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Continuous dust monitoring in headings in underground coal mines

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A B S T R A C T

The article presents hazardous conditions of airborne dust based on the results of measurements of dust concentration taken at work-places at a underground rock-coal face drilled by a heading machine with combined ventilation (suction and forced ventilation with dust collector). The measurements were taken using three methods in order to examine and assess the actual conditions within the excavation subject to the study. The measurement results and conclusions show major difficulties in achieving MAC levels. Research conclusions indicate the low efficiency of collective and personal measures applied to protect against dust harmful to health as well as the need to improve them.

1. Introduction

During mining of seams of mineral rawmaterial, air is polluted with dust. Dust is moving together with the ventilation air (Bhaskar, 1986) and it settles at the wall and equipment in the excavation (Nawrat, Szponder, & Obracaj, 2002; Prostański, 2015). Dust presented in the ventilation air poses a risk to health and it has negative influence on working conditions. Another hazard related to the presence of mine dust - explosion hazard - results from its flammable properties. Settled dust may become a secondary source of dustiness having a negative influence on hazardous conditions. The essence of all actions aiming at fighting of dusts harmful to health, directly related with the pneumoconiosis morbidity, is monitoring of the dust exposure of an individual worker. The results of the monitoring provide the basis for undertaking effective preventive measures depending on the type of works performed (Lebecki & Bywalec, 1998, pp. 111–116). The methodology of measurements and their frequency are described in relevant standards and regulations concerning mining law (Ordinance of the Minister of Economy, 2002; Ordinance of the Minister of Labour and Social Policy, 2014; PN-Z, 2004). These regulations specify that the measurements should be made once a year, and the maximum concentrations of dust containing free crystalline silica from 2% to 50% is: for total fraction 4 mg/m^3, while for the respirable fraction 1 mg/m^3. The measurement methods currently used for the determination of the hazard concerning dust harmful to health (in case of dust concentration measurements) are based on the results of measurements averaged over time - gravimetric method (Vincent, 2007). Due to a dynamic character of the phenomenon of dust transport with ventilation air and various sources of dustiness, these methods do not reflect the actual conditions within the excavations. That is why the studies have been carried out, in order to determine the risk posed to the workers, inclusive of measurements with gravimetric dust sampler, collection of samples of settled dust and determination of their size distribution using the method of laser diffraction as well as taking measurements of concentration of dust suspended in air using optical dust samplers that register instantaneous concentration of respirable dust. The issues concerning the influence of dust on health and life of people employed in the mining industry constitute a serious problem (Li, Qin, Yang, & Tian, 2011) both in Poland and over the world (Ji et al., 2016). Objective of study is to demonstrate that continous improvement of dust suppression methods is necessary to achieve the diminishing of pneumoconiosis probability in underground coal mines.

A huge attention was paid in this article to the description of measurement methods applied and the interpretation of results. Comparative results of measurements obtained using the measurement methods applied during the study have also been presented.

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2. Materials and methods

2.1. Place and course of investigation

In order to determine the hazard concerning dust harmful to health, a face drilled with a heading machine below the level of 800 m in a colliery has been selected. The heading was drilled in a seam with a thickness between 0.3 m and ca. 2.1 m. The resistance of coal to uniaxial compression was between 5.0 and 11.0 MPa. Rocks surrounding the seam characterized with a high resistance to uniaxial compression between ca. 20 to over 100 MPa. The seam was classified as less prone to self ignition, also as gaseous with coal dust explosion conditions. The excavation was ventilated in a suction and forced-air separate ventilation system. A dust collector UO-630 (air flow from 400 to 600 m^3/min) was used to fight the dust that occurred during excavation and its emission to the ventilation stream. The distance of the exhaust air duct (exhaust fan of the dust collector) from the working face during mining was less than 3 m and the inlet to the air duct was located near the roof of the excavation (Krause, & Łukowicz, 2000). Moreover, a rotational-type air duct was placed at the end of the forced ventilation air duct. The air duct was working with dust extracting equipment which was used for proper formation of the air stream during excavation, so that the air ventilates the entire area of the heading (in particular, under the roof of the excavation) and was going to the working face with a rotary and force motion. The purpose of this solution was also to stop spreading of dust that forms within the area of the heading machine unit (Jedziniak & Frydel, 2011). That is how the so-called Coanda effect was obtained. This phenomenon consists in adhesion of a medium stream (gas or liquid) to the nearest surface. Due to the type of the equipment used and primary temperature of rocks in the excavation, an air cooler was also used which allows to improve working conditions. The air flow velocity was between 0.5 and 0.8 m/s, the measurements were taken with a manual and stationary vane anemometers. Chart presenting the equipment within the excavation, location of measurement instruments and arrangement of crew during the study can be found in Fig. 1.

The measurements were taken between January and June during several working shifts. During the period when data were collected and measurements taken, the geological conditions of the excavation drilled were changing significantly. The thickness of the seam was decreasing and the amount of sandstone in the cross-section was increasing. Such changes directly affected the dust concentration value in the outlet air stream as well as the amount of free crystalline silica in dust collected with gravimetric dust collector.

Mining and geological conditions also had influence on the progress of the excavation drilled which was significantly limited from 7.2 m/day to 3.2 m/day due to an increase of the rocks hardness.

The measurements of dust fraction in the air that flows out from the excavation were taken with the use of gravimetric dust samplers CIP-10R and CIP-10I which were located directly near the optical dust samplers PL-2 (Fig. 2). The sets were suspended 100 m and 200 m from the working face of the heading. A person trained in terms of samples collection from the ventilation division of the colliery was designated in order to ensure a proper operation of dust samplers CIP-10, and that person was providing sets of dust samplers to the laboratory after each measurement shift.

Dust samplers were replaced by the telemetrical division of the colliery along with the progress of works, so that a constant distance from the place of cutting coal was maintained. Dust samplers PL-2 optical system were cleaned by an authorized person before each measurement and calibrated once a month by an authorized unit with use of a chamber where the dust taken from excavation was airborne. Settled dust were also collected for a comprehensive determination of hazard and tested in terms of the granulometric distribution with the use of a laser diffraction method. The samples were collected by a point-by-point method from the places near the dust samplers installed in the excavation. The samples were collected on a flat surface and then they were placed in the containers. The containers for the samples were made of glass and closed tightly. The basis for the selection of such containers was to avoid contamination, approve for use in a colliery as well as their safe transport. Each container was marked for further identification of a sample. The next step was to prepare the samples for tests. The samples were placed in opened containers and brought to the air-dry conditions. The samples were dried and then screened. A sieve

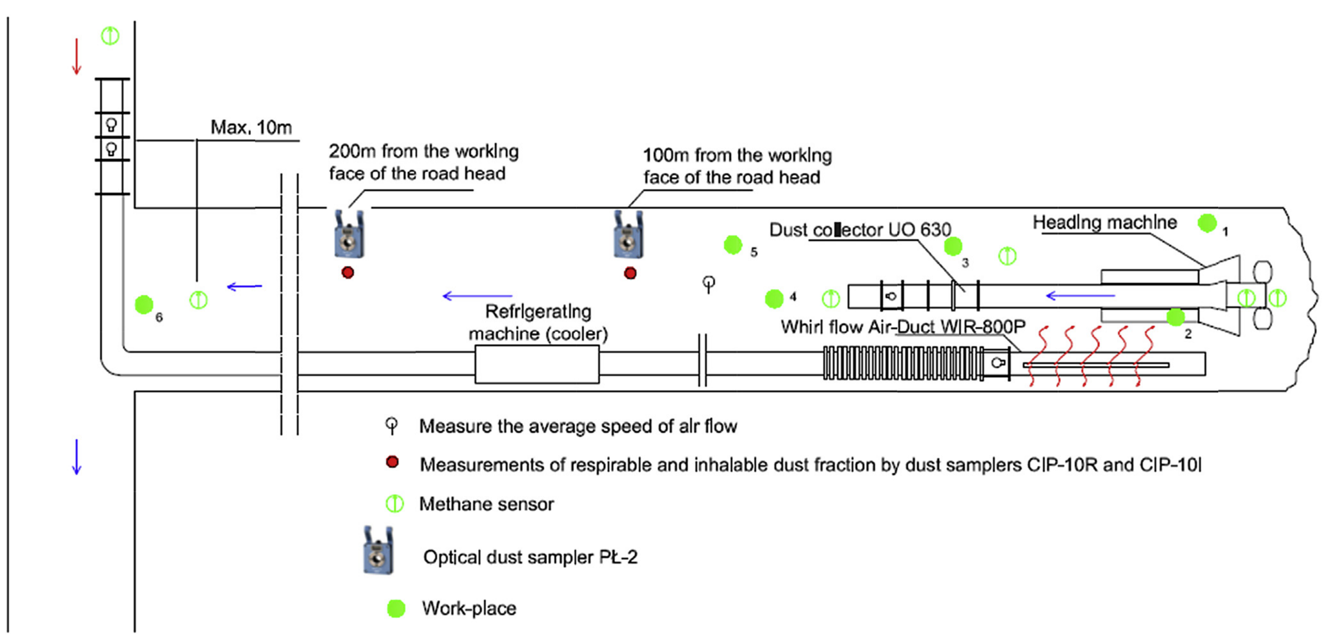

Fig. 1. Heading with equipment and sensors.

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