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Model of environmental life cycle assessment for coal mining operations

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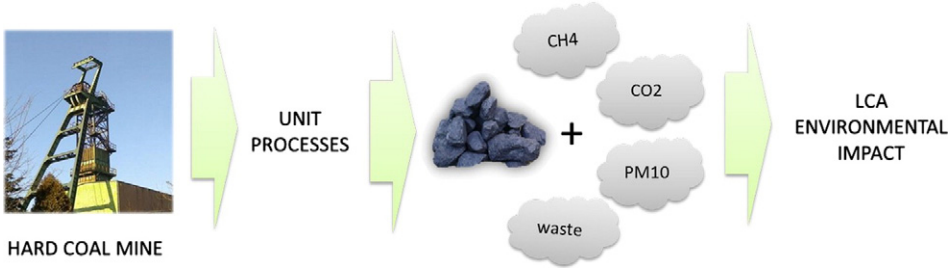
HIGHLIGHTS

- A computational LCA model for assessment of coal mining operations
- Identification of the unit processes of coal mining operations
- Greenhouse gas emissions of the coal mining operations in Poland
- Damage categories of the coal mining operations at a national level

GRAPHICAL ABSTRACT



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ABSTRACT

This paper presents a novel approach to environmental assessment of coal mining operations, which enables assessment of the factors that are both directly and indirectly affecting the environment and are associated with the production of raw materials and energy used in processes. The primary novelty of the paper is the development of a computational environmental life cycle assessment (LCA) model for coal mining operations and the application of the model for coal mining operations in Poland. The LCA model enables the assessment of environmental indicators for all identified unit processes in hard coal mines with the life cycle approach. The proposed model enables the assessment of greenhouse gas emissions (GHGs) based on the IPCC method and the assessment of damage categories, such as human health, ecosystems and resources based on the ReCiPe method. The model enables the assessment of GHGs for hard coal mining operations in three time frames: 20, 100 and 500 years. The model was used to evaluate the coal mines in Poland. It was demonstrated that the largest environmental impacts in damage categories were associated with the use of fossil fuels, methane emissions and the use of electricity, processing of wastes, heat, and steel supports. It was concluded that an environmental assessment of coal mining operations, apart from direct influence from processing waste, methane emissions and drainage water, should include the use of electricity, heat and steel, particularly for steel supports. Because the model allows the comparison of environmental impact assessment for various unit processes, it can be used for all hard coal mines, not only in Poland but also in the world. This development is an important step forward in the study of the impacts of fossil fuels on the environment with the potential to mitigate the impact of the coal industry on the environment.

1. Introduction

Poland is one of the top ten world producers of coal, and its annual production of coal is approximately 70 million tons (IEA, 2014). Currently, there are 31 coal mines in Poland. At the end of 2014, there were nearly 71 billion tons of hard coal in Polish coal mine deposits, of

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which 3.76 billion tons were operated. According to Durucan et al. (2006), the world currently produces approximately 6.5 billion tons of coal annually. Production of hard coal is crucial for providing Poland's energy security. Thus, developing calculation methods and reducing greenhouse gas emissions in the environment are crucially important. Hard coal will still be the primary energy source in both the power industry and the heat industry in Poland for the next 20 years. Thus, there is a need to develop a method for environmental assessment of the coal mining operation and to demonstrate the determinants of a reduction in greenhouse gas emissions, which is an important element of climate policy in Europe.

Taking into consideration the growing importance of innovative research associated with production and the use of coal, as well as minimizing the effects of the mining industry on the environment, it is important to seek out new methods that will enable both assessment and optimization of mining processes. In recent years, the mining industry has had to pay increasing amounts of attention to the environmental aspects of their activities, which is mainly an effect of growing requirements imposed by the European Union (EU). The EU's priority is environmental protection, which is why following the environmental rigors associated with coal mining is such an important issue. Yet, the question of how to identify the biggest sources of pollution remains a great challenge. Additionally, due to increasingly stricter requirements concerning greenhouse gas emissions, methane emissions and the use of methane from methane drainage stations also became important issues. Development of scientific and research activities concerning hard coal mines is aimed at fighting natural hazards, perfecting mining and organizational methods, and considering environmental protection requirements. The above-mentioned factors influence the selection of mining technology, which should consider the absolute safety and the efficiency of production, together with minimizing its negative influence on the environment (Dubiński and Turek, 2007). Due to that fact, it is very important to develop systems of environmental management aimed at preventing pollution and following the Environmental Protection Law and environmental requirements. One of the key requirements of environmental management is constant assessment of environmental activities (Staš et al., 2015).

Currently, the results of the LCA for coal mining in the literature are very generally shown as part of the entire chain of energy production, without specifying the determinants of environmental assessments. In the literature, there are no results for greenhouse gas emissions and damage categories for coal mining operations. To date, there has been no method for assessing the environmental performance of mines that considers direct and indirect influences of mining production processes on the environment. Therefore, in response to a methodology gap in the literature, the authors proposed a computational LCA model in this paper. The model can be used to evaluate the coal mining operations with regard to these indicators, which is an important step towards environmental assessment and abatement of emissions. Additionally, an environmental assessment was performed based on the application of the proposed model for national coal mines. Coal mines in other countries can perform a comparative analysis using the proposed model based on their own input data.

At present, assessment of the influence of coal mining focuses on a few of the most important environmental impacts caused by associated processes. Significant negative environmental aspects of hard coal mining include methane emissions into the atmosphere, mining waste and drainage water (Kugiel, 2010). The methane hazard is one of natural hazards accompanying underground operations in the Polish hard coal mining industry (Krause and Krzemień, 2013, Krause and Smoliński, 2013). Methane is one of the greatest dangers accompanying hard coal mining operations (Turek, 2010, Ju et al., 2016). Another important environmental aspect of hard coal mines is mining waste and processing waste. Mining waste management requires considering multiple issues associated with both environmental and economic aspects (Jonek-Kowalska, 2014, Michalak and Nawrocki, 2015, Sierpińska and Bąk, 2012, Sierpińska and Bąk, 2013, Gawor, 2012, Gawenda and Olejnik, 2008, Cała, 2013). Another important environmental aspect of hard coal mines is drainage water (Jonek-Kowalska and Turek, 2013). Apart from the natural inflow, it contains process water, which is supplied into a mine (Pluta and Dulewski, 2006, Dulewski et al., 2010, Pluta, 2005).

However, such an approach does not refer to the influence of coal mining operations related to their inputs and outputs, and it only refers to direct impacts caused by mining activities. A new approach to the problems of environmental aspect assessment is the life cycle approach, which enables assessment of mine activities and processes conducted there, together with assessment of all used materials and energy. It is

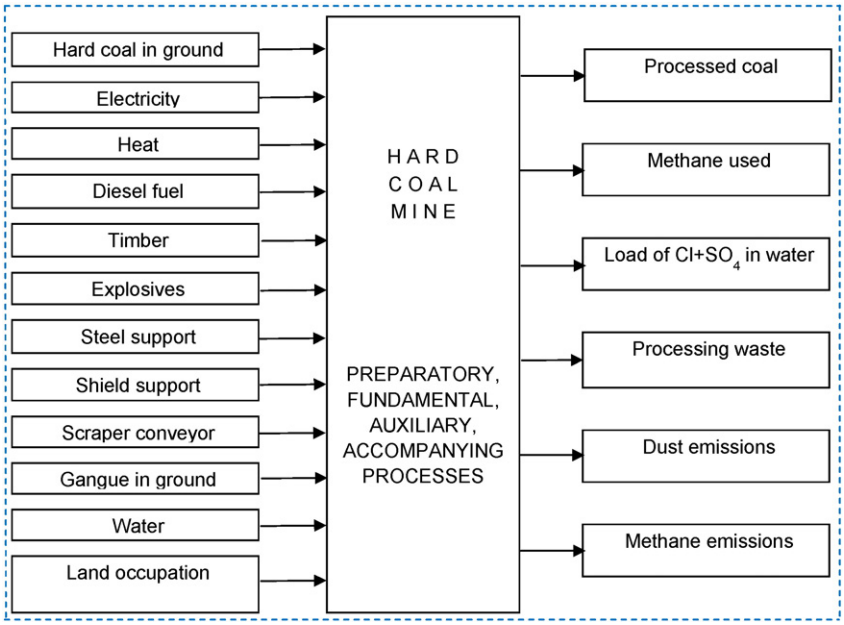

Fig. 1. Coal mining system boundary.