Research paper

Life cycle cost estimation and environmental valuation of coal mine tailings management

Joni Safaat Adiansyah a, b, *, Michele Rosano a, Wahidul Biswas a, Nawshad Haque c

a Curtin University, School of Civil and Mechanical Engineering, Sustainable Engineering Group, Perth, Australia
b Universitas Muhammadiyah Mataram, Department of Mining Engineering, West Nusa Tenggara, Indonesia
c CSIRO Mineral Resources, Private Bag 10, Clayton South, VIC 3169, Australia

1. Introduction

Environmental management is a crucial tool for any activity that generates adverse impacts and mining is one such activity. Mining operations pose potential hazards to human health and the environment during exploration, production, and closure stages (Adiansyah, Haque, Rosano, & Biswas, 2017). These impacts, presented in Table 1, should be avoided/minimized and managed to prevent environmental disasters. Developing hazard management strategies is also necessary in order to obtain a social license to operate mines.

The first step of managing environmental impacts is to prepare a comprehensive environmental management plan. This document mainly describes potential environmental impacts and risks, environmental monitoring, measurement activities, control strategies, and environmental audits (Commonwealth of Australia, 2014). The tools that are usually employed to study the environmental impacts of different systems include life cycle assessment, life cycle costing, net present value, and benefit-cost analysis (Ahlroth, Nilsson, Finnveden, Hjelm, & Hochschorner, 2011; Erkayaoglu & Demirel, 2016; McLellan, Corder, Giurco, & Green, 2009). These tools can be used to determine the feasibility of the environmental management strategies for mining operations.

Tailings, categorized as mine waste, are among the materials that might contribute to environmental contamination, as presented in Table 1. In coal mining, tailings are generated from fine coal, which represents about 10–20% of the Coal Handling and Preparation Plant (CHPP) feed (Honaker, Kohmuench, & Luttrell, 2013; Kumar, Bhattacharya, Mandre, & Venugopal, 2014). There are two main arguments for considering coal mine tailings to be a critical issue in waste management. First, global coal reserves are estimated to be 860 billion tonnes (Thomas, 2013). Second, coal is listed as the second-largest energy source in the world (Energy Information Administration, 2016; Perusahaan Listrik Negara, 2015; World Nuclear Association, 2013). The International Energy Outlook 2016 report published by the U.S. Energy Information Administration predicts an increase in coal consumption between 2012 and 2040 at an average rate of 0.6% per annum (Fig. 1) (Energy Information Administration, 2016). This means that the global consumption of coal could increase from 153 quadrillion Btu in 2012 to 180 quadrillion Btu by 2040, which would cause a
corresponding increase in the volume of tailings.

Mining projects currently apply various types of tailings disposal strategies, including conventional tailings disposal, thickened tailings, and tailings paste (Adiansyah, Rosano, Vink, & Keir, 2015). The two most important sustainability indicators (water and energy) used for selecting the best tailings disposal method are discussed by Adiansyah, Rosano, Vink, Keir, and Stokes (2016). This study assesses the links between these indicators in order to determine the feasible scenario associated with water and energy consumption. The implementation of sustainability criteria in all mining activities has also been endorsed by the International Council of Mining and Metals (ICMM) since the organization was introduced by Adiansyah et al. (2015) and consists of eight steps including analyzing the water-energy nexus, environmental assessment, and economic analysis. These steps enable mining companies to determine the most effective and efficient strategy for the disposal of their tailings.

Mining development also requires a large investment for capital expenditures and operating costs. For example, a copper mine in Indonesia that produces around 240 million attributable pounds of copper annually has an initial investment of approximately US $1.8 billion (Newmont, 2016; Newmont Nusa Tenggara, 2016). Other examples include the Barruecopardo project in Spain with a total capital cost of €70 million, the Hemerdon project in the United Kingdom with a total operating cost of £12.48 per tonne of ore, and the Pilbara Iron Ore project in Western Australia with a direct mine capital cost of AUS $726 million (Gordon, 2014; Sánchez et al., 2015). Therefore, cost becomes one of the critical factors when determining the feasibility of mining development projects.

Mining companies commonly conduct financial analysis at the beginning of a project, i.e. at the planning stage. Life cycle costing (LCC) and environmental valuation are two commonly used tools to assess various options necessary for mining operations including mine tailings disposal, processing technology, and power generation. These options assist decision makers in selecting the most appropriate strategy for the exploration, production, and post-mining stages.

LCC and environmental assessment have not been studied as widely in the mining industry as in other fields, such as building and forestry. Epstein et al. (2011) discussed the LCC of coal mining in the Appalachia region of the United States. The life cycle considered in that study was extraction, transport, processing, and combustion. The cost analysis, called the “externalities cost”, was based on a waste stream that created multiple impacts on human health and the environment. The authors proposed a number of recommendations including reducing the number of coal-fired
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