Sustainability Management Accounting Techniques for Acid Rock Drainage Management: A Literature Review

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Abstract

Acid rock drainage (ARD) is a sustainability problem in the mining industry, which requires considerable efforts for its management. This paper addresses the environmental, social and economic issues associated with ARD prevention and assessment. Although hydrological and mineralogical tools have been generally used in these two managerial parts of ARD, Sustainability Management Accounting Tools (SMATs) as instruments useful in providing sustainability information have never been implemented. Therefore, various SMATs are presented for effective management of ARD prevention and assessment. Moreover, the findings propose ways that these may help to solve problems in a sustainable manner.

Keywords: Acid rock drainage, prevention, assessment, sustainability management accounting tools

Introduction

Acid rock drainage (ARD) and acid mine drainage (AMD) are major environmental problems occurring during and after mining activities (de Almeida et al. 2015: 353, Wolkersdorfer 2008) and might pollute land or local ground and surface water (Fan et al. 2017). This leads to water quality problems, scarce water resources and menace to aquatic animals (Dyantyi 2014). Above all, it may pose a threat to human health (Betrie 2014). Therefore, two sustainability elements, namely environment and community are main concerns of ARD. While ARD management focuses on the minimization of environmental influences (Frostad 1999, Wolkersdorfer 2008), costs remain a main challenge and economic incentives can be important for decision-making (Fan et al. 2017, Kazadi Mbamba et al. 2012: 13). Hence, both environmental impacts and financial benefits are substantial elements of ARD management (Nleya et al. 2016). However, sustainability has been poorly perceived in ARD management. Furthermore, its components, including environmental, social and economic aspects, are often taken only separately into account. Developing effective ARD management strategies is therefore a challenge, since these strategies should be aligned with ARD risks (Parbhakar-Fox et al. 2014: 11). In line to these strategies, various models and methods have been used as ARD tools to provide geological, hydrogeological and mineralogical information (Parbhakar-Fox and Lottermoser 2015, Becker et al. 2015: 33). However, although ARD is naturally associated with sustainability issues, sustainability models and methods have never been developed and implemented, besides sustainable rehabilitation as a focus of Anawar (2015). Nevertheless, such tools could be helpful in providing environmental, social and economic information and they could be flanked by employing Sustainability Management Accounting (SMA). SMA can be understood according to Arroyo (2012: 287–288) and Maas et al. (2016:241) as the generation/collection, analysis and use of monetary and non-monetary sustainability information in order to achieve

and communicate organisational, environmental, social, and economic performance, i.e. a sustainable organisation.

This paper aims to determine, by means of a literature review, the extent to which sustainability is considered in ARD management and to show how Sustainability Management Accounting (SMA) could help in this area. Therefore, it discusses sustainability management accounting techniques that are able to support the delivery of sustainability information associated with ARD prevention and assessment. Problems associated with the integration of sustainability into ARD are investigated in order to identify appropriate sustainability management accounting tools (SMATs) that could be used for the effectiveness of its management in general and particularly of its prevention and assessment.

Literature Review

Sustainability Issues in Acid Rock Drainage Management and Possible Anchor Points for Sustainable Management Accounting

This section reviews the environmental, social and economic problems associated with ARD prevention and assessment. Environmental issues have been the concern of some recent studies conducted in ARD prevention and assessment. For instance, Abrosimova et al. (2015) evaluated two combinations of test protocols to refine the predictive accuracy of the acid potential. Their findings showed that the most ecologically dangerous species predominated in the drainage solutions, and the co-precipitation with goethite and hematite had a positive effect on the environment. Therefore, as already acknowledged by Jasch (2003), there appears to be a need to identify such environmental influences physically and monetarily. In a like fashion, Betrie et al. (2015, 2016) offered a methodology for assessing ecological risks through probability bounds. They found the existence of a high probability of ecological risk caused by metals transported into a nearby lake, requiring the implementation of probability estimation techniques. Regrettably, the probabilistic risk analysis method implemented by Saha et al. (2017) was found to be difficult since the input parameters failed to be remediated as fixed-point values. Hence, this may require the use of appropriate tools. However, Zmijewski (1984) already asserted that the lack of using appropriate estimation techniques leads to biased parameters in the study on methodological issues associated with the estimation of Financial Distress Prediction Models. These parameters include: oversampling falling within choice-based sample biases and the "complete data" falling into sample selection biases. Hence, there is a need of good probability estimation techniques that could provide reasonable probability information. Further, Jeen et al. (2014) evaluated the mixtures of amendments for treatment of acid rock drainage. While the cost of reactive material was low, long-term maintenance costs were required. Nevertheless, the implementation of organizational decision making often pays only little attention on regular maintenance costs (Fryling 2010). Thus, it would be useful to have an estimation maintenance costs technique.

Both environmental and economic problems have been addressed by Nuzzio et al. (2011) through the assessment of techniques used to differentiate and identify water samples from different ARD sources. They believe that this will economically control ecological changes and remediation efforts. Therefore, it will be necessary to develop monetary techniques for controlling environmental development as e.g. explored by Darnall and Edwards (2006). Furthermore, Alakangas et al. (2013: 7908) used mixtures of methods as a neutralization fashion of preventing ARD. They found that economic and logistical factors could be the limitation to supplementary neutralizing materials. Logistics costs are countless and considerably unstable which has led to them being estimated as high (Engblom et al. 2012). Therefore, there appears to be a need of identifying such costs for material acquisition. Moreover, environmental problems were also presented by a high potential of pH leachates, requiring the identification of adequate information addressing them in the context of ARD prevention. Further, Mäkitalo et al. (2014) applied the green liquor dregs for preventing ARD formation and mitigating its negative effects including environmental deterioration and high maintenance costs which required the reduc-

tion of such expenses (Kokubu and Kitada 2015). To assess the environmental and human toxicity, Life Cycle Assessment was used by Broadhurst et al. (2015) to evaluate the broader environmental consequences of the pre-disposal treatment. Although the process revealed substantial reduction in the effects of ARD on human toxicity and eco-toxicity to the environment, some effects, such as more carbon consumption, fossil fuel depletion, terrestrial acidification higher emissions of carbon dioxide, sulfur dioxide and xanthate to the environment, were remarkable. Hence, the authors recommend the environmental benefits capture of improved resources. Therefore, techniques should be able to provide information about the state of the present and the future of an environment and the community as well as about the benefits of its management, even though, from the operational level, not all environmental issues can be addressed (Papaspyropoulos et al. 2012).

Finally, the environmental, social and economic problems associated with the use of mine technology for the minimization of acid formation were revealed by Kefeni et al. (2017). This included alternative solutions for the environmental problems caused by AMD, the reduction of environmental pollution, an employment rate increase and the establishment of cost treatment and benefits. This requires the use of sustainability tools.

Sustainability Management Accounting Techniques (SMAT)

SMATs reviewed in this paper include: Environmental Management Accounting, EMA (Jasch & Lavicka 2006: 1214, 1226; Sands et al. 2016: 135), which encompasses both the monetary and the physical aspects (Burritt et al. 2002: 39, 48f). Also, the link between EMA and Environmental Reporting is useful in disclosing ecological information merely for industry activities associated with environmental impacts (Sulaiman and Mokhtar 2012: 85, 97). EMA metrics for internal decision-making include both: physical metrics for material and energy consumption, flows, and final disposal, and monetarized metrics for costs, savings, and revenues related to activities with a potential environmental impact (Jasch 2003). Cost-Volume-Profit Analysis provide probability information in supporting decision-making under uncertainty, and Risk Heat Maps focus on the internal control of the likelihood and the impact of physical asset risk by representing the resulting qualitative and quantitative evaluations of the probability of risk occurrence and providing visual information about the risk assessment process (CGMA 2016). Cost-Benefit Analyses provide information for prioritizing the measurement and effectiveness of disaster risk management (Mechler 2016). In addition to this, Petcharat and Mula (2009: 56) applied the Activity-Based-Costing method, in which environmental and social cost information is delivered to support internal decision-making. Similarly, Rodríguez-Olalla and Avilés-Palacios (2017: 1, 7, 10, 13f) suggested the incorporation of an Activity-Based Sustainability model for the delivery of information supporting all activities involved in the business process. Moreover, van Heeren (2001: 1, 2, 12) implemented the Balanced Business Scorecard and in a similar fashion, Sands et al. (2016: 134–135) the Sustainability Balanced Scorecard for the measurement of sustainability performance. Environmental performance indicators summarise environmental data into relevant information enabling the control, target setting, outlining performance improvements, benchmarking and reporting (Jasch 2009), while Risk Management Accounting can be useful in identifying, assessing, treating, monitoring risks and evaluating its effectiveness (Soin and Collier 2013). Multi-Criteria Decision Analysis and Costs Probability distributions can be used for prediction and decision making purposes.

Learnings from Literature: SMATs for ARD

Above, we revealed firstly, environmental issues and secondly, three groups of concurrent sustainability problems associated with ADR prevention and assessment such as environmental and economic, environmental and social as well as social and environmental, social and economic. Applying SMATs as presented earlier, allows responding to these concerns as follows:

Environmental solutions: In order to facilitate the identification of environmental impacts

as addressed by Abrosimova et al. (2015), Environmental Performance Assessment may be combined with Management Accounting Control to assess positive environmental impacts and collect environmental information for the management and maintenance of these impacts. The Activity-Based Sustainability model may be useful in supporting all activities involved in the identification of environmental impacts, while the Sustainability Balanced Scorecard can enable the measurement of environmental impacts and their benefits. Besides this, it also provides Environmental Performance Indicators that can be used for future performance improvement. Environmental Reporting can be used to report the actual state of the mine site environment. Moreover, Multi-Criteria Decision Analysis allows for future decisions about measures, strategies formulation and costs involved in maintaining these positive impacts. In relation with the issue raised by Betrie et al. (2015, 2016), both, Cost-Volume-Profit Analysis and Risk Heat Map allow assisting the assessment of ecological risk. The former technique provides reasonable probability information to support decision-making under uncertainty as well as information on the future volume of activities related to of the environmental risk assessment as well as the estimated costs and future benefits of such activities. The later tool quantitatively and qualitatively assesses the risk and its impacts. Costs Probability distributions can be used for the prognosis of environmental risks caused e.g. by metals transported into a nearby lake, estimated costs, probable effects and possible decision-making purposes. Furthermore, these profanities have to be analyzed. Risk Management Accounting can control all processes of risks management including identification, assessment and treatment of potential dangers of the mine site. In order to solve the problem associated with long-term maintenance costs for ARD assessment, as revealed in the study of Jeen et al. (2014), Environmental Management Accounting can provide satisfactory information about all current and future costs associated with the maintenance of the mine site. This can help in determining costs at a low rate. In the same way, these techniques will assist in providing information on the environment in terms of maintenance reduction costs problems as addressed by Mäkitalo et al. (2014), likewise to overcome the economic, logistical factors and material acquisition that could be the limitation to ARD prevention (Alakangas et al. 2013: 7908).

Environmental and Economic Solutions: In response to Nuzzio et al. (2011), Environmental Cost Management is suggested for the monitoring of current and future costs associated with the effects of ecological changes and of remediation efforts respectively to ARD assessment. Accordingly, this will develop the benefits of ARD assessment.

Environmental and Social Solutions: For the case described by Broadhurst et al. (2015), information may be available within the Environmental Management Accounting tool; in particular, its physical component can be used to prevent and assess physical environmental damages through relevant information.

Environmental Social and Economic Solutions: Activity-Based Costing and Activity-Based Sustainability can be simultaneously used to deal with the problem mentioned by Kefeni et al. (2017). While the first method deals with environmental and social cost information, the second one supports all activities involved in the process of ARD impact assessment. Thus, together they can effectively support the internal decision-making. Above these, management accounting tools allow for the provision of sustainability information (Matambele, 2014: VI) through the collection of information related to sustainability problems, effects, impacts, assessment, reparation and costs.

Conclusions

Our results show that ARD prevention and assessment firstly face environmental problems and secondly simultaneous environmental and economic, environmental and social as well as environmental social and economic issues. This confirms that sustainability is a fundamental concern for ARD management. Since SMA allows for monitoring, evaluating managing and communicating sustainability issues, this paper suggested various SMATs with the potential of solving the mentioned

problems. The findings support the view that SMATS could be indeed helpful and suitable for the effectiveness of ARD prevention and assessment.

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