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The Challenges in Estimating the Water Footprint of Mined Commodities

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ABSTRACT: *The concept of a 'water footprint' has gradually developed over the past decade as an extension to the 'virtual' or 'embodied water' concept. A 'water footprint' estimate attempts to quantify the environmental impacts that arise from the use of water during the manufacture, use or disposal of a product or service. Methodologies for estimating water footprints have been evolving to account for factors such as changes to water quality and the relative scarcity of water in different regions. Recently an international standard for water footprinting (ISO 14046) was developed to provide an over-arching framework for how studies should be conducted and presented.*

Despite this progress there are still challenges to address to improve the methodology underpinning water footprinting studies, particularly when applied to mined products. As an example, mines are often transient in nature. The production only lasts a decade or few decades before the closure, rehabilitation or abandonment of the mine occurs. Following open cut mining, pit lakes sometimes form, leading to permanent drawdown of the surrounding groundwater levels. Current methodology provides little guidance on how to account for long-term hydrological and water quality impacts that occur after mine closure, when assessing the water footprint of a mined product.

Addressing these types of methodological issues will enable competing mineral processing technologies, individual mines and commodities to be fairly and consistently benchmarked against each other on the basis of their impact to water resources. Key areas that need to be improved for future water footprint estimates of mined commodities include: the spatial resolution of water consumption and availability data, understanding how to model and incorporate long-term changes in hydrology and water quality, and developing consistent geographical and temporal boundaries of assessments.

KEYWORDS: mining, water footprint, water scarcity, water stress, water deprivation potential

1 Introduction

Recently there has been significant research focus placed upon the best way to account for water use impacts during environmental assessments of products and processes. Concepts such as the 'virtual' or 'embodied' water required to produce a product are being extended using life cycle assessment based methodology to provide more sophisticated estimates of environmental impacts associated with water use. From this a variety of approaches have arisen to produce stand-alone 'water footprints' of products and services, in a way that is analogous to a carbon footprint.

Despite the large environmental impacts associated with the mining industry, there have been relatively few attempts to quantify water related impacts from the industry using these methods.

Within Australia, CSIRO has developed estimates of the embodied water use (including supply chain water use) for various metal commodities and production technologies [1] [2]. More recently CSIRO has begun to consider the use of impact assessment methods that account for relative differences in regional water scarcity and stress [3]. Monash University has also conducted a range of related assessments of 'water use intensity' (excludes supply chain water use) using corporate sustainability reporting data [4] [5].

Internationally, we are aware of only several other groups that are involved in quantifying the water footprint associated with mined products. Notably studies have been conducted for several mines and mineral processing operations in Chile [6] and South Africa [7] [8].

2 Water Footprinting Methodology

An international standard, "ISO 14046:2014 Environmental Management - Water Footprint - Principles, requirements and guidelines" [9], has recently been developed to provide more consistency to the way that assessments of water footprints are conducted and presented. The approach advocated by the water footprinting standard is similar to the related standard for life cycle assessment, ISO 14044 [10], in that it describes four distinct phases of a water footprint assessment. These are:

1. Goal and Scope Definition
2. Water Footprint Inventory Analysis
3. Water Footprint Impact Assessment
4. Results interpretation.

The ISO standard emphasises the need to take a life cycle perspective when quantifying a water footprint. A key aspect of this approach is that estimating water use on a purely volumetric basis is insufficient to improve water management outcomes. Rather decision making should be based on fair and consistent estimates of the impacts that occur as a result of water use. At a simplistic level, water use impacts can be categorised into those associated with the physical consumption of water and those associated with the degradation of water quality.

2.1 Consumptive Water Use Impacts

Consumptive water use impacts are those that are related to changes in the volume of water in a catchment that is available for use by different end-users. The impacts associated with consuming a given volume of water will be very different depending upon whether water in a region is very scarce or highly available. Due to this there has been a variety of indices proposed to account for the relative water scarcity or stress of different regions. Several of these indices are shown in Figure 1. Each of these indices is based upon a different perspective of water use:

The Water Stress Index (WSI) [11] provides a measure of competition for water resources in an area. If there is only limited withdrawals of water in an area (e.g. central Australia), then the WSI will be low despite the relatively low physical availability of water.

The Water Depletion Index (WDI) [12] provides an indication of the risk that consumption of water will reduce the long-term availability of water in an area.

The Water Deprivation Potential (WDP) [13] provides an indication of the potential of water consumption to deprive other users of water. This index is Water Use in LCA (WULCA) working group's preliminary recommendation for quantifying water scarcity footprints.

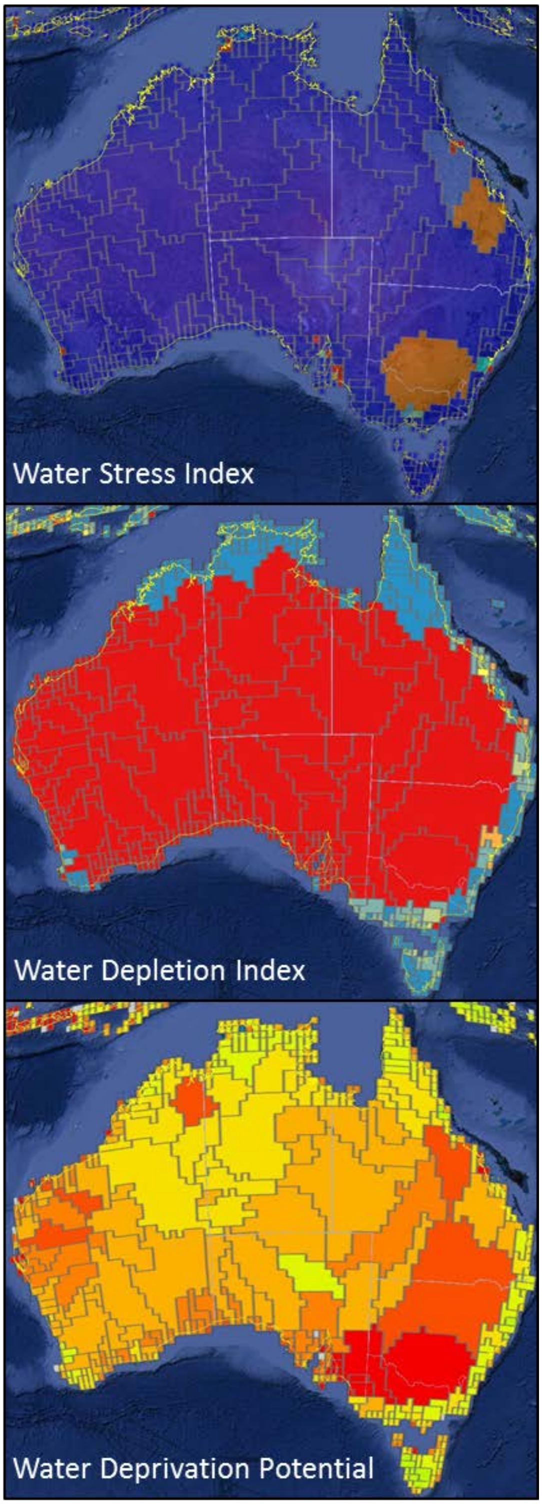

Figure 1: Several indices are available to evaluate the relative impacts of water use occurring in different regions [11] [12] [13].

2.2 Degradative Water Use Impacts

Degradative water use impacts are those that arise from changes to water quality. The types of impacts that can occur are varied, but may include: aquatic acidification, eutrophication, eco-toxicity (freshwater or marine), human toxicity, thermal pollution, etc. Standardised approaches to quantifying these impacts are available through the use of life cycle assessment impact characterisation methods. However due to the site specific nature of these impacts, estimates usually involve large uncertainties that make interpretation of the results difficult, particularly when considering more than one impact category at once.

2.3 Combining Consumptive and Degradative Water Use Impacts

The use of the different indicators available to assess water use impacts may lead to conflicting recommendations on how to reduce water use impacts. For instance, should a process alteration that reduces water consumption be adopted if it leads to increased water quality degradation? In order to handle these types of questions, there have been several methods proposed that attempt to combine aspects of water consumption and water degradation impacts into a single indicator. These have been based upon the notion that water quality degradation is equivalent to water consumption as it can deprive end-users of water suitable for their purposes. An example of this approach is the Water Impact Index (WII) [14], which is described in equation (1) below.

$$WII = \sum_i W_i . Q_{W_i} . WSI_i - \sum_j R_j . Q_{R_j} . WSI_j \qquad (1)$$

Where,

- W is the quantity of water withdrawn from water body i.
- R is the quantity of water returned to water body j.
- Q is a water quality index.
- WSI is the Water Stress Index of the water body.

Although single-indicator approaches lose valuable information of the type of water related impacts that may occur, their relative simplicity may lead to easier interpretation of results by decision makers.

3 Challenges for quantifying the water footprint of mined products

The development of water footprints of mined products is heavily dependent upon rigorously quantified estimates of the flows of water into and out of production processes, and the quality of water associated with these flows. The Minerals Council of Australia and the University of Queensland recently developed the ‘Water Accounting Framework for the Minerals Industry’ that provides a method for individual mining companies to consistently record and report water flow, quality and storage data for their individual operations [15]. Overtime the increased adoption of this framework should lead to improvements in the quality and availability of data that can be used in water footprint assessments. However, due to the types of interactions that mining has with local water resources, additional data may be required to develop rigorous water footprint estimates for mined products.

3.1 Temporal scales

The data that is available for mined products within process inventory databases generally assume ‘steady state’ conditions, where all the flows into and out of the process are for a fixed period of production. This data is suitable for providing estimates of the short-term, ‘instantaneous’ impacts associated with a mined product; however it may be not be suitable for estimating the true longer-term impacts.

Whereas the agricultural industry can be assumed to produce food products from a given location indefinitely (and so water related impacts will always occur at the same time as production), the mining industry is relatively transient in nature. The exploration, development, operation, closure and rehabilitation of an individual mine may take place over a period of just a decade or two. Unfortunately the impacts to water resources associated with a mine often occur long after a mine has ceased production, due to changes in topography, hydrology and the mobilisation of pollutants. Therefore it may make sense to incorporate these long-term impacts into the water footprint estimate of a mine’s product.

3.2 Long-term impacts

There are many different types of long-term hydrological and water quality impacts that can occur from mining and mineral processing operations. The types of impacts that will occur from an operation are highly site specific and depend on a variety of factors, such as: local climate, site topography, groundwater levels, mine type and depth, soil and waste rock chemistry, and the overall success of site rehabilitation measures.

As an example, an open cut mine could have a range of different impacts upon groundwater in an area. When the mine intersects an aquifer, a pit lake may form and the evaporation from this could lead to permanent drawdown of groundwater levels. The pit lake would likely also accumulate salt due to this process and become hypersaline overtime. However, if the mine was located in a region of high rainfall, then the mine could act as a recharge zone and permanently increase surrounding groundwater levels.

Given the range of long-term impacts that can occur, further methodology development is required to provide guidance on how to account for these impacts fairly and consistently between individual mine sites.

Conclusions

Improvements to society's interactions with water resources are essential if we are to meet the challenges of the 21st century. Recent developments in water footprinting methodology provide new opportunities to quantify and reduce the impacts associated with individual products, services and processing technologies. The use of these methods enable us consistently track the progress of our process improvements, identify more efficient ways to source materials and reduce our overall impact on the environment.

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