

“Formation of a complex of management decisions on the reduction of environmental pollution during the development of coal mines”

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ARTICLE INFO	Beata Gibesova, Yuliia Halynska, Vaclav Zubiček and Eliška Fiedlerova (2017). Formation of a complex of management decisions on the reduction of environmental pollution during the development of coal mines. <i>Problems and Perspectives in Management</i> , 15(2-1), 246-254. doi: 10.21511/ppm.15(2-1).2017.08
DOI	http://dx.doi.org/10.21511/ppm.15(2-1).2017.08
RELEASED ON	Wednesday, 26 July 2017
RECEIVED ON	Thursday, 29 December 2016
ACCEPTED ON	Thursday, 29 June 2017
LICENSE	 This work is licensed under a Creative Commons Attribution 4.0 International License
JOURNAL	"Problems and Perspectives in Management"
ISSN PRINT	1727-7051
ISSN ONLINE	1810-5467
PUBLISHER	LLC “Consulting Publishing Company “Business Perspectives”
FOUNDER	LLC “Consulting Publishing Company “Business Perspectives”



NUMBER OF REFERENCES

20



NUMBER OF FIGURES

0



NUMBER OF TABLES

0

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BUSINESS PERSPECTIVES



LLC "CPC "Business Perspectives"
Hryhorii Skovoroda lane, 10, Sumy,
40022, Ukraine

www.businessperspectives.org

Received on: 29th of December, 2016

Accepted on: : 29th of June, 2017

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Václav Zubiček, Eliška Fiedlerová,
2017

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FORMATION OF A COMPLEX OF MANAGEMENT DECISIONS ON THE REDUCTION OF ENVIRONMENTAL POLLUTION DURING THE DEVELOPMENT OF COAL MINES

Abstract

The problems of environmental pollution in the conditions of high dust content in the air during the development of coal mines in the territory of the Czech Republic are considered. A mechanism for making managerial decisions was developed using an integrated approach using the new technological process *Nástup Tušimice* (DNT) aimed at eliminating pollutant emissions and managing workers in dusty conditions in mining operations. The recommendations of active and passive measures aimed at reducing dustiness in the process of coal mining have also been developed.

Keywords

environmental pollution, mechanism for making
managerial decisions, assessment of air pollution levels,
coal mining, environmental damage

JEL Classification

Q51, Q53, Q55

INTRODUCTION

Despite the constant increase in the costs of raising the industrial safety and labor protection levels, the effectiveness of measures in the field of occupational safety and labor conditions in the coal enterprises cannot be considered as sufficient. The adequate legal, economic, technical and social measures aimed at reducing the occupational risks remain relevant and require implementation in many countries of the world, including the Czech Republic. The Ministry of the Environment authorized the Czech Hydrometeorological Institute to perform activities related to assessing the level of pollution in accordance with Section 35 of Act on the protection of the environment. This enabled to conduct the additional tests of the new modern technology and analyze information on the state of industrial safety and labor protection both in the industry as a whole and in the individual organizations. Along with the issues of environmental and economic consequences, attention is increasingly focused on issues of environmental consumption and “green marketing”, which are links in one chain. Today, the need for green marketing has grown, as environmental issues facing the world have become more pronounced (Govender & Govender, 2016).

The subsoil exploitation has a significant impact on the environment. The large areas of agricultural lands are taken out of use, the soils, forests are damaged, the hydrological regime of large areas is changing and their productivity is reduced, even the terrain and the movement of air currents are changing. Extraction of mineral raw materials leads to the creation of areas of surface subsidence above mine fields and the like on the significant areas of anthropogenic ally-mining landscape, for which both surface accumulations of rock masses (dumps, waste pits, slimes) and negative forms of relief – quarries – are typical. In these areas, the entire surface is being rebuilt, the composition of the primary vegetation is dramatically depleted, the biological productivity of soils is falling, and the groundwater is depleted. The subsidence areas in lowland, on the contrary, are often swamped and taken out of the national economic use. A significant source of environment pollution is harmful gases, as well as mineralized water, which is pumped from mines, quarries and discharged into the surface watercourses. All surface accumulations of rocks become an active source of fine dust. Mine rocks in slag heaps are prone to spontaneous combustion, pollute the air and soil with combustion products and, above all, sulfur compounds. It is typical that heavy metals that fall on the ground move freely with water and are often concentrated in bottom sediments (Rubayah, Zulkornain, 2015).

The atmospheric pollution in mining operations is mainly due to dust and gases, which are formed during explosions, as well as due to natural gas emission in mines and pits. It is estimated that on average, about 8 million tons of gas are released annually in the world during explosions, which is much less than natural gas emission, because only 90 million tons of methane enter the atmosphere in the coal fields. The above brief review gives us a clear understanding of the impact of mining on the environment. The value of this factor will grow with time. The impact of mining on the environment begins with geological exploration. Here we can distinguish such types of environmental disturbances:

- geomechanical (changes in the natural structure of the mountain massif, terrain, surface soil, ground, including deforestation, surface deformation);
- hydrogeological (changes in reserves, traffic conditions, quality and groundwater level, water regime of soils, removal of harmful substances from the bowels of the earth into rivers and reservoirs);
- chemical (changes in the composition and properties of the atmosphere and hydrosphere, including acidification, salinity, water pollution, increase in phytotoxic elements in water and air);
- physicommechanical (air pollution, its heating, changes in the properties of soil cover, etc.);
- noise pollution, soil and rock mass vibration, rock outbursts during explosions, deterioration of the atmosphere transparency and other possible phenomena that accompany mining, negatively affecting the environment (Chernov, Vologodski, Cherkasov, 1973).

Coal dust is a collection of finely dispersed solid particles of organic or mineral origin, formed in the mine workings in various production processes and mainly during the operation of cleaning and penetrating combines. Thus, the main share of dust formation in coal mines is accounted for by the work of cleaning and penetrating combines. To achieve maximum allowable concentrations, it is necessary to use a complex of dust-removing measures with a total dust suppression efficiency of more than 99%, which is a very difficult task (Kuznetsov, Kuznetsova, Minibaev, 2016). A successful solution to the problem of combating dust suspension and dust formation in the coal mines is possible only by finding effective physical and chemical methods aimed at both binding the dust already formed as a result of coal mining and reducing the dust formation during the reservoir production. The dust presence in the mine air is also undesirable for a number of reasons:

- firstly, it is harmful to human health;
- secondly, the dust content of air significantly reduces visibility, which, in turn, increases the overall danger of work performance;
- thirdly, a mixture of air and coal dust leads to explosions at a certain concentration.

The significant increase in dust formation in mines is explained, firstly, by a decrease in the natural moisture content of coal seams and rocks with an increase in the depth of development (Kirin, 1983; Kudryashov, 2000). Secondly, at greater depths, the rock pressure forces are more active, under which the coal seams and host rocks are destroyed before the excavation, and their propensity to dust formation is significantly increased. At deep horizons, the gas content increases, so an effective ventilation of the mines becomes possible only with an increase in the amount of air supplied, an increase in the speed of its movement along the mine workings. The speed of the air flow movement often exceeds the optimal "Safety Rules in Coal Mines" (Likhachev, 1964) according to the dust factor, which are established by the international regulations and rules in the field of industrial safety. At the same time, all larger dust particles become suspended, increasing the dust concentration in the air (Kirin, 1983; Kudryashov, 2000). Thirdly, the mining and geological conditions for the development of coal deposits by the underground method continue to become more complicated. A significant part of miners continues to be exposed to hazardous and harmful production factors of various nature, their health suffers from significant damage, manifested in the development of industrial conditioned and occupational diseases. Violation of technological modes of mining, untimely provision of individual and collective protection means increase the threat of harm to life and health.

The analysis shows that in a complex of factors ensuring the stable operation of extractive enterprises, a significant role was played by correctly accepted and timely implemented decisions of strategic and operational management of the enterprise. So, studies related to the justification and development of methods for assessing management decisions and monitoring the production activities of coal mines in an unstable economy are quite relevant.

Production management is always a difficult task, even if it is assumed that the economic mechanism is established. The constant collection of information and its analysis, the adoption of management corrective solutions support the stable operation of the enterprise. If the market is not balanced, then all stages of management become more complicated. At the same time, the risk of making an incorrect or insufficiently correct decision is significantly increased.

1. LITERATURE REVIEW

Year after year, the level of atmospheric pollution is constantly increasing, which has already caused a number of environmental problems, the most acute of which relate to the state of atmospheric air. The governments of some countries are trying to solve the problem of air pollution by shifting responsibility to other countries. At the same time, Brandt, Nannerup (2013) note that such actions are costly and incentives to pass the main burden of reduction to other countries.

The harmful emissions of industrial enterprises fill the air with a lot of greenhouse gases and dust: ni-

trous oxide, chlorine-containing substances, methane, etc. An increase in the concentration of these gases leads to an inevitable heating of the atmosphere and a climatic shift toward higher temperatures. The most dangerous atmosphere pollutants are carbon monoxide and methane.

Studies have shown that in reality, the amount of methane that enters the atmosphere as a result of the operation of mines is at least twice as large due to an additional dispersed supply over the entire subsided surface through cracks and pores that have arisen and persist long in the subsided rocks, causing its aerodynamic connection with the surface (Bokiy, 2016). It might be confirmed by the cases when

methane came to the surface in certain mountain-geological conditions (outcrops of reservoirs or porous rocks under a layer of low-power sediments) (Pechuk, 1962). There it became the cause of outbreaks in domestic and industrial premises. Accurate measurement or calculation of this flow is extremely difficult, and utilization of the methane taken out by it is practically impossible. The harmful effect of mine methane on the ecological situation is also manifested in the fact that, being substantially lighter than air and rising into the upper layers of the atmosphere, it reaches the ozone layer, where its inertness is insufficient to resist oxidation with chemically active ozone (O₃). Among the sources of dust and methane emissions into the atmosphere, the coal industry takes the lead. In this regard, there are a number of tasks that need to be addressed:

- firstly, the main task of environmental legislation around the world is the organization of environment protection and rational use of natural resources;
- secondly, it is necessary to improve technologies for the extraction and processing of coal using new methods to reduce dust and gas pollution of the atmosphere.

The studies have shown that existing criteria and practices for assessing the environmental safety of mining enterprises and industries are not effective, since it is difficult to establish a quantitative relationship between environmental safety of production and the criteria for its evaluation.

Currently, the following basic approaches are applied:

- deterministic assessment of the ecological state of the facility in comparison with the regulatory or background values;
- probabilistic assessment of damage that can be caused by the occurrence of adverse environmental events according to the statistical data;
- assessment of the ecological state of environment by subjective criteria, indirectly assessing the level of human health, flora and fauna (Kuznetsov, Kuznetsova, Minibaev, 2016).

The use of the last criterion is the least statistically reliable, since it is difficult to separate the natural ecological and seasonal causes of deterioration in human, flora and fauna based on the subjective assessment.

It is also necessary to pay attention to the high rates of occupational diseases among workers in the mining industry. On average, it is accounted for 10 thousand of the diseased working population by the following types of economic activity: extraction of fuel and energy minerals – 90.23%, extraction of minerals, except for fuel and energy – 47.61%, metallurgical production and production of finished metal products – 28.9%.

In order to significantly reduce the level of injuries and morbidity of workers with pneumoconiosis, the governments of the Czech Republic have adopted a number of laws aimed at developing the new techniques for reducing dustiness in the mine and coal atmosphere in the production processes, as well as for conducting a comprehensive analysis of the technical level of other sources of particulate matter emissions (for example, surface mines of minerals) for the purpose of to minimizing the costs of implementing measures to reduce emissions in the development of coal mines. When governments are changing the environmental policies due to a structural change such as change in production costs, demand and gross pollution, they have to consider the opposite effects on welfare. While welfare is affected positively from producer surplus and consumer surplus with increasing production, it is negatively affected via disutility from pollution with decreasing production. Pollution abatement technology plays its key role at this point (Kayalica, Kayakutlu, 2016).

The main idea of this research is the development of theoretically grounded and practical recommendations on the formation of a complex of management decisions, the effectiveness of which ensures a reduction of environmental pollution in the development of coal mines

The research consists of two parts:

1. Assessment and methods of reducing environmental pollution in the process of applying the new technological process *Nástup Tušimice* (DNT).

2. Management of workers in dusty conditions in mining operations.

1. Assessment and methods of reducing environment pollution in the process of applying the new technological process *NástupTušimice* (DNT)

The main contractor is the company Severočeskédoly a. s. (North-Bohemian Mines), which is the largest mining company engaged in surface mining of lignite in the Czech Republic. The company Severočeskédoly a.s. (SD, a.s.) was established on 1 January 1994 by transformation of the former state enterprises Doly Nástup Tušimice (*Nástup Tušimice* Mines) and Doly Bílina (*Bílina* Mines). It operates in the North Bohemian brown coal basin and in addition to mining, it also deals with treatment and marketing of coal and related raw materials. In cooperation with the Research Institute for Brown Coal, there has been developed the technological process of coal mining Doly Nástup Tušimice (DNT), which reduces the amount of pollutant emissions in the form of solid particles, as well as at the subsequent processing of coal and its transportation. These activities are based on accurate and detailed monitoring of the situation and assessment of air pollution levels, as well as the implementation of appropriate active and passive measures that reduce the amount of dust in the coal mining process.

The establishment of Doly Nástup Tušimice (DNT) consists of several operating parts with a number of listed stationary sources of polluting the environment. These operating parts can be divided into those related to direct technology connection to surface mining and the parts that constitute the underlying infrastructure.

Mining of overburden masses takes place, and, consequently, will also take place simultaneously on three overburden slices. The actual mining takes place or will be conducted using two coal slices divided into two mining blocks.

From the nature of stationary sources, it is evident that the introduction of pollutants into the atmosphere occurs in a fugitive manner and from enormous areas. In the Czech Republic, the operators of stationary sources are not obliged to determine

the level of air pollution, therefore, it is not detected. For that reason, the above mentioned data on PM emissions have to be considered as working and unofficial estimates (Bajer, 1979; Rubayah, Zulkornain, 2016).

In the case of the assessed stationary sources, the amount of emissions cannot be determined by measurements. It can be calculated using the emission factors or specific production emissions. Emission factors have not been established the Ministry of Environment yet. Based on unofficial calculation of emissions through specific production emissions, we can arrive at a value of about 88.9 tons of PM/year for DNT quarry and about 10.5 tons of PM/year for coal stocks. Other emissions are insignificant (Alias, Noriszura, 2015).

2. Management of Workers in Dusty Conditions in Mining Operations

As noted above, the increased content of methane and dust leads to the accumulation of heat in the technogenic mine natural and industrial system. This system includes underground mine workings and the mountain massif containing them, a surface complex of a mining enterprise that serves its populated area, their social environment, infrastructure elements, and nearby agrarian or forest land plots. In turn, this negatively affects the health and quality of life of people who work in the mining industry [33, 34]. Thus, reducing the dust content of air in coal mines is an important social, scientific, technical and economic problem in the coal industry to date.

Analysis of scientific researches and technical solutions aimed at protecting workers from mine dust in the coal mines has shown that the main way to combat dust is hydro-sprinkling (irrigation), i.e., capture and precipitation of dust particles with droplets of liquid. Along with certain successes achieved in the implementation of this method of dust suppression, it remains necessary to develop optimal parameters for the irrigation of coal dust. It should be noted that the tasks of increasing the efficiency of air dedusting with a drop liquid shall be solved in a complex manner with the use of modern technologies for the extraction of natural resources.

According to the analysis (24, 25, 26, 27, 28, 29, 30, 32, 33), the most effective methods for combating coal dust in the coal mines are the following methods and ways of irrigation during the operation of cleaning and penetrating combines: preliminary moistening of coal seams (preliminary water injection into the reservoir), irrigation, pneumatic hydro drainage, water curtains, water-air ejectors, hydro-reactive sprayers, dust collection (dust extraction, shell construction on overflow, fabric partitions), dedusting ventilation. To date, various methods have been developed, tested and implemented, as well as technological schemes and means of injecting liquid for various conditions of occurrence of coal seams briefly described below.

So, taking into account all the above, we draw the following conclusions: 1. The adoption of managerial decisions is a complex task, the decision of which is devoted to a number of studies with its approaches and methods. 2. A modern mine is a SYSTEM with complex interweaving of internal and external connections, feedback and a well-defined purpose. The description of such a system is practically impossible to perform at the level of deterministic representations. 3. There are no fairly simple and effective methods for assessing the state of prudence as a whole as a single economic mechanism that would allow for the current control of production activity with a certain precondition. It would allow to adjust the made management decisions.

Taking into account the specifics of the research conducted, namely, the emergence of a risk to the health of workers in dusty conditions during the coal mining, the scientists of the Czech Republic have developed recommendations for reducing dust content for certain categories of workers.

According to Faster (2008), Galeshchuk (2014), Rassuzhday, Bratkov (2011), the work performed at the workplaces of the individual internal organizational units operating within the district in relation to objectively determined current working conditions and depending on the degree of risk of dustiness into categories is classified from 1 to 4.

In this regard, recommendations have been developed to reduce the risk to health workers who work in dusty conditions:

1. Other activities include "other professions" including THZ.
2. Working conditions due to fibrogenic dust occurring at mining sites are evaluated once a month. The assignment of work to the risk of dustiness has to be continuously refined according to objective documents always by the 10th day of each subsequent month.
3. The management of an organization designated for this purpose by an expert commission is responsible for the proposal for the ongoing assignment of work to the risk of dustiness. Basic (permanent) committee composition, organization leadership, anti-dusting technician, trade union representative.
4. Proper records shall be kept on the assignment of work to each dust hazard class, as well as on monthly changes and shall be available for inspection by the competent public health authority. A copy of the records must be sent to the appropriate public health authority within 10 days of the date of the meeting of the expert committee.
5. When assigning work to individual risk classes, the dust exposure is determined as the mean value (arithmetic mean) of the respirable powder fraction from the dust measurement carried out during ten full-shift measurements. These measurements are carried out in the following shifts immediately following the completion of ten shifts. In the case of a new workplace, the working conditions are evaluated immediately after the workplace has been placed on the planned production and technological parameters.
6. While obscuring working conditions (the same technology, the same geological conditions, adherence to all prescribed technical anti-dusting measures), dust measurements are valid for the entire duration of

the workplace, but no longer than one year. For others, measurements are valid for two years. After the expiry of these deadlines, and if the working conditions change, the measurements must be repeated without delay.

7. For work at workplaces operated for only two months, the arithmetic average of the respirable fraction of the dust fraction shall be calculated from six total dust measurements. These measurements are made in the immediately successive shifts.

8. Calculate the percentage of HAE drawdown as follows:

$$\left[\frac{t_1}{tp_1} + \frac{t_2}{tp_2} + \dots + \frac{t_n}{tp_n} \right] \cdot 100 = \%NPE, \quad (1)$$

where t – exchanges in the relevant risk class;
 p – the lifetime allowable number of shifts in the relevant risk class.

1. The limit exposure time is reached if the HAE calculated according to the formula has reached 100%.
2. Dust exposure is evaluated by monitoring the number of shifts in the relevant risk class. Records of dust exposure must be kept for all workers working in mine workplaces. The number of shifts worked must be recorded monthly. For THZs classified in dusting classes 1 and 2, shifts can be made at annual intervals until the 95% HAE is reached.
3. Employees with unplanned HAE can work at all mining sites, in accordance with a review by the preventive care practitioner.

4. Employees who have already reached 100% of the NPE may continue to work in workplaces, i.e., work in the dust hazard classes 1 and 2.

5. As of 1 September 2005, for all employees who have not yet reached the exposure limit, the HAE in % was retroactively adjusted, depending on the number of mines actually worked. The calculation of % of HAE achieved according to the existing system was kept separately in the record of risk work in accordance with §40 of Act No. 258/2000 Coll., On Public Health Protection, as amended and according to Galeshchuk (2014).

The organization monitors the number of shifts in each dusting category for all employees. If the technical measure improves the dust category, then, 100% of the HAE miners will be filled. For example, risk class 3a sets the number of shifts to fill 100% of HAE 5335. It follows that this risk class may work 288.4 months to reach the exposure limit. If there are technical measures to improve the classification of the workplace in category 2, the employee can work 7000 shifts, which is 378, 4 months. The working life of an employee working in the dust class 2 versus dust class 3a is 90 months, which is about 7.5 years. This is why management is working to improve the workplace's dustiness class by working with new anti-dusting devices, thereby extending the working lives of employees as much as possible.

The financial effect of this mode of redeployment is difficult to ascertain. According to various studies, it can reach as much as US\$ 5,000, per employee, for the duration of his work with the organization (Augustinos Dimitras, Stelios Papadakis, Alexandros Garefalakis, 2017).

CONCLUSION

Thus, there is great activity at the DNT quarry that adversely affects the atmosphere directly. This applies mainly to mining and transportation, coal mining and coal transportation. Additional resources are HMGS and the large capacity coal stock, which are used for treatment and subsequent storage of coal. The authors offered recommendations on the use of active and passive measures in order to reduce dustiness at operation, both active and passive measures are applied, which are intended to minimize impacts of dustiness on the surrounding environment.

Active measures are implemented directly in individual mining slices, dump layers, homogenization dump (HMGS) and large capacity coal stocks.

- Calculate the percentage of HAE drawdown as follows. The rules of elimination and liquidation of heating and fires causing air pollution by gaseous components are observed.
- In the cyclical mining, measures are applied to reduce dustiness during transportation of mined materials. Above all, it is sprinkling of roads and speed limits for movement of vehicles in the enterprise premises at 30 km. hod – 1.
- At HMGS, pressurized water supply from the automatic pressure station has been introduced, which conducts pressurized water to places with a great dustiness. It is a transfer point PD S2, dividing device SD1, extending head PD S7, transfer point PD S8 and dividing device SD2, where the pressurized water is fed into the sprinkler ramps with spray nozzles.
- Passive measures are implemented again on mining slices, dump layers, HMGS and large capacity coal stocks. These measures include:
 - Based on the regulation and operational measures, the amount of operating mass is minimized. Unnecessary areas are passed to reclamation, while annexation of foreland occurs only to the extent necessary.
 - Based on the plan of remediation and reclamation, protective measures are constructed and maintained on the border between the mining area and the surroundings – protective embankments, borrow pits, forest belts, walls, and other measures to reduce dustiness and noise.

The results of the research show that in order to solve the problems of atmospheric pollution in the development of coal mines in the Czech Republic, it is necessary to apply a comprehensive approach. This approach should primarily focus on the application of the new technological process *Nástup Tušimice* (DNT), which will help reduce emissions of pollutants. Secondly, the development of methods for managing workers in dusty conditions in mining operations, with the aim of reducing morbidity and increasing the socio-economic situation in the regions. Thirdly, it is necessary to correctly and timely be able to make a decision that will not cause negative consequences. Therefore, the developed complex of measures to reduce the dustiness of the environment in the development of coal mines in the context of the adoption of management decisions is relevant and timely.

ACKNOWLEDGEMENTS

This paper was compiled within the Project of Specific University Research (SGS) no. SP2017/30 Evaluation of dustiness on surface mine near Bilina town. The authors would like to thank the Faculty of Mining and Geology of VŠB - Technical University of Ostrava for the project support.

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