Journal of Cleaner Production 21 (2012) 71–82

Contents lists available at SciVerse ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

Reducing mine water requirements

A.J. Gunson*, B. Klein, M. Veiga, S. Dunbar

Norman B. Keevil Institute of Mining Engineering, University of British Columbia, 517 6350 Stores Road, Vancouver, BC V6T 1Z4, Canada

ARTICLE INFO

Article history:
Received 27 January 2011
Received in revised form
20 August 2011
Accepted 25 August 2011
Available online 31 August 2011

Keywords:
Mine water
Water consumption

ABSTRACT

Mining is a water intensive activity, and reducing water consumption is a key requirement in moving toward a more sustainable mining industry. This paper identifies mine water reduction, reuse and recycle options, and demonstrates cases where these options have been implemented around the world. A mine water system model is developed and used to show potential water saving strategies through six scenarios. Apart from the base case, these scenarios include the introduction of evaporation reduction strategies, paste tailings disposal, filtered tailings disposal, ore pre-sorting and a combination of the most effective options. The results of the modeling show how an open-pit copper mine with a traditional layout can move from having an average water withdrawal of 0.76 m^3/t of ore processed to 0.20 m^3/t of ore processed or lower. A key result of the modeling is the discovery that a combination of ore pre-concentration and filtered tailings disposal can reduce water consumption by 74% or more. This finding demonstrates an opportunity to significantly lower water consumption on mine sites.

1. Introduction

Mining consumes large quantities of water; the copper mining industry alone withdrew over 1.3 billion m^3 of water in 2006 (Gunson et al., 2010b). On a global scale, however, mine water use accounts for a small portion of overall water use. Even in relatively dry, mining-intensive countries like Australia, Chile, and South Africa, mine water consumption is only 2–4.5% of national water demand (Brown, 2003; Bangerter et al., 2010). Nevertheless, when mining takes place in areas where water is scarce, mine water consumption can severely impact local supplies. Acid rock drainage, leaks from tailings or waste rock impoundments, or direct disposal of tailings into waterways can additionally contaminate surface and groundwater (MMSD, 2002; Nedved and Jansz, 2006; Akcil and Koldas, 2006; Cohen, 2006). Mines require large pumping, treating, heating and/or cooling water systems, which are often large energy consumers. Better mine water systems can reduce both water and energy consumption. Improving water system design and practice are key strategic requirements in moving toward a more sustainable mining industry.

This paper addresses conventional base-metal or precious-metal mine sites, which typically consist of an underground and/or open pit mine and a mineral processing plant, or mill. Ore is extracted from the mine and processed through the plant to produce a saleable concentrated product. Tailings, or waste material, are then deposited in a tailings storage facility (TSF). Any rock removed from the mine with no economic value, or waste rock, is stored without being processed. Most mills use wet processes, such as froth flotation, in order to separate valuable minerals from the non-valuable minerals in the ore. Wet processes can use large quantities of water. Flotation, the most common separation process, typically takes place at 25–35% solids by mass. A plant not reusing or recycling any water would thus require 1.9–3.0 m^3 of water per tonne of ore processed. In addition to flotation, water is used for various applications including grinding, screening, dust scrubbing, wash water, dust suppression, pump gland seal water (GSW), and reagent mixing. However, most major mines now practice at least some water reuse and recycling. Modern mines often recycle all available water; in Canada, metal mines recycle a higher percentage of water than any other industry (Statcan, 2008). The high rate of water recycling means water consumption depends not on the amount of water required for individual unit operations, but the amount of water lost to permanent water sinks, such as evaporation, seepage or retention in the concentrate or tailings material. Brown reported that average mine water use currently ranges from 0.4 to 1.0 m^3/t of ore processed (2003). A cross-sectional study of water usage in the copper mining industry in 2006 found that conventional flotation-based copper mines' water withdrawals ranged from 0.34 to 2.07 m^3/t of ore processed, with a weighted mean of 0.96 m^3/t (Gunson et al., 2010b).

* Corresponding author. Tel.: +1 604 720 9863; fax: +1 604 822 5599.
E-mail address: ajgunson@interchange.ubc.ca (A.J. Gunson).

0959-6526/$ – see front matter
doi:10.1016/j.jclepro.2011.08.020

Key terms in this paper are defined as follows:

- Raw water refers to water that is brought to or captured on site and has not been previously used for any purpose within the site. Typical sources include surface water, groundwater, sea water or water from an external industrial or municipal site.
- Water withdrawal refers to any raw water captured or brought to site.
- An operation in a mine that involves water, such as dust suppression, is referred to as a task or a water user (ADRET, 2008). A water user requires water directly from a raw water source or from reused or recycled water.
- Reuse is when water from one user is passed directly to another user without transformation. An example would be using discharged cooling water directly for another task in a plant.
- Recycling is when water is treated to improve its quality before it is reused, through a method like clarification or filtration.
- Water consumption refers to raw water that has been made unavailable for reuse in the same basin, such as through conversion to steam, losses to evaporation, seepage to a saline sink, or contamination (Gleick, 2003).
- Water stores are facilities on the site that hold and/or capture water (Cote et al., 2009).

This paper first details past approaches used or suggested to improve mine water system performance by reducing mine water consumption and reusing or recycling water available on site. A mine water system model is developed and six scenarios are used to show the potential water and energy saving achievable using these approaches. This paper demonstrates how to quantify the individual and combined potential impact from different water saving approaches.

While all the water saving options described here have been described elsewhere, this is the first model that allows a quantitative estimate of the individual and combined effects of a variety of different water saving options. A key finding is that the combination of ore pre-concentration and filtered tailing disposal can dramatically reduce mine site water consumption.

2. Mine water and energy use in the context of sustainable development

Over the past two decades, civil society and governments have encouraged the global mining industry to move toward sustainable development, a move now largely accepted by the industry (NRCan, 1994; MMSD, 2002; ICMM, 2003; MAC, 2004). With respect to mining, sustainable development has encompassed a number of areas including corporate social responsibility, human rights, risk management, health and safety, biodiversity and the environment, recycling, community relations and transparency. Much has been written about applying sustainable development industrial or business models to the industry to allow companies to address these areas (Hilson and Murck, 2000; Damigos, 2006; Basu & van Zyl, 2006; van Berkel, 2007a; van Berkel, 2007b; Handelsman, 2009). Kemp et al. (2010) focus specifically on the impact of mine water use on human rights.

Continual improvement of environmental performance and environmental management systems in mining is a key facet of the push toward sustainability (MMSD, 2002; ICMM, 2003; MAC, 2004; Hilson and Nayee, 2002; Hilson, 2003; Driussi and Jansz, 2006a,b). Hilson (2000) has also discussed the significant legislative, technical, and economic barriers the mining industry faces in implementing cleaner technology. van Berkel (2007a) undertook a comprehensive review of efforts to integrate sustainability into the mining industry. He described five hierarchical levels of models for environmentally friendly sustainable business operations and categorized commonly known models such as Industrial Ecology, The Natural Step, Green Engineering, Eco-Efficiency and Cleaner Production within these levels. A common theme in these models is the need for the mining industry to improve the efficiency of water use.

Several efforts have been made to quantify and understand mine water use, with a focus on life cycle analysis and key indicators (Azapagic, 2004; Norgate and Lovel, 2004; Suppen et al., 2006; Mudd, 2008, 2009; Tejos and Proust, 2008; Worrall et al., 2009; Cote and Moran, 2009; Cote et al., 2009; Norgate and Haquea, 2010). For mining companies aiming to improve the efficiency of their water use, there are dozens of options available, including water recycling, reducing evaporation and reducing the water content in concentrates and tailings (Gunson et al., 2010a). Some companies, such as Rio Tinto, have well thought-out water management policies (Rio Tinto, 2010). However, little work has been done on how to systematically design water systems specifically related to the mining industry. The best available efforts include The Centre for Water in the Minerals Industry at the Sustainable Minerals Institute, University of Queensland, which has developed a "hierarchical conceptual systems approach" to analyze mine water management (Cote et al., 2007a), and the South African Department of Water Affairs and Forestry best practice guidelines on mine water management (DWAF, 2006a). In addition, the World Resource Institute has released a working paper on water-related risks associated with the mining industry (Miranda et al., 2010).

3. Options to improve mine water system performance

The first step toward improving or designing mine water systems is to develop a good understanding of the mine's existing system. No effort should be undertaken to improve a mine water system until a reasonably accurate site water balance has been completed. Putting effective water metering technologies or methods in place and having an accurate site water model is critical (ERS, 2008; Mayer et al., 2008; ICMM, 2009; DWAF, 2006b). Mining companies should consider implementing a comprehensive water management strategy; Gibson et al. (2003) describe an example of such a strategy. Any water management plan should ensure that existing facilities are well run and maintained. Basic steps such as fixing leaky pipes and valves, replacing undersized or worn-out pumps, and improving thickener or clarifier operation can lead to inexpensive and impressive improvements (Chambers et al., 2003; Stegink et al., 2003; Thompson and Minns, 2003).

Better water system design revolves around two key concepts: first, running all processes at the highest solids density possible without negatively impacting the process and, second, supplying all processes with the poorest acceptable quality water, that does not impact process performance (Bagajewicz, 2000; DWAF, 2006a).

Past efforts to improve mine water system performance by reducing mine water consumption and reusing or recycling water available on site can be categorized into the three components of the decades-old waste management hierarchy: reduce, reuse, and recycle.

Efforts to reduce mine water use include:

- Reducing wet area/open area in the TSF
- Reducing clay generation during grinding to lower tailings water retention
- Improving tailings thickener performance
- Reducing water losses through thickened tailings or paste tailings disposal