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Reduction of Dust in the Longwall Faces of Coal Mines: Problems and Perspective Solutions

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Abstract

Despite the increasing reliance on alternative and renewable energy sources in recent years, coal is set to continue being the most vital element of the global energy sector. The world coal supply (1,070 billion tons) shall last for 130 years with the current mining levels. In contrast to some large countries (such as the USA and Germany) reducing their coal production and consumption, Russia plans to increase the coal production levels as part of its strategy regarding the future of the coal mining industry. The annual volume of coal output is more than 440 million tons, 1/3 of which is extracted underground. The current and projected levels of underground coal mining present a set of issues pertaining to elevated dust concentration in the air and increased dust dispersion. High dust concentration in the air leads to damage to the skin, mucous membranes and respiratory organs of workers. Also, with high dust content, visibility in the longwalls decreases, the risk of injury and accidents increases.

The present article deals with the formation of detrimental dust conditions that happen in the course of cleaning and preparatory mining operations in coal mines. The article reviews the international practices on dust reduction in coal mining operations and provides an overview of studies on dustiness levels and airborne dust composition in longwall faces of coal mines. It also presents mathematical models dealing with projections on dust composition, including projections on most hazardous dust particles the size of 0.1-10 and 0.1-35 µm. The article also presents a newly developed wetting method showing increased effectiveness.

Keywords

Underground coal mining, longwalls, dustiness, pneumoconiosis, aerosol dispersed composition, dust control, forecast of dust conditions, complex dedusting measures, dust wettability.

Introduction

The current state of the global energy industry is such that, despite the commitment from the leading countries to decrease carbon emissions, eliminating the reliance on coal does not appear to be a viable option for a number of reasons. Firstly, energy from coal amounts to 27% of the global energy mix (as of 2019). To give context, natural gas amounts to 24.2%, and alternative energy sources together with nuclear energy and hydroelectric power amount to only 15,7%. Secondly, at current consumption levels, the global coal reserves should last for 132 years, and for some areas — even longer (for NA the estimates put the reserves levels at 367 years, and for CIS countries — at 338 years) (BP Statistical Review of World Energy, 2020).

The main coal deposits are located in four countries, which together account for 65% of global reserves: the US (23%), the Russian Federation (15%), Australia (14%) and China (13%). At present, global coal reserves are estimated to contain 1,070 billion tons. Despite some decline in coal consumption in 2019 and a drop in global coal prices, the coal industry remains promising and continues expanding (BP Statistical Review of World Energy, 2020).

When it comes to Russia, coal remains not only a valuable energy source but also one of the country's main exports, which means it contributes greatly to the Russian economy and employment levels. Coal mining and coal processing enterprises account for 160,00 jobs. Russia's yearly coal production level is 440 million tons, one-third of which is mined underground. As per the forecast of socio-economic development of the Russian Federation for the period until 2036, Russia is expected to raise the production levels to 670 million tons a year by 2035, as well as to expand exports to the Asia-Pacific region (Projections on social and economic development of Russia for the period up to 2036, 2018; Tarazanov and Gubanov, 2020; BP Statistical Review of World Energy, 2020).

The increase in production is achieved via the implementation of highly efficient mining equipment, with feed rates of up to 50 m/min, increased lengths of longwalls (up to 400 m) and extraction columns (up to and exceeding 2,500 m) and improved labour efficiency. With the increased frequency of preparatory mine works and creation of new longwall faces comes a worsening in the dust- and gas-related working conditions, which leads to worsening of occupational health and safety (Gendler and Nguen, 2018; Chemezov, 2019; Magomet et al., 2019; Smirnyakov and Smirnyakova, 2016; Zhikharev et al., 2018).

The goal of the present study is to develop suggestions, recommendations, and practical solutions for dust reduction in the longwall faces of coal mines.

The objectives are as follows:

1. To analyze the international practices on improving dust conditions in coal mines.
2. To study the factors influencing the dustiness and aerosol dispersion composition in the mine faces.
3. To develop suggestions, recommendations, and practical solutions for dust reduction in longwall faces of coal mines.

Analysis of dustiness-related working conditions at coal mines and associated occupational diseases. Defining the problem

The methods currently employed in Russian coal mines do not lower the time-weighted average (TWA) dust contents to maximum permissible concentration (MPC) or even to levels close to it. The mining works also don't involve particle-size distribution tests, which are vital to assessing the effectiveness of dust reduction methods and the rate of development of occupational respiratory diseases. The most severe diseases of respiratory and cardiovascular systems of the body are caused by the accumulation of not airborne dust per se, but specifically by small dust particles with sizes up to 2.5, 10 and 35 µm (Haritonov et al., 2019; Air quality guidelines: global update 2005. Particulate matter, ozone, nitrogen dioxide and sulfur dioxide, 2006; Danilov et al., 2017; Pope et al., 2002; Samoli et al., 2008). In the process of defining the working levels of dust concentration and choosing the wetting method, the mechanical properties and the contents of the coal dust are often ignored, despite the fact that these factors are very wide-ranging. Data on projected dustiness levels are not factored into decisions regarding changes to wetting methods and modes. Sometimes the control of air quality and soundness of wetting and mining equipment is not performed at all. This results in increased dustiness levels, which negatively affect not only the miners' skin, mucous membranes and respiratory organs, but also leads to various occupational diseases, reduces visibility in the face area, and makes the working conditions more hazardous.

Dust reduction is a relevant issue for the mining industry (Danilov et al., 2017; Gendler et al., 2019; Kovshov and Barkan, 2016). The majority of working zones in coal mines are characterized by hazardous dustiness levels of varying severity. For example, at the mines of one of the world's largest Russian coal mining companies, "SUEK, JSC", at 79% of working areas, the concentration of dust in the air exceeds the MPC. At the same time, 51% of workplaces can be classified as class 3.1, 21% – as class 3.2, 7% – as class 3.3 (Tab. 1) of hazardous working areas classification. Of those, 51% of working zones fall under class 3.1, 21% – under class 3.2, and 7% – under class 3.3 (Tab. 1).

The number of occupational diseases caused by exposure to industrial fibrogenic aerosols changes dramatically from one mine to the next (Fig. 1) and, in some cases, reaches 30% of total occupational diseases (Fig. 2).

Tab. 1. Results of the assessment of working conditions at the company mines from 2015 to 2018

Mine №	Total employees / work spaces		Total employees / work spaces ranged by working condition class				Total employees / work spaces ranged by working condition class (classification by severity of fibrogenic aerosols)		
			2	3.1	3.2	3.3	3.1	3.2	3.3
1	Work spaces	591	223	193	165	116	340	36	20
	Employees	1505	117	357	450	475			
2	Work spaces	526	92	163	138	133	154	127	26
	Employees	1495	189	240	549	517			
3	Work spaces	435	67	200	117	51	162	71	16
	Employees	967	141	273	298	255			
4	Work spaces	402	93	143	116	50	179	65	23
	Employees	571	126	201	162	82			
5	Work spaces	831	156	282	229	164	329	127	31
	Employees	1797	226	561	577	433			
6	Work spaces	354	66	106	93	89	107	153	18
	Employees	827	103	134	281	309			
7	Work spaces	225	12	74	52	87	128	10	64
	Employees	470	39	123	127	181			
TOTAL	Work spaces	3364	603	1161	910	690	1399	589	198
	Employees	7632	1047	1889	2444	2252			

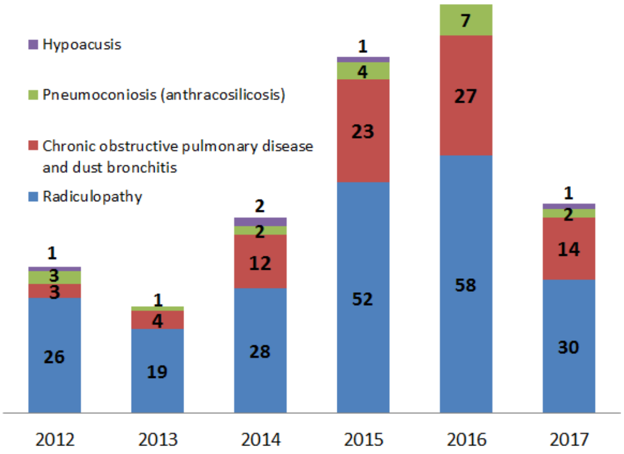

Fig 1. Data on occupational diseases from a mine in Eastern Donbass (Source: Authors)

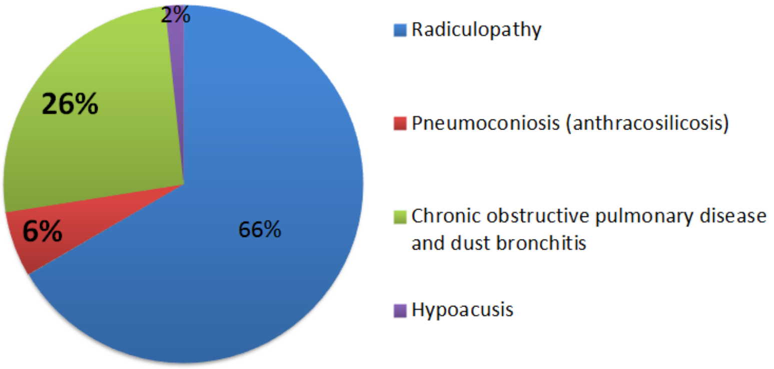

Fig. 2. Occupational diseases at a mine in Eastern Donbass from 2012 to 2017 (Source: Authors)

Anthracosilicosis, dust bronchitis and other respiratory afflictions are more frequent in workers who spend most of their shifts in areas of high dustiness (such as longwall faces): machine operators, miners, wiremen, and overseers (Tab. 2) (Romanchenko et al., 2016; Haritonov et al., 2019; Chebotarjov, 2019; Han et al., 2015).

Tab. 2. Distribution of occupational respiratory diseases by profession

Job title	Number of diseases reported for the first time		
	Anthracosilicosis	Chronic obstructive pulmonary disease and chronic bronchitis	Total dust-related diseases
Shaft miner	4	10	14
Stope miner	2	11	13
Overman	2	10	12
Underground wireman	1	11	12
Shot-firer	1	9	10
Underground miner	0	8	8
Prospector	1	4	5
Overseer	0	4	4
Mine captain	1	2	3
Hoist operator	1	2	3
Explosives' distributor	0	3	3
Operator of rock removing machines	1	1	2
Surface wireman	1	1	2
Deputy captain	1	1	2
Shift manager	0	2	2
Deputy Chief Engineer for Maintenance	1	1	2
Bulldozer operator	1	1	2
On-duty wireman for repairs	0	1	1
Operator of underground installations	1	0	1
Mine undermanager	0	1	1
Service-man for manual welding	1	0	1
TOTAL	20	83	103

Silicosis and chronic (dust) bronchitis account for almost half (41-47 %) of all occupational respiratory diseases (Projections on social and economic development of Russia for the period up to 2036, 2018).

High occupational morbidity levels caused by dustiness is not a Russia-specific problem. The same can be observed in mines of China, US and Australia. Surveys of 29.5 thousand US miners conducted from 1996 to 2002 showed 886 people with various lengths of service diagnosed with pneumoconiosis. From the 1970-s to the start of the 21st century, almost 70,000 miners died from pneumoconiosis (Colinet et al., 2010). In China, the miners receive tens of billions of dollars yearly for working in hazardous dust-related conditions (Han et al., 2015; Ji et al., 2016; Wang et al., 2016; Xia et al., 2014).

Overview of dust reduction methods in coal mines

All technical measures for dust reduction can be divided into several types based on the means, principles, and areas of application. Let us take a look at those that are predominantly used in longwall faces (Federal regulations on industrial safety. Regulations on explosion prevention of dusty gas-air atmospheres in coal mines, 2013; Federal regulations on industrial safety. Instructions on dust control in coal mines, 2019).

The first type includes measures pertaining to reducing the concentration of small airborne dust particles with an input of fresh air. In other words, the dust cloud is hit with an air jet moving at an appropriate speed.

The second type includes measures pertaining to the removal of polluted air via special air control systems (built-in or outgoing) that is followed with the scrubbing of that air using dry or wet filters (CFT GmbH Compact Filter Technic. Consistently high quality. Dry dedusting, wet dedusting, dedusting for dry drilling, 2020).

The third type includes measures pertaining to dust wetting, a process of spraying dust clouds with water through nozzles. This incorporates wetting through nozzles located under shearer blades, a procedure aimed to prevent frictional ignition of coal and methane. In addition to nozzles located under the blades, shearers also have nozzles on their bodies. Modern shearers by Eickhoff and JOY come with nozzles of different sizes that can supply water to the blades at volumes from 0.94 to 4.13 l/min. Total water consumption levels depend on the shearer model. For JOY 7LS shearers, for example, the consumption levels range from 313.3 to 520.0 l/min (Korshunov and Romanchenko, 2016; Romanchenko et al., 2016; Romanchenko et al., 2011).

Sections of the canopy support set-ups of wetting measures where water is sprayed either towards the face to ensure dust suppression or the opposite way (to the gob, under the roof) to reduce dustiness during the sliding of the canopy sections. In such a case, a wetting curtain (water, mist, or fabric filter) is set up in a face-adjacent drift with an upcast air current (20 m from the roadhead).

The fourth type includes measures pertaining to the pre-emptive pumping of water into the seam (water infusion) to increase saturation and reduce dustiness. This process involves making calculations to determine the optimal number and length of holes that are to be drilled into the seam, the distance between the holes, their sealing depth, and the required volume of water. The water infusion method has some limitations, however. For example, it is not used for seams with a water saturation level of over 12%, low moisture capacity (up to 2%) or low porosity (up to 5%).

The effectiveness of water infusion (η) depends on physical and filtration-related properties of the seam, as well as on the hole parameters and the chosen water delivery method (Pozdnjakov et al.,1982):

$$\eta = \mu \cdot \frac{q_l}{n_e} \cdot 100, \tag{1}$$

Where:

μ – factor of proportionality;

q_l – liquid discharge intensity, m^3/t;

n_e – effective porosity, %.

The effectiveness of the water infusion method varies from 50 to 80%. The highest reduction in dustiness (up to 80%) after the infusion was observed in the mines of the Pechora basin. The lowest effectiveness was observed in the coal beds of Donetsk and Karaganda basins. In those mines, the effectiveness of water infusions did not exceed 55%.

The full range of dust suppression measures that are to be carried out during the mining process (tunnelling, extraction, transporting, transhipment, etc.) is provided in the regulations (Federal regulations on industrial safety. Regulations on explosion prevention of dusty gas-air atmospheres in coal mines, 2013; Federal regulations on industrial safety. Instructions on dust control in coal mines, 2019).

The international experience on dust suppression (American, Australian, African, Chinese, Indian) shows that the most effective methods of dust reduction in longwall faces involve the following:

– maintaining air flows of optimal speed to prevent dust from rising, and to prevent the formation of static dust clouds (Gendler and Nguen, 2018; Colinet et al., 2010);

– taking advantage of splitter arms on the shearer to separate the working area and the zone with the highest dust concentration (Colinet et al., 2010);

– installing additional jet fans and nozzles to ensure faster dust removal and better dust suppression (Colinet et al., 2010);

– installing water-mist-based Venturi systems along longwalls (Ren et al., 2011);

– equipping shearers with scrubbers to provide dust extraction and dust suppression in the drum area (Ren et al., 2011; Ren et al., 2011);

– using sprinkling techniques that involve mixing the water with surfactants to improve the effectiveness of coal dust wetting (Wang et al., 2016; Wang et al., 2016).

It should be noted that, in some cases, the parameters and application areas for dust suppression methods are chosen based on the data on dust distribution along the longwall's length and cross-section. There exist specialized software solutions (such as Ansys and flowvision) that are used to model the dust distribution within the mine and thus provide a more reliable picture of the dust conditions therein (Smirnov and Ivanov, 2018).

Analysis of the existing patents for dust-wetting and dust-suppressing solutions has shown this avenue of research to be very promising, given the great number of registered formulas (Glebov, 2013; Zhmaev and Kuznecov, 2019; Konabe and Kavazoe, 2010; Lobanov et al., 2014; Joao, 2008).

When it comes to Russian mines, the most commonly used wetting agents are anionic and nonionic sulfactant-based ones by Elfor-M. Some mines use wetting agents by SMUG and Neolas, but these are not as common due to their relatively lower wetting ability.

These days, the research for more effective and less harmful wetting agents is conducted in both Russia and abroad (Kovshov and Kovshov, 2017; Wang et al., 2016; Wang et al., 2016), which is indicative of the fact that the currently used wetting agents do have a number of shortcomings (such as low wetting ability, high production costs, and adverse effects on the environment, workers and the extracted materials themselves).

Material and Methods

The research included the following:

- on-site measuring of dustiness levels in high-yielding longwall faces at various Russian coal mines;
- laboratory testing of dispersion composition of airborne dust taken from longwall faces;
- analysis of factors determining the dust conditions;
- laboratory research on a new wetting agent;
- on-site testing of the newly-developed dust suppression method.

The dust concentration was measured using the PKA-01 and AERA portable dust samplers at three locations: directly next to the shearer (operator working space), 5-6 meters away from the shearer along the air jet direction (canopy operator working space), and 10-15 meters away from the canopy operator's space (Fig. 3).

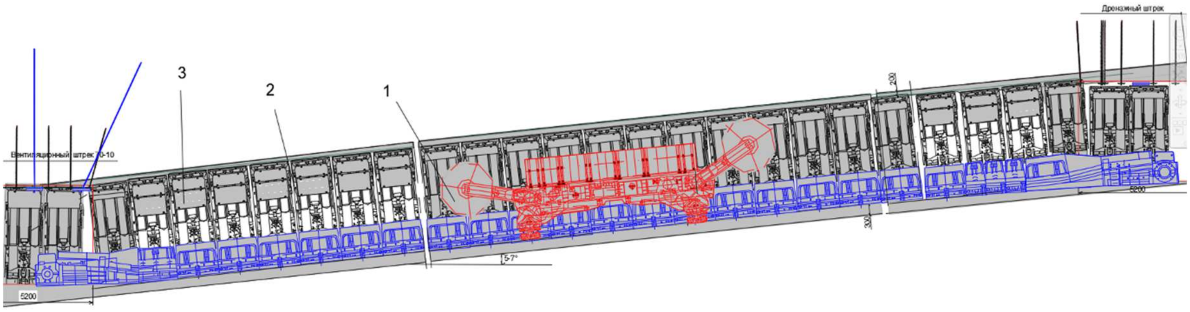

Fig. 3. Location of measurement points for dustiness tests in longwall faces
1 – directly next to the shearer; 2 – 5-6 m away from the shearer, 3 – 10-15 m away from the shearer (Source: Authors)

Additionally, dust samplings were taken at specified locations using dust filters (Fig. 4). They were then transported to a laboratory for dispersion composition testing. Particle-size analysis of the aerosol was conducted using electron microscopy (Fig. 5).

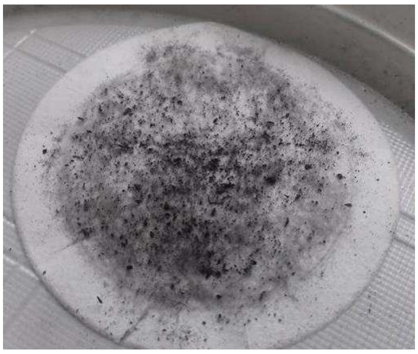

Fig. 4. Coal dust sampled on a filter (Source: Authors)

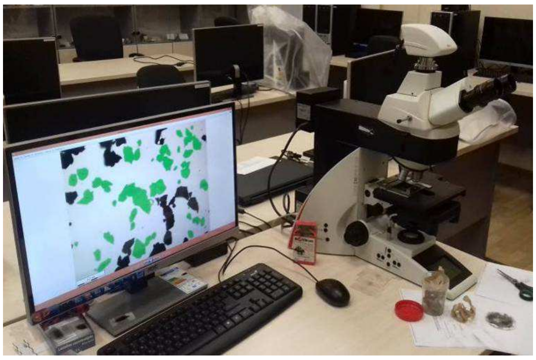

Fig. 5. Process of sample analysis via the "Leica DM4000 B LED" electronic microscope and corresponding software (Source: Authors)

Each section of the filter was studied at 100x magnification. The images were processed using specialized software that would provide data on the number and parameters of the detected particles (their corresponding diameter and area). A single sampling counted no fewer than 3,500 particles, sized 0.656-987 µm. The standard deviation of σ did not exceed 0.0628 mm.

The type of dependence of the dustiness level and the aerosol particle size on various factors was determined using correlation and regression analysis. The baseline data for the analysis is presented in Tab. 3.

Tab. 3. Dust sampling conditions

Parameter	Mine name			
	A.D. Ruban	Taldinskaya-Zapadnaya-2	V.D. Yalevsky	S.M. Kirov
Seam name	Polysaevsky-2	70	52	Boldyrevsky
Coal grade	Д (D)	Д (D)	ДГ (DG)	Г (G)
Seam thickness, [m]	4.70	4.81	4.34	2.55
Hardness coefficient, f	2.5	1.8	2.5	1.5
Moisture content, W^r_t, [%]	8.5	11.9	9.0	4.11
Ash content, A^d_{ex}, [%]	12.0	13.0	13.5	35.4
Al_2O_3 content in ash, β_{Al2O3}, [%]	16.6	23.4	25.6	20.5
SiO_2 content in ash, β_{SiO2}, [%]	60.4	60.9	61.6	63.7
Inertinite content, I, [%]	8.0	15.0	15.6	5.0
Shearer type	SL-500	SL-500	SL-500	Joy 7 LS-20
Shearer productivity, P, [t/min]	11.99-12.15	14.70-14.80	20.71-20.82	14.19-14.25
Face output, Q, [t/h]	719.1-728.7	882.1-888.0	1242.5 1249.0	851.1-854.8
Air flow speed, v, [m/s]	1.15-1.38	0.79-1.11	2.10-3.54	3.67

The development of a wetting agent contained several stages: selection of promising components, assessment of wetting ability and properties of various surfactants and their mixes, laboratory testing and on-site testing of the new wetting agent with a concurrent assessment of usability parameters. The initial stages of the project involved a comparative analysis of the commonly used wetting agent by Elfor-M, its dynamic viscosity (Fig. 6) and pH (Fig. 7) for solutions with different concentration levels.

After that came the assessment of the wetting ability of the various selected surfactants in regards to the coal dust from the aforementioned seams. For that purpose, lumpy coal samples would be crushed into pieces of -63 µm. Dust sample of 0.1 g would be placed into a prepared surfactants solution, and the time until full submersion would be measured with a stopwatch (Fig. 8). A shorter submersion time would signify better wetting ability. As per (STO 00173769-005-2014), the threshold for the optimal wetting ability of solutions was understood to be 60 s.

The on-site testing of the dust wetting solutions involved injecting them into the spraying systems of the shearers (Fig. 9) and taking measurements of dustiness during the shearing. Additionally, the tests incorporated air sampling for airborne dust particle distribution analysis.

Fig. 6. Viscosity analysis using SV-10 vibro-viscosimeter (Source: Authors)

Fig. 7. Analysis of pH levels using HI 2216 pH-meter by HANNA Instruments (Source: Authors)

The same method was used to compare the effectiveness of the new wetting agent and the Elfor-M wetting agent.

Fig. 8. Assessment of surfactant viscosity (Source: Authors)

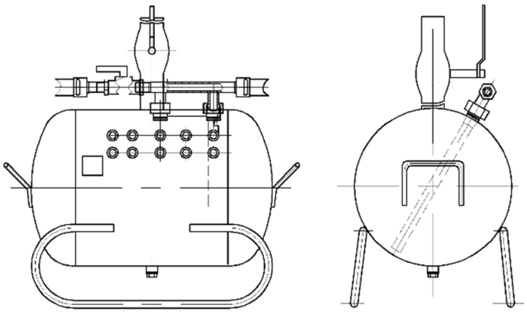

Fig. 9. DS-50/200 wetting dosing system (Source: Wetting dosing system DS, 2020)

Results and discussion

The following Tab. 4 contains the data compiled at the longwall faces of the SUEK-Kuzbass (JSC) mines following the procedures on measuring dust concentration and particle size analysis, as outlined above. The results are presented in the table and Fig. 10-12.

Tab. 4. Dustiness levels in longwall faces of coal mines

Measurement site	Average dustiness values C, [mg/m³] at longwall faces							
	A.D. Ruban		Taldinskaya-Zapadnaya-2		V.D. Yalevsky		S.M. Kirov	
	C, [mg/m³] (AERA)	C, [mg/m³] (PKA)	C, [mg/m³] (AERA)	C, [mg/m³] (PKA)	C, [mg/m³] (AERA)	C, [mg/m³] (PKA)	C, [mg/m³] (AERA)	C, [mg/m³] (PKA)
Next to shearer	194.44	178.29	184.38	200.57	221.57	238.8	47.67	42.5
5-6 m from shearer	138.89	155.01	100.00	85.48	198.67	198.17	27.86	26.61
10-15 m from shearer	83.33	81.16	25	39.23	172.2	184.8	40.61	40.73

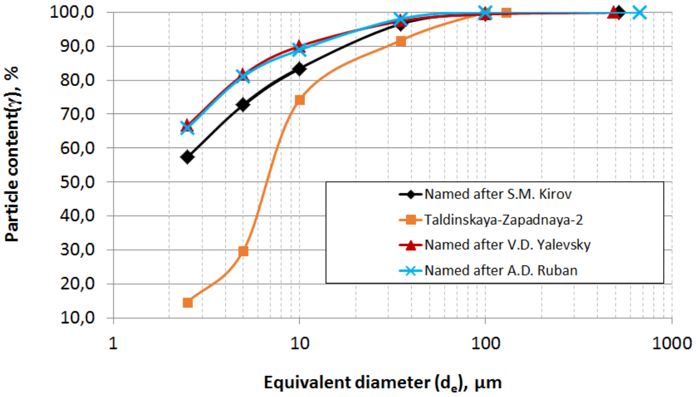

Fig. 10. Results of dust particle size distribution analysis (next to shearer)(Source: Authors)

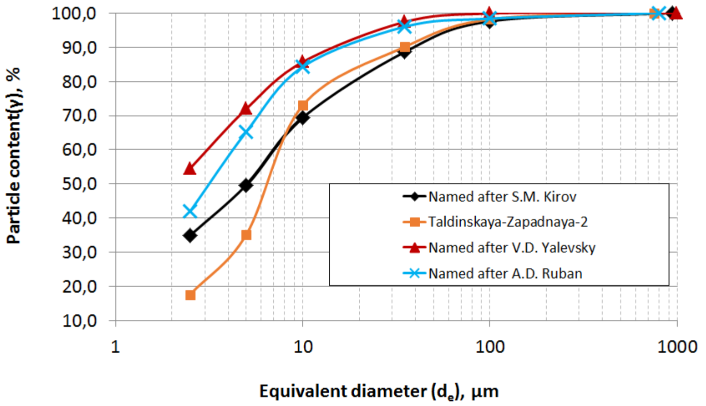

Fig. 11. Results of dust particle size distribution analysis (5-6 m from shearer) (Source: Authors)

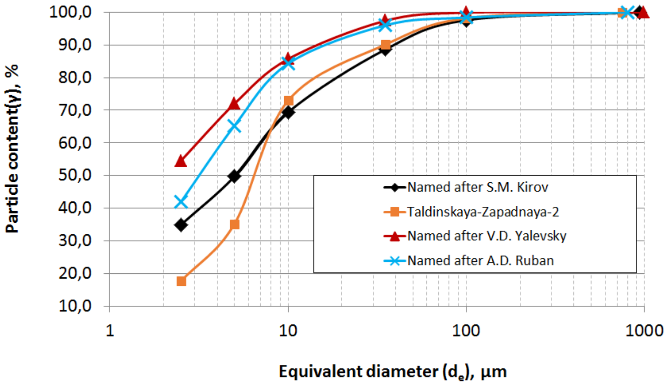

Fig. 12. Results of dust particle size distribution analysis (10-15 m from shearer) (Source: Authors)

Analysis of the acquired data shows that with the increased distance, the level of dustiness and the content of the finely dispersed particles in the aerosol decrease. For instance, while next to the shearer particles under 35 µm account for 91.8-98.1 % of the aerosol, at 15 m away from it, their share falls to 75.6-89.7 %. At the same time, it should be noted that the dust content of respirable (up to 10 µm) and thoracic fractions (up to 35 µm) at the same workspaces of different mines is markedly different from each other. As such, the highest content of finely dispersed particles at the shearer operator's work spaces was observed at the V.D. Yalevsky and A.D. Ruban mines: $\gamma_{0,1\text{-}10} = 90.0$ %, $\gamma_{0,1\text{-}10} = 88.8$ % and $\gamma_{0,1\text{-}35} = 97.4$ %, $\gamma_{0,1\text{-}35} = 98.1$ %, respectively. Given the higher dustiness levels at these mines, the amount of finely dispersed particles reaching the workers' lungs and bronchi is going to be bigger.

In order to be able to take appropriate protective measures in a timely manner and ensure working safety (such measures include, for example, adjusting operation hours of mining equipment and dust suppression mechanisms, taking steps to reduce dustiness and concentration of fine dust, limiting the time of stay for workers operating in hazardous zones, issuing better personal respiratory protective equipment (PPE), etc.), it is necessary to constantly monitor the dust environment and predict changes in it. The results of the correlation and regression analysis of the collected data and adjacent factors allowed for the creation of mathematical models that can predict changes in the air of the longwall faces: changes in airborne dust concentration (Eq. 2) and in the contents of individual small fractions — respirable (Eq. 3) and thoracic (Eq. 4).

$$C = -232.71 + 57.88 \cdot f + 0.94 \cdot t + 24.92 \cdot m + 7.73 \cdot P - 5.23 \cdot R \qquad (2)$$

Where:
C – actual dust concentration at the measurement point, mg/m^3;
f – coal hardness coefficient as per prof. M.M. Protodyakonov scale;
t – wetting time for finely dispersed coal particles, sec.;
m – extracting seam thickness, m;
P – shearer productivity, t/min.;
R – distance from shearer to measurement point, m.

$$\gamma_{0.1\text{–}10} = 50.18 + 12.35 \cdot f - 0.43 \cdot W_t^r + 0.83 \cdot P - 1.58 \cdot R \qquad (3)$$

$$\gamma_{0.1-35} = 80.4 + 4.65 \cdot f - 0.04 \cdot W_t^r + 0.45 \cdot P - 0.96 \cdot R \tag{4}$$

Where:

$\gamma_{0.1-10}$, $\gamma_{0.1-35}$ – respective fractions of respirable and thoracic particles in total mass of airborne dust, %;
f – coal hardness coefficient;
W^r_t – water saturation of extracted coal, %;
P – shearer productivity, t/min.;
R – distance from shearer to measurement point, m.

It has been proven that the timing of wetting of dust particles during the formation of dust clouds (i.e. shearing of coal) has a great impact on the dustiness levels. Data also shows that the speed of dust suppression depends not only on the size difference between the water droplets and dust particles but also on the spraying speed, which itself depends on the type and concentration of the wetting agent, as well as on the properties of dust.

In this regard, it is recommended to use the following formulas for predicting the fine dust contents in the areas next to the shearers (the denotations of the symbols have been provided above):

$$\gamma_{0.1-10} = 65.2 + 16.51 \cdot f - 1.85 \cdot W_t^r + 0.34 \cdot P - 0.1 \cdot t \tag{5}$$
$$\gamma_{0.1-35} = 88.47 + 3.66 \cdot f - 0.53 \cdot W_t^r + 0.03 \cdot P - 0.1 \cdot t \tag{6}$$

It is recommended to use a wetting agent that includes nonionic (decylglucoside and cocoglucoside) and amphoteric (kokamidopropylbetaine) surfactants to reduce dustiness and concentration of the most hazardous fine dust particles. The experiments (Fig. 13) show that composition 2, made of the aforementioned components, displayed the highest wetting ability when used on G (Г) grade coal dust from the Breevsky seam of the Polysaevskaya mine, and when used on coal dust from other seams (Fig. 14).

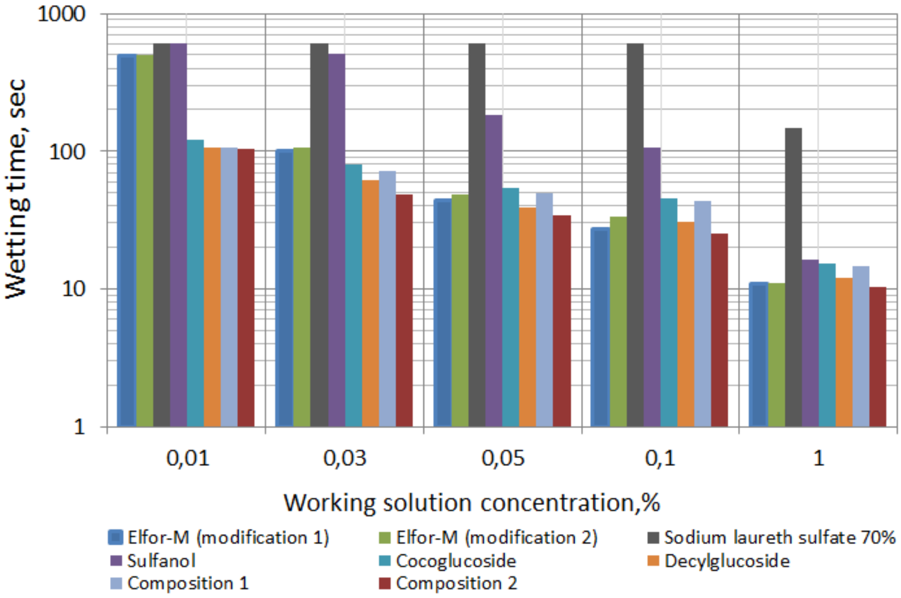

Fig. 13. Assessment of the wetting ability of 1 % surfactant solutions (Source: Authors)

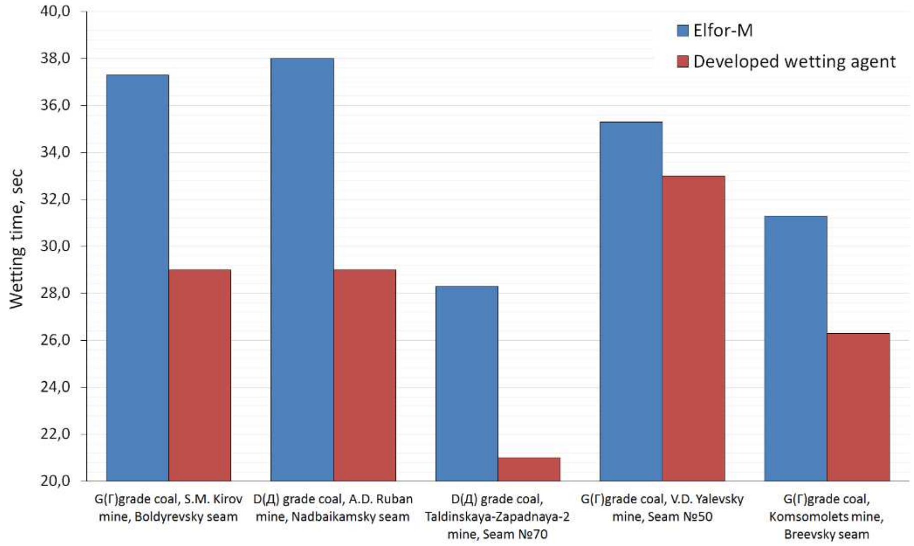

Fig. 14. Effectiveness assessment of the developed solution tested on coal dust from various seams (0.1 % solutions used)(Source: Authors)

The on-site (longwall face at the Polysaevskaya mine) testing of the developed wetting agent has proven its effectiveness when compared to the commonly used wetting agent. (Tab. 5 and Tab. 6).

Tab. 5. Results of the on-site testing (assessment of dustiness)

№	Seam name	Measurement point for dustiness	Airflow speed, [m/s]	Work type	Average mass concentration of dust, mg/m3 upon using a wetting agent	
					Elfor-M	Experimental agent
1	19-01	Shearer operator workspace	0.66	Coal/rock shearing	224.0	188.8
2	19-01	30 m away from shearer	0.32	Coal/rock shearing	160.0	143.6

Tab. 6. Results of on-site testing (particle size study)

Measurement point	Test №	Particles with equivalent diameter per fraction, γ,[%]									
		0.656-2.5 [µm]	2.5-5 [µm]	5-10 [µm]	10-35 [µm]	35-100 [µm]	100-1000 [µm]	0.1-10 [µm]	0.1-35 [µm]	Avg. 0.1-10 [µm]	Avg. 0.1-35 [µm]
Shearer operator work space	1	44.6	16.6	14.4	22.8	1.5	0.1	75.6	98.4	75.3	98.9
	2	41.9	17.1	15.3	25.0	0.5	0.2	74.3	99.3		
	3	43.1	16.5	16.5	23.0	0.8	0.1	76.1	99.1		
30 m away from shearer	4	33.8	14.5	14.8	19.2	12.3	5.4	63.1	82.3	63.8	83.0
	5	34.5	15.1	13.2	20.1	12.5	4.6	62.8	82.9		
	6	34.9	14.8	15.7	18.4	10.0	6.2	65.4	83.8		
Shearer operator work space	7	22.2	15.5	20.5	14.7	19.4	7.7	58.2	72.9	59.2	74.6
	8	23.8	14.3	22.0	16.0	17.8	6.1	60.1	76.1		
	9	22.4	16.6	20.2	15.6	18.6	6.6	59.2	74.8		
30 m away from shearer	10	14.7	13.3	19.6	14.3	23.6	14.5	47.6	61.9	48.8	64.4
	11	15.9	14.5	18.3	15.8	20.9	14.6	48,7	64.5		
	12	15.0	14.9	20.1	16.7	21.2	12.1	50.0	66.7		

The effective decrease in dust concentration when using a 0.05 % wetting agent solution was observed to be at 10.3 -15.7 %. The respirable dust fraction was reduced by 19.1-24.6 % and the thoracic fraction was reduced by 20.4-25.9 %.

Conclusions

The main issues holding back the improvement of the dust conditions in the longwall faces are as follows: high work intensity, untimely and often exclusively nominal dust control measures; failure to perform maintenance of underground equipment and dust suppression devices in a timely manner; uninformed and arbitrary selection of dust reduction tools, methods and their ways of application; inflexibility of dust control systems and, as a result, their inability to dynamically change the modes and parameters of dust control based on the operational and projected data.

International dust control practices involve continuous efforts towards betterment and improvement of the existing means of dust reduction (such as the implementation of modern Venturi systems or redesign of spraying nozzles), efforts aimed at increasing the seams' water saturation levels, adoption of new equipment (scrubbers, aspiration systems, splitter arms), as well as utilization of a computer-based particle size analysis with projections on future dust conditions, which makes it possible to make informed decisions on dust control methods and their application.

With increasing dust dispersion levels-elevated by an increasing energy intensity and growing capabilities of mining efforts – it is vital to monitor the fine dust particle content of the air and to make projections on its fluctuations. For that purpose, a number of mathematical models have been developed, capable of taking into account the influence of a multitude of factors on the projected dustiness levels and aerosol dispersion composition, factors such as: water saturation levels and hardness levels of coal, and even shearer productivity.

The principal means of dust suppression proposed hereby is a newly developed wetting agent, proven to be effective both in laboratory testing and during on-site testing. Aside from that, other ways to improve dust suppression in longwall faces include optimizing the timing of water spraying, maintaining a stable shearing intensity, performing timely maintenance of nozzles and other dosing and dedusting devices, and performing timely maintenance on the shearer parts in order to manage the shearing intensity and dust formation.

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