3 December 2019

Workshop on Improving Estimates of Releases from Mine Tailings in Life Cycle Assessment

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8. International Copper Association, Ltd., Washington, DC, USA
9. International Aluminium Institute, London, United Kingdom
10. International Council on Mining and Metals (ICMM), London, United Kingdom

5 December, 2019

Thanks

- **Sponsors**
  - ICMM
  - International Copper Association (ICA)
  - International Aluminium Institute (AIA)
- **For getting this off the ground**
  - Charles Dumaresq
  - Gilles Tremblay
  - Bill Price
- **Steering Committee**

The Short, Short Version

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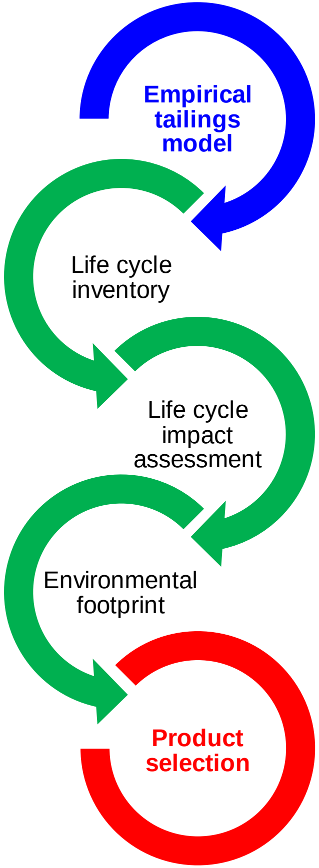
- **Life cycle assessments (LCAs) on consumer products are being used to estimate impacts (e.g., ecotoxicity, global warming potential, etc.) associated with all stages of their production and life (raw materials to end-of-life)**
- **LCAs are expected to increasingly form the basis for selection of materials in products (e.g., Product Environmental Footprints in the European Union)**
- **Based on recent LCAs of metal-containing products, releases of metal(loid)s from mine tailings can be the primary driver of impacts in human health and ecotoxicity impact categories**
- **These releases are estimated with an empirical tailings impoundment model developed from a landfill model by LCA researchers**
- **The empirical model does not necessarily reflect current tailing management practices and may overestimate long-term releases of metal(loid)s**
- **Goal: Gather mining and LCA experts together for a workshop to (1) raise awareness *within the mining sector* of how impacts from mine tailings are currently being assessed in product LCA (2) discuss the merits/shortcomings of the empirical model currently in use, and (3) consider data needs and alternate approaches for estimating releases moving forward**
- **The following presentation summarizes the findings of this December 3, 2019 workshop**



Slide revised March 2020

Two overarching issues:

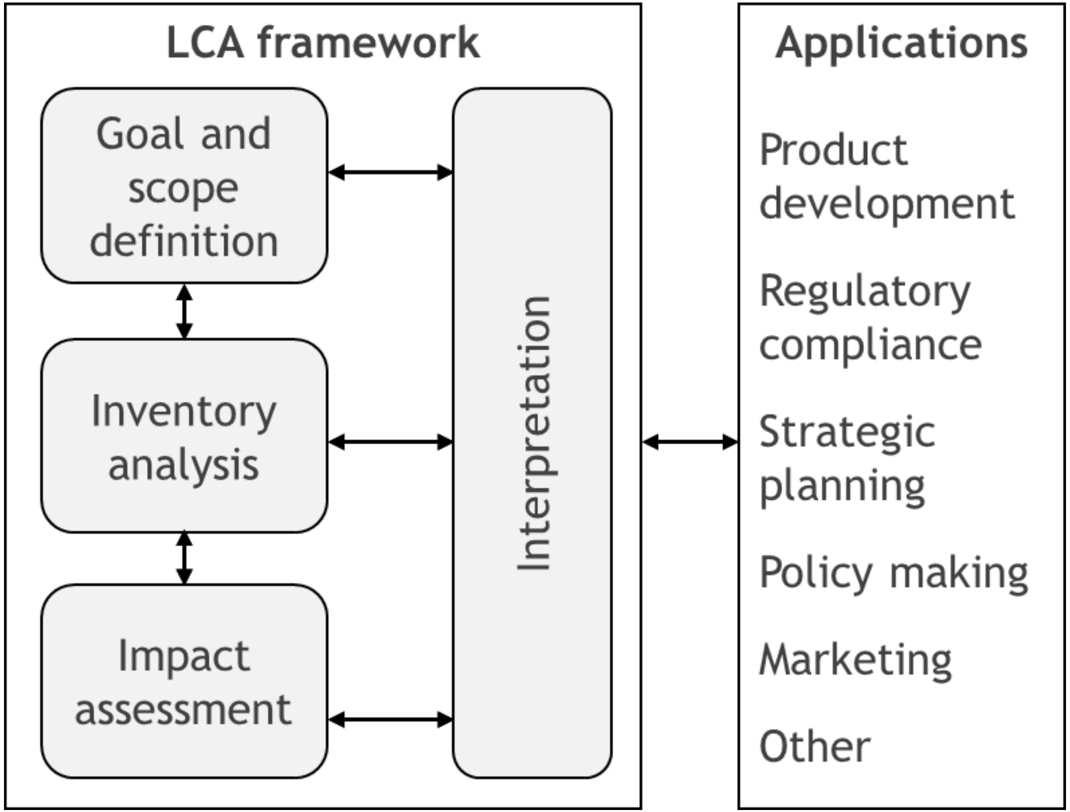
1. **Find common ground between:**
   – need for single, or small number of, average estimate of releases from tailings (LCA Community)
   – recognition of wide diversity of ore and tailings types, tailings management (past and present), chemistries, and leachates (mining and producer Companies)

2. **Need to predict releases far into the future (beyond active management by companies)**

Workshop Outline

- **Plenary Session**
  - LCA Intro (A. Landfield Greig)
  - LCA of Tailings Management (D. Turner)
  - Tailings Management (C. Dumaresq)
  - Implications of LCA for Mining Industry (J. Drielsma)
  - Geochemistry of metal releases from mine waste (S. Barabash and D. Skruch)
- **Break-Out Groups**
  - Model validation and data collection
  - How to incorporate tailings treatment/management/BMPs into tailings LCI
  - Geochemistry
  - Regulatory issues and how LCA can influence

Methodology of LCA



Adapted from ISO (2006) & JRC (2010)

What is LCA?

- Well-established
- Standardised (ISO 14040/44)
- Comparative
- Relative, not absolute

Life Cycle Inventory (LCI)

- **Resource Inputs (kg)**
  - ✓ coal
  - ✓ oil
  - ✓ natural gas
  - ✓ mineral sands
  - ✓ water
- **Energy Inputs (MJ)**
  - ✓ total primary energy
- **Air emissions (g)**
  - ✓ carbon dioxide (CO_2)
  - ✓ carbon monoxide (CO)
  - ✓ hydrocarbons
  - ✓ methane
  - ✓ nitrogen oxides (NOx)
  - ✓ particulates
  - ✓ sulfur oxides (SOx)
- **Water effluents (g)**
  - ✓ chemical oxygen demand (COD)
  - ✓ chlorides
  - ✓ heavy metals
  - ✓ suspended matter
- **Solid waste (kg)**
  - ✓ total waste
  - ✓ mining waste

- **First outcome of an LCA**
  - “Balance sheet” of env’l inflows & outflows
- **List of flows exorbitant**
  - 1000s of inputs, outputs
- **Public LCIs use most relevant flows**

Life Cycle Inventory (LCI) databases

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- ***"An organised collection of LCI datasets that completely or partially conform to a common set of criteria including methodology, format, review, and nomenclature"*** **(UNEP, 2011)**
- **Allow for interconnection of individual datasets to create background LCI models**
- **Many different databases available**
- **Limited interoperability due to differences in data management**

What LCI databases are available?

Database	n datasets	Geography	Focus
ecoinvent	16,896	Global	-
GaBi	13,846	Global	-
ESU World Food	6,910	Global	Agriculture
Agri-footprint	6,342	Global	Agriculture
idea	3,847	Japan	-
PEF database	3,185	Europe	-
NEEDS	933	Europe	Electricity
US LCI database	720	US	-
ELCD	608	Europe	-
The Evah Pigments Database	193	Global	Pigments
bioenergiedat	178	Germany	Bioenergy

Life Cycle Impact Assessment (LCIA)

- **The part of the LCA "aimed at understanding and evaluating the magnitude and significance of the potential environmental impacts" of a product (ISO 14040)**
- **Commonly used & accepted impact categories**
  - Examples: Global warming potential, acidification potential, Smog formation, total energy…
- **New impact categories not yet widely accepted (high uncertainty)**
  - Examples: Human health toxicity, ecotoxicity, resource depletion …

LCA Applications - External

- Marketing – compare products
- External reporting of environmental milestones: Sustainability reports, annual reports
- Participate in green purchasing programs
- Address stakeholder requests for information
- Product Environmental Footprints, Env’l Product Declarations
- Carbon footprints / GHG accounting

Tailings Management in LCA

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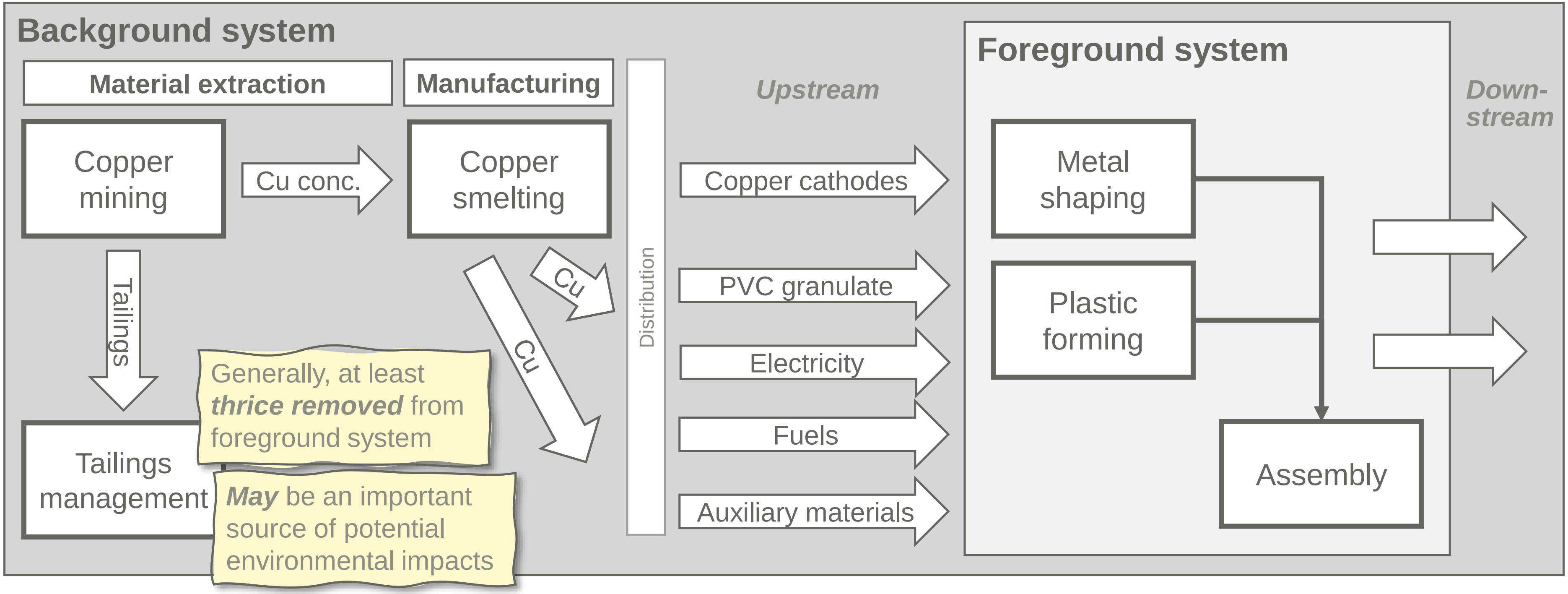
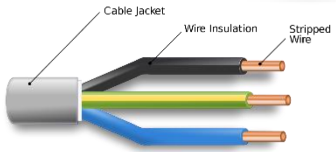
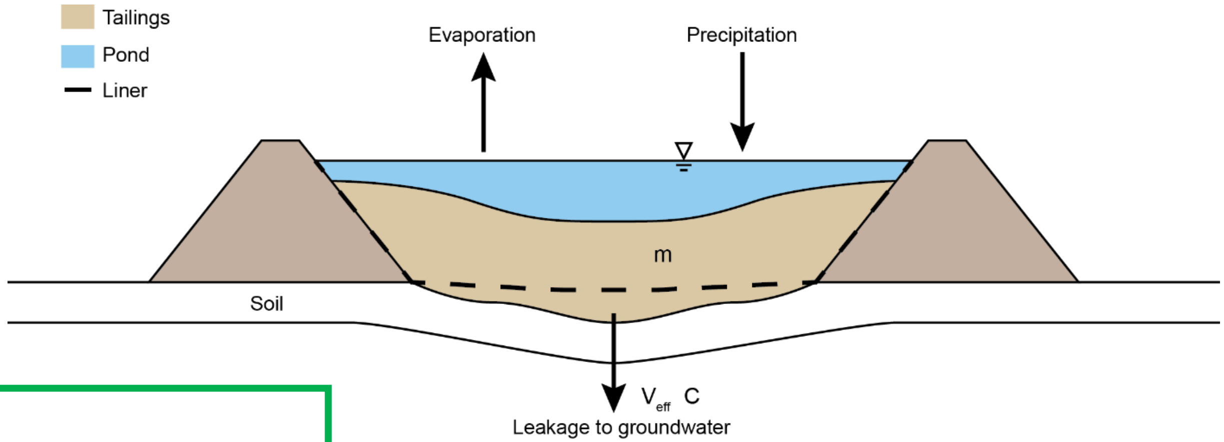




LCA can involve 1000s of processes

Tailings Model



Generic Leachate Chemistry, C_0

Generic Tailings Composition, *m*

Specific Leachate Volume, *Veff*

Specific Transfer Coefficient (TK)

Specific Tailings Composition, m_S

Specific Emission

- Empirical model based on the principle of mass balance
- Differentiation of short term (≤100 yr) vs long term (≤60,000 yr) emissions

Tailings composition

- Calculated average composition of tailings produced at metal mine sites globally
- Metal-specific not region-specific

Average tailings compositions

	Copper mine tailings	Nickel mine tailings*	Lead mine tailings	Zinc mine tailings
Geometric mean (mg/kg) ± geometric standard deviation (%)				
As	300 ± 111%	290 ± 111%	570 ± 129%	420 ± 139%
Cd	4.3 ± 104%	5.0 ± 105%	14 ± 125%	21 ± 123%
Cr	61 ± 103%	56 ± 104%	33 ± 114%	32 ± 116%
Cu	920 ± 106%	260 ± 175%	240 ± 121%	570 ± 124%
Hg	0.46 ± 109%	0.48 ± 109%	1.2 ± 144%	1.2 ± 141%
Ni	20 ± 117%	730 ± 156%	17 ± 118%	29 ± 128%
Pb	140 ± 107%	170 ± 107%	1,700 ± 120%	2,000 ± 122%
Sb	40 ± 105%	39 ± 105%	130 ± 132%	49 ± 162%
Zn	210 ± 107%	160 ± 107%	1,400 ± 124%	3,800 ± 120%
…	…	…	…	…

* Due to lack of data, Ni tailings composition based on “generic” tailings composition, except for Cu & Ni contents, for which Ni tailings-specific data were available

Tailings disposal datasets in ecoinvent v3.6

Sulfidic tailings disposal

- gold
- silver
- copper
- nickel
- zinc-lead
- mercury
- “generic”

42 datasets

Other tailings disposal

- “generic” non-sulfidic
- salt talking (potash)
- uranium
- red mud (aluminium)

6 datasets

Created with mapchart.net ©

Mine tailings issue from LCA and LCI data

- **Potential issues:**
  - ecoinvent data users may not dive down into results, or report on the *implications* of using highly uncertain data
- **There is a real potential for harmful outcomes for products containing these metals when these data are used and when toxicity impacts are included**
  - Results not “checked” or understood could potentially:
  - Jeopardize development of new products/markets
  - Get current products pulled off the market
  - Jeopardize companies’ or industries’ reputations

Comparative LCA of EV batteries

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Life cycle assessment of high capacity molybdenum disulfide lithium-ion battery for electric vehicles

CrossMark

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- **Deng et al. (2017) article compared molybdenum disulfide (MoS_2) anode and Nickel-Cobalt-Manganese oxide (NMC) to conventional NMC-Graphite battery**
- **141% - 271% more impacts in ecotoxicity and human health impact categories caused in part by emissions from mining process**
- **"…the overwhelmingly larger toxicity impact of the NMC-MoS_2 will pose significant environmental concerns."**

Comparative LCA of EV batteries

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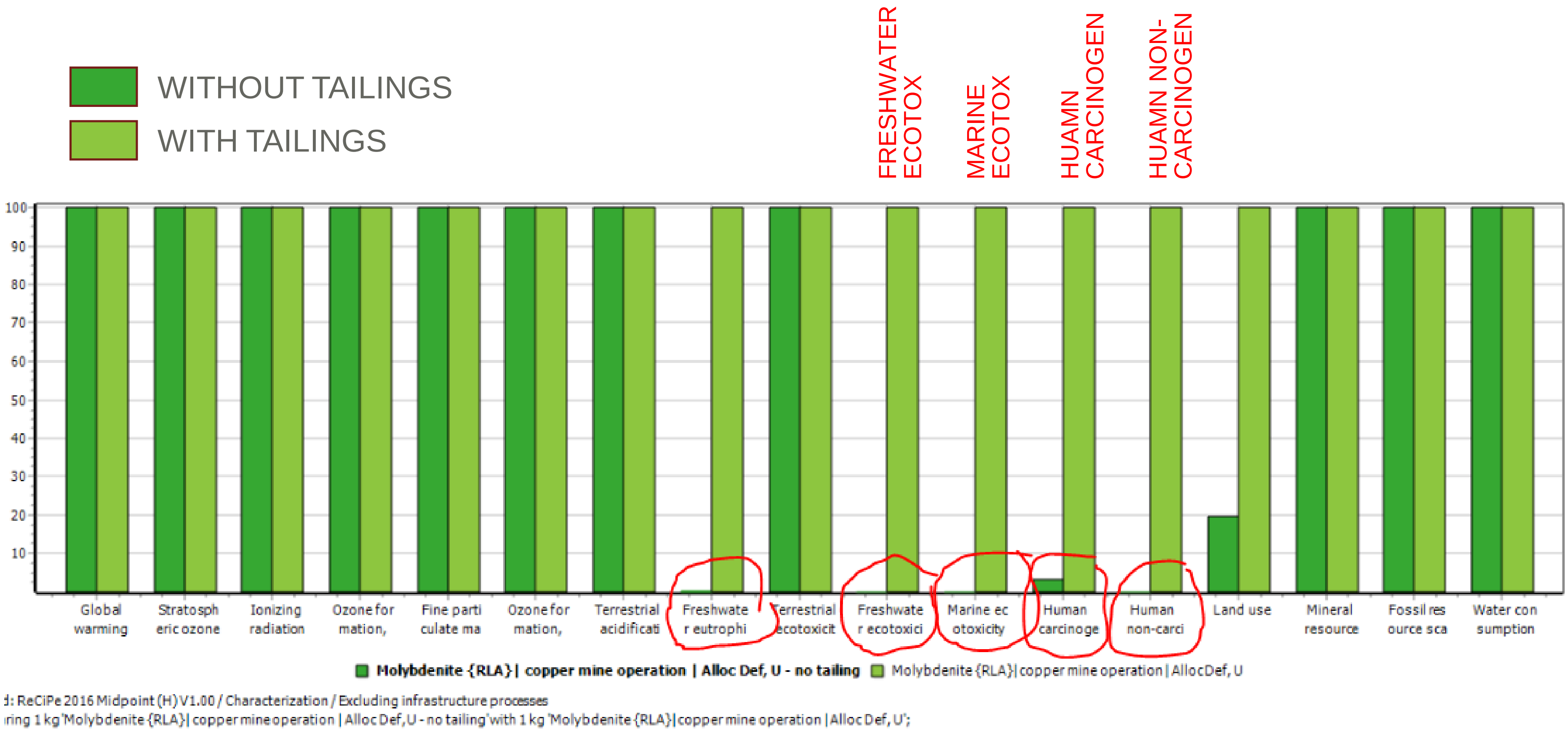
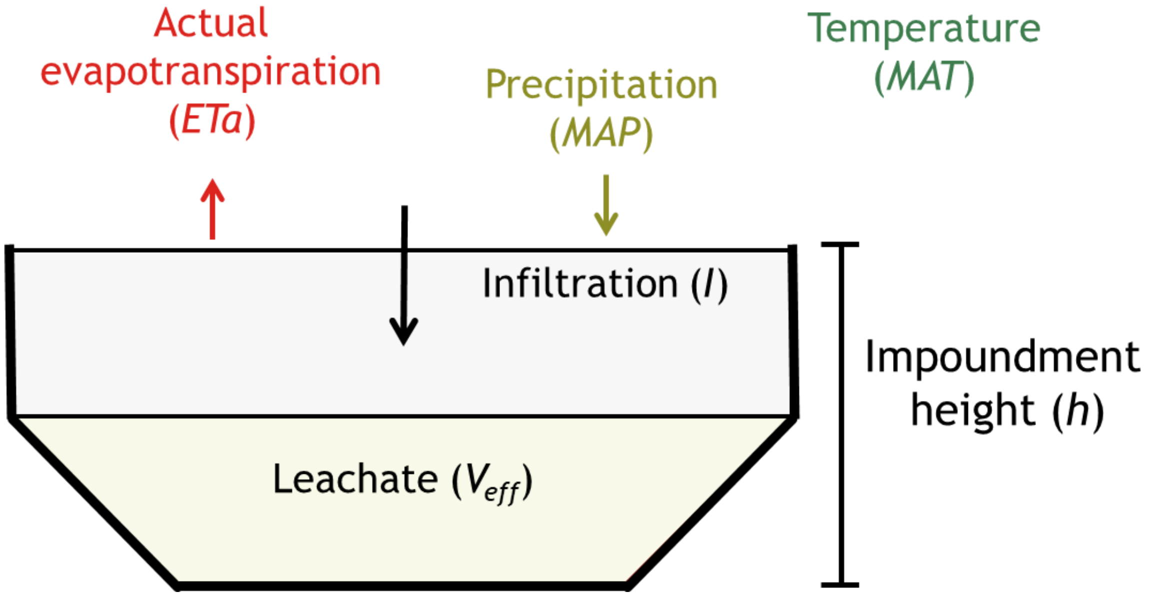


Water Management

- **Water management is always key to tailings management**
- **Tailings facilities may be constructed to manage water through use of:**
  - Water-retaining dam (eg impermeable core built of clay or glacial till)
  - Construction on low permeability foundations
  - Use of caps, liners
  - Grouting of bedrock
- **Strategy used depends in part of the risk profile (e.g., tailings emissions minimization vs dam failure) and the risk management strategy**


Actual evapotranspiration (ETa)
Precipitation (MAP)
Temperature (MAT)
Infiltration (I)
Impoundment height (h)
Leachate (V_{eff})

Water Management

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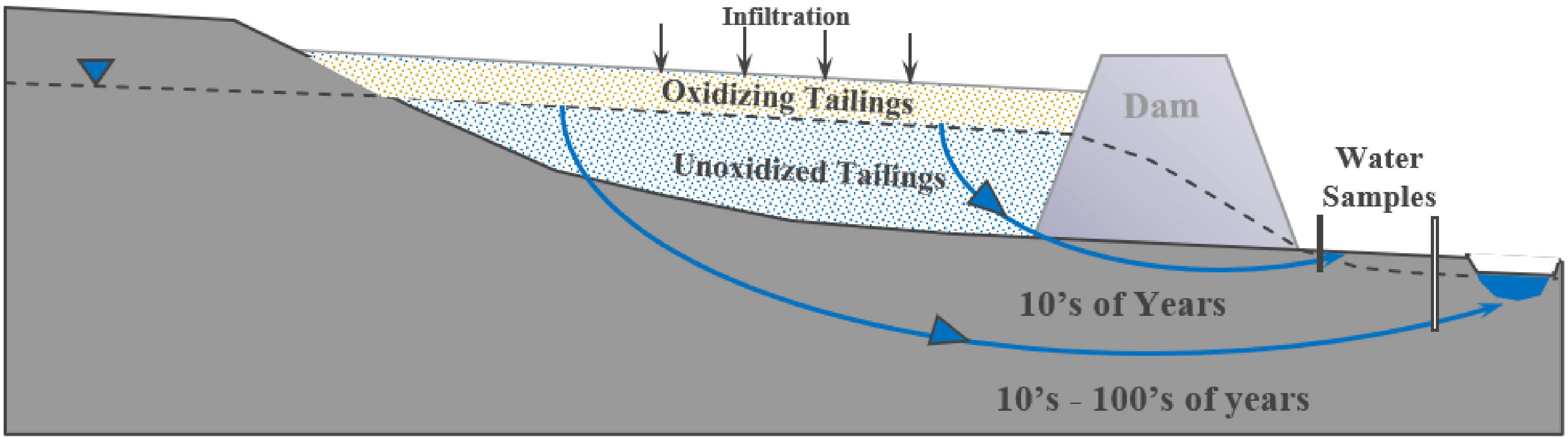
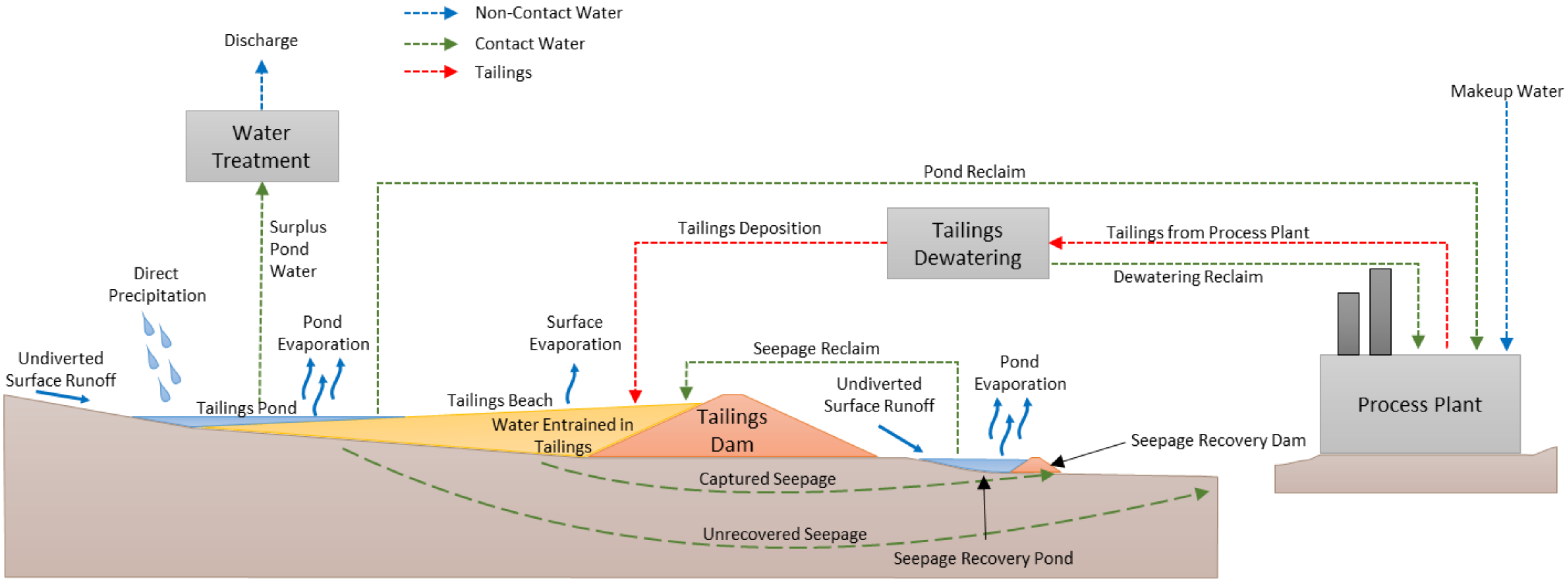


Water Management



Managing Chemical Risks – Water Treatment

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- **Effluents must meet nationwide or local regulatory requirements (water standards, permit limits)**
- **Water from tailings facilities is almost always treated before it is released to the environment (even with other mitigation measures in place)**
- **Treatment systems are site-specific, and depend on the contaminants to be treated and the performance objectives**
- **A wide range of treatment technologies exist, which may be employed alone or in series to achieved the intended effluent quality**
- **Technologies include:**
  - Active treatment methods (requiring ongoing inputs of reagents and/or energy) typically used at operating mine sites and some closed sites
  - Passive (largely self-sustaining) or semi-passive (requiring periodic maintenance or inputs) methods that can be more suitable to closed or inactive sites, and more suitable to meet requirements for long-term treatment
- **Some entity will always bear responsibility for ensuring compliance**

Unaligned Incentives

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- **LCA assesses impacts per functional unit:**
  - A **product** perspective
  - The concerns of **Users**
  - E.g., Carbon Footprint

- **Mining assesses impacts over time:**
  - A **site** perspective
  - The concerns of **Hosts**
  - E.g., Local ecotoxicity of leachate

Market/Regulator Focus

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EU

Study of potential market rules for solar photo voltaic modules

- *Including pilot Category Rules for Environmental Footprint (LCA) calculation*

Study on sustainability requirements for rechargeable batteries

- *Including pilot Category Rules for Environmental Footprint (LCA) calculation*

EN 15804 standard on Environmental Product Declarations

- *Amendment for more consistency with pilot Environmental Footprint (LCA) method*

EU Sustainable Finance Taxonomy

- *Exploring use of Environmental Footprint methods (LCA) to define criteria for sustainable investments*

The Future (?)

Registration,
Evaluation
&
Authorisation
of products

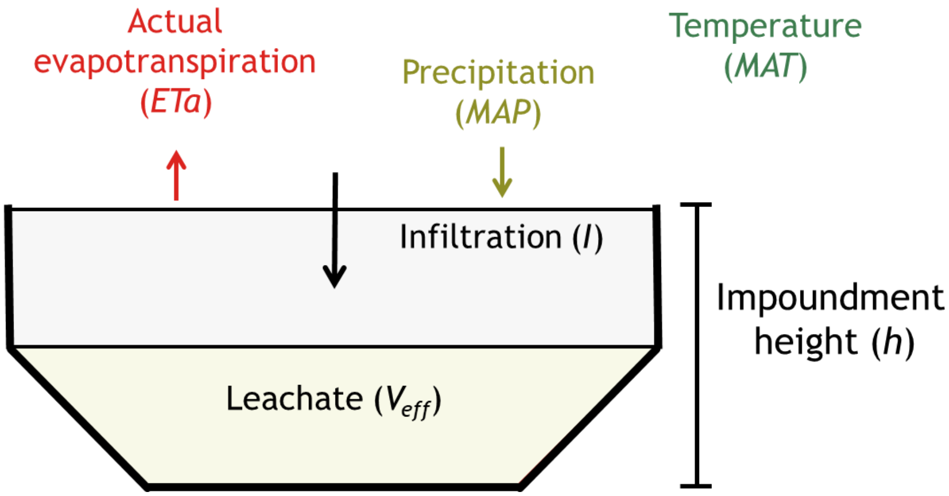
Access to large consumer markets

Access to capital

Conceptual Model Comparison

LCI Tailing Model Basis: MSW landfill model (Belevi and Baccini, 1989)

A MSW landfill is a half-continuous **fixed bed reactor**. The fixed bed consists of deposited MSW. Water is the other input which enters the reactor continuously by precipitation…landfill is considered as a **homogeneous reactor without concentration gradients in it.**



$$C = C_0 e^{-\frac{\dot{V}_m C_0}{m'(TK_\infty)} t}$$

Rate term is augmented at a point in the future to reflect the onset of acidic conditions if they occur within Time frame of the analysis (100 or 60,000 years)

Conceptual Model Comparison

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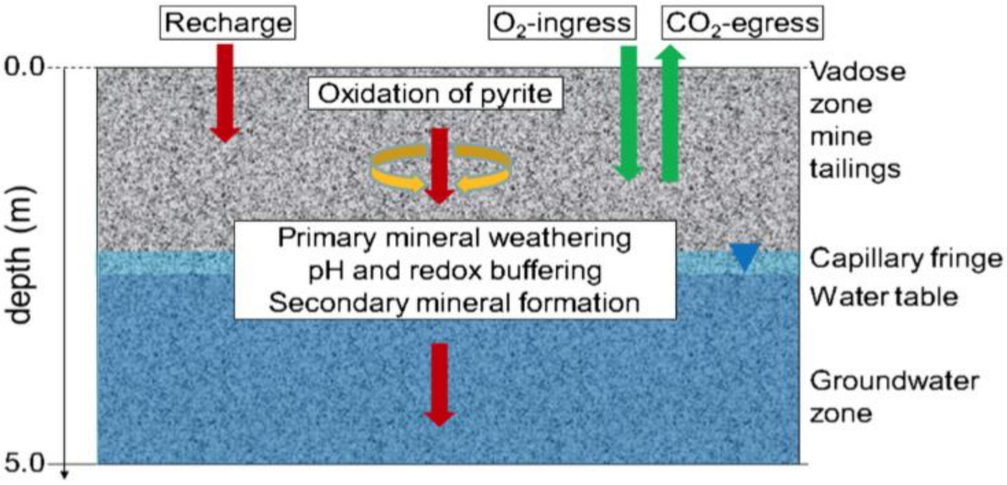
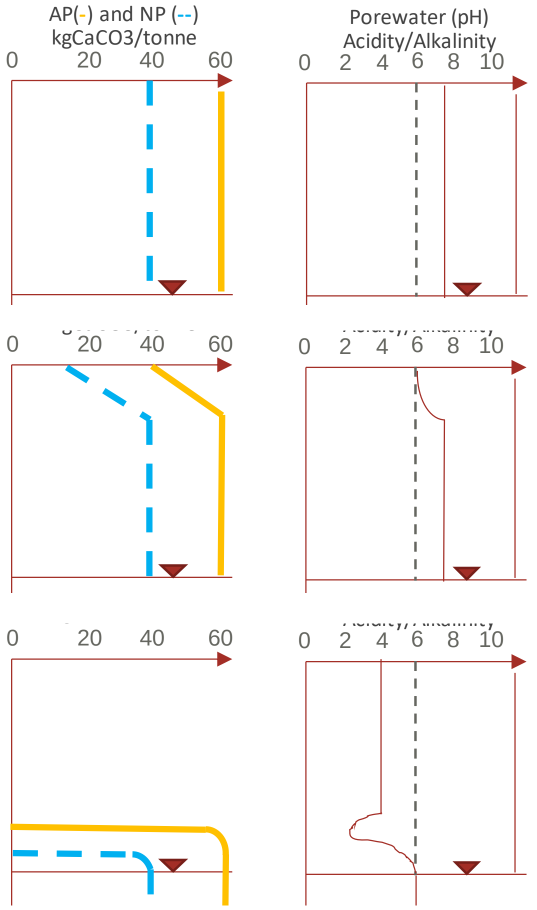


Conceptual Model of ARD Generation and Attenuation

(Mayer et. al., 2015)



Breakout Groups

- **Geochemistry**
- **How to incorporate tailings treatment/management/BMPs into tailings LCI**
- **Regulatory issues and how LCA can influence**
- **Model validation and data collection**

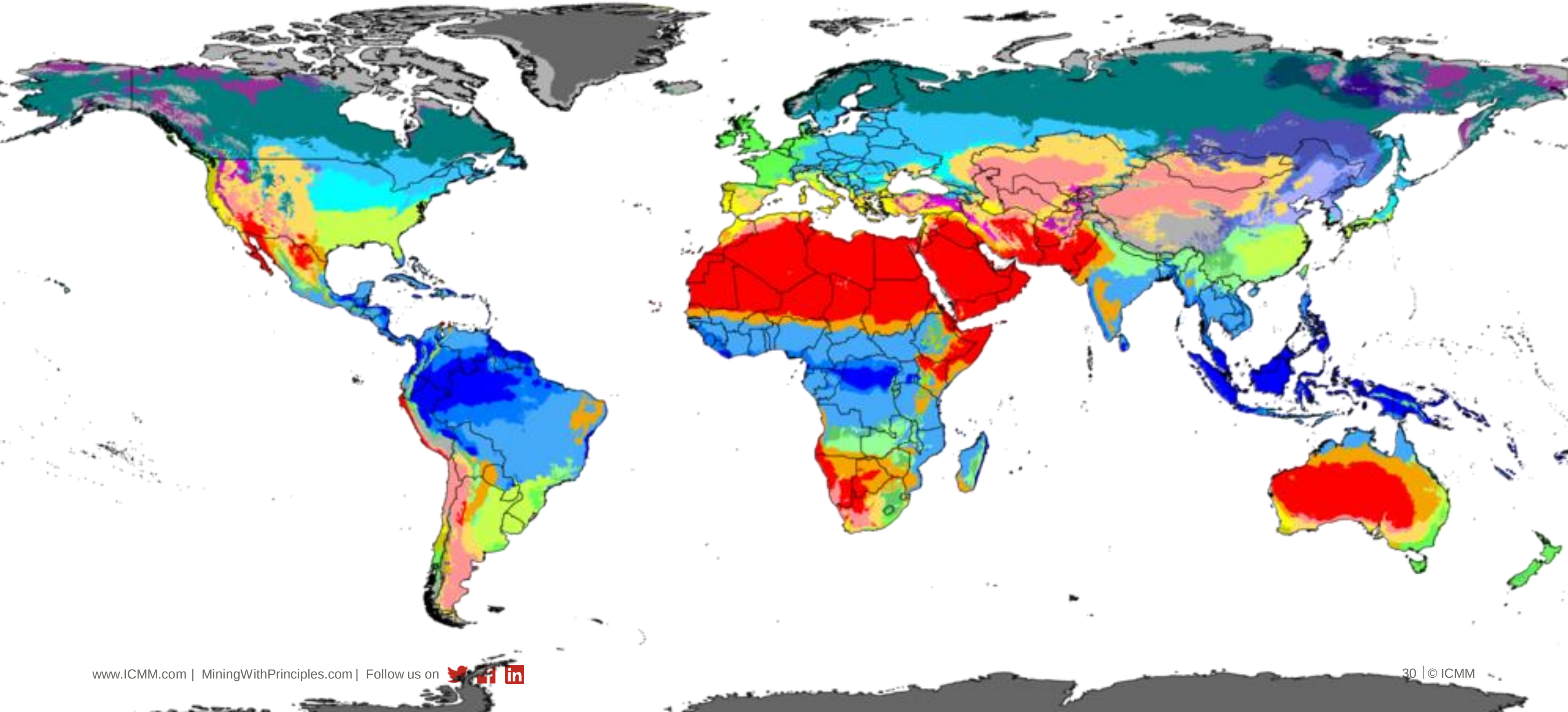
Feedback from Breakout Groups

- **Data and Treatment Groups**
  - "Leachate" data considered should be "end of pipe" and inclusive of any treatment.
    - This likely integrates more than just releases for tailings…but isn't that the point?
  - Important question: how long can active treatment be sustained and what is the role passive treatment.
  - There needs to be a guidance document that informs the types of data (e.g. leachate) to be used for the tailing LCI development. This needs to be drafted by industry.
    - Data quality and binning/filtering
  - Concentration vs load based estimates of releases from tailings
  - What about other mine wastes (e.g., waste rock)

Feedback from Breakout Groups

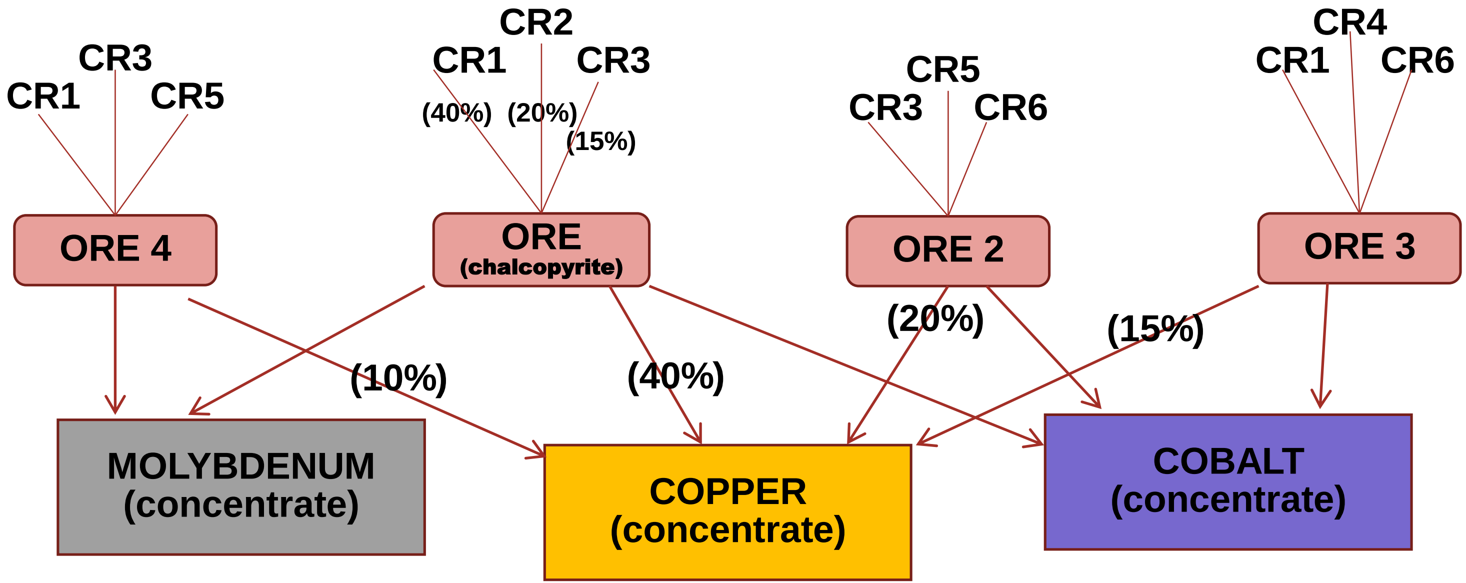
- **Geochemistry Group**
  - First: Let’s use the **data** we have
  - Data binning/filters
    - Ore Type, Köppen-Geiger climate classification, metallurgic processes, treatment/management practices, etc.
  - Need to get representatives from producers involved in the discussion
  - Mechanistic model may needed to evaluate long-term behavior
    - Maturity of these models
  - Work to get a better understanding of the current model

Köppen–Geiger climate classification map (1980–2016)



Filters/Bins by Primary Metal, Ore Type, …

C.R. = Climate Region



Feedback from Breakout Groups

- **Regulatory Issues**
  - Mine regulation (site-specific) vs environmental policy (company- or nation-wide)
  - EU Product Environmental Footprint (PEF) initiative does not directly involve mining interests, but assumptions about upstream mining processes have **major** effect on the LCA results for products using metals
  - Industry needs to actively engage in guiding the EU program(s) for product sustainability (5-yr timeframe). Industry must highlight the current immaturity and uncertainties of the process, and must take the lead in developing guidelines for incorporating metals data.
  - LCA is dealing with potential worst-case impacts → Regulators and consumers may view them as actual impacts, and confuse comparative LCAs with threshold-based Risk Assessments
  - Mining industry's concerns about sharing "leachate" data for use in LCA, that contradicts site-specific reporting - confusing regulators & stakeholders

Path Forward

- **January 2020** - Review of outcomes and recommendations of workshop by ICMM Life Cycle Management Working Group

- **Q1 2020** - Potential establishment of an ICMM LCMWG project team to take supported recommendations forward.

- Work during Q1 and Q3 to be undertaken through:
  - Telecons or webinars for small workgroups, organized based on recommendations of Breakout Groups
  - Side meetings at conferences

- Volunteers and other sponsors welcome!

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