

Common knowledge: the emperors new clothes



*Private knowledge: person A knows something and person B knows it**



*Common knowledge: person A knows that person B knows, and B knows that A knows it**

- *Having private knowledge that something is wrong will not result in change until it becomes common knowledge: which is the emperors new clothes scenario*

*Figures and concepts from Pinker 2025: When everyone knows that everyone knows

The danger of "Common Knowledge"

- Barry Marshall: Australian Physician that discovered stomach ulcers and stomach cancer are caused by *Heliobacter pylori* was ostracized by the medical community for a decade…….. until he won a Nobel prize for this discovery
  - *"the greatest obstacle to knowledge is not ignorance, it is the illusion of knowledge"*
- *This can also be considered as form of "group think" and typically results from the development of "conventions" which themselves are developed because people have a desire for a focal point*
  - *Adopt whatever solution is commonly known as a solution*
- *People have an incentive to "conform" as long as others do*
  - *Self reinforcing myth, as long as everybody believes in the same fiction we can obey the same laws*
    - *e.g. fiat (paper) money*

- **Standardized, Repeatable Testing**
  - Humidity cells follow recognized protocols (e.g., ASTM D5744).
  - Provides consistent results for regulatory submissions and environmental assessments.

*Figures and concepts from Pinker 2025: When everyone knows that everyone knows

HCT as convention

Evolved common knowledge: HCT's have become the convention for water quality prediction and sulfide oxidation rate estimation, even though they are not suited for both of these purposes

- Based on evidence from "scientific" papers, public reports, guidance documents and tests using AI, it can be concretely established that Kinetic testing, specifically humidity cell tests have in practice over time become widely adopted as a convention to provide data for the prediction of water quality and sulfide oxidation rates. This is likely because:
    - Need for a focal point "adopt whatever solution is commonly known as a solution"
    - Ambiguity in the wording over the "purpose" of the tests
    - Guidance documents specifically stating HCT can be used for water quality assessment
    - Numerous "scientific" papers making reference to HCT data in the context of water quality prediction
    - Regulatory requirement "to do kinetic testing" to inform water quality prediction
    - Laboratories commercial incentive to only carry out "standard" testing (i.e. commercial supply)

AI test: "Can HCT be used to predict water quality from mine waste"

Yes, **humidity cell tests (HCTs) are a standard kinetic method used specifically to help predict water quality from mine waste**. They provide essential long-term data on potential acid generation (acid rock drainage or ARD) and metal leaching that cannot be obtained from short-term static tests.

Examples of typical HCT Conventions

Industry Conventions	Implication
1.HCT is an accelerated test	Results viewed as conservative
2.HCT is a conservative test	Results viewed as “worst case”
3.HCT has finer particle size than field	Reason for accelerated convention
4.HCT can be used for water quality assessment	Results can be used for model inputs
5.Leachate from HCT can be compared to guideline values to assess water quality risk	Note convention 2 means risk is assumed to be overestimated
6.HCT can be used to determine “release rates” of metal(loid)s	Note convention 2 means release rates are assumed to be overestimated
7.HCT can be used to determine lag time to acid formation	Note convention 1 means lag times are assumed to be worst case
8.Ignore the first flush and use “steady state results”	Steady state conditions used for model inputs

Where do conventions for HCT derive from?

Common knowledge and thus conventions derived from guidance: GARD Guide:

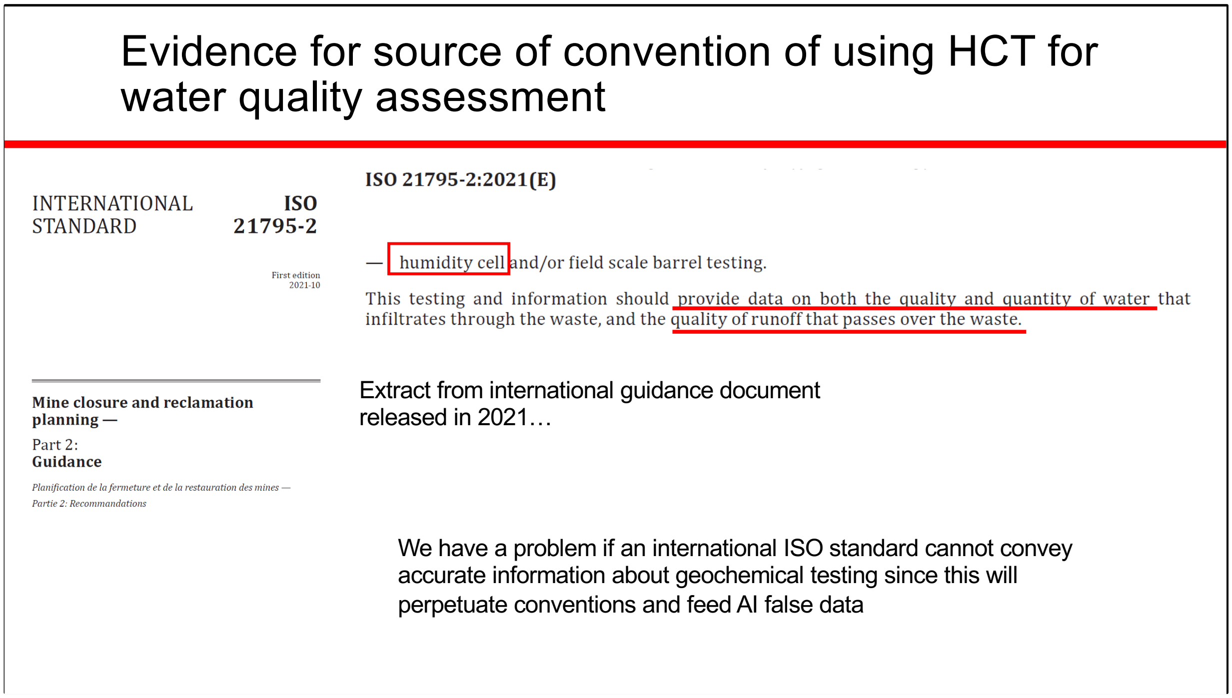
5.4.12 Laboratory Kinetic Tests

Laboratory kinetic testing methods are used to validate and interpret static test methods, and predict long-term weathering rates and the potential for mine wastes and geologic materials to release discharges that may have impacts on the environment. Both acid generation and metal leaching can be evaluated through kinetic testing.

Easy to see how a convention can develop based on the above paragraph taken in isolation since the literal interpretation of the above could lead to the conclusion that :

- HCT is a kinetic test
  - Therefore metal leaching can be evaluated using this test
    - Therefore environmental risks of metal leaching can be evaluated using this test

But recall that: secondary mineral precipitation. Measurement of drainage chemistry and primary mineral weathering are often mutually exclusive.



First off I would like to outline what I consider from over a decade of working in the industry to be some general assumptions that are held by many practitioners when it comes to the topic of kinetic testing. While I cannot speak for everyone it is none the less important to accept that generalised consensus views can have significant impact on the development of approaches and methodologies when it comes to technical aspects like testing methods.

It is assumed, and in most cases required due to regulations, that to make “accurate” predictions about drainage water quality that kinetic testing provides an essential basis for technical assessments. Also that this provides “appropriate” data for use in development of models, setting input values and making predictions. Secondly it is assumed that appropriate kinetic testing methods are those that have already been developed, standardised and published by respected sources (ASTM, AIMIRA etc). Thirdly it is assumed that using standardised kinetic testing does in fact produce “useful” data for use in prediction of drainage water quality and quantification of acid and metalliferous drainage (AMD) risk.

Lastly it is assumed that anyone using, or relying on, kinetic testing data understands the limitations of the methods and approaches, and understands the fundamental science that lies behind the testing.

And more evidence…

Applied Geochemistry
Volume 81, June 2017, Pages 109-131

A geochemical examination of humidity cell tests

Abstract

Humidity cell tests (HCTs) are long-term (20 to >300 weeks) leach tests that are considered by some to be the among the most reliable geochemical characterization methods for estimating the leachate quality of mined materials. A number of

Introduction

Humidity cell tests (HCTs) are long-term (weeks to years) laboratory tests conducted under oxidizing conditions for estimating the leachate quality of mining materials and wastes. The tests are usually conducted before mining begins using exploration drill core

effects of long-term sulfide weathering on leachate composition. Predictions of the quality and sometimes the quantity of acid water discharged to receiving streams are often made based on the results of HCTs and additional hydrologic and geochemical information (INAP, 2009).

- This is from peer reviewed paper for a respected journal written by very experienced authors (i.e. this is not an outlier of a reference)
- Note reference to industry guidance (INAP)
- Need also to consider the impact of AI which has access to this information since it is online

The paradox: Established limitations of the method are also “common knowledge”

- Standard kinetic tests like humidity cells have very high flushing rates (HCT has annual L:S of ~27) and will not capture the effects of slow dissolution/ precipitation/sorption processes which occur under typical field conditions of unsaturated drain-down conditions with extended pore water residence times
- Pore water pH and EC is affected by dilute conditions in the test (H+ concentration order of magnitude lower in HCT tests than in field) meaning pore water acidity/alkalinity and ionic strength unrealistically weak
- Dilute leachate means that metals may be detected at LOD in the test but in the field may be significantly higher
- Small size (~1-2kg) and standard size reduction (~8mm) limits the applicability of the testing to simulate heterogeneous waste rock drainage conditions (tailings more suitable).
- **Tests such as the HCT are often used for the objectives of determining kinetic mineral weathering rates AND drainage water quality, however in trying to achieve both objectives the method is inherently flawed.**

Q: If the above is “common knowledge” why are HCT used as convention to establish parameters they inherently were not designed for and are known to produce misleading results for?

Conclusion is this is an emperor's new clothes scenario

Particle size: “common knowledge”

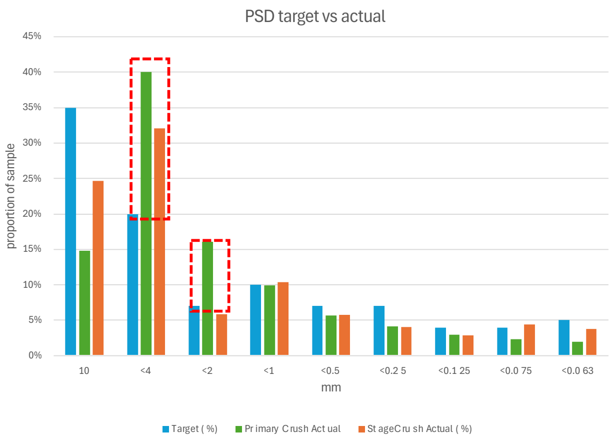
Particle size is key since surface areas are much higher for smaller particles

The proportion of the smallest particle sizes is the key determinant to reaction rates

- Therefore it is important that very small particle sizes are represented in testing

- **Common knowledge:** HCT uses size reduction by crushing material therefore they are “conservative”.
  - Evidence: crushed material has smaller median size than mine rock material
  - Common knowledge: HCTs are typically conducted on smaller, more homogenous and finer-grained samples than what is found in large, heterogeneous field waste rock piles. The larger surface area in lab samples can lead to faster reaction rates
- **Counterfactual evidence:**
  - Crushing using a jaw crusher to <6mm **does not guarantee that the surface area of the sample is actually higher than field conditions**
  - The use of the median particle size is an incorrect and misleading metric since surface area increases in non linear way with particle size, what matters is PSD distribution <2mm

Example of counterfactual evidence



- Single stage crushing does not simulate the PSD profile of field condition (blasting)
- Much more material in the 1-6mm fraction due to the nature of the crushing
- Much less material in all fine fractions (<0.25mm) in particular <0.063 fraction

Note that:

- **100g of 4mm size = 556cm^2**
- **3g of 0.1mm size = 657cm^2**

- Staged crushing and recombining of staged crushing improves sample “representativeness”

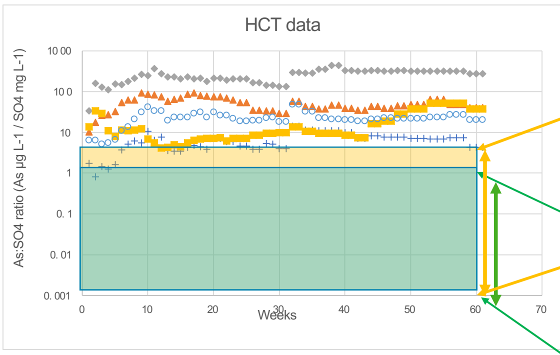
Target: is the PSD profile of mine rock based on field data (existing mine rock stockpile)

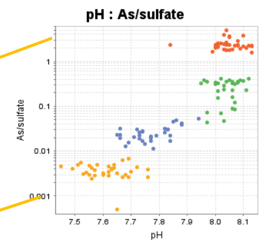
Reaction rates “common knowledge”

- **Common knowledge:** the HCT test is an “accelerated” test meaning reaction rates are conservative
  - Evidence: size reduction, over supply of water, temperature
  - Common knowledge: HCTs operate under controlled, optimal conditions (consistent temperature, regular oxygen supply, weekly flushing) to accelerate reaction kinetics and provide an "upper bound" on expected reactivity
- **Counterfactual evidence**
  - Water supply is not rate limiting step in these tests so flushing does not “accelerate” rates
  - The total surface area of material (m^2/kg) after crushing may not be significantly higher than that of blasted mine rock even though the median particle size is smaller
  - Dilute conditions means pH will be overestimated (under acid environment), pH is fundamental to reaction rates (both sulfide oxidation and mineral dissolution) since reaction rates increase rapidly once pH <3.5
  - Temperature may be lower than field conditions (inside mine rock piles temperatures can be >30 degrees)

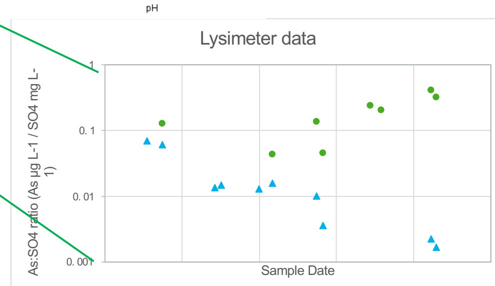
It is highly misleading to state generally that HCT’s are “conservative” with respect to reaction kinetics, and that they are an “accelerated” test

Common knowledge: “Release rates” can be estimated from HCT data





IBC data (field testing)

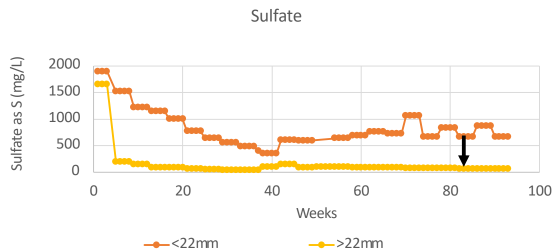


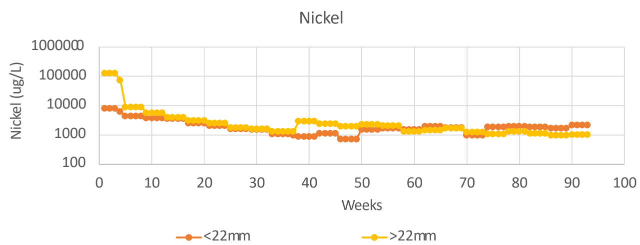
Counterfactual evidence is that release rates cannot be estimated from HCT data since HCT data provides “weathering rates” not “release rates”

Note that pH and PSD both control “release rates” under field testing conditions

What is meant by release rate?

>22mm <22mm



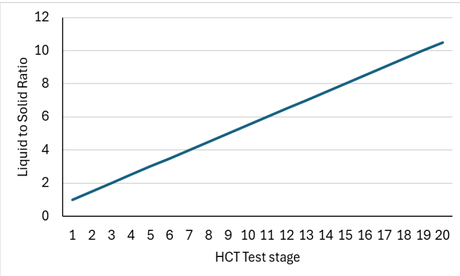


Sulfate is ~10 times higher in fines (expected based on classical theory of sulfide oxidation and surface area) and **can be called a "release rate"**

But nickel "release" broadly the same

Because same sulfide mineral source this means >90% of the nickel in the <22mm is not being released into solution but is being released from the sulfide mineral phase into a secondary mineral phase

Usefulness of leachate chemistry "common knowledge"

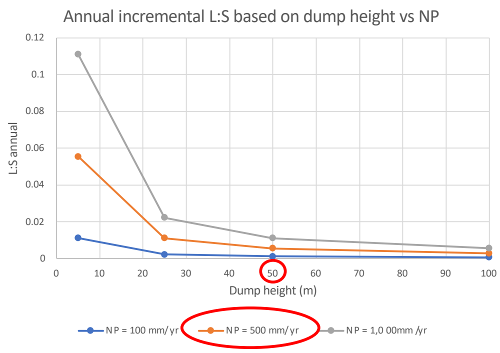


- Common knowledge the HCT is done under very dilute conditions compared to field
- Field conditions take decades to get to L:S of 1, the HCT gets there is stage 1…(so called first flush)
- By the end of the minimum 20 weeks of operation (assuming no loss of sample mass) the L:S ratio will have reached a minimum of 10.5
- Note that pH is related to concentration of acidity
  - Dilution is 10x higher than field value pH will be 1 unit higher
  - Dilution is 100x higher than field value pH will be 2 units higher
  - pH 3.5 in HCT may therefore be 1.5-2.5 in the field

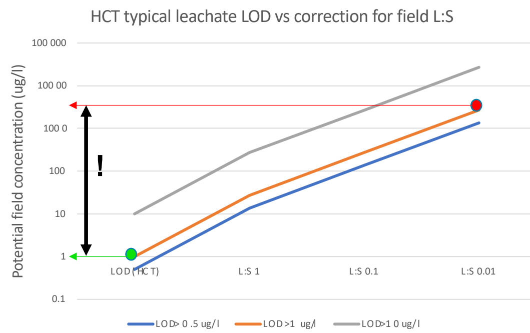
GARD Guide:

It is important to select the method that most closely simulates the site-specific ambient environment and leaching conditions (e.g., solution to solid ratio, nature of lixiviant, grain size, agitation). In addition, selection of a test method has to take into account the anticipated use of the leach test results (e.g., for prediction of seepage vs. runoff quality, incipient vs. terminal water quality). Regulatory requirements and expectations may also govern selection of a particular methodology. Many jurisdictions have well-defined regulations for evaluation of metal mobility and potential impacts to water resources and in

Counterfactual evidence for “usefulness”



	LOD (ug/l) HCT lab	Potential field concentration (ug/l)	
	L:S = 27	L:S = 0.1	L:S = 0.01
as,co,u	0.5	135	1,350
cr, mn, se	1	270	2,700
al	10	2,700	27,000

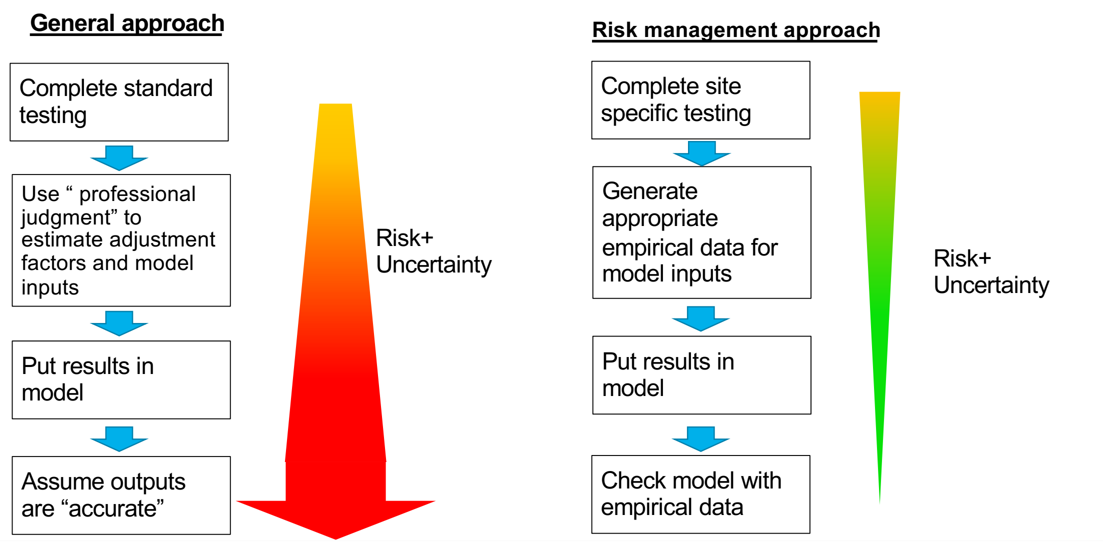


Because of extreme L:S ratio, it is highly misleading to use the results of HCT’s to either predict water quality or worse to compare results with typical water quality guidelines to determine regulatory water quality risks

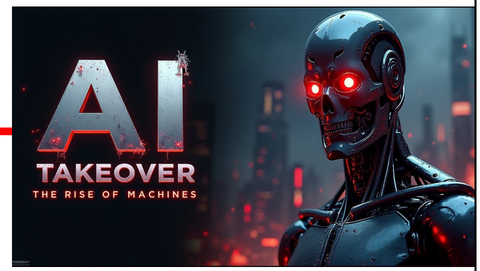
Conventions and suggested “best practice”

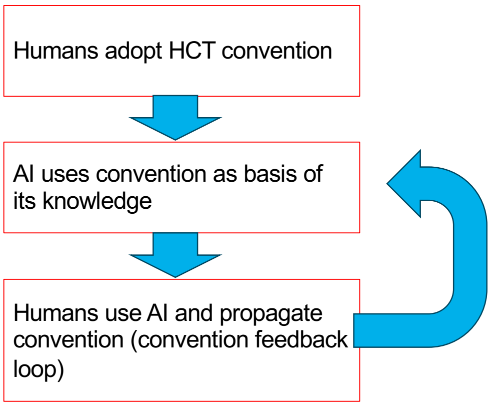
Industry Convention (bad practice)	Best practice
1.HCT is an accelerated test	Cannot be assumed, complete column test under site conditions
2.HCT is a conservative test	Cannot be assumed, complete column test under site conditions
3.HCT has finer particle size than field	Always check PSD of any crush and develop crushing method for simulating field PSD
4.HCT can be used for water quality assessment	Unlikely, complete column test under site conditions
5.Leachate from HCT can be compared to guideline values to assess water quality risk	Absolutely not under any circumstances
6.HCT can be used to determine “release rates” of metal(loid)s	Check logic on what “release rates” is taken to mean, complete column test under site conditions
7.HCT can be used to determine lag time to acid formation	Check your logic (PSD and fragementation), complete column test under site conditions
Ignore the “first flush”	The “first flush” is actually the conditions experienced for many decades in mine rock storage facilities >20m high

Important because this relates to risk management



AI danger!!





- It should be obvious to anyone using AI tools that they are prone to forming doomed feedback loops like this
- There is evidence for "convention feedback loops" already forming for topics like HCT
- This will get worse over time since humans:
  - Are inherently lazy
  - Seek to cut cost
  - Preference conventions

Image: https://www.youtube.com/watch?v=x-N7kdA_InY

Thank you

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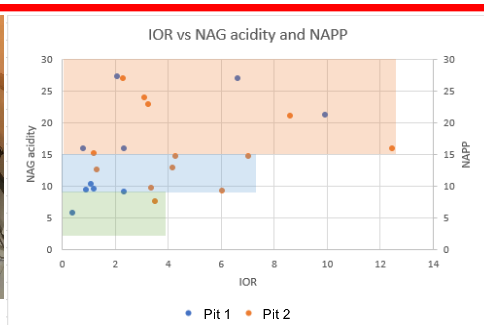
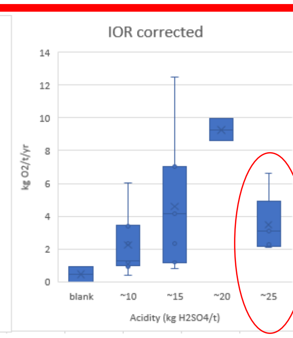
Mine Environment Management Ltd

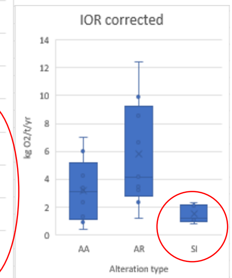
Sulfide content and reaction rates

- Common knowledge
  - Thermodynamic assumption is that there is a liner relationship between sulfide content and reaction rates
- Evidence: HCT data can be used to determine sulfide oxidation rate data
- Counter factual evidence
  - All parameters are the same in the HCT test except the type of material loaded therefore it is highly likely a linear relationship between sulfide content and reaction rates will be simulated in the test conditions.
  - Other parameters are not evaluated in the test therefore it cannot be proven that sulfide content is the most important parameter that controls reaction rates (directly and in a linear way)

Example of counterfactual evidence



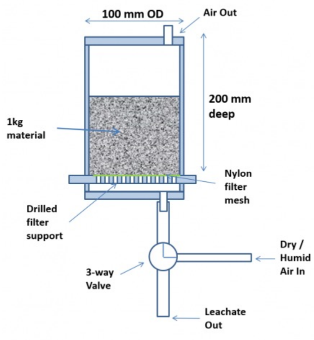




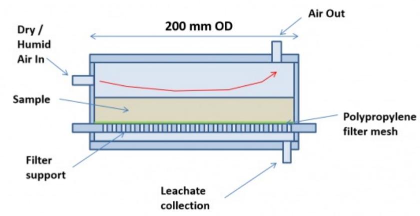
- Kinetic oxidation rates are very material specific as is obvious from the range in the data
- In this case alteration type has significant influence on IOR, i.e. the IOR does not have the same relationship with sulfide grade in all material types (SI has higher sulfide content but lower IOR)
- Compared to tests like HCT the advantage of tests like the oxygen consumption tests is they can be easily established on site and tests can be run in <30 days and are designed to achieve 1 objective (IOR) not multiple (like HCT).

HCT– typical design

Waste Rock



Tailings

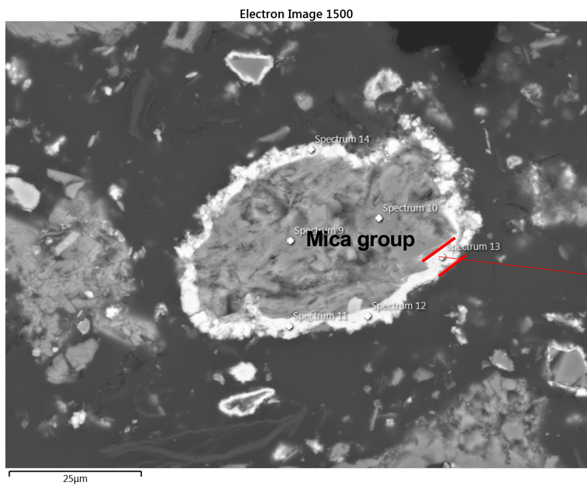


- DI water is introduced via drip at the top of cell, slowly enough to avoid undue agitation of sample. However, divots / wells can result from this causing a thinning of the waste and thus a preferential flow path
- The relatively thin nature of the tailings makes it susceptible to desiccation cracks, which again can lead to preferential flow through the waste

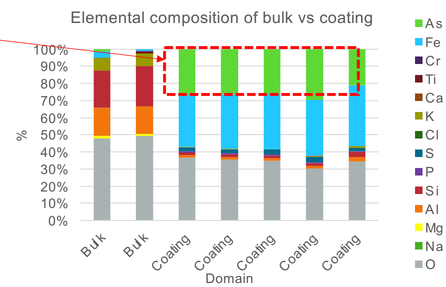
Image credit: Geochemic Ltd, Blaenavon, UK

Specifically waste rock at top but not under the water inlet

Common knowledge: Secondary mineral formation can be "modelled"

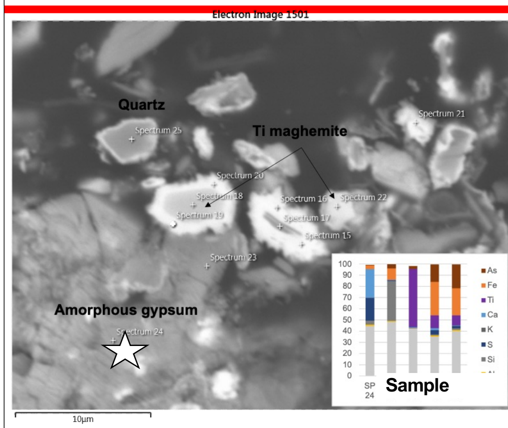


- SEM image showing a Fe oxide coating of a secondary mineral over the primary mica-group grain.
- The coating has high Fe content and is interpreted as an amorphous Fe oxy-hydroxide
- The coating seems of relatively uniform composition and is ~5um thick
- The coating has elevated arsenic content

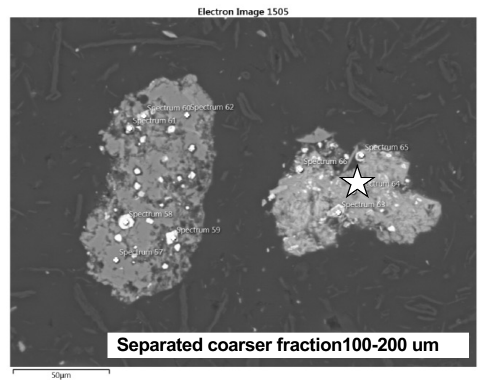


Here is another image showing a larger mica group grain with a well-developed coating around it. This coating appears more crystalline than the coatings on the previous slide. As before, the coating has high iron and arsenic content.

Counter factual evidence: the effect of secondary mineral formation is not “simple to model”



Sample ID	Sample	Coarser fraction 100-200
O	44.72	49.59
Na	0.53	
Mg	0.22	
Al	1.15	0.15
Si	3.48	0.39
S	20.27	22.16
K	0.27	
Ca	25.28	26.84
Fe	**3.53**	**0.84**
As	**0.53**	

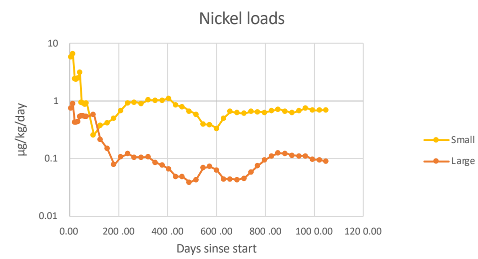


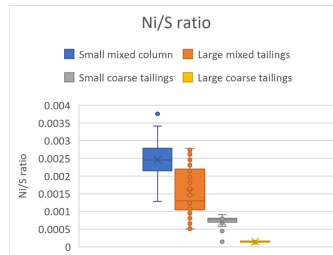
Counter factual evidence: secondary mineral formation is not always “textbook”

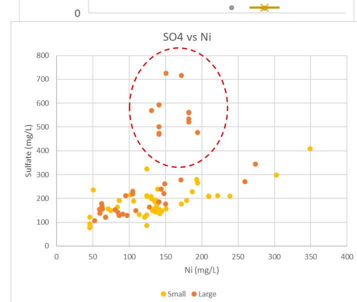
- No As and low Fe is reported for the gypsum grain in the size-separated samples
- The 'Undifferentiated', cloudy-looking grey mass visible has gypsum chemistry containing Fe and As

Interestingly, gypsum could be seen in two forms – as grains for example in the separated coarser fraction of the sample, and as amorphous material as in the figure on the left. Both phases contained similar amounts of calcium, sulfur and oxygen supporting the identification of the phase Notably, however, the well-formed grain contained only ~ one quarter of the iron that was associated with the amorphous calcium sulfate, and no detectable arsenic, while the amorphous mass contained arsenic at ~0.5%. These result further support the arsenic release mechanism observed in the upflow being related to sulfate release, which is interpreted as resulting from the dissolution of the relatively abundant amorhpus calcium sulfate phases such as the one in the left figure.

Further counterfactual evidence: Effect of material thickness/residence time on release rates







- Results from column testing indicate that the thickness of the column significantly influences the nickel release rate
- Based on nickel to sulfate ratios it is interpreted that increased sorption is occurring in the large column which is reducing nickel concentration relative to sulfate
- Tests like HCT will not account for a variable like thickness

Further counterfactual evidence