https://doi.org/10.32056/KOMAG2021.2.6

Occupational health and safety management in hard coal mines in the aspect of dust hazard

Received: 04.03.2021

Accepted: 02.06.2021

Published online: 30.06.2021

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Abstract:

The article presents interdisciplinary knowledge on the management of occupational health and safety in hard coal mines with special attention paid to a control of the dust hazard. Shaping the safety culture is analyzed in the social, organizational and technical aspects. It should be borne in mind that accidents at work-places result not only from dangerous conditions but also from dangerous behaviours of workers. Shaping of safe work conditions in the mining industry is essential due to a high degree of complexity of technological processes and also due to natural hazards. In the article some information is given on the reasons of accidents in the coal mining industry. A model of the safety culture impact on a frequency of accidents and occupational diseases as well as the conditions for undertaking safe behaviours are discussed. It is highlighted that safety culture requires a complex approach oriented onto an investigation of relationships among: man-labour-environment. The article is ended with a description of the conception of occupational health and safety management in the aspect of dust hazards. It sorts out the knowledge and gives pragmatic guidelines, concerning the safety issues.

Keywords: work safety, work safety culture, work safety culture management, dust hazards

1. Introduction

Work safety management is a method of professional risk management in a given enterprise or organization. It is perceived as a process of taking decisions in the scope of considering the safety criteria and also as a process meeting the assumed state on an acceptable risk level by workers [1].

The occupational health and safety management in underground mine workings is regulated by the Decree of the Minister of Energy dated 23rd November 2016 on detailed requirements concerning conducting operations in underground mining plants [2]. The Decree regulates conducting operations in underground mining plants in the scope of occupational work and safety including an assessment and documenting of the professional risk and an application of indispensable solutions reducing this risk.

Among the research priorities in the scope of work safety in the EU-27 countries there were tests concerning shaping of occupational health and safety through an introduction of the occupational health and safety management, strengthening the role of the business social responsibility and a dissemination of scientific discoveries and examples of good practices [3]. A commonly known fact is that the occupational health and safety regulations constitute the law but life develops in its own rhythm. That is why the culture of occupational health and safety becomes so important, both from the point of view of the occupational health and safety as well as from the social aspect of work. Tests and analyses of reasons of experienced events indicate that most often an inabidance by elementary safety regulations, and in consequence a human error, lead to a disaster [4].

Accidents in work-places result from dangerous conditions and from dangerous behaviours. An approval of dangerous conditions, a permission for their existence and also taking and tolerating dangerous behaviours of co-workers is a symptom of low and unwelcome safety culture, contributing to accidents [5].

Undertaking activities in the scope of an identification and shaping work conditions in the mining industry is essential due to a high degree of complexity of technological processes. A big number of collaborating technical means, the people working in their direct vicinity, in difficult environmental conditions, require a consideration of a series of factors, which have a direct impact on work safety. An elaboration of new design solutions requires a series of analyses differentiated in relation to the work conditions as well as to the condition of technical means. Shaping of safe work conditions requires, in turn, an application of engineering tools as well as of the knowledge repositoria, enabling a quick implementation of developed methods [6].

2. Work safety culture in underground mines

Polish underground mining is characterized by complex geological and mining conditions and the occurrence of the natural hazards such as: methane, coal dust explosion, rock bursts, caves, fire, water, gas and rock outbursts and climatic.

The reasons of accidents in the coal mining industry differ in individual countries, what results from mining-and-geological conditions, conducted prevention and to a large extent from the level of the safety culture. In different countries the occupational health and safety management, whose part incorporates the safety culture, is on a very differentiated level. Safety management systems, implemented in most of the mines may be characterized by low efficiency, if simultaneously the workers' attitudes towards hazards and risks are not changed and if acceptable values are not connected with the behaviours being in compliance with the regulations and safety standards when a risky behaviour is not assessed negatively and treated as unwelcome.

According to 0 many accidents and incidents in a mine have a reason due to misunderstood regulations which are to prevent against an incident occurrence. The reasons include a lack of awareness or understanding, an ignorance or intentional breaking the rules. The tests, presented in the work 0, unianomously show that accidents are mainly caused because of a low training level of the occupational health and safety, and in consequence avoiding emergency barriers, insufficient trainings and a lack of equipment knowledge and additionally other factors creating the safety culture.

Another test, presenting 25 accidents in coal mines all over the world, showed that many incidents happened because miners 0:

- did not know the rules,
- were aware but did not understand the rules,

- followed the rules in an incorrect way,
- ignored the rules,
- intentionally broke the rules,
- took risk,
- were not capable of identifying dangerous situations,
- were badly trained or did not have sufficient education.

An impact of safety culture on an occurrence of accidents and occupational diseases shows the diagram below (Fig.1).

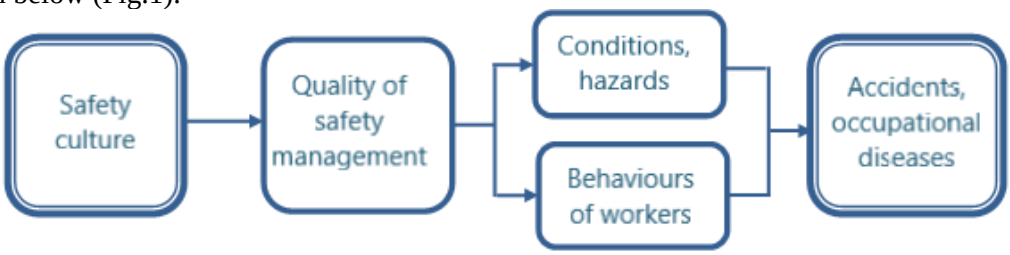

Fig. 1. Model of safety culture impact on a frequency of accidents and occupational diseases 0

In the work 0 an assumption was made that safety level of workers' behaviours is a function of possibilities and motivations (Fig. 2). The possibilities concern organizational aspects, facilitating an undertaking of safe or risky behaviours (efficiency of safety management systems and work organization) and subjective factors, i.e. workers' professional competences and competences connected with safety (knowledge of procedures, correct risk assessment, ability of hazards control, talents, abilities, personalities). Motivations for undertaking safe behaviours should encompass an internal necessity of acting according to the requirements of formal standards (resulting e.g. from a high level of safety in an individual hierarchy of values) attitudes towards the hazards standards, risks and formal safety standards as well as preferred patterns of behaviour.

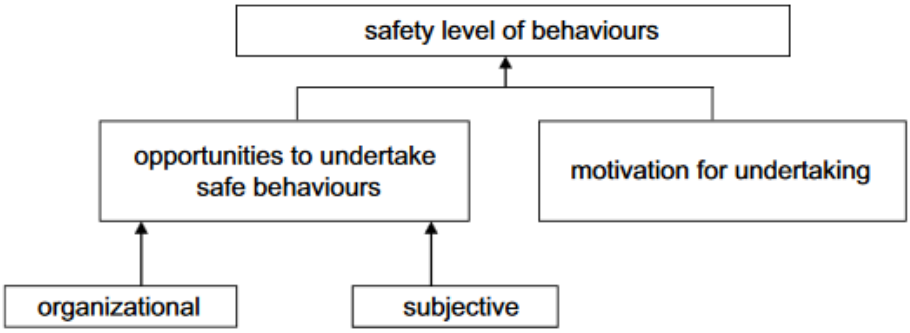

Fig. 2. Conditions for undertaking safe behaviours 0

The safety culture 0 in an enterprise is shaped by an involvement of all the workers, their work in groups and a feeling of belonging to the company as well as their proper education. Special attention should be paid to three elements:

- Work physical environment (tools, machines, organization of work-places).
- Behaviours of workers (compliance with occupational health and safety regulations, transmission of information and collaboration, demonstration of care as regards safety exceeding duties)
- Internal features of workers (knowledge, abilities, motivation).

Shaping the expected safety culture must be a continuous process because a real cultural change is difficult and it requires time. Technical and organizational activities 0 form frames for work safety culture. According to the state-of-the-art concepts of safety management, it is recommended to apply psychological actions (Fig. 3) apart from preventive technical and organizational actions. Beside the present technical-and-organizational activities, it is essential to equip people with knowledge, experience, but in particular with a motivation for undertaking safe behaviours and avoiding risks 0.

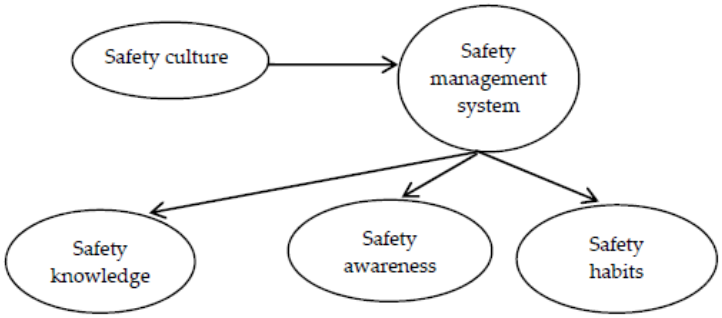

Fig. 3. Safety culture – aspects of assessment 0

Lack of social acceptance of work in the conditions threatening the health and life of workers can be seen more and more clearly. At present, technical means, used for an improvement of occupational health and safety, have achieved the level satisfactory enough, so the reasons of accidents (dangerous events) result mainly in the sphere of attitudes (behaviours) of the people engaged in the work processes. Due to that, human mistakes, reasons of their occurrence and potential consequences to which they can lead 0, are analyzed more and more often. In other words, apart from testing reasons and circumstances of accidents, the activities of preventive character, oriented onto testing of so called hazard potential (analyses of dangerous situations) caused by a human behavior, are undertaken. Apart from observing the occupational health and safety, it is extremely important to convey information and to collaborate as well as to demonstrate care of safety through motivating workers to observe the occupational health and safety regulations, making them aware of the consequences resulting from risky behaviours such as a hazard of losing health or life an also a dismissal from work. It lacks motivating techniques in mining plants, used in other branches of industry such as motorization or electronics. Recently imposing of objectives and an assessment of workers, among others with use of Kaizen programme [1], is one of popular methods used in these branches of industry. This method enables the workers to suggest improvements at their work-places and in their plant, for which they obtain additional points in periodic assessments. A use of this technique causes an involvements of workers in the activities of their organization and it has a positive impact on work organization. It also improves relationships among the managerial staff and the workers, supporting a construction of the workers' good attitudes and behaviours.

An assessment of the safety culture level is conducted mainly based on a survey among workers of all the positions 0-0. Six equal safety aspects, as regards their weight factor such as: values in the scope of safety, relationships among workers and affiliation to the company, responsibility and awareness in the scope of occupational health and safety, safe behaviours, an involvement of the managerial staff and a participation of workers as well as occupational health and safety trainings and analyses of accidents, were used in one of such tests 0. An assessment of the culture level of work safety was determined as an average of these assessments (Fig. 4).

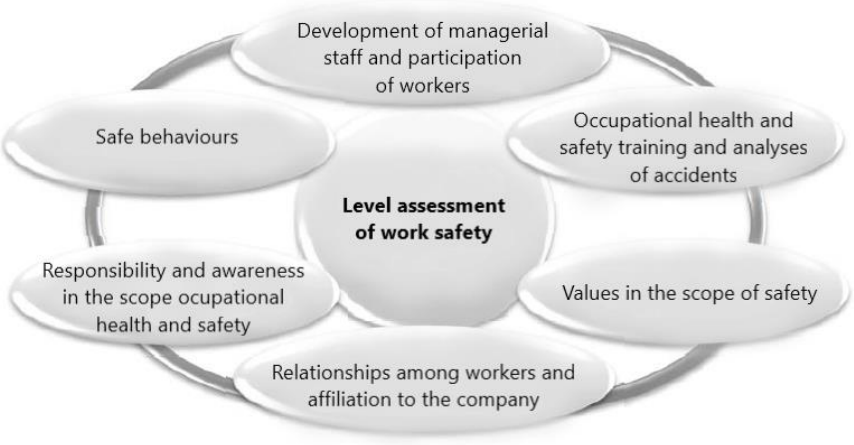

Fig. 4. Safety culture in an enterprise – aspects of assessment [17]

The assessment results showed that in the enterprises with the implemented certified and formalized system of the occupational health and safety management, the level of work safety culture was higher than in those which did not implement the management systems. A higher assessment of the level of work safety culture is related to all the aspects. Simultaneously it can be seen that irrespective of implementing the management system of occupational health and safety, the occupational health and safety trainings and analyses of accidents were assessed in the lowest way.

3. Hazards caused by dust

The content of dust in the air is one of the biggest hazards, occurring in hard coal mines. It is generated in the result of mining seams and driving roadways. Coal dust has explosive properties and in the determined conditions it may cause a disaster, whereas rock dust has a harmful impact on human respiratory system, contributing to pneumoconiosis. Both kinds of dust occur in the mine air simultaneously but in different proportions and concentrations 0.

As regards rock dust, a long-term exposure of the respiratory system to this dust causes pneumoconiosis which belongs to the oldest occupational diseases and it is inseparatebly connected with the mining industry. Pneumoconiosis is defined as an accumulation of dust in lungs and a reaction of the lung tissue to its presence. This disease is caused, inter alia, in the result of breathing in, by a miner, of dust generated during a drivage of coal and stone workings and mining of hard coal 0.

The workers, employed at work-places, where there is a hazard of harmful dusts (containing free silica), are equipped with appropriate means of individual protection of respiratory tract, adapted to the size of the occurring hazard and meeting the requirements of the Act from 13th April 2016 on systems of conformity assessment and market supervision (Official Gazette, Item 542, 1228 and 1579 as well as from 2017, Item 1089).

A selection of means for an individual protection of respiratory tract is executed for individual work-places, based on measurements results of dust concentrations in the air, conducted during the technological process generating the biggest amount of dust (CIP-10 dustmeters, Barbara 3A dustmeters and AP-2000EX type aspirators). In mining plants, exploiting hard coal, workers employed at work-places, where the highest permissible concentrations of dust are exceeded, have a possibility and a duty of using single use half-masks or multi-use masks completed with cleaning elements – filters of appropriate protective class (P-1, P-2, P-3 classes).

An anti-dust mask should protect the worker's respiratory system and it should be comfortable for wearing and breathing. An incorrectly selected anti-dust mask may cause breathing difficulties and cause a hazard of loosening or an accelerated tiredness due to breathing. A relinquishment of using masks may have a negative impact on health after a significantly longer period of time, even a dozen years or so.

The values of the highest permissible dust concentrations can be accepted as a criterion for an assessment of occupational risk as regards an exposure to dusts. The PN-ISO7708:2001 Standard gives definitions of dust fractions used for an assessment of health hazard:

- total dust – all the particles contained in a determined volume of air,
- inhaled dust – a part of the total dust mass breathed in by nose and mouth. Additionally, respirable dust is distinguished which is a part of the inhaled dust reaching the direct part of respiratory tract.

Hard coal mines, collaborating with the entities supervising work safety and with research organizations, conduct expanded activities oriented onto a reduction of dust in the air of mining plants, protecting the people against its harmful impact 0. It is assessed that in the year 2019 3800 miners working in longwalls, and 1150 miners working in roadway drivage experienced an impact of harmful dusts. According to the State Mining Authority, which conducted its own statistics **Błąd! Nie można odnaleźć źródła odwołania.** of pneumoconiosis rates in active hard coal mines over the years 2015-2019, despite of the increase in 2019 from 4 to 9 cases concerning professionally active workers and from 131 to 145 cases concerning ex-workers, a decreasing trend is maintained.

4. Technical and organizational means preventing dangers in the aspect of dust hazards

An efficiency of activities, oriented onto an improvement of workers safety and health protection, requires their conducting within the framework of well-ordered management system implemented in these organizations. The International Labour Organization defines the management system of occupational health and safety as a system of interconnected and interacting elements serving an establishment of the policy and objectives of occupational health and safety and an achievement of these objectives.

This system requires a broader approach to the issues of occupational health and safety – a complex approach requiring a look at the system: man-labour-environment. Safe labour conditions and safe behaviours do not appear autonomously. A correct management is the most efficient way of ensuring appropriately high level of occupational health and safety. The management of occupational health and safety is an element of the Integrated Management System implemented in each of the Polish mining companies 0-0. Within the framework of the System the activities, oriented onto a maximization of protecting workers against hazards, are conducted. The common element of creating and implementing the Integrated Management System by mining enterprises is a so called social responsibility.

A creation and implementation of the management system of occupational health and safety is only the first step towards an improvement of occupational health and safety in an organization. This system must be supervised, i.e. monitored to operate efficiently. It must be subject to controls and audits. Such an audit concerns an assessment of work safety level and of activities, undertaken by the organization leading to a reduction of hazards and a reduction of the occupational risk level. The basic task of audit is a total assessment of the system of work safety functioning and detecting potential infringements of managing staffs and an elimination of these mistakes.

The first element in the process of reducing, inter alia, of the dust hazard, includes trainings in the scope of compliance with the rules and standards, concerning occupational health and safety at work-places. One of the basic legal acts, regulating this issue is the Decree of the Minister of Economy and Labour from 27th July 2004 on training in the scope of occupational health and safety. The basic trainings include: introductory training and periodic training. Introductory training is indispensable before allowing a worker to start his work. It consists of two stages: general training and work-place training. Work-place training is conducted for each employee at his work-place, where a hazard resulting from harmful, arduous or dangerous factors, occur.

It is also conducted for a worker who is transferred to a new work-place. A worker, doing his work at a few work-places, should have work-place trainings on each of these work-places. However, in the case of organizational changes at the work-place or changes of the technological process, the worker employed at this work-place must have a work-place training again in the changed labour conditions. The objective of periodic training consists in up-dating and grounding of knowledge in the scope of occupational health and safety and getting the training participants acquainted with new technical-and-organizational solutions in the scope of occupational health and safety.

The knowledge transfer to workers is not limited only to periodic trainings, but it is also realized in a continuous mode, using different forms of knowledge presentations. A training efficiency depends, to a big extent, on its form, so mining plans started to use Internet as a medium enabling a knowledge transfer. It is oriented onto increasing an involvement of trainings participants and thus absorbing a bigger amount of information by them. An availability of the internet platform to the workers does not cause itself an increase of the involvement in the learning process. A motivation for learning is very important. Therefore, the occupational health and safety as well as trainings departments organize competitions in the scope of knowledge of occupational health and safety regulations, in which attractive prizes are given. It causes an increase of the workers' interest in this kind of platforms and has a positive impact on their involvement in the process of a continuous improvement due to deepening of knowledge 0. For example in the first stage of the competition "I work safely", lasting from April till the end of September 2020 the workers of the PGG Company solved 215 thousand tests, which included 6.5 million questions projected on the screens 0.

Correct behaviours at work-places may be also shaped by schooling films, which are used during trainings. They are developed most often on the basis of a real event and show an impact of a dangerous behaviour on health or life. These films also serve for gaining knowledge, how a worker should behave in the case of a dangerous event occurrence.

As regards shaping of safety in the scope of dust hazards, it is inadmissible to use machines and equipment which generate dust in technological processes and they are not equipped with efficiently operating devices, reducing dustiness and inefficient devices and means used for a reduction of dust concentration in the air. Designing of such devices must take into consideration work comfort of their future users. It is inadmissible to use solutions which decrease work comfort, leading to their intentional switching off.

The basic corrective measures, which reduce dust in mines, also include spraying installations of longwall shearers and roadheaders. Although they are applied obligatorily in all the cutting machines, they rarely enable to reduce dustiness to the values below the highest permissible concentrations.

Dust control equipment and spraying installations are usually located in the areas of 0:

- cutting machines (on cutting drums and cutting heads),
- canopies of powered roof supports,
- run-of-mine transfer areas of conveyors,
- in roadways – as safety barriers,
- as a part of a ventilation system.

Water, low pressure spraying installations, supplied directly from the fire-pipelines achieve a small degree of water spraying through the nozzles at the water output in the range of 10 dm^3/min. Additionally, they often impede activities of the workers in the area of transfer points, which results in their intentional switching off. An optimization of water consumption, in relation to the achieved effect, is very important because an increase of the water amount may not give the effect of dust reduction. It is essential to conduct tests of the optimum location of spraying installations before their placing in the areas of the ventilation air stream 0. Due to the fact that an excessive amount of water should not make the work more difficult, in each individual case it is needed to establish a proper water flow intensity, build the installation correctly and condition its operation e.g. on an operation of the conveyor or on a presence of the feed on the belt or on the dust concentration, controlling the spraying installation by the dust sensor.

In recent years air-and-water systems, using the pressure of compressed air for a generation of mixture and spraying of the water stream to droplets of very small diameters, find more and more broad applications for a reduction of dustiness in hard coal mining industry. This type of spraying is characterized by a big efficiency of dust reduction and one of the leaders of such an approach is the KOMAG Institute 0, where the majority of air-and-water spraying installations, functioning in the Polish mining industry, have been designed.

The first spraying systems of such a type have been designed for longwall shearers. After having conducted stand and exploitational tests, they were implemented in mines. These implementations enabled to confirm their higher efficiency in comparison with the systems used so far.

Problems with exceeding dust concentrations in the air also occur in roadway faces. There are many solutions of internal and external water spraying installations for roadheaders. The first ones are characterized by a big degree of complications and high maintenance requirements and the other ones – by a low efficiency of dust reduction.

An alternative is an external, air- and- water spraying installation ensuring an efficient protection of the cutting process against methane ignition and a high efficiency of dust reduction. This installation operates on a similar principle as the installations developed at the KOMAG Institute, which are described above 0.

Apart from longwall shearers and roadheaders the air- and water spraying installation of the BRYZA type is used for a dust reduction in roadway workings of mines. Another possibility of using this solution concerns transfer points of conveyors, where too big dustiness is a real problem. In the case of conveyors, transporting the-run-of-mine, it is most essential to apply the spraying stream directly to the place, where the biggest amount of dust is generated during a discharge of the-run-of-mine from one conveyor to the other one. These installations have an efficiency of about 70% as regards dust reduction 0.

The last solution, discussed in the article, is dedicated for use in exploitational longwalls. It is a spraying installation of selective operation in the spot, where the cutting machine, generating dust, appears. Its design solution consists in a construction of spraying batteries on selected powered roof support units, along the whole longwall and in a generation of the air- and- water mixture in the zone of dust laden air in the result of a longwall shearer operation 0.

5. Conception of occupational health and safety management in the aspect of dust hazard

Occupational health and safety management in the aspect of dust hazards, both rock ones as well as coal ones, should be started and ended with the safety culture. Introductory trainings as well as those at work-place must be designed in an interesting and attractive way. An application of computer methods for shaping safe labour conditions is a requirement of our times. A typical lecture, as the basic form of training, has become an inefficient tool. The available IT solutions enable to stimulate to activity the participants of trainings, using inter-active games or ensuring an interesting form of the knowledge transfer through e.g. a presentation of an accident reconstruction, using computer animations. The developed materials take into consideration a change in the way of thinking of the young generation 0. Following this path, it should be borne In mind that designing of means and devices for a protection against excessive dust must take into consideration work comfort of a future user. Starting from the means of individual protection of respiratory tract, which apart from a correct selection to the kind of threat should be adjusted to the worker, who should have knowledge about their wearing and using in the way, ensuring their efficiency. In the case of designing machines and equipment, the designers, due to a development of IT tools have broad possibilities of assessing the developed design solutions with use of ergonomic analyses. They can evaluate not only an efficiency of designed solutions, but also an impact of the solution on servicing machines and equipment. Designed solutions cannot cause arduousness, because then they will be intentionally ignored by the personnel.

Summing up, the safety model must contain technical and organizational activities based on the occupational health and safety regulations in power. These activities must be reflected in all the available types of trainings, in work-place trainings, theoretical ones and practical trainings at work-places, taking into consideration available knowledge and technical means. A creation of safe labour conditions must predict equipping work-places with protective means both of personal protection (half-mask), as well as devices or infrastructure, ensuring a safe work environment (e.g. spraying or dust control installations). Ensuring the proper level of safety should be realized with use of remote monitoring of the hazard level or cyclic controls performed by servicemen, monitoring the mine safety conditions or by the staff, supervising the work in hazardous areas. A prevention at work-places is essential because e.g. by using proper exploitation, ventilation system or by protecting against generating dust by haulage equipment (Fig. 5), the hazards can be controlled.

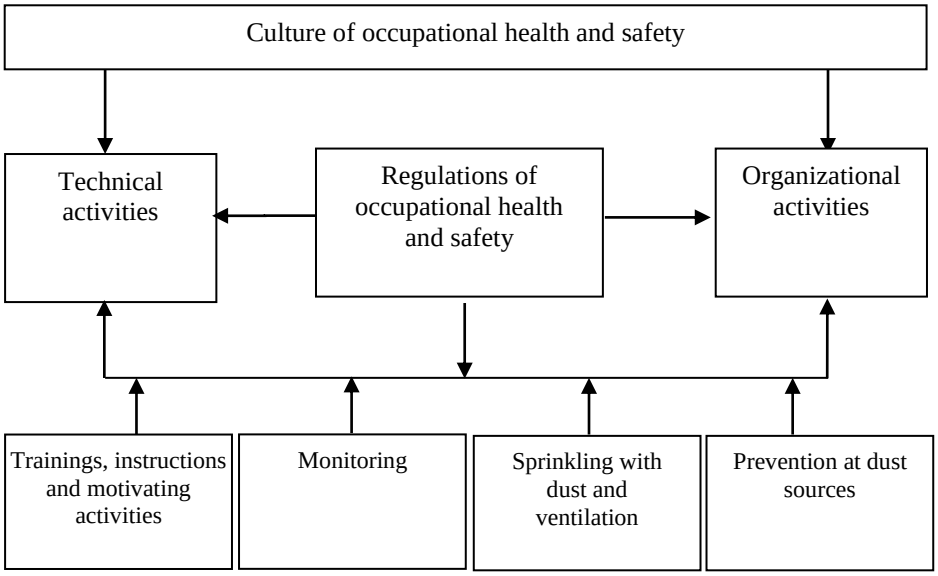

Fig. 5. Complex model of safety culture in the aspect of dust hazard (own work).

A hazardous condition is usually generated, when more than one of the factors, included in the complex model of work safety, are neglected and active functioning of all its elements guarantees the work safety level which has no negative impact on a worker's health in a hazardous work environment.

6. Conclusions

The mining industry should be characterized by high safety culture because it is an industry which is most dependent on natural conditions and an unseparable element of its functioning includes many hazards to health and life of workers. Dust hazard occurs in each mine nearly in all the areas both in the exploitational ones as well as in the processing ones. Work safety management in the aspect of dust hazard consists of a series of means starting from trainings, through personal protection means and ending with equipping machines and devices with installations reducing dust in the ventilation air. The regulations establish the majority of issues in the scope of individual protection means as well as of monitoring. The superintendent of the mining plant decides about equipping machines and devices with installations along the whole route from the place of the-run-of-mine cutting to its exit from the preparation plant. In the Polish mines the trend of pneumoconiosis cases is still significant, although it decreases year to year. It is connected both with a reduction of coal production, as well as with use of more and more innovative installations, designed by research institutes. A dissemination of scientific discoveries is in accordance with the research priorities from the scope of occupational health and safety in the EU-27 countries.

In an enterprise not only employers or designated staff should be responsible for the matters of occupational health and safety but all the workers should perceive the occupational health and safety issues in the categories of rights which they are entitled to, but mainly duties or simply an absolute necessity. The safety level of workers, employed in a given enterprise, depends on the safety culture in it. Therefore, it is extremely important to equip people mainly with the knowledge about hazards and about their behaviour in the conditions, threatening their health and life.

A generation of regulations, concerning the issues of occupational health and safety and an application of innovative solutions, improving work safety, will be successful if the people become aware and convinced of the advantages resulting from a use of certain equipment and about complying with the occupational health and safety regulations. Such an approach is connected with a continuous increase of the safety culture level. Such initiatives as competitions, organized by the Polish mining companies (PGG S.A. - I work safely, JSW S.A. – Competition on the knowledge of occupational health and safety principles and regulations for the Cup of the Chairman of Jastrzębska Spółka Węglowa S.A, LW BOGDANKA – Safe Mining), motivate for deepening knowledge on the principles of safe work and for using this knowledge in everyday life. It is inadmissible to mention lack of using the required individual protection means by the workers or intentional switching off the spraying installations as reasons and circumstances of accidents connected with dust hazards.

A development and use of newer and newer safety management models, which contain experience resulting from the technical solutions functioning up till the present time and beneficiate from new technical solutions and developed management models, may contribute significally to a further increase of the safety level.

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