sciendo DOI 10.2478/ntpe-2019-0001

2019
Volume 2
Issue 1
pp. 11-19

Assessment of efficiency in reduction of dust concentration in mineral processing plants using the state-of-the-art technical measures

Dominik Bałaga
Instytut Techniki Górniczej KOMAG, **Poland**

Date of submission to the Editor: 05/2019
Date of acceptance by the Editor: 07/2019

INTRODUCTION

Dust generation in hard coal processing plants results from the following processes: classification, grinding and beneficiation. Run-of-mine consisting of hard coal and waste rock, which undergoes the process of grain degradation is a source of dust. Airborne coal dust present in the atmosphere of coal processing plant adversely affects the respiratory tract of humans but it can also be reason of explosion. Dust concentration level in the coal processing plants is highly diversified and depends on applied processes and machines (Lutyński 2016). Coal dust generation is a phenomenon depending on:

- type of coal (degree of coalification, mineral composition, hardness, content of impurities, etc.),
- fraction size, degree of coal grinding.
- coal processing technology (type of equipment, their layout in the processing plant and intensity of operations).

The generated dust rises and flows in the atmosphere of processing plant along with the air stream, and consequently sediments on machines and equipment surfaces as well as on structural elements of buildings. Coal dust containing more than 10% of volatile particles is potentially explosive.

The analysis of natural and technical hazards in hard coal mining industry in the scientific papers (Central Mining Institute, 2017) unambiguously indicates that there are atmospheres that pose coal dust explosion hazard at the workplaces in coal processing plants. Risk assessment of formation of potentially explosive atmosphere in processing plants divides potentially explosive areas into three zones: zone 20, zone 21, zone 22. Periodic tests conducted in 2017 in the plants showed (Lutyński 2015), that nineteen cases of zones “20” were identified. In turn, zone “21” occurs rarely (16 workplaces), and zone “22” occurs in most of plants (193 workplaces).

Coal dust is also harmful, causing increasing number of cases of diseases e.g. pneumoconiosis amongst the coal mine workers. The analysis in hard coal processing plants showed that almost in all plants there are the workplaces where the maximum allowable dust concentration (MAC) was exceeded (inhalable or respirable dust). MAC was defined in the regulation (Regulation, 2018) and it is 10 mg/m^3 (for hard coal and lignite) for inhalable fraction and 2mg/m3 for respirable dust fraction. 636 workplaces were threatened by the presence of dust in the 0.5 ÷ 1MAC range, and 380 workplaces above the MAC were identified (Central Mining Institute, 2017) in total in 2017. The number of workplaces and their distribution varies depending on the each plants. The above figures show that there is a serious problem of dust hazard in processing plants. Therefore, there is a need to take actions to reduce the dust hazard.

METHODS OF DUST CONTROL

The elimination of dust hazards with technical methods consists in actions aimed at eliminating or at least minimizing the amount of dust generated around the workplace to the concentration that do not endanger the explosion and do not exceed the maximum allowable dust concentrations (MAC). There are the following most commonly used methods of reduction of dust concentration: air-tightening, dust removal and spraying. Air-tightening of the dust sources in processing plants is difficult to implement due to the specificity of the technologies used. The cases of air-tightening concern the individual processing devices, such as housings and shields, usually connected to a dust extraction system. The schematic diagram of the housing of a conveyor transferring point is shown in Fig. 1.

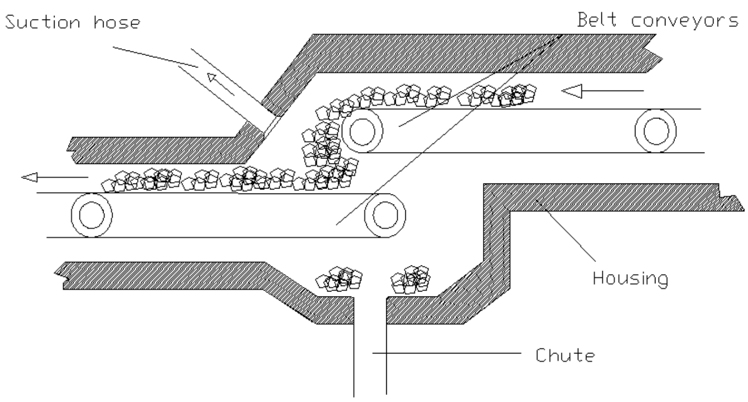

Fig. 1 Scheme of the housing of a conveyor transferring point
Source: (Juda and Nowicki, 1979)

Dust collectors are another solution currently used for the structural purification of air from dust particles. In order to neutralize the explosive properties of a mixture of coal dust and air, in most cases wet dust collectors are used for dust removal. The use of dry dust collectors, whose operating principle is based on fabric filtration, is limited to places where the coal dust share in the total dust does not pose an explosion hazard. The principle of operation of a wet dust collectors is based on implementation of a sequence of two basic processes, i.e. contact of dust with water and separation of the dust and water slurry from the air stream (Bałaga et al., 2015). Schematic diagram and operation principle of the wet dust collector is shown in Fig. 2.

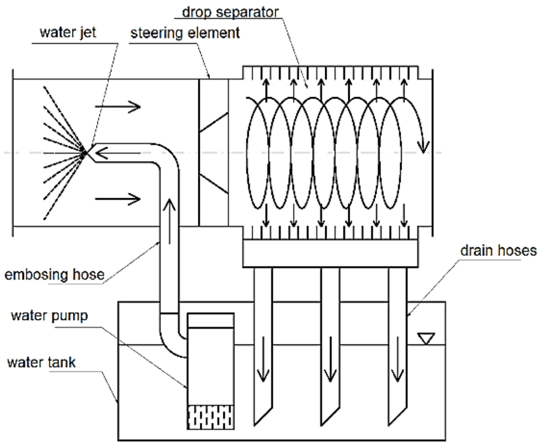

Fig. 2 Schematic diagram and principles of operation of the wet dust collector
Source: (Bałaga et al., 2015)

Dust collectors together with ventubes make a complete dust removal system for central or local purification of air from dust.
Another method of dust reduction is the use of spraying, which is widely used to precipitate and capture dust particles from the air using the atomized water stream or an pressurized air-water mixture. The continuous development of this method of dust control (Bałaga et al, 2016) allows producing the water droplets that ensure effective capture of PM10 and PM5 dust particles (dry mist systems). The effectiveness of dust elimination using water spraying results from the quality of sprayed water drops. The smaller the droplets of water, the greater efficiency in capturing the dust particles, what results from the fact that the surface of dust absorption increases, and thus the total area of all droplets of the spray stream, without changing their total volume. The schematic air-water spraying arrangement is shown in Fig. 3.

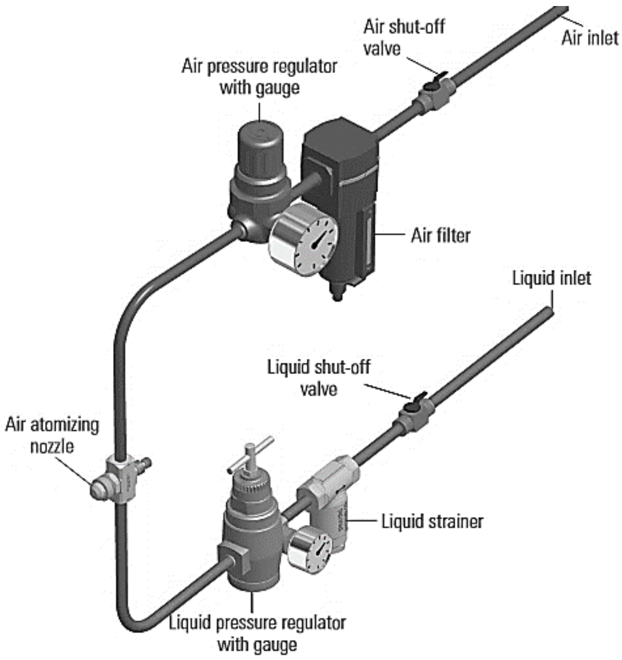

Fig. 3 The schematic air-water spraying arrangement is shown in Fig. 3
Source: (Automatic…,2019)

ASSESSMENT OF EFFICIENCY IN REDUCTION OF DUST CONCENTRATION IN THE PROCESSING PLANTS

On the basis of the results from tests conducted in coal mechanical processing plants equipped with the MB-M-25 circulating dust collector installed to control dust explosion hazard (Lutyński, 2016) as well as the results of stand tests of the NEPTUN spraying system (Bałaga et. al, 2019) used to reduce dust concentration to the level accepted by the standards for inhalable and respirable dust concentration (Regulation, 2018), the effectiveness of dust reduction was assessed and they were compared with the results obtained by the state-of-the-art technical solutions.

In the first case, in one of the hard coal mechanical processing plant, the central MB-M-25 circulating dust collector, adapted for cooperation with an external water circuit was installed. In vicinity of the places threatened by dust generation, dust extracting tubes were installed to capture dust particles and to direct them to the dust collector (Fig. 4)

Fig. 4 MB-M A circulating dust collector

Source: (Dust collector…,2019)

In the second hard coal mechanical processing plant, the NEPTUN mist spraying system was installed in five workplaces, each with individual spraying installation. Each of the installations has a unified way of preparation and distribution of spraying media and a method for activating the flow of water and compressed air to each spraying nozzle (Fig. 5)

Fig. 5 Two-media nozzles, being a part of spraying installations, reduce dust concentration are installed and directed to the source of dust generation

Source: (Bałaga et al, 2019)

Determination of dust concentration in the processing plant equipped with the central dust collector

Measurements of dust sedimentation intensity were taken for four different dust collector efficiencies. Measurements of circulating dust collector efficiency were taken by the method of dust precipitation on the measuring plates according to the PN-G-04036,1997 standard. Plates of dimensions 0.25 x 0.25 m were deployed in the places, which were recognized as those, where coal dust is generated. After 24 hours the plates were collected and analysed. Measurements of dust concentration were taken during a normal operation of the processing plant (Lutyński, 2015). For each dust collector output (20%, 40%, 60% and 80%) two measurements of the deposited dust were taken. At the same time the measurement of the deposited dust without operation of dust collector was also taken to determine efficiency of the tested dust collector in dust reduction. The results of dust deposition tests without operation of dust collector enabled determination of average dust deposition rate and that result was compared with the results obtained for the circulating dust collector in the case of the following outputs 20%, 40%, 60%, 80%. Efficiency in dust removal at each selected point for the circulating dust collector output equal to 80% is presented in Fig. 6 and Fig. 7

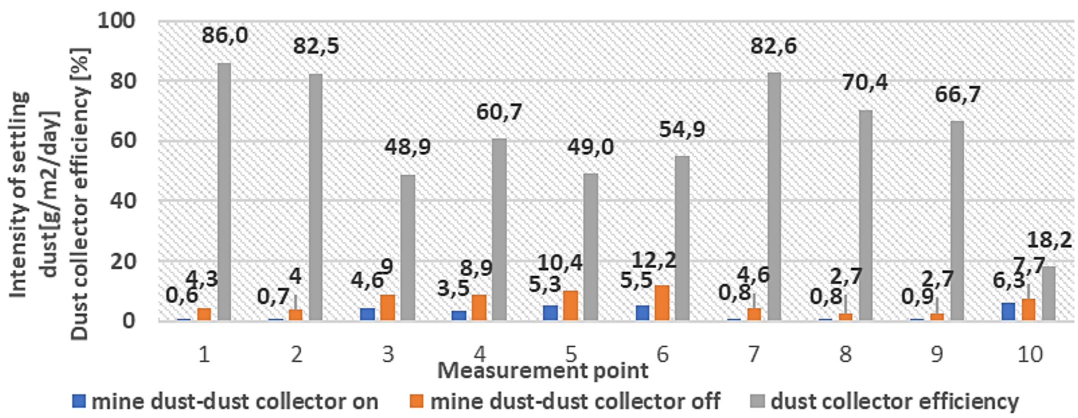

Fig. 6 Effectiveness of mine dust removal by the MB-M-25A wet circulating dust collector in the points 1÷10

Source: (Lutyński, 2015)

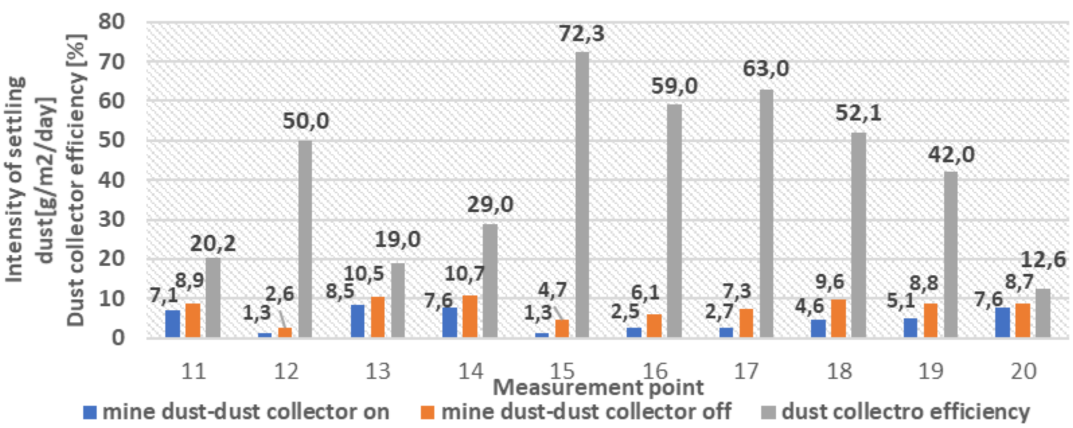

Fig. 7 Efficiency in capturing mine dust by MB-M-25A wet circulating dust collector in the points 11÷20

Source: (Lutyński, 2015)

The lowest amounts of deposited dust were observed in all the measuring points in the case of highest output of dust collector equal to 80%. The results for each point with dust collector operating with output 80% were compared with the results obtained in the case when the dust collector was switched off. That enable to calculated the efficiency in dust removal at the tested measuring points.

The results show a significant reduce of sedimented dust on the surfaces around the workplaces during operation of the dust collector. The highest reduction in amount of deposited dust (the highest efficiency of the dust collector) was observed around the upper drives of the belt conveyor 1 and 2 (86% and 82.5%) as well as by the bucket conveyor 1 drive (72.3%). The lowest reduction in amount of deposited dust were observed ahead of the belt conveyors No. 5 and No. 6 (18.2% and 20.2%) as well as by the belt conveyor No. 8 (12.6%). By the screens No. 3 and No. 4, the efficiency was 19.0% and 29.0%.

Determination of dust concentration in the processing plants equipped with the neptun spraying system

For the workplaces protected by spraying installations, dust concentration was determined to assess efficiency of dust control, using the standard on clean air protection at workplaces (PN-Z 04008-7, 2002) and the results were analysed. The tests on determination of airborne dust concentration were conducted during a normal work shift and the effects of using the NEPTUN spraying installation at workplaces were assessed. Two types of gravimetric personal dust meters i.e. CIP-10R to measure the dust respirable fraction and CIP-10I to measure dust inhalable fraction, were used.

Dust masses from dust meters at each workplace enabled determination of respirable and inhalable dust concentration and comparing them with the same results obtained when the spraying installation are switched off. Thus, determination of dust control efficiency was possible. Level of dust concentration reduction defined as quotient of difference between dust concentration (inhalable and respirable) measured at the spraying installation switched off and dust concentration (inhalable and respirable) measured at the spraying installation switched on is the measure of dust removal efficiency (1).

Dust reduction degree expressed in percent, is determined for the following formula:

$$\eta_{red\ zap} = \frac{\overline{S}_1 - \overline{S}_2}{\overline{S}_1} x100\% \quad (1)$$

where:

S¯_1- dust concentration at the spraying installation switched off, mg/m^3

S¯_2- dust concentration at the spraying installation switched on, mg/m^3

Determined efficiencies in dust removal when using the NEPTUN spraying installation at each workplace are presented in Fig. 8 and Fig. 9 (Bałaga et al, 2019).

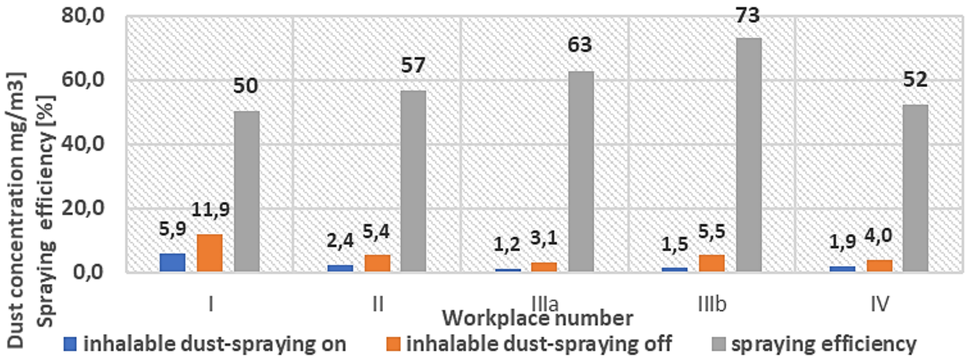

Fig. 8 Efficiency in respirable and inhalable dust reduction at each workplace during operation of NEPTUN spraying installation

Source: (Bałaga et al, 2019)

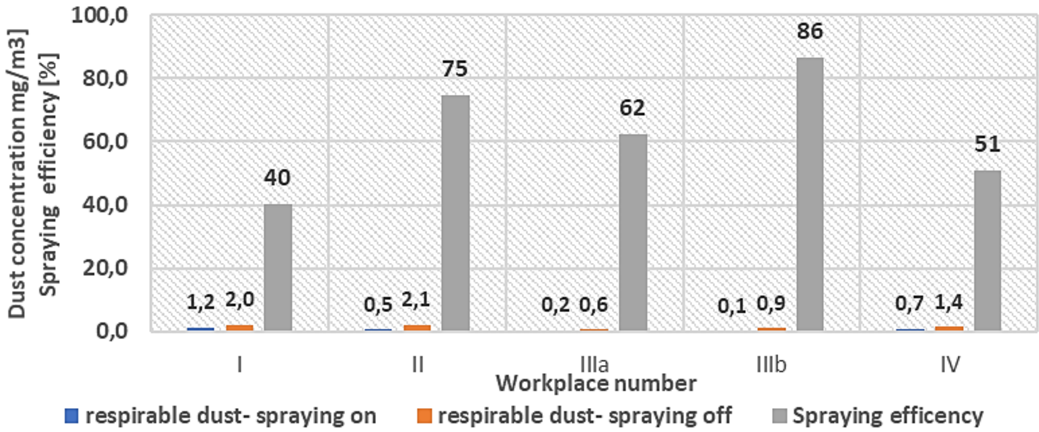

Fig. 9 Efficiency in respirable dust reduction at each workplace during operation of NEPTUN spraying installation NEPTUN

Source: (Bałaga et al, 2019)

On the basis of dust concentration measured when the spraying installation is switched off and when it is switched on it was determined that respirable and inhalable dust reduction efficiency at each workplace was over 50%. The lowest value of dust reduction efficiency equal to 50% was determined at the workplace No. 1, where there was an additional dust source not covered by the spraying system operation. The highest inhalable dust reduction efficiency was obtained at the workplaces IIIa (63%) and IIIb (73%).

Similarly, after comparing the results of the respirable dust concentration measured with the operating spraying system and full time of the feed with the results of the respirable dust concentration measured with the spraying system turned off and part time of the feed in the worst case (workplace I) efficiency in dust reduction was about 40% (Fig 9). In other cases, the effectiveness in respirable dust reduction (apart from the workplace IV, where efficiency was 51%) reached the value above 60%. The highest values of the effectiveness in respirable dust reduction by the spraying system were achieved on the workplaces II (75%) and IIIb (86%).

CONCLUSIONS

Dust removal solutions discussed in more details on the example of the MB-M-25A circulating dust collector and the mist system on the example of the

NEPTUN spraying system, clearly indicate the purposefulness and direction of development of the solutions used to reduce dust concentration in coal mechanical processing plants. The compared latest solutions for dust-reducing devices, despite differences in dust removal technologies, show high efficiency. On the basis of the presented test results, it can be concluded that central dust removal system (at 80% of dust collector's efficiency) most effectively eliminates dust concentration near the belt conveyors drives (point 1 – 86%, point 2 – 82.5%, point 7 – 82.6%), which results directly from the technical capabilities of the conveyor drive airtight housing. The situation is completely different when the screen is protected, as it is not possible to air-tighten it and the suction range decreases, and the dust reduction efficiency drops dramatically (in point 5 – 49%, point 6 – 54.9%, point 13 – 19%, point 14 – 29%). Also near the conveyor belts, dust reduction does not exceed 20% of effectiveness, which results from the secondary rising of dust particles, in places where the range of the suction is decreasing (point 11 – 20.2%, point 20 – 12.6%). At the remaining measuring points, central dust removal eliminated dust concentration with an efficiency of 40÷70%.

Similarly, the NEPTUN spraying system can be assessed for ability in reduction of inhalable (total) dust. The efficiency assessment showed at least 50% effectiveness in reducing inhalable dust around workplaces equipped with screens (point I – 50%, point II – 57%, point IV – 52%). Higher efficiency of the NEPTUN spraying system showed near the belt conveyor transferring points, where it reached 60 ÷ 70% (point IIIa – 63%, point IIIb – 73%).

The analysis of the test results, taking into account the differences resulting from the place of use and the installation method of the protected places, indicates trends in dust removal with the aforementioned dust reduction technologies. Central dust removal system is very effective in the places where the drives can be sealed inside housing. At the same time, the efficiency of dust reduction in the case where there is no technical possibility of using airtight housing of the suction near the protected places, drops drastically, even below 20%. Spraying systems in most cases reach dust reduction efficiency above 50%. Spraying systems in relation to dust reduction systems have the undoubted advantage of their expansion potential by the possibility of simple adding additional spraying nozzles to protect new dust generation points, which is more and more widely used in coal processing plants.

REFERENCES

Automatic and air atomizing spray nozzles. [online] Spraying Systems Co. Available at: https://www.spraying.pl/literature_pdfs/CAT76AA_METRIC.pdf [Accessed 25 June. 2019].

Bałaga D., Kalita M. Siegmund M. and Klimek Z. (2019). Measurements of dust concentration work stations of a hard coal mine processing plant after the NEPTUN spraying system. IOP Conf. Ser.: Mater. Sci. Eng.545 012005

Bałaga D., Jedziniak M., Kalita M., Siegmund M. and Szkudlarek Z (2015). Metody i środki zwalczania zagrożeń pyłowych i metanowych w górnictwie węglowym. Masz. Gór. nr 3 pp. 68-81.

Bałaga D., Kalita M. and Siegmund M. (2016). Nowe urządzenia zraszające. KOMTECH 2016, Innowacyjne techniki i technologie dla górnictwa. Bezpieczeństwo – Efektywność – Niezawodność, Instytut Techniki Górniczej KOMAG, Szczyrk, pp. 52-62.

Juda J. and Nowicki M. (1979). Urządzenia odpylające. Warszawa: PWN.

Lutyński A. (2015). Ograniczenie zagrożeń pyłowych w zakładzie przeróbki mechanicznej kopalni węgla kamiennego. In: K. Krauze, ed, Mechanizacja, automatyzacja i robotyzacja w górnictwie. Lędziny, Kraków: Centrum Badań i Dozoru Górnictwa Podziemnego sp. z o.o, pp. 84-91.

Lutyński A. (2016). Zagrożenia metanem, pyłem i hałasem występujące w zakładach przeróbki mechanicznej kopalń węgla kamiennego. Gliwice: Instytut Techniki Górniczej KOMAG.

Odpylacz mokry przewałowy MB-M. [online] ADS Construction. Available at: http://asdconstruction.pl/odpylacz-mokry-przewalowy-mb-m [Accessed 25 June. 2019].

PN-G-04036:1997 Zabezpieczenie przeciwwybuchowe zakładów górniczych – Zabezpieczenie przed wybuchem pyłu węglowego – Oznaczanie intensywności osiadania pyłu (1997)

PN-Z 04008-7:2002 Ochrona czystości powietrza – Pobieranie próbek – Zasady pobierania próbek powietrza w środowisku pracy i interpretacji wyników

Raport roczny o stanie podstawowych zagrożeń naturalnych i technicznych w górnictwie węgla kamiennego (2017). Katowice: Główny Instytut Górnictwa.

Rozporządzenie Ministra Rodziny, Pracy i Polityki Społecznej z dnia 12 czerwca 2018. w sprawie najwyższych dopuszczalnych stężeń i natężeń czynników szkodliwych dla zdrowia w środowisku pracy (2018) [Dz. U. z 2018 r., poz. 1286].

Abstract.
Airborne coal dust hazard at the workplaces in hard coal processing plants in Poland is presented. The methods for dust control in coal processing plants are discussed. The results from testing the dust control efficiency at the workplaces are given. The test results of airborne dust concentration are analysed as well as advantages and disadvantages of used technical measures are indicated.

Keywords: mechanical coal processing plant, coal dust, airborne dust control, dust removal, spraying