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Predicting emission releases from mine tailings: spatially and temporally resolved life cycle assessment modelling

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1. Introduction

Tailings are one of the major wastes flows generated during mining activities [1]. A new modelling framework to estimate emissions releases from mine tailings impoundment is proposed, which integrates most importantly site-specificity factors such as tailings characteristics (elemental compositions, mineralogy) as well as local climate conditions (net infiltration) throughout time. The novely of the model lies on the inclusion of geo chemical factors in the tailings as the input parameters for capturing toxic species evolution into the environment. This work provides an improved prediction method to calculate life cycle inventories (LCIs) of leached species from specific tailings impoundment with a systematic procedure.

2. Materials and methods

The modelling framework comprises of several important steps, namely: site-specific data collection, geo chemical simulation and life cycle assessment as shown in Figure 1. The input parameters for this modelling work are split into two different types that indicate its source of origin. Initially, the framework is built by generating a hypothetical tailings dataset where the information of tailings elemental compositions are taken from currently available data in Ecoinvent [2] while some other information are retrieved from reasonable input values (e.g. mineralogy data is fulfilled from dominant buffering minerals composition [1]).

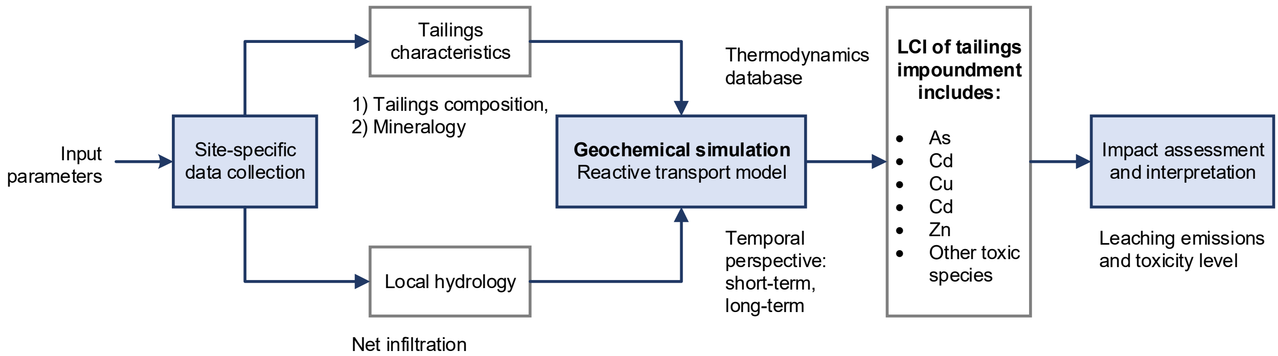


Figure 1: Modelling framework of tailings impoundment emission releases and life cycle assessment approach

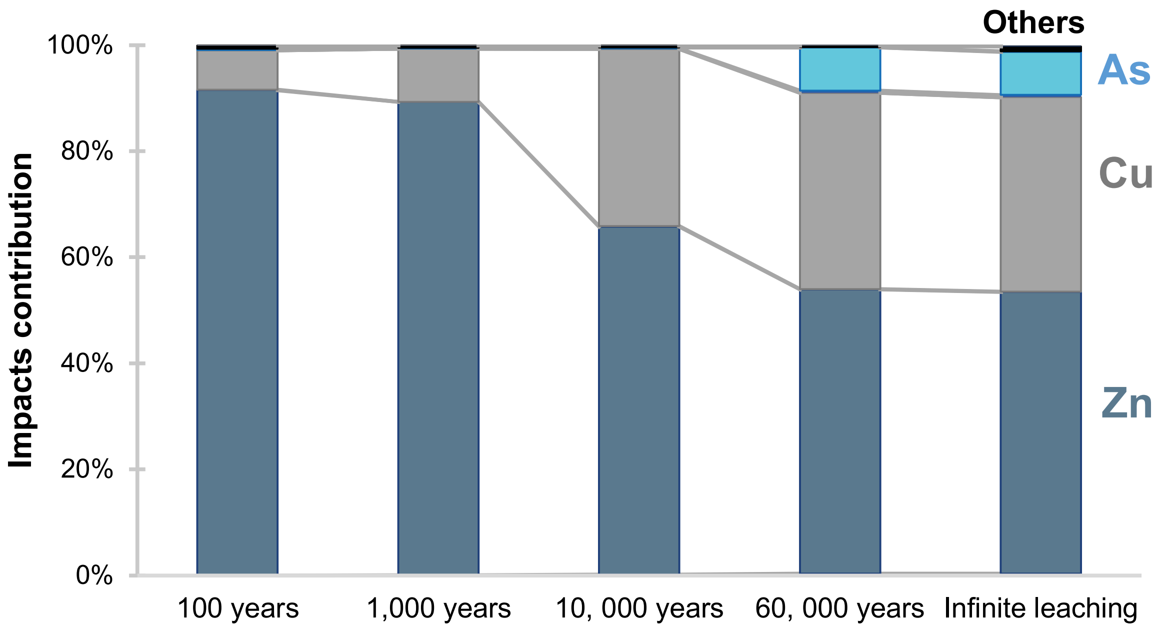
Following the completion of input parameters, a geochemical modelling is run to obtain the dynamics of tailings chemistry throughout the time. This step captures changes of both harmless and toxic species in the system as well as their releases behaviour. The geochemical simulation is modelled using reactive transport module of Phreeqc [3], in which it contains necessary thermodynamics database for chemically equilibrium system.

The main outputs of this simulation are life-cycle inventory (in the form of species emission as a function of time) that can be further environmentally assessed via relevant impact category in LCA. An example of such methods of this system is a recommended characterization factors for toxicity, USETox® [4]. A specific freshwater ecotoxicity method has been chosen as one of the environmental metrics in this work, assuming that all environmental impacts caused by emission releases into ground water compartment are equivalent to their releases into fresh water due to unavailability of characterization factor.

3. Results and discussion

The output of this modelling framework is an inventory containing releases of toxic species as a function of tailings input and time. For instance, using this framework on tailings compositions recorded in Ecoinvent [2] database (sulfidic tailings impoundment) as initial condition provides life cycle impact assessment results in Figure 2. Three notable figures that dominate in all time frames are zinc, copper and lastly arsenic releases. In short term, zinc clearly controls the emission releases due to its reactivity in the system, in addition to the metals mobility under relatively neutral pH condition. The stability of the system, however, is disrupted after 10, 000 years where results of geochemical simulation witnesses the appearance of arsenic (approximately after 50, 000 years in this first run when the pH becomes more acidic). An extension of the time frame is performed to investigate the total release (100% transfer of composition to the environment) but it shows roughly similar results as 60, 000 years frame.

In overall, the release of toxic species from tailings impoundment depends highly on the time frame considered in the assessment as evidenced by the freshwater ecotoxicity values. Furthermore, the incorporation of geo chemistry into the modelling framework enables such phenomenon to be identified and thus increasing reliability of modelled tailings impoundment model.



Total (CTUe)	7.0	66.9	205.2	394.3	397.8

Figure 2 Contribution analysis of tailings impoundment environmental impacts in different time frames

4. Conclusions

The framework allows integration of geochemistry factors involved in the system as well as other relevant site-specific parameters such as tailings characteristics and water infiltration data for addressing the gaps of LCA modelling in the previous models. This is crucial since the linkages of the models give better accuracy and higher understanding of influencing parameters in the system before a life cycle assessment modelling is performed. Apart from other input parameters, the behaviours of chemical releases are highly dependent on tailings chemistry which should be accounted for better prediction. Thus, despite its own gaps and areas of improvement, it constitutes an advance in how end-of-life stage of tailings is addressed in LCA over previously empirical models.

5. References

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