

Sustainability Reporting and Water Resources: a Preliminary Assessment of Embodied Water and Sustainable Mining

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Abstract This paper presents a preliminary compilation and analysis of the water reported to have been consumed by a range of various mineral commodities and compares it to mine production data. This has been undertaken to assess and quantify the ‘embodied water’ of mineral products—a key aspect of sustainability (embodied water is the total water required to produce a good or service). At present, although the use of formal reporting protocols such as the global reporting initiative (GRI) is increasing, there are still critical weaknesses. Some key aspects to facilitate proper water accounting are not listed in sustainability reports, including the extent of recycled water used, mine site water inventories, the quality of various waters, and impacts on water resources. Based on the data compiled, there is wide variation in the water used for different mineral commodities as well as for the same commodity. There is little evidence for ‘economies of scale’ in base metals and bulk minerals, though for precious metals (gold, platinum), greater throughput does tend to lead to greater efficiency. For many mines, there is little evidence of improving efficiency over time, although some mines have made substantive improvements in reducing water consumed. The grade of ore being processed is clearly critical in understanding the embodied water of minerals, with declining ore grades leading to an increased chance of higher embodied water in the future. Given that many metals are declining in average ore grade, the sensitivity of embodied water to ore grade provides a major sustainability challenge for mining generally. In summary, the

embodied water of minerals is clearly significant, and will likely gradually increase in the future, and so must be more completely accounted for to understand a fundamental aspect of sustainability and mining—that of water resources.

Keywords Embodied water · Sustainable mining · Sustainability reporting · Water consumption · Water resources

Introduction

A major strategic issue for all sectors of the global mining industry is the use and management of water resources (MCMPR and MCA 2006). The issues and concerns revolve around the quantity of water consumed by mining, as well as competition between mining and other sectors such as agriculture, and concerns about perceived, potential, and actual impacts on water quality (which, in turn, often affect water availability) (Younger and Wolkersdorfer 2004). The debate about water is often very sensitive due to its fundamental importance to life, society, and the environment—a debate often informed, rightly or wrongly, from historic legacy sites or accidents at mines (e.g. Younger 2006).

There has been a steadily increasing focus on mining and water issues, leading to more stringent regulations governing water rights and responsibilities, and more attention to water management and potential environmental impacts associated with mining. In particular, over the past decade, the global mining industry has embraced a paradigm shift to include sustainability as part of their mandate for continuing operations. This has been primarily through the industry-led project called ‘Minerals Mining and

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Sustainable Development’ (MMSD) (IIED and WBCSD 2002). The MMSD project was undertaken as a major contribution to the 2002 Johannesburg Earth Summit, the ‘Rio + 10’ United Nations Summit on the environment. As discussed by Younger (2006), the MMSD project did not systematically address water issues, stating that:

“... Issues related to water are only included where associated with other impacts such as acid drainage. This is partly because water consumption in minerals production, while an important impact, ends when operations end and thus does not constitute a long-term liability. ...” (pp. 233, IIED and WBCSD 2002).

The application of sustainability principles to water resources is challenging, due to the large spatial and temporal scale of affected catchments, the potential for significant time lags before problems are evident, and widely differing cultural issues and values associated with water. It is therefore imperative that water issues in mining be addressed and not downplayed as minor; water is, without doubt, a critical sustainability issue facing the mining industry globally (e.g. Moran 2006; Younger 2006).

A fundamental tool for sustainability analyses is that of life-cycle assessment (LCA), which seeks to estimate the total costs of a particular product over its full life (Guerin 2006; Norgate and Rankin 2002; Stewart and Petrie 2006). LCA has introduced the concepts of ‘embodied energy’ (to estimate the potential for energy efficiency and/or greenhouse contributions) and an equivalent term, the ‘embodied water’ of various products. Embodied water is the total water required to produce a good or service. At present, there is very little information on the underlying factors that contribute to the embodied water of various minerals and metals, but, in concert with evolving global sustainability practice, there are many mining companies that are now actively reporting their performance with respect to a range of sustainability indicators, with water always being a fundamental aspect of such reports. Thus, it is now possible to compile and analyse the embodied water of mining to more accurately inform LCA and other sustainability studies.

This paper provides a preliminary review of the use of water in various mining sectors, and presents an extensive range of compiled data on water consumption in mining. The data are then analysed with respect to factors such as project scale, ore grade, and commodity sector, leading to a review of the embodied water of different minerals and metals, arguably the first such wide-ranging study for mining. The paper concludes with a discussion of sustainability reporting practice for water and mining and the long-term implications for the mining sector, thereby

contributing to the evolving sustainability debate about water and mining.

Sustainable Mining, Water Resources, and Embodied Water

The mining industry and water resources are critically linked; mining needs substantive amounts of water to proceed but can also have major impacts on surface and ground water resources. Given water’s primary role in sustaining ecosystems, communities, and economies, the mining industry is recognising the challenges posed by sustainable water resource management and is embracing the opportunities it presents.

The most common starting point for discussing sustainability is the definition proposed by the 1987 World Commission on Environment and Development (WCED, or the ‘Brundtland Commission’), namely “to meet the needs of the present without compromising the ability of future generations to meet their needs” (WCED 1990). Sustainable water resource management is commonly taken to mean maintaining the availability of water resources and the services they provide (human and environmental) while ensuring no long-term compromise in its quality. The site-specific meaning of this will vary according to climatic conditions, ecosystem behaviour, mine configuration and operations, as well as the long-term success of minesite rehabilitation. Thus, for a given mining project, it is critical to understand its links with surrounding water resources, ecosystems, and communities in both a strategic and operational sense. Further detail and discussion is given by (among others) Brown (2003), MCMR and MCA (2006), Moran (2006), and Younger and Wolkersdorfer (2004).

In assessing the embodied water of mineral products in a strategic sense, one must be able to make fair and accurate comparisons for the same output. That is, the data should be effectively equivalent and for the same components. For mining projects, there are a number of factors that can affect the embodied water of a metal or mineral output, including:

- Climate conditions (e.g. temperate, arid, tropical)
- Primary water source: surface water, ground water, or saline water (marine or otherwise)
- Ore mineralogy and geochemistry (especially as this affects processing)
- Tailings and waste rock/overburden management (especially as this affects water management)
- Type of commodity (e.g. uranium requires extensive dust suppression)

- The extent of re-use and recycling
- Minesite water management regime (e.g. allowable discharges or not; treatment)
- Surrounding communities, land uses, and/or industries (e.g. towns, national parks, farms)
- Project design and configuration (e.g. open cut and/or underground mining, concentrator and/or smelter, hydrometallurgical plant, heap leaching, solvent extraction, electrowinning)
- The initial moisture content of the ore and waste rock
- If the mine is above or below the water table; and
- Surrounding hydrogeological conditions (e.g. high permeability aquifers; artesian ground water depressurisation issues).

For example, two open cut porphyry copper mines with flotation mills both produce a concentrate output but one is located in the tropics while another is in an arid region; although the project configuration may be nearly identical, the water resource needs and impacts will be very different. Thus, although it is critical to understand the embodied water per unit copper, there is no absolute figure which could be argued as ‘acceptable.’ Rather, it is critical to think of the embodied water relative to similar projects or industry averages, as these can point to opportunities to target and realise water savings, improve project efficiency, and thereby reduce embodied water and improve sustainability performance.

The recent emergence of sustainability reporting frameworks now facilitate a more comprehensive picture of water consumption and use in the mining industry. The most common protocol used by the mining industry is the ‘Global Reporting Initiative’ (GRI) (now in its third edition, GRI 2006), which requires them to report a range of sustainability indicators covering environmental, economic, social, and human rights aspects of mining. There is a range of key environmental indicators and data that are considered ‘core’ to report against, as well as a range of additional or voluntary indicators. Thus, it is possible to link production data with water data from sustainability reporting and analyse embodied water more comprehensively than in the past.

With regards to the long-term sustainability of mining and water resources, there are a number of fundamental issues that need to be considered. First, the ever-expanding scale of modern mining will require more water to meet growing demands for minerals and metals. Second, long-term declines in ore grades for most metals, e.g. copper (Mudd 2007a; Ruth 1995) or gold (Mudd 2007b), will require ever-increasing amounts of ore to be mined and processed to sustain mineral supply, again suggesting increasing water requirements. To achieve a large ore throughput, projects are typically open cut, giving rise to substantive quantities of waste rock, overburden, and

tailings, which needs to be managed with respect to potential impacts on surface and ground water resources. Third, more refractory ores are now commonly being exploited (Mudd 2007c); these often require more intensive processing and thereby have relatively higher embodied water than less refractory ores. Fourth, the role of mineral processing technology is critical in understanding embodied water—e.g. will heap leaching and solvent extraction–electrowinning realise a lower or higher embodied water than conventional flotation and smelting? Given declining ore grades and more refractory ores, the long-term direction for mineral processing technology is critical to ensure that the embodied water does not increase significantly in the future. Related to this dilemma is the potential compromise between water and energy; that is, reducing embodied water at the cost of increasing embodied energy (e.g. desalination). However, at present, there is minimal data publicly available to enable substantive analysis of all of these issues.

The embodied water of mineral products is clearly a fundamental aspect of sustainable development, and is directly linked to a region’s economic, social, and environmental health. To understand the existing embodied water of mineral products and the potential trends for embodied water in the future, the remainder of this paper compiles and analyses publicly reported data on water and mineral production. As research in the field of sustainability reporting and mining is in its infancy, the work presented in this paper is considered preliminary, though hopefully still useful.

Methodology

As noted previously, the mining industry has now embraced the concept of sustainability, and many companies now commonly report annually on sustainability performance. As a critical aspect of sustainability, water is addressed by most companies, though with variable detail.

Individual mine production data from annual corporate reports were compiled and compared with water consumption data published in sustainability reports (on an annual basis). Extensive data for gold mining was included from Mudd (2007b). To the extent practicable for consistency and comparability, water consumption data was defined as what had been reported as total consumption, including recycled water. Mines have been excluded from the master data set where it was clear that data reported was only raw or recycled water and not both (this is a very small number relative to the master data set). The accumulated data for individual mines range from a single year to nearly 15 years (depending on when a company began sustainability reporting).

Table 1 Companies used for data compilation

Alcan Gove Ltd	Gold fields Ltd	North Ltd
Anglo American Ltd	Goldcorp Inc.	Oxiana Ltd
Anglo Coal Australia Ltd	Harmony Gold Ltd	Perseverance corporation Ltd
AngloGold Ashanti Ltd	Homestake mining company	Placer Dome Inc.
Barrick Gold corporation	Kelian equatorial mining Ltd	Placer Dome Asia Pacific Ltd
BHP Billiton Ltd	Kennecott Ltd (incl. associates)	Resolute Ltd
Codelco Ltd	Leviathan resources Ltd	Rio Tinto Ltd
Comalco Ltd	Lihir Gold Ltd	Rössing Uranium Ltd
Dominion mining Ltd	Mt Isa mines Ltd	Teck Cominco Ltd
Emperor mines Ltd	Newcrest mining Ltd	WMC resources Ltd
Energy resources of Australia Ltd	Newmont mining corporation	Xstrata Ltd
Glamis Gold Ltd	Normandy mining Ltd	Zinifex Ltd

For GRI-based reporting (GRI 2006), water aspects include total withdrawal by source (indicator EN8, core) and the percentage and total volume of water recycled and re-used (indicator EN10, voluntary). A further voluntary GRI indicator is water resources significantly affected by withdrawal of water (EN9). EN9 is rather vague; in addition to native water resources (e.g. streams, ponds), tailings water, ground water abstractions not used in processing, impacted surface or ground water resources, and the like could conceivably be reported. However, EN9 data are rarely reported (the author has yet to find a quantitative example, though some qualitative discussions exist; further comment is provided later).

A complete list of all companies used in this study is shown in Table 1, with a list of metals/minerals and the countries included in Table 2.

Data were analysed with respect to two key metrics: water consumed per tonne of ore processed and water consumed per unit metal/mineral produced (e.g. kL/t ore vs. t ore/year, kL/t metal vs. ore grade). The data have been grouped into principal ore type, since such mines commonly have similar processing and infrastructure. Site-specific aspects, such as underground or open cut mining, heap leaching, solvent extraction or flotation milling, and climatic regime have not yet been analysed in detail, though it appears that some limited interpretation is possible. This simple approach allows the effects of mine scale and lower ore grades on water consumption to be assessed. This approach also allows a comparison between the water consumed by various sectors of the mining industry.

Results

Base metals, bauxite, and energy minerals (black coal and uranium) are presented in one graph while gold, platinum, and diamonds are presented separately. The results for water consumption with respect to ore throughput are presented in

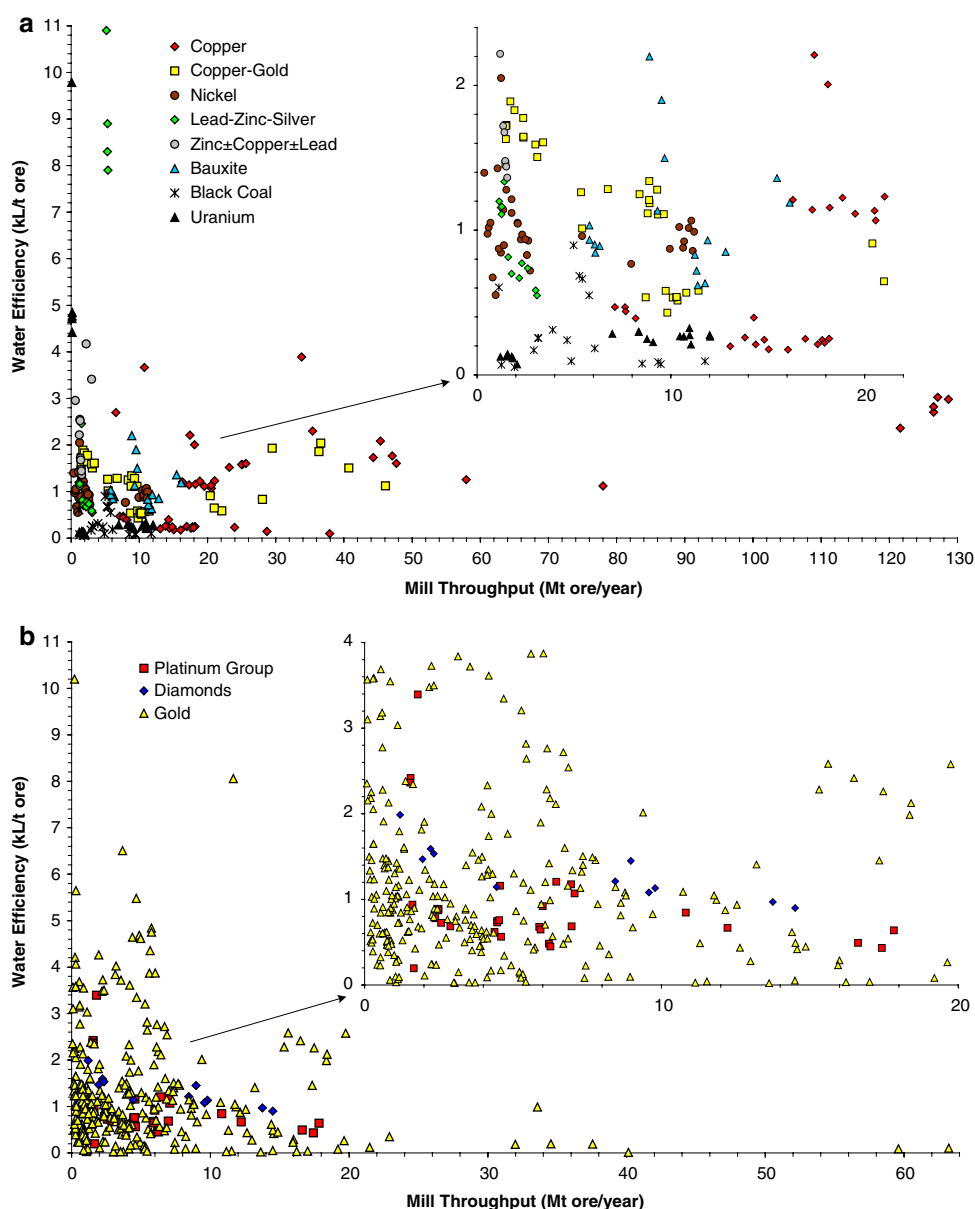
Fig. 1, with insets of parts of each graph enlarged for clarity. In general, the higher the ore throughput, the more likely that unit water consumption per tonne of ore will be lower (i.e. economies of scale), but as ore throughput declines, there is an increasing likelihood that unit water consumption per tonne of ore will be relatively higher (particularly for gold). It is perhaps not surprising that for many significantly different ore types, the unit water consumption is within the same magnitude (e.g. copper, nickel, uranium); this is most likely related to the similar nature of the processing configurations utilised (e.g. grinding, flotation, hydrometallurgy). At common ore throughputs (between 0.1 and 20 Mt/year), there is a degree of scatter in the data, which is likely related to mine site differences, reporting issues, or other factors (discussed further below).

The results for water consumption with respect to ore grade are presented in Fig. 2, including enlarged insets. The ore grades for the metallic ores analysed vary

Table 2 Major mineral commodities and countries incorporated into data compilation

Ore type	Countries	
Bauxite	Australia	Mali
Black coal	Bolivia	Mexico
Copper	Brazil	Namibia
Copper–gold	Canada	New Zealand
Copper–zinc	Chile	Papua, New Guinea
Diamonds	Fiji	Peru
Gold	Ghana	South Africa
Lead–zinc–silver	Guinea	Tanzania
Lead–zinc–silver–copper–gold	Indonesia	United States
Nickel (sulfide)	Ireland	Zimbabwe
Platinum group		
Uranium		
Zinc		

Fig. 1 Water efficiency versus mill throughput: *top* base metals, uranium, bauxite, and black coal; *bottom* precious metals and diamonds



significantly, from about 0.3% Cu to 22.5% Pb + Zn, with the results suggesting that as metallic ore grades decline, there is a strong probability of an increase in embodied water for that metal (s). For gold, platinum group minerals, and diamonds, similar results are apparent, with large ore throughputs showing relative water efficiencies (due to economies of scale); at lower throughputs, while there is significant scatter, it is also clear that lower grades have an increasing chance of very high embodied water per unit metal/mineral.

The combined average data for major mineral ore types is summarised in Table 3, including the total number of years of data for various mines and the standard deviation for that mineral group.

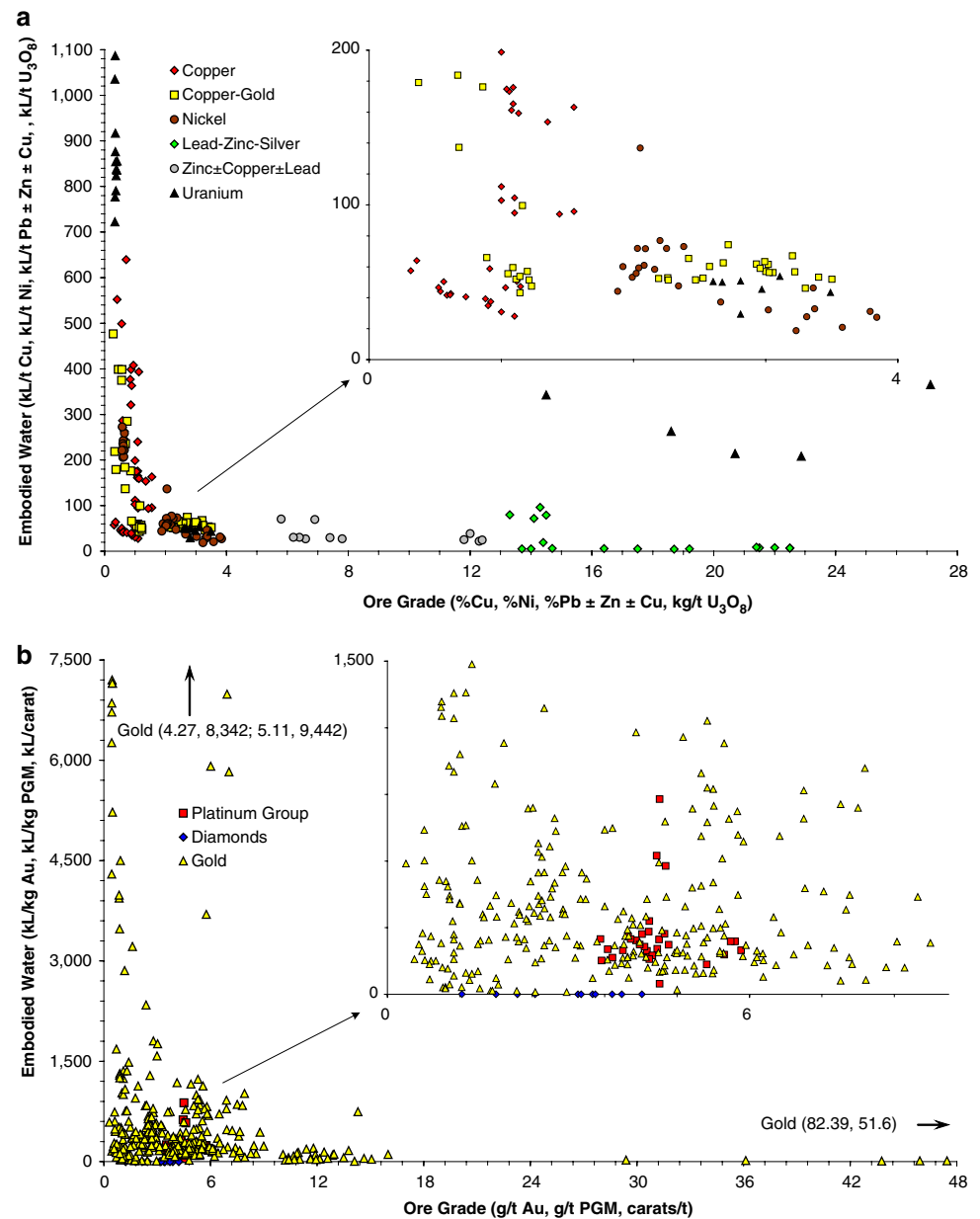
Discussion

There are a range of issues which the compiled data sets raise, centred on water efficiency, embodied water, and especially sustainability reporting.

Water Efficiency

With respect to water efficiency, the compiled data demonstrate two principal aspects. First, the consumption of water per tonne of ore milled with respect to ore throughput (Fig. 1) shows a degree of variability between and within metals and minerals, as demonstrated by the standard deviation being close or equal to the average water

Fig. 2 Embodied water versus ore grade: *top* base metals, uranium, bauxite and black coal; *bottom* precious metals and diamonds



consumption (Table 3). Some mining projects consume significantly more water than other similar projects. For example, one lead–zinc–silver mine consumes 8–11 kL of water per tonne of ore compared to all others at 0.6–2.5 kL/t ore, or a gold mine that consumes 28–48 kL/t compared to all others at 0.5–3 kL/t ore; given site-specific issues and consistency over time, it is believed these examples represent valid data. The trend over time for many mines, though not presented, is variable—with some mines showing efficiency improvements while others have increased water consumption. In general, particularly for precious metals (e.g. gold), data in Fig. 1 suggest that as ore throughput declines, there is an increased likelihood

of higher water consumption. Second, with respect to throughput scale, there is surprisingly no clear evidence that larger scale leads to greater efficiency in base metals and bulk minerals. For example, some porphyry copper projects milling 10–30 Mt/year consume less water per tonne of ore than a porphyry copper project milling 120–130 Mt/year. For gold, platinum, and diamonds, however, there is reasonable evidence (Fig. 1) that a larger project scale does lead to greater efficiency. It cannot be automatically assumed, therefore, that larger-scale projects will help drive economies of scale and lower water consumption per tonne of ore processed. Additionally, larger-scale projects inevitably require larger total volumes of water.

Table 3 Summary data for water consumption and different mineral commodities

Mineral/metal	Total number of years of data	v. ore throughput (e.g. kL/t ore)		v. ore grade (e.g. kL/t metal)	
		Average	SD	Average	SD
Bauxite (kL/t bauxite)	17	1.09	0.44	–	–
Black coal (kL/t coal)	18	0.30	0.26	–	–
Copper (kL/t ore; kL/t Cu)	48	1.27	1.03	172	154
Copper–gold (kL/t ore; kL/t Cu)	42	1.22	0.49	116	114
Diamonds (kL/t ore; kL/carat)	11	1.32	0.32	0.477	0.170
Gold (kL/t ore; kL/kg Au) ^a	311 ^a	1.96 ^a	5.03 ^a	716 ^a	1,417 ^a
Zinc ± lead ± silver ± copper ± gold (kL/t ore; kL/t Zn ± Pb ± Cu)	28	2.67	2.81	29.2	28.1
Nickel (sulfide) (kL/t ore; kL/t Ni)	33	1.01	0.26	107	87
Platinum group (kL/t ore; kL/kg PGM)	30	0.94	0.66	260	162
Uranium (kL/t ore; kL/t U ₃ O ₈)	24	1.36	2.47	505	387

^a If one mine is removed from the data (five points), which ranges from 28 to 48 kL/t ore and 5,800 to 9,442 kL/kg Au, the average and standard deviation become 1.372 and 1.755 kL/t ore and 609 and 1,136 kL/kg Au, respectively

Embodied Water

The embodied water of the mineral commodities presented varies significantly, both between and within ore types. Gold clearly has the highest embodied water per tonne of mineral/metal, with platinum very close behind; this is presumably due to the very low grade of gold and platinum ores (i.e. parts per million compared to percent for base metals). Conversely, the embodied water of base metals varies significantly, clearly related to the ore grades of copper versus lead–zinc or uranium ores. For example, lead–zinc has an embodied water of about 29.2 kL/t Zn ± Pb (± Cu) while copper has 172 kL/t Cu, and uranium 505 kL/t U₃O₈, where ore grade is typically 10–15% Zn ± Pb, 1–2% Cu and 0.04–0.3% U₃O₈, respectively. Lead–zinc and copper ores are often processed first through flotation, meaning the embodied water is largely a function of ore grade, while uranium is processed using hydrometallurgical techniques and the ore grade is fractions of a percent (e.g. 0.04–0.3% U₃O₈). The effect of ore grade, overall, is demonstrated in Fig. 2 for base and precious metals. It shows that high-grade mines will have less embodied water; the lower the grade, the higher the probability of increased embodied water per unit mineral or metal.

The underlying variability in water consumption, both for a given mineral type and between mineral types, suggests that there are a number of factors likely to influence water consumption and hence embodied water. This could include mine type (open cut or underground), ore mineralogy, mill configuration and design (e.g. flotation, hydrometallurgy), water quality, project age, climate (arid, temperate, tropical), long distance slurry pipelines (e.g. >25 km), and finally whether a smelter and refinery is also included. This makes the issue of equivalence between

sites somewhat problematic. Further research is required to undertake the complex process and statistical analysis that might be able to illuminate the principal contributions of the numerous factors identified in the potential embodied water of metals and minerals.

Sustainability Reporting

A critical area of sustainability reporting is water consumption and resources (GRI indicators EN8, 9, and 10). This paper has not included an analysis of the proportion of companies reporting specifically under each indicator, although EN9 is particularly rare (with only qualitative examples observed infrequently in reports).

A critical issue in ensuring that the embodied water is equivalent between operations is the clarity of data reported. Some companies and/or mines appear to report data under EN8 (total water withdrawal by source) differently than other similar mines. When projects with a similar configuration (mill, climate, mine type, etc.) report significantly different water consumption, is this due to greater conservation/efficiency or a different way of compiling the data? In addition, the proportion of water reportedly re-used or recycled (indicator EN10, voluntary) for the same mine can vary significantly over time. Sometimes this is due to the implementation of water efficiency projects, or changing mine ownership, corporate sustainability assessment, or reporting procedures, but more commonly there is no explanation given for major fluctuations over time. For example, one copper–gold mine used to report total water consumption of about 2.2–2.6 GL/year (5 years data), but this suddenly changed to 0.6 GL/year (3 years data), without any report of water recycling or any discussion of changing corporate reporting practice. As this mine has undergone no change in

configuration during this time, the sudden decline in reported total water consumption has been cautiously interpreted to be due to a high degree ($\approx 75\%$) of water recycling and a change in corporate ownership and associated policies and procedures, though the relevant sustainability reports do not discuss or elaborate on such aspects. A further example is a copper heap leach mine, where although water is re-circulated extensively, the only reported water consumption for many years has been drinking water (and hence this site was excluded in the data presented). Given that many companies do not report re-use or recycling under EN10, it is difficult to trust data under EN8 since almost all mines practice water re-use and recycling (some even claim 100% recycling), e.g. reclaim water from a tailings dam.

A substantive volume of water at mining projects is often contained in either water retention ponds or tailings storage facilities. In theory, indicator EN9 (water resources significantly affected by withdrawal of water) could be adopted to report year end totals for such water storage. In practice, it would be easier to report against by assigning separate indicators to such water resource aspects.

Additionally, many mining projects treat large volumes of contaminated waters to a standard that minimises potential environmental issues (e.g. to allow discharge during a wet season). This water is not ‘consumed’ directly in milling and so is variably included or not as total water consumed (i.e. indicator EN8) in reports.

A further area of weakness in the current GRI guidelines is that of water quality. At present, there is no indicator for the quality of the water consumed, the water source, or the potentially impacted water resources. Typically, water is generally judged suitable for particular uses based on salinity, although trace elements can be very important (primarily nutrients, heavy metals, or radionuclides), especially in acid and metalliferous drainage situations where mine drainage is causing severe pollution. Thus, in assessing the equivalent ‘embodied water’ of minerals, should water of any water quality be considered equal? When there are multiple sources of water of varying quality for a given mining project, how should this be assessed and reported? Furthermore, how should impacts on water resources of varying water quality, such as seawater versus fresh water, be treated in terms of sustainability reporting? These questions are clearly critical in any realistic assessment of embodied water with respect to mining and sustainability but current practice cannot address them.

The number of mining companies using the GRI guidelines for sustainability reporting is increasing, and this is helping to facilitate greater consistency in reports. However, the fact that indicator EN10 remains voluntary severely hampers trust in other reported data, such as water consumed (EN8—like the Cu–Au example). Given the

significant degree of water re-use and recycling in most mining projects, it makes sense that indicator EN10 should be core. There is also a strong case to consider reporting other water streams for mining projects such as stored waters in tailings facilities and retention ponds as well as treated waters. Most of this data, if not all, is already collected to facilitate sound operational performance and manage associated water-related risks.

The question of the full extent of data to be reported by the mining industry on water issues is multi-faceted. Many communities, governments, and shareholders expect accountability for the rights given to mines and companies for their access to water and the potential impacts that mining can have on water resources—both during operation and after rehabilitation. It is therefore reasonable for stakeholders to expect sufficient detail and rigour in sustainability reporting, which facilitates sound understanding of performance against permits, licences, and other relevant criteria (e.g. GRI indicators). All that needs to occur is for existing data to be used more systematically for sustainability reporting. In order to address this in the future, reporting procedures need to be tightened and public sustainability reporting needs to be more transparent, explicit, and consistent over time. For example, GRI indicators EN9 and EN10 could be made compulsory, with new indicators for water quality and minesite water inventories.

Finally, the issue of mandatory or voluntary reporting is somewhat vexing. The GRI is a voluntary system although it is increasingly being adopted by mining and many other sectors. A complicating issue is that a company can choose how they adopt the GRI—in part or in whole. There is one view that all water-related data should be made mandatory in the GRI, or through the additional mining sector supplement (GRI 2005). However, an alternative view is that water resource management is a fundamental role of government. The presentation of extensive water data in sustainability reporting does not impede this, and indeed should help to improve water resource management, transparency, and accountability by all involved. Ultimately, whether the GRI and all water data should be made compulsory remain critical policy decisions at the community, corporate, and government level.

Mining is the first stage in the production of minerals and metals, with many projects producing a metal concentrate that is shipped to smelters and then to refineries. To produce a given tonne of pure metal (or mineral), there is often significant additional water required by the smelting and refinery stages. The choice of smelting technology significantly affects the embodied water for numerous metals (e.g. Norgate and Lovel 2006). For complete life cycle assessments of the embodied water of metals and minerals, it is critical to ensure that all relevant stages are assessed, although this is often beyond the scope

of mining companies alone (unless they also operate smelters and refineries in conjunction with projects, e.g. Mt Isa, Olympic Dam).

It is clear that sustainability reporting of water issues is still evolving and that the scale and complexity of these issues is only beginning to be realised with respect to mining.

Conclusion

This paper has presented a preliminary compilation and analysis of the water reported to have been consumed by a range of various mineral commodities with respect to mine production data. This has been undertaken to assess and quantify the embodied water of mineral products, a key aspect of sustainability. At present, although the use of formal reporting protocols such as the GRI is increasing, there are still critical weaknesses. Some key aspects to facilitate proper water accounting are not reported in sustainability reports, including the extent of recycled water used, minesite water inventories, the quality of various waters, and the impacts on water resources. Based on the compiled data, there is wide variation in the amount of water used for different mineral commodities as well as for the same commodity. There is little evidence for ‘economies of scale’ in base metals and bulk minerals, though for precious metals (gold, platinum), greater throughput does tend to lead to greater efficiency. For many mines, there is little evidence of improving efficiency over time, although some mines have apparently made substantive improvements in reducing water consumed. The potential factors underlying the variability in embodied water, such as mine type, mill configuration, ore characteristics, climate, requires further research. The grade of ore being processed is clearly critical in understanding the embodied water of minerals, with declining ore grades leading to an increased chance of higher embodied water into the future. Given that many metals are declining in average ore grade, the sensitivity of embodied water to ore grade provides a major sustainability challenge for mining generally. In summary, the embodied water of minerals is clearly significant, looks likely to gradually increase in the future, and must be more completely accounted for to understand a fundamental aspect of sustainability, that of water resources.

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