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Environmental performance indicators of hard coal mine

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Abstract. Mining is a specific type of business, which causes environmental interference unusual in other industries. On one hand, mining companies directly cause depletion of natural resources, but on the other - mining exploitation is the reason of immediate and long-term unfavorable environmental effects. Therefore, it is necessary to establish a uniform method for determining the environmental impact exerted by mining companies. The said method shall make it possible to compare the companies in terms of their adverse environmental impact and show efficiency of activities undertaken by such companies in the field of environmental protection. The above-mentioned assumptions may be implemented by appropriately defining and selected efficiency indicators of environmental activities. The objective of the article is to determine ecological efficiency indicators of coal mines by identifying and assessing environmental aspects. The article outlines ecological efficiency, including efficiency in the micro- and macroeconomic field. It also describes the application of microeconomic ecological efficiency indicators, with special emphasis on non-financial ratios. Last but not least, the article presents significant environmental aspects of hard coal mines. On the basis of the identified and assessed environmental aspects, six groups of efficiency indicators of hard coal mines were suggested, which - in the author's opinion, could be used to manage various environmental aspects. Additionally, the proposed indicators may be used to draft reports on efficiency of the environmental activities undertaken by Polish coal companies.

1. Introduction

Mining is a specific type of business, which causes environmental interference unusual in other industries. The fundamental mission of the mining companies is to excavate useful minerals, which constitute finite and non-renewable resources. Therefore, on one hand, mining companies directly cause depletion of natural resources, but on the other - mining exploitation is the reason of immediate and long-term unfavorable environmental effects.

The extent to which mining companies are able to notice and acknowledge social and environmental consequences of their decisions determines the level of the management culture and awareness of social responsibility. The level of environmental management of the mining companies is reflected in their actions undertaken to mitigate adverse environmental impact. What is also helpful is the implementation and maintenance of formal environmental management systems, with special emphasis on efficient management of environmental aspects of the company.

To properly analyse and assess the impact of the environmental aspects, it is essential to establish an appropriate group of indicators, which should inform the management staff of the mining company and interested parties about reaching the level of efficiency of the undertaken environmental activities. The article describes indicators grouped into six areas. According to the author, the above-



mentioned indicators could be used to manage environmental aspects and report on environmental activities of the hard coal mines.

2. Ecological effectiveness

Basic prerequisites for all actions, including management, shall be effectiveness and efficiency.

The source literature includes various definitions of effectiveness depending on a possibility of understanding and interpreting this term. Without going too deeply into theoretical considerations, effectiveness is usually defined in economic terms as a result of activities determined by the ratio of effects to outlays. In accordance with the above definition of effectiveness, the management process may be evaluated as positive if the ratio of effects to outlays (obtained results) reaches its maximum.

The concept of effectiveness in comparison with the concept of efficiency is much broader and superior, referring to both efficacy and potency of activities. Efficiency refers to the level of actions undertaken to accomplish a given goal, whereas potency of activities means optimum use of the resources owned [5].

Effectiveness may be also treated on a multi-dimensional basis. Apart from economic effectiveness, the following may be distinguished [3]:

- material effectiveness related to the implementation of the missions of the organization,
- technical and production effectiveness related to the optimization of selection and use of economic resources,
- environmental (ecological) effectiveness related to the emergence and development of scientific paradigms of environmental management,
- effectiveness based on quality related to the paradigm of management quality,
- social effectiveness related to the concept of corporate social responsibility,
- ethical and cultural effectiveness related to the creation and promotion of ethical and cultural norms within the framework of the broad social and economic environment of the organization,
- behavioral effectiveness aimed at satisfying the interests of people in the organization.

In Polish realities, the companies pay more attention to the economic effectiveness, which is the basis for all key decisions and creates general image of their condition. Within the last few years, due to, among other things, dynamically changing surrounding and raised awareness of the issues of environmental protection, the ecological effectiveness has become the subject of interest for many companies. The ecological effectiveness constitutes the subject of interest of various interested parties, for whom the activities mitigating the adverse environmental impact exerted by the companies are of key importance.

According to M. Węgrzyńska, we may speak of the ecological effectiveness when the economic result of the undertaken pro-ecological actions informs about the effectiveness of such actions in the shorter or longer perspective [13]. Due to the fact that the ecological effects are not always visible at the time of completing the said pro-ecological actions and may occur even after a few years, two periods for evaluating such effects were provided.

The ecological effectiveness may be examined at the level of the unit or within a macroeconomic framework.

2.1. Macroeconomic ecological effectiveness

Macroeconomics is a part of economics, which deals with economic phenomena in the national economy, i.e. economic growth, economic development, economic cycle, unemployment, inflation and economic policies [12].

In terms of macroeconomics, the ecological effectiveness may be understood in two ways. First of all, to define effectiveness, it is crucial to use the selected indicators for the purpose of identifying and describing processes that occur in certain economic units that go far beyond the unit. Second of all, the ecological effectiveness may be also treated as the result of pro-ecological activities compared with the expenditures incurred by the state to implement such activities. The applied indicators may be of financial or non-financial nature.

In terms of macroeconomics, the environmental financial indicator is a direct or indirect value related to the environment, which deliberately describes, as a number, the current state of environmental issues in a given country. The value is aimed at protecting environment, including indirect improvement in people's standard of living [13]. Model financial indicators:

- expenditure on reduction of gaseous and particulate pollutants,
- expenditure on sewage treatment,
- expenditure on waste collection and processing,
- expenditure on reduction of municipal waste,
- expenditure on waste storage,
- expenditure on noise reduction,
- expenditure on reduction of water consumption,
- expenditure on research in the field of environmental protection,
- percentage share of expenditure on pro-ecological tasks in GDP.

2.2. Microeconomic ecological effectiveness

Microeconomics is a part of economics that deals with research into economic phenomena on a microscale: households, enterprises, markets, and microeconomic effects of state operations [12].

When different companies want to research the effects of their pro-ecological actions, they may use specific environmental indicators. The system of indicators, due to, among other things, specificity of a given company and industry, in which it operates, should be constructed individually. The indicators used to define microeconomic evaluation of ecological efficiency may be divided into financial and non-financial indicators. The financial environmental indicators are used to assess profitability of ecological undertakings. The most important indicators include return on investment (ROI) and indicators based on discounted cash flow, including: indicators based on net value of future flows, internal rate of return (IRR), analysis of costs and gains, cost efficiency.

Non-financial indicators describe correlations between enterprises and environment. In accordance with the classification pursuant to ISO 14031, the non-financial indicators are divided into:

- management performance indicators (MPI): efficiency indicators with regard to the compatibility of provisions on management policies and programs connected with social relationships,
- operational performance indicators (OPI): system input indicators (materials, energy, services supporting operational activities, technical devices and equipment) and system output indicators (products, waste, emissions, services rendered by organizations),
- indicators of the health of the environment: air, water, soil, fauna and flora [10].

3. Environmental aspects of hard coal mines

The interest of companies in management of their environmental aspects is directly linked to the development of environmental management systems.

Initially, Polish mining companies had a possibility of implementing various projects as part of the concept of greener production, which was promoted in AGENDA 21 as a modern strategy for environment management aimed at sustainable industry development.

Greener production is defined as a strategy for environmental protection in the form of constant, integrated, preventive actions relating to processes, products and services and risk mitigation for people and natural environment [6]. The implementation of the greener production action plans could be considered one of the stages preparing a company for implementing environmental management system based on formalized system requirements.

The formalized environment management systems include the system based on the EMAS regulation and the system established in compliance with ISO 14001 standard. The hard coal mines or mining companies are interested in the implementation of integrated systems, including the environment management system based on ISO 14001. Table 1 includes the scope of certification under the integrated systems implemented in Polish mining companies.

Table 1. The scope of certification under the integrated management systems in mining companies.

	Polska Grupa Górnicza sp. z o. o.	Jastrzębska Spółka Węglowa S.A.	Tauron - Wydobycie S.A.	Lubelski Węgiel "Bogdanka" S.A.
Mining of hard coal	+	+	+	+
Processing of hard coal	+	+	+	+
Sale of hard coal	+	+	-	+
Mining services, renovation works, modernization and production of mining machines	+	-	-	-
Development of IT and ICT systems	-	-	-	-
Management of waste	+	-	+	-
Rehabilitation of lands after extraction	-	-	+	-

Source: own elaboration

Currently, all mining companies have implemented the integrated management system, which is composed of the following: environment management system based on ISO 14001, quality management system – ISO 9001, and OHS management system – PN-N-18001. The environment management system is a part of the organization management system, used to develop and implement its environmental policy and manage its environmental aspects [8].

In compliance with ISO 14001, the environmental aspect means elements of an organization's activities, products or services, which can interact with the environment [9]. The concept of the environmental impact, which means any change to the environment, whether adverse or beneficial, wholly or partially resulting from an organization's activities, products or services, is closely related to the environmental aspect [8]. Therefore, the environmental aspect may be considered a cause of the environmental impact, whereas the environmental impact may be considered the effect of such cause. In compliance with the standard, the companies should ascribe the impact to particular environmental aspects.

The companies often divide the aspects in the implemented environment management systems according to various criteria. The most often applied criteria are the following: duration of the environmental aspect, conditions of the aspect and possibility of its control. The division of the environmental aspects and criteria for their division are shown in Table 2.

Table 2. Division of environmental aspects.

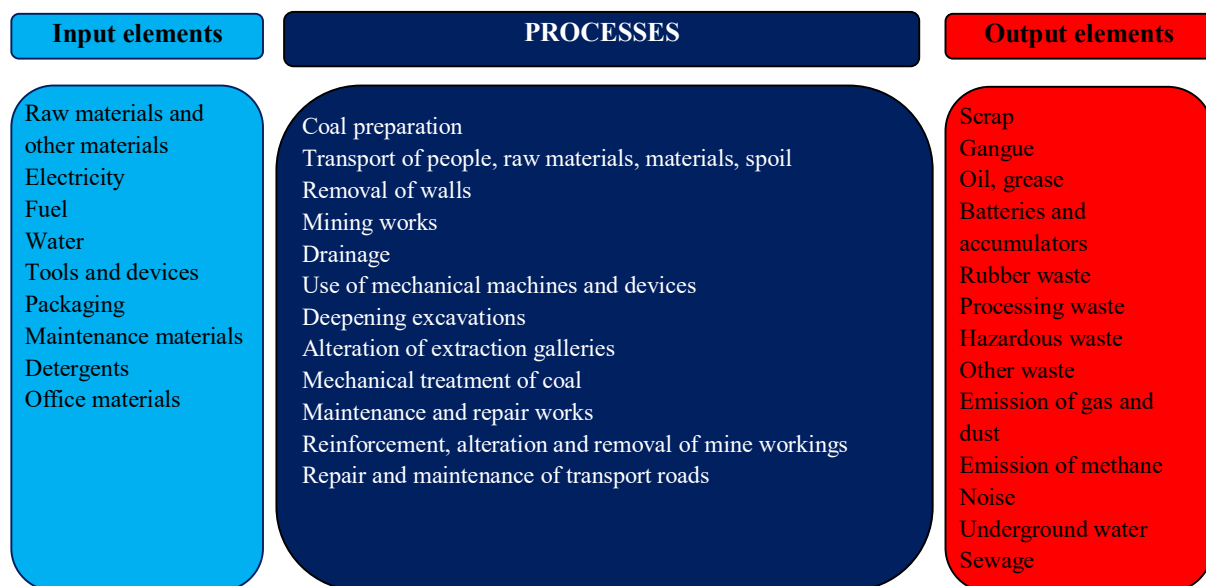
Environmental aspects		
Duration:	Conditions:	Possibility of control:
- current	- in normal operating conditions	- direct
- resulting from past actions	- in special operating conditions	- indirect
- future	- in emergency situations	

Source: own elaboration

Normal conditions are most frequent conditions, set to accomplish goals and tasks of the company. Special situation is when all planned and intentional actions proceed differently than in case of normal situations; it refers to start-up and switch-off of devices, maintenance, repair and renovation. Emergency situation is unplanned and unintentional, caused by failures or natural disasters.

Direct environmental aspects are related to actions, products and services of an organization, of which it exercises internal control. Indirect environmental aspects may be determined by the relationship between the company and third parties, on which the organization may have impact to a certain extent only [8]. Third parties are mainly subcontractors, suppliers and recipients working within the area of a plant.

To manage environmental aspects, it is essential to identify them properly. A very popular method is to analyse the processes in the production systems implemented by the companies, including definition of their input and output elements. Entries include everything related to the supply of the enterprise. Then, all processes conducted in the enterprise using the introduced resources are analyzed, and at the end of the discussed approach waste, sewage, noise, etc. are registered. Identification of environmental aspects should be carried out both in the input and output elements - figure 1.

**Figure 1.** Identification of environmental aspects based on input and output elements of the selected processes implemented in hard coal mines.

Source: own elaboration

It is possible in a typical hard coal mine to identify as many as approx. 700 aspects and their environmental impact. The above number results from the fact that the aspects and their impact are qualified in a very detailed manner, with the distinction into several dozen of waste types.

Additionally, some aspects occur in several different regions of the mines, during different processes, and they are treated separately. The list of significant environmental aspects and their impact is shown in table 3.

Table 3. Significant environmental aspects and their impact identified in hard coal mines.

No.	Aspect	Impact
1	Exploitation of hard coal	Change of water conditions
2	Exploitation of hard coal	Decrease of hard coal resources
3	Exploitation of hard coal	Settlement and deformation of land
4	Emission of gases	Greenhouse effect
5	Emission of gases	Atmospheric air pollution
6	Noise pollution	Change of acoustic climate
7	Emission of methane	Greenhouse effect – methane
8	Emission of methane	Atmospheric pollution
9	Emission of dust	Atmospheric pollution with dust
10	Emission of exhaust gases	Air pollution with exhaust emissions
11	Storage and sale of coal	Environmental pollution
12	Hazardous waste	Environmental pollution with hazardous waste
13	Other waste	Environmental pollution with waste
14	Excavation waste	Environmental pollution with excavation waste
15	Drainage of rock mass	Disruption of water balance
16	Water intake	Depletion of environmental water resources
17	Electromagnetic field	Adverse impact on the health of employees
18	Fires	Atmospheric pollution
19	Development of mines	Changes in landscape composition and environment
20	Radioactive substances	Environmental pollution with radioactive substances
21	Sewage	Contamination of surface waters
22	Transport, fuel consumption	Consumption of non-renewable resources
23	Discharge of salted waters	Contamination of surface waters
24	Consumption of wood	Depletion of natural resources – forests
25	Consumption of electricity	Consumption of non-renewable energy sources

Source: [7]

4. Ecological efficiency indicators of hard coal mines

The applied formal environment management systems are constantly improved. The companies having such systems should undertake actions aimed at reducing the adverse environmental impact and decreasing material and energy consumption during the production process. To ensure that the above-mentioned objectives are met, it is essential to have efficient tools for monitoring and controlling emission of contaminants.

The mining companies, due to the specificity of their business activities in the form of negative environmental impact, should apply appropriately selected ecological efficiency indicators. The ecological efficiency indicators may be in the form of management tools designed to provide the managerial staff with reliable and confirmed information used for the purpose of determining whether the effects of environmental actions undertaken by the companies meet the criteria previously set by the managers and whether they are in compliance with the planned environmental policy. The indicators allow to accurately evaluate efficiency of management of environmental aspects in the mine. Additionally, constant collection and analysis of data based on such indicators allows not only to assess the effects of actions on an ongoing basis, but also to forecast certain trends in time.

The relationship between the hard coal mines and environment may be best described by using non-financial indicators from the group of indicators of operational performance effects. To describe the impact of the company's operational activity on the environment, the indicators pertaining to the

results of the operating activity of the hard coal mines were divided into six basic groups: consumption of raw materials, waste, sewage, air emission, noise pollution, etc. For the purpose of explicit determination of ecological efficiency of the actions undertaken by the hard coal mining companies, the indicators should refer to annual coal excavation. The obtained ratio shall indicate the emission and consumption per 1 ton of excavated coal.

$$W_E = \frac{W_C}{\text{Annual coal output}}$$

where:

W_E - efficiency indicator

W_C - total annual emission (consumption)

4.1. Consumption of raw materials

The indicators belonging to this group provide information on the use of input elements in the production system.

The group includes the following indicators:

1. Total consumption of water per 1 ton of excavated coal
2. Consumption of wood per 1 ton of excavated coal
3. Consumption of energy per 1 ton of excavated coal
4. Consumption of steel per 1 ton of excavated coal
5. Consumption of underground water per 1 ton of excavated coal
6. Consumption of surface water per 1 ton of excavated coal

The total consumption of wood, steel or finished elements used, for example, in the opening works, may be also provided in relation to 1 linear meter of extraction gallery.

Figure 2 shows water intake and consumption in Polish hard coal mining companies.

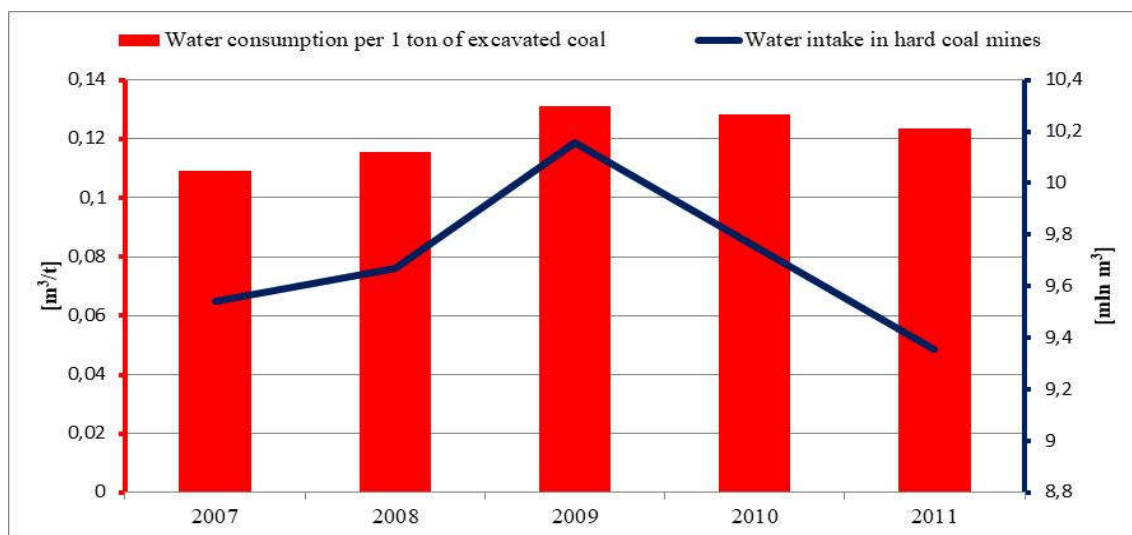


Figure 2. Water intake and consumption in hard coal mines in 2007-2011.

Source: own elaboration on the basis of [1]

4.2. Air emission

In case of hard coal mines, the emission of methane has the most adverse environmental impact in the discussed group of environmental aspects. Ventilation shafts pumping air from ventilated mine workings constitute the main source of the methane emission. It should be also added that some part of methane is captured and used economically to produce electricity and heat energy.

The mines use air conditioners with cooling factors that may have negative impact on the ozone layer, i.e. hydrofluorocarbons (HFCs).

The suggested indicators are as follows:

1. Efficiency of methane management ((amount of used methane/amount of captured methane) $\times 100\%$)
2. HFC emission per 1 ton of excavated coal
3. Methane emission per 1 ton of excavated coal
4. Dust emission per 1 ton of excavated coal
5. Nitric oxide emission per 1 ton of excavated coal
6. Carbon monoxide emission per 1 ton of excavated coal
7. Economic use of methane per 1 ton of excavated coal

The values of indicators pertaining to the emission of gas are shown in figure 3, whereas the values of indicators pertaining to the released and used methane - in figure 4.

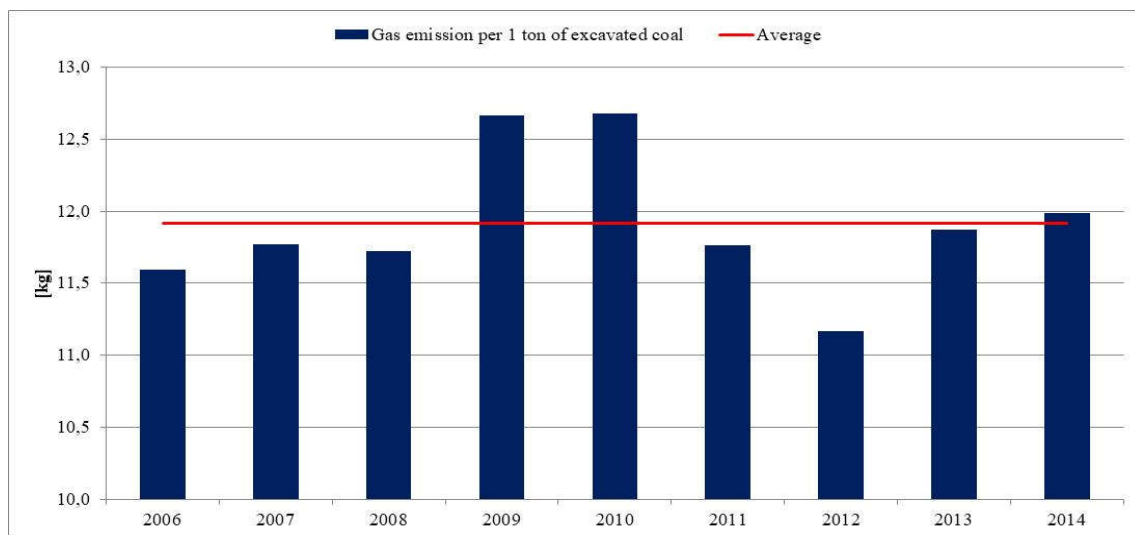


Figure 3. Emission of gas and dust by hard coal mines.

Source: own elaboration on the basis of [1]

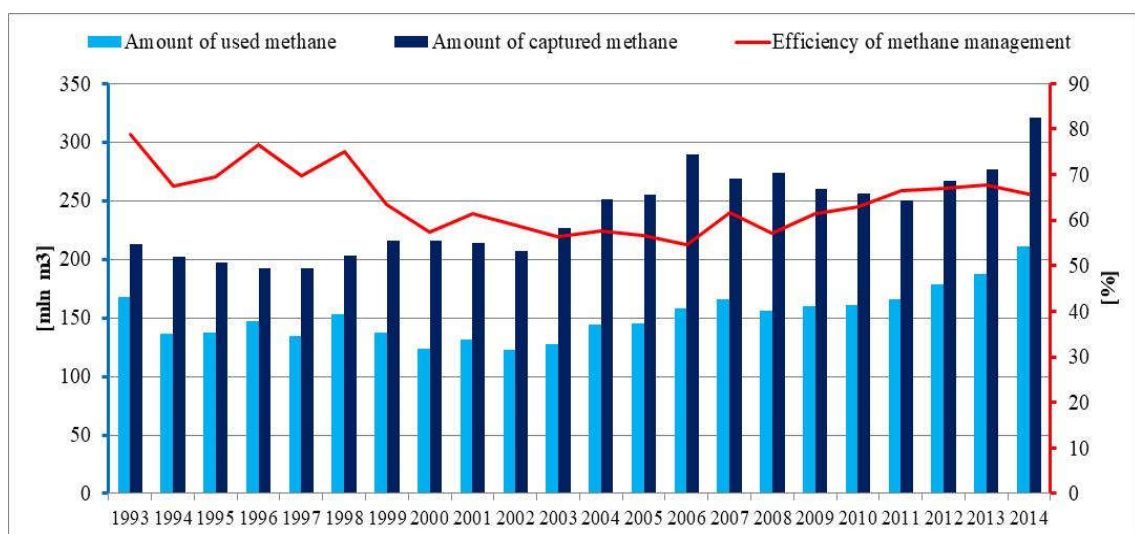


Figure 4. Amount of captured and used methane.

Source: own elaboration on the basis of [11]

4.3. Sewage

The discharge of salted waters due to mine drainage processes is the most serious environmental problem for the hard coal mines. Mine waters constitute nearly 95% of all sewage discharged to surface waters. Municipal wastewater, rinsing water and precipitation water constitute other types of sewage.

Water and sewage discharge may be monitored based on their quality parameters, i.e. suspended solids, total amount of chlorides and sulphates, chemical oxygen demand (ChZTCr), five-day biochemical oxygen demand (BZT5), and content of particular heavy metals.

The sewage group includes the following indicators:

1. BZT5 per 1 ton of excavated coal
2. Chlorides per 1 ton of excavated coal
3. ChZTCr per 1 ton of excavated coal
4. Hardened surface - precipitation or thawing waters per 1 ton of excavated coal
5. Sulphates per 1 ton of excavated coal
6. Mine waters discharged to surface waters per 1 ton of excavated coal
7. Mine waters used for technological purposes per 1 ton of excavated coal
8. Water and sewage discharged to surface waters per 1 ton of excavated coal
9. Conditioned water per 1 ton of excavated coal
10. Heavy metal content per 1 ton of excavated coal
11. Suspended solids per 1 ton of excavated coal

Values of model indicators are shown in figures 5.

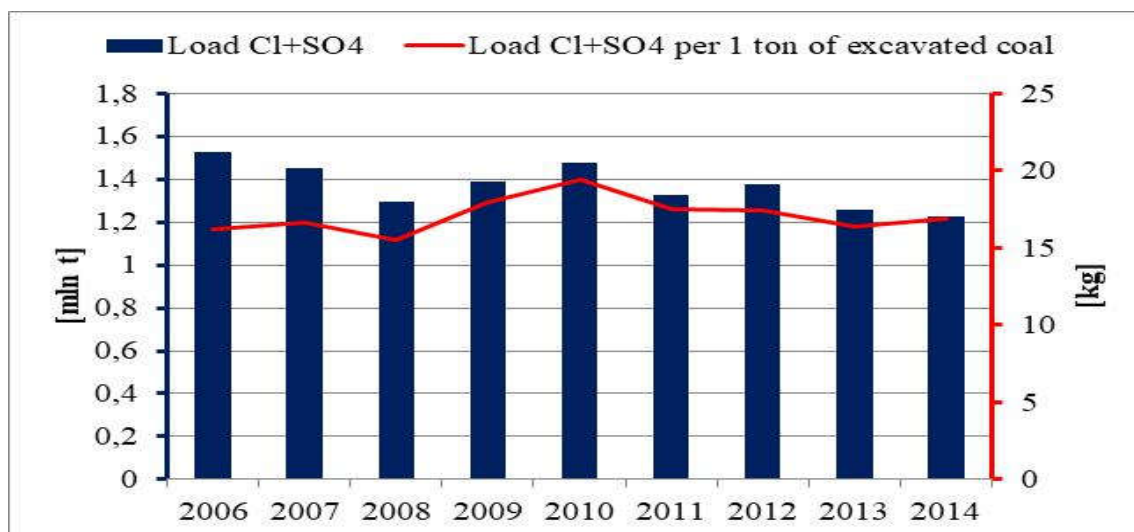


Figure 5. Load Cl+SO₄ in underground waters.

Source: own elaboration on the basis of [1]

4.4. Waste

The mining companies usually apply the following waste division: mine waste, hazardous waste and other non-hazardous waste.

The group includes the following indicators:

1. Mine waste per 1 ton of excavated coal
2. Non-hazardous waste per 1 ton of excavated coal
3. Hazardous waste per 1 ton of excavated coal
4. Waste for economic use per 1 ton of excavated coal
5. Waste for mine use per 1 ton of excavated coal
6. Percentage ratio of waste for economic use to generated waste

Figure 6 shows generated mine waste and used waste.

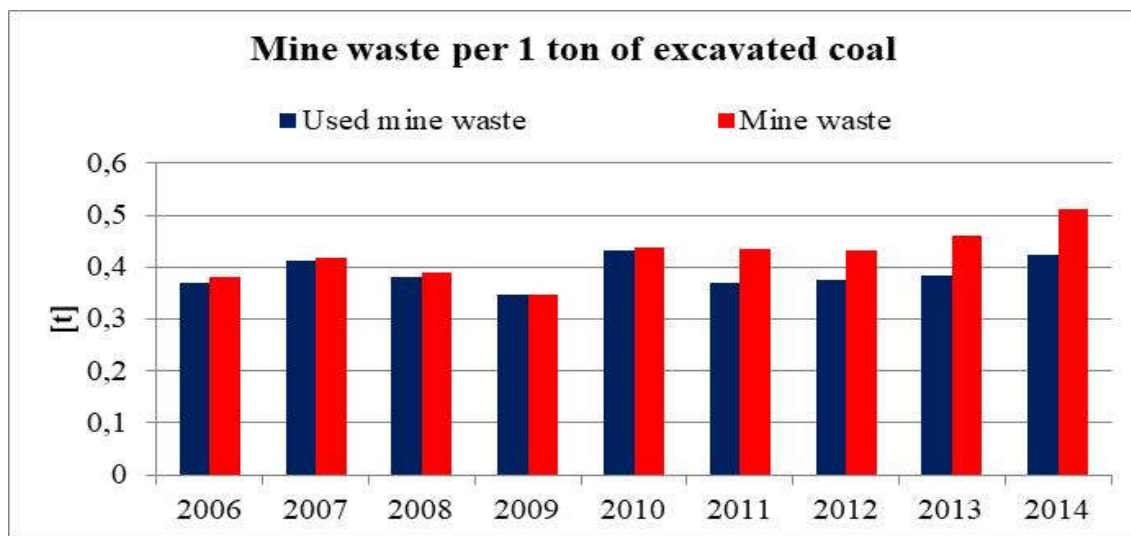


Figure 6. Generated and used mine waste from hard coal mines.

Source: own elaboration on the basis of [1]

4.5. Noise

Noise pollution in hard coal mines is mainly caused by the work of mineshafts, coal processing plants and coal transport in the plant. The indicators should include any increase or decrease in the level of noise pollution during a day and night as well as at certain locations directly adjacent to the mine.

4.6. Other

The group needs to include such indicators that could describe the environmental impact of significant aspects, which are hard to be ascribed to any of the predefined groups of indicators.

The suggested indicators are as follows:

1. Combustion of fuels in combustion engines per 1 ton of excavated coal
2. Ratio of degraded area surface covered by rehabilitation works to the total degraded area surface
3. Use of deposits

5. Conclusion

The study of ecological efficiency poses a challenge for current economics, as it is difficult to determine and value benefits, in particular those that are of non-financial nature. It is also challenging to select appropriate indicator for measuring ecological effects. In case of economic assessment of ecological investments, the selection of appropriate indicators seems relatively easy, but in case of determining environmental impact of activities of the mining companies with hundreds of environmental aspects, the selection of the right indicators may be time-consuming and troublesome. While choosing the indicators, the procedure for identification and assessment of the environmental aspects should be applied. Such procedure allows the mining companies to obtain the list of material environmental aspects. With key environmental aspects, it is possible to choose the right indicators for describing environmental impact. Monitoring, gathering and processing of such data should make it possible to determine the actual environmental impact exerted by the mining companies and allow better management of environmental aspects. Thanks to the aforementioned indicators, the mining companies may verify efficiency of their environmental policies.

In hard coal mining, there is an intensification of environmental and social risks, manifested in the extremely unfavorable impact of exploitation on the natural environment and in the opposition of local and regional communities in connection with mining operations [2,4]. It is evident that today's mining

companies are interested in environmental issues, ecology and pro-ecological activities as well as social issues. The above results from the fact that, among other things, such companies are willing to obtain social acceptance for running their business activities. Both maintenance and implementation of the environment management system based on EMAS requires publication of the so-called environmental statements by the company. The key element of such statement is to assess the effects of environmental activities. The provision of reports on environmental activities with the interested parties seems to be just the matter of time, therefore, it is necessary to prepare a group of appropriate indicators. The ecological efficiency indicators of hard coal mines, whose selection was based on the identification and assessment of environmental aspects should be included in the future non-financial reports of the mining companies.

It should be also remembered that improper shaping, use and exploitation of the environment and also incorrect application of ecological efficiency causes environmental damage and makes environmental protection inefficient. Therefore, the right choice of ecological efficiency indicators is of key importance when it comes to determining future pro-ecological activities of polluting companies.

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