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Prevention of Dust Hazards Affecting Workers in Hard Coal Mines

Eugeniusz Orszulik[1]* and Wojciech Dudek[2]

[1]Central Mining Institute, Katowice, Poland
[2]Przedsiębiorstwo Produkcyjno – Handlowe ADW sp. z o.o., Wyry, Poland

Abstract

This paper presents the results of the tests conducted with the ZWILKOP ZW-10 dust control preparation (Patent P. 394235) used in the air and water sprinkler systems at mining facilities. The tests aimed to assess the inhalation exposure of the mining personnel to respirable/1 and inhalable2/dust fraction and to chemical agents when using ZWILKOP ZW-10 (MSDS 2013) preparation.

This publication contains the results of the measurements performed to evaluate concentrations of the hazardous chemical substances: 2-(2-butoxyethoxy)ethanol and 2-ethylhexan-1-ol, which are the components of the ZWILKOP ZW-10 preparation, and respirable1/ and inhalable2/ dust fractions at mining personnel workstations.

The tests were performed with the use of the mist systems during extraction works in:

- Borynia - Zofiówka - Jastrzębie Hard Coal Mine, inclined drift C31, seam 420/1-2;
- Budryk S.A. Hard Coal Mine, seam 341, wall Dz-1, where hard coal type 35.2(PN-68/G-97002) was extracted;
- Pokój Hard Coal Mine, wall 219, seam 502, where hard coal type 34.1 (PN-68/G-97002) was extracted;
- Halemba Hard Coal Mine, wall 5, seam 507/H, where hard coal type 34.2 (PN-68/G-97002) was extracted.

The assessment of the prevention of respiratory dust hazards affecting the personnel with the use of the ZWILKOP ZW-10 preparation was conducted in mines selected depending on the type and classification of extracted coal (PN-68/G-97002).

Keywords: Air dustiness; Chemical agents; Hazard; Reduction of airborne dust

Introduction

Prevention of dust hazards [1] and inhalation exposure of the mining personnel to chemical agents [2] are important issues influencing optimisation of OHS conditions at mining facilities. Increased coal extraction results in higher dust immissions at a workplace, posing an explosion hazard and leading to development of lung diseases in mining personnel due to the presence of free silica in coal dust.

The new air and water sprinkling solutions implemented in the mining industry [3] reduce substantially airborne dust pollution in mines. However, water sprinkling systems commonly used at mining facilities are not effective enough in reducing dust immissions. Air dampeners are used to further improve OSH conditions as regards dust concentrations.

1. Respirable fraction - aerosol fraction penetrating the respiratory tract posing a threat to health once deposited in the gas exchange area. Definition of respirable fraction corresponds to the definition of respirable dust.

2. Inhalable fraction - aerosol fraction penetrating through the nose and the mouth posing a threat to health once deposited in the respiratory tract. Definition of inhalable fraction corresponds to the definition of total dust.

Experimental Methods

Application of the ZWILKOP ZW-10 preparation

Surface tension is decreased by adding agents containing active substances and improving humidification of coal dusts. ZWILKOP ZW-10 preparation [4] is an agent which humidifies airborne coal dust in mines.

Studies were conducted at the Central Mining Institute [5] aimed to demonstrate the reducing effect of WILKOP ZW-10 on coal dust volatility and the resulting improvement in the working conditions. Studies were also performed to assess the inhalation exposure of the mining personnel to chemical substances contained in ZWILKOP ZW-10 [6].

The aim of the tests was to verify whether the use of the preparation in the air and water sprinkler systems intended for reduction of airborne dust contamination poses a risk of exposure to harmful substances for the mining personnel and whether the substance is efficient in preventing coal dust volatility.

As it turns out, no health or life hazard is posed by the preparation for the workers and it does not have a major environmental impact. The opinion was given based on the submitted documents and the results of the relevant tests [6]. ZWILKOP ZW-10 was given positive assessment for its toxicity and harmfulness. The assessment was issued by the Medical University of Silesia, Department and Institute of Medicine and Environmental Epidemiology, and the agent received a certificate [7] issued based on the submitted test results [6] confirming that it is safe and can be used at mining facilities.

***Corresponding author:** Eugeniusz Orszulik, Central Mining Institute, Katowice, Poland, Tel: +48322592274; Fax: +48322592267; E-mail: e.orszulik@gig.eu

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Dust humidification with ZWILKOP ZW-10

The procedure consists of preparing water solution for coal dust humidification. Carbonic solution is prepared in water systems which supply air and water sprinkler systems for spraying dust contaminated air used in the mining industry [3].

The process of preparing ZWILKOP ZW-10 water solution involves water treatment. Water is treated to increase its dampening potential and, therefore, reduce dust at places where it occurs. The process consists of two water treatment stages.

• The first stage consists of water demineralisation using a magnetic field and removal of sludge;

• The second treatment stage consists of adding a dampening agent (ZWILKOP ZW–10) to water (pretreated at the first stage) to lower its surface tension.

Water demineralization is aimed to remove sludge from water. The water demineralisation process consists of magnetic treatment. In the magnetic water treatment, a permanent magnetic field with specified intensity exerts an effect on the flowing water stream causing inductive changes in the potential of the outer electrons of water and salt molecules contained in it. As a result of this action, the building up of the sediment layers of calcium carbonate ($CaCO_3$) and magnesium carbonate ($CaCO_3$) contained in water is prevented, which prevents in effect the formation of calcium carbonate ($CaCO_3$) and magnesium carbonate ($MgCO_3$) on piping surfaces. Water demineralisation and purification is performed in a sedimentation and inertial magnetic strainer. The magnetic strainer uses flat magnets of which the magnetic axis, and therefore the lines of force of a magnetic field are perpendicular to the flow direction of treated water. Such system increases deposit removal efficiency, allowing the finest grains to be removed, provided that they have magnetic properties or contain magnetic substance inclusions. In practice, the above conditions are almost always met; because raw water is sent through steel pipes, the finest suspensions are iron corrosion products, self-contained or overgrown with mineral calcium compounds, and the products of other salts present in water. Non-permanent location of magnets on partitions allows easy removal in order to clean the sludge deposited on their surfaces. A shielded strainer has additional functions of magnetic water treatment which speed up the crystallization of compounds present in water (corrosion, etc.).

The next stage of the process consists of removing from water suspended solids having a wide range of granularity, such as sediments formed from magnetic effect, and post installation impurities, corrosion layer peels and mineral sediments contained in raw water. Therefore, as well as ensuring high efficiency in stopping the finest suspension, the magnetic strainer has a magnetic treatment function.

The second stage of water treatment is aimed to reduce its surface tension. Surface tension of water is decreased by adding ZWILKOP ZW-10 dampener to remove airborne active substances and increase the humidifying effect on coal dusts. The dosing procedure consists of pumping an appropriate amount of ZWILKOP ZW-10 into the flowing water with a dosing pump at the moment a sprinkler station is started. Such technological solutions are commonly used in sprinkler systems in dust chambers, excavations or mining galleries with high dustiness where dusts must be removed to avoid dust concentrations exceeding explosive limits or non-compliant with OSH standards applicable to mining personnel. In Figure 1 shows a schematic diagram of the system for water demineralisation and reduction of water surface tension through adding ZWILKOP ZW-10 dampening agent to water

Tests were performed [8] to assess the inhalation exposure of the mining personnel to chemical substances contained in the ZWILKOP ZW-10 preparation. The aim of the tests was to verify whether the use of the preparation in the dust control air and water sprinkler systems in mines poses a risk of exposure to harmful substances for the mining personnel.

Two hazardous substances which are the components of the ZWILKOP ZW-10 preparation (Sheet 2013) were selected according to (Order ... 2002):

- 2 - (2-butoxyethoxy)ethanol,
- 2-ethylhexan-1-ol,

They may pose a risk to mining personnel if permissible concentrations of these substances in the air are exceeded. Tests assessing concentrations of the hazardous substances: (2-butoxyethoxy)ethanol and 2-ethylhexan-1-ol, which are the components of the ZWILKOP ZW-10 preparation, were conducted in inclined drift C31, seam 420/1 – 2 in Borynia - Zofiówka – Jastrzębie, Ruch Borynia Hard Coal Mine.

Tests and measurements were performed at material loading points and in the areas where the mining personnel were operating, and where the mist systems were used.

The excavation parameters in inclined drift C31, seam 420/1 in which measurements were performed were respectively:

- excavation height: 3.6 meters
- excavation width: 5.5 meters
- excavation cross section (F): 20.8 square meters
- average speed of air flowing through the excavation: 1.0 m/s (up to maximum 1.6 m/s)
- air flow rate to $V_{nom\ dia}$=20.17 m^3/s

The Figure 2 shows a layout of measurement points and ventilated air flow directions in inclined drift C31, seam 420/1 in the mine.

Mist system equipment was mounted to the excavation ceiling at a point indicated in Figure 2.

The TELESTO mist system equipment provided during tests had the following characteristics:

- single nozzle capacity: 1 dm^3/min.
- number of nozzles provided: 11
- water per curtain: 11 dm^3/min.
- curtain supply water pressure: 0.4-0.6 MPa.

The tests were conducted at three selected reference points:

- reference point No. 1 - 50 meters from the mist system device
- reference point No. 2 - 100 meters from the mist system device
- reference point No. 3 - 20 meters from the gallery exit

The tests involved water solution of ZWILKOP ZW-10 at a concentration of 20‰ vol. Mine air samples were taken at selected reference points as per the applicable standards [9-11] during normal working hours of the mining personnel. Hazardous substances, i.e., (2-butoxyethoxy)ethanol and 2-ethylhexan-1-ol, which are the components of the WILKOP ZW-10 preparation, were determined using the gas chromatography method with flame ionisation detection

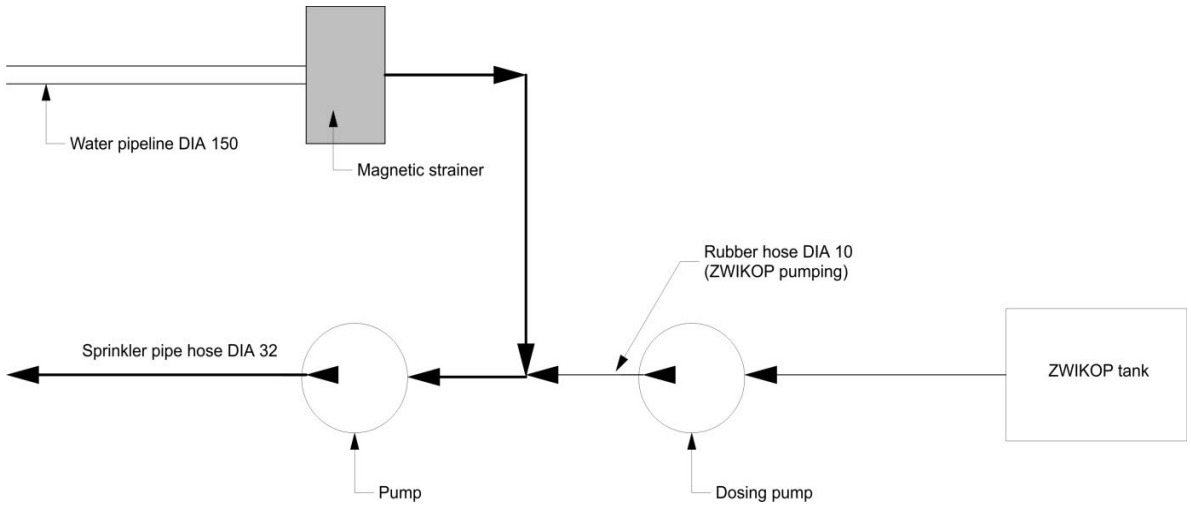

Figure 1: Demineralisation and water surface tension reduction system 4. Tests involving ZWILKOP ZW-10 to assess inhalation exposure of the mining personnel to chemical agents.

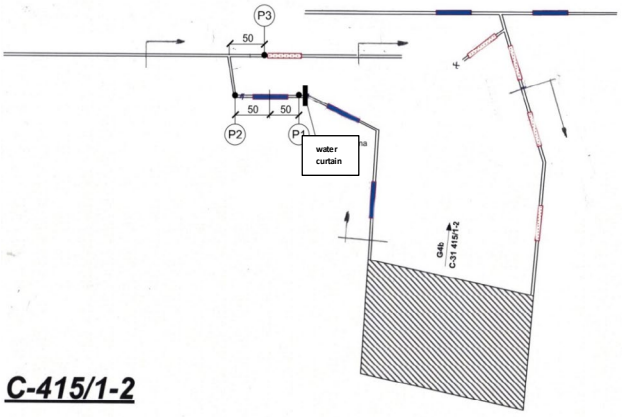

Figure 2: Layout of measurement points and direction of ventilated air flow in inclined drift C31, seam 420/1: → – air flow direction, P1, P2, P3 – measurement point.

(GC-FID) as per the own PA-16 analytical procedure: "Assessment of the content of volatile organic compounds (LZO - mixture 3) in the occupational air and in waste gases using gas chromatography." The tested air stream was let through the absorbing pipes filled with active carbon with the volumetric flow rate of 30 l per hour. The samples from active carbon were desorbed in carbon disulphide with 2% methanol solution and (2-butoxyethoxy)ethanol and 2-ethylhexan-1-ol contained in ZWILKOP ZW-10 were determined using gas chromatography.

The results of the tests assessing concentrations of the hazardous substances, i.e., (2-butoxyethoxy)ethanol and 2-ethylhexan-1-ol, contained in the mine air are presented in Table 1.

The results of the tests presented in Table 1, performed to assess concentrations of hazardous substances in the mine air, i.e., 2-(2-butoxyethoxy)ethanol and 2-ethylhexan-1-ol, contained in ZWILKOP ZW-10, show that no ELs or STELs were exceeded. The use of water solutions containing ZWILKOP ZW-10 at a concentration of 20‰ vol does not cause permissible concentrations of 2-(2-butoxyethoxy)ethanol and 2-ethylhexan-1-ol (Order …2002), contained in ZWILKOP ZW-10 to be exceeded in the mine air.

Results and Discussion

The assessment of the efficiency of the ZWILKOP ZW-10 agent to reduce inhalation exposure to coal dust

Tests and measurements assessing inhalation exposure of the mining personnel to respirable and inhalable fractions containing crystalline silica (Order ... 2004) were performed by the Central Mining Institute and Mine Ventilation Personnel [12-14]. The studies present concentration levels for airborne respirable and inhalable dusts to which the mining personnel may be exposed and which may pose a threat to health of mine workers. The test was also aimed to verify the concentrations of respirable and inhalable fraction in the air after applying ZWILKOP ZW-10 in the dust control air and water sprinkler systems used in mines.

The assessment of the concentrations of respirable and inhalable dusts containing crystalline silica present in the mine air was conducted in:

- Budryk S.A. Hard Coal Mine, seam 341, wall Dz-1, where hard coal type 35.2 [15] was extracted;
- Pokój Hard Coal Mine, wall 219, seam 502, where hard coal type 32.1 [15] was extracted;
- Halemba Hard Coal Mine, wall 5, seam 507/H, where hard coal type 34.2 [15] was extracted.

The tests were aimed to prove the efficiency of the ZWILKOP ZW–10 agent in reducing the concentration of airborne respirable and inhalable fractions of dust containing crystalline silica present at workstations and in the areas where the mining personnel are operating, in mines extracting hard coal types 32.1, 34.2 and 35.2.

The assessment of the efficiency of the ZWILKOP ZW-10 agent to reduce inhalation exposure to coal dust in Budryk Hard Coal Mine

The assessment of the concentrations of dusts containing crystalline silica present in the mine air was conducted in Budryk Hard Coal Mine, seam 341, wall Dz-1, where hard coal type 35.2 (PN-68/G-97002) was extracted.

Measurement point	Ventilated air parameters	ZWILKOP ZW-10 preparation concentration, ‰	**Concentration, mg/m³**		Permissible concentrations as per the Ordinance of the Minister of Labour and Social Policy of 29 November 2002 on the maximum allowable concentrations and intensity of agents harmful to health in the workplace (Journal of Laws 02.217.1833 as amended)			
			2-(2-butoxyethoxy) ethanol	2-ethylhexan-1-ol,	2-(2-butoxyethoxy) ethanol		2-ethylhexan-1-ol,	
					EL	**STEL**	**EL**	**STEL**
P1-50 m from the water curtain	V=0.8-1 m/s t=27.7°C p=1073 hPa	20	below LOQ	0.0203	**67**	**100**	**160**	**320**
P2-100 m from the water curtain	V=0.9-1 m/s t=28.7°C p=1073 hPa	20	0.0043	0.0137	**67**	**100**	**160**	**320**
P3-20 meters from the gallery exit	V=1.4-1.5 m/s t=26.1°C p=1073 hPa	20	0.0040	0.0140	**67**	**100**	**160**	**320**

Description of denotations contained in Table 1:

- V-air flow speed in the gallery
- t-air temperature in the gallery
- t-air pressure in the gallery
- P1, P2, P3-reference measurement points
- below LOQ-below limit of quantification
- EL (exposure limit): Average weighted value of concentration which, when having an effect on a worker within an 8-hour working day and for an average weekly working time specified in the Labour Code, for the duration of such worker's working life, should not have an adverse impact on their health or the health of their future generations
- STEL (short-term exposure limit): average value of concentration which should not cause adverse changes in a worker's health if it is present in the workplace for no more than 20 minutes and not more frequently than 2 times during a work shift, at a time interval of not less than 1 hour.

Table 1: Results obtained at measurement points in inclined drift C31, seam 420/1-2.

Tests and measurements were performed at material loading points and in the areas where the mining personnel were operating, and where the mist systems were used.

The excavation parameters in wall Dz-1, gallery Dz-1 in which measurements were performed were respectively:

- excavation height: 2.6 meters
- excavation width: 2.0 meters
- excavation cross section (F): 5.2 square meters
- average speed of air flowing through the excavation:5.0 m/s
- air flow rate to $V_{nom\ dia}$=26.0 m³/s

The mist system equipment provided for the tests had the following characteristics:

- single nozzle capacity: 1 dm³/min
- number of nozzles provided: 5
- water per curtain: 5 dm³/min.

Mist system equipment was mounted to the excavation ceiling at a point indicated in Figure 3.

The tests were performed at two selected reference points (Figure 3):

- reference point No. SP 1 - 70 meters from the mist system device
- reference point No. SP 2 - 5 meters from the longwall

The Figure 3 shows a schematic diagram of measurement points location and ventilated air flow directions in wall Dz-1, seam 341.

An optimum ZWILKOP ZW-10 concentration of 20‰ vol in a water solution was used for the tests. Mine air samples were taken at selected reference points as per the applicable standards (PN-Z-04008-7-2002, PN-91/Z-04030.04, PN-91/Z-04030.05, PN-91/Z-04030.06, PN-EN 482:2002, PN-EN 689:2002) during normal working hours of the mining personnel. The concentration level assessment results for dusts containing crystalline silica contained in the mine air before and after the use of the ZWILKOP ZW-10 preparation are shown in Table 2.

In Budryk Hard Coal Mine where hard coal type 35.2 was extracted, the test results presented in Table 2 indicated the following:

- preparation use in the water mist sprinkler systems resulted in decreased concentrations of respirable dusts: - at SP1 reference point, from 2.32 to 2.17 mg/m³, i.e., by 6.5%.
- - at SP 2 reference point, from 6.46 to 6.02 mg/m³, i.e., by 6.8%. At all SP1 and SP2 reference points, exposure limits for respirable dust fractions were exceeded before and after applying a water solution of the ZWILKOP ZW-1 preparation.
- preparation use in the water mist sprinkler systems resulted in decreased concentrations of inhalable dusts: - at SP1 reference point, from 3.58 to 3.34 mg/m³, i.e., by 6.7%.
- - at SP2 reference point, from 10.20 to 8.40 mg/m³, i.e., by 17.6%. At SP1 and SP2 reference points, exposure limits for inhalable dust fractions were not exceeded after applying a water solution of the ZWILKOP ZW-10 agent.

The assessment of the efficiency of the ZWILKOP ZW-10 agent to reduce inhalation exposure to coal dust in Pokój Hard Coal Mine

The assessment of the concentrations of dusts containing crystalline silica present in the mine air was conducted in Pokój Hard Coal Mine, wall 219, seam 502, where hard coal type 32.1 was extracted (PN-68/G-97002).

Tests and measurements were performed at material loading points and in the areas where the mining personnel were operating, and where the mist systems were used.

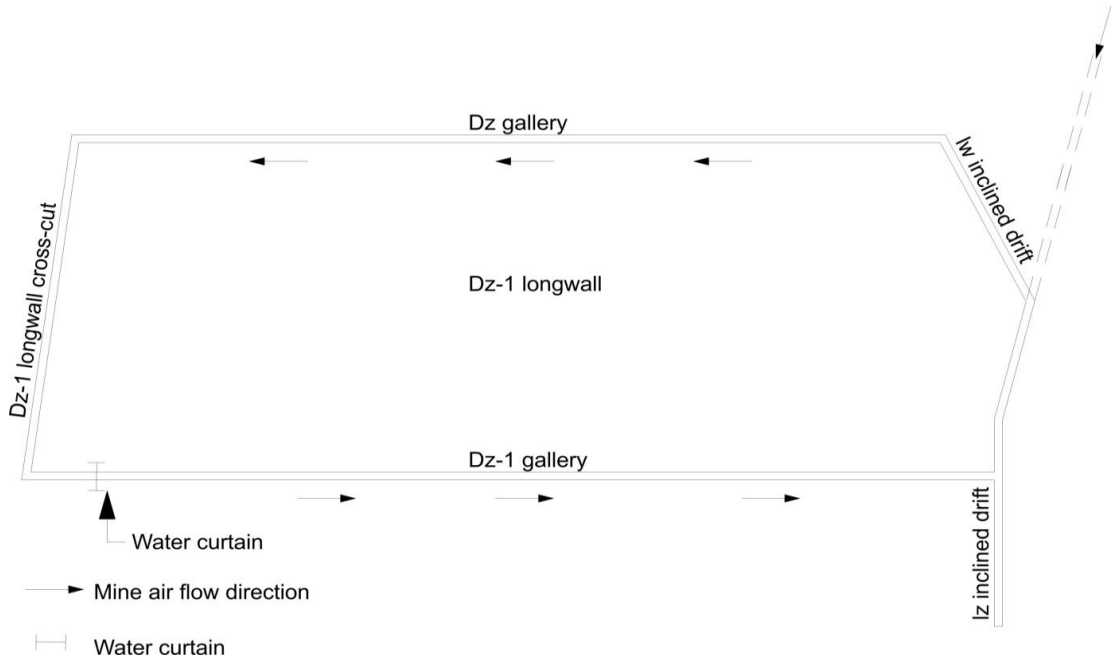

Figure 3: Measurement points location and ventilated air flow directions in wall Dz-1, seam 341 in Budryk Hard Coal Mine.

Measurement point	Ventilated air parameters	ZWILKOP ZW-10 preparation concentration ‰	**Dust concentration, mg/m³**				Permissible dust concentrations as per the Ordinance of the Minister of Labour and Social Policy of 29 November 2002 on the maximum allowable concentrations and maximum allowable intensity of agents harmful to health in the workplace (Journal of Laws 02.217.1833 as amended)	
			respirable fraction		inhalable fraction		respirable fraction	inhalable fraction
			before preparation use	after preparation use	before preparation use	after preparation use	**EL**	**EL**
SP1-70 meters from the gallery exit	V=5.0 m/s t=20.7°C p=1063 hPa	20	2.32	2.17	3.58	3.34	**1**	**4**
SP 2-5 meters from the longwall	V=5.0 m/s t=20.7°C p=1063 hPa	20	6.46	6.02	10.20	8.40		

Description of denotations contained in Table 2:

• V-air flow speed in the gallery

• t-air temperature in the gallery

• t-air pressure in the gallery

• SP1, SP2, SP3, SP4-reference measurement points

• EL (exposure limit): average weighted value of concentration which, when having an effect on a worker within an 8-hour working day and for an average weekly working time specified in the Labour Code, for the duration of such worker's working life, should not have an adverse impact on their health or the health of their future generations

• STEL (short-term exposure limit): average value of concentration which should not cause adverse changes in a worker's health if it is present in the workplace for no more than 20 minutes and not more frequently than 2 times during a work shift, at a time interval of not less than 1 hour.

Table 2: Measured concentrations of respirable and inhalable fraction of dusts present in the mine air at the measurement points in wall Dz-1, gallery Dz-1, seam 341 in Budryk Hard Coal Mine.

The excavation parameters in wall 219, seam 502 in which measurements were performed were respectively:

- wall height: 2.5 meters
- excavation width: 204 meters
- excavation cross section (F): 385.0 square meters
- average speed of air flowing through the excavation: 5.2 m/s
- air flow rate to $V_{nom\ dia}$=2000 m³/s

Figure 4 shows a schematic diagram of measurement points location and ventilated air flow directions in wall 219, seam 502. The mist system equipment was mounted to the gallery lining at a point indicated in Figure 4.

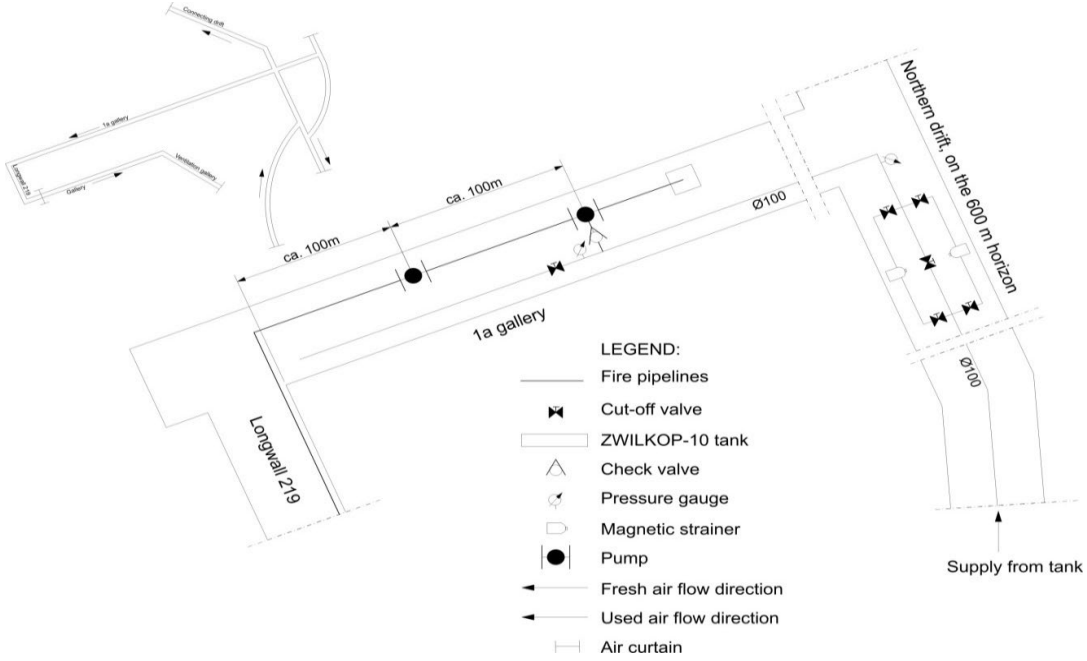

Figure 4: Measurement points location and ventilated air flow directions in wall 219, seam 502 in Pokój Hard Coal Mine.

The mist system equipment provided for the tests had the following characteristics:

- single nozzle capacity : 1 dm^3/min
- number of nozzles provided: 6
- Water per curtain: 5 dm^3/min.

The tests were performed at the two selected reference points (Figure 4):

- Reference point No. SP1 located 20 meters from the longwall and from the mist system device
- Reference point No. SP2 located 20 meters from the longwall and from the mist system device

An optimum ZWILKOP ZW-10 concentration of 20‰ vol in a water solution was used for the tests.

Mine air samples were taken at selected reference points as per the applicable standards (PN-Z-04008-7-2002, PN-91/Z-04030.04, PN-91/Z-04030.05, PN-91/Z-04030.06, PN-EN 482:2002, PN-EN 689:2002) during normal working hours of the mining personnel. The concentration level assessment results for dusts containing crystalline silica contained in the mine air before and after the use of the ZWILKOP ZW-10 preparation are presented in Table 3.

In Pokój Hard Coal Mine, where hard coal type 32.1 was extracted, the test results presented in Table 3 indicated the following:

- preparation use in the water mist sprinkler systems resulted in decreased concentrations of respirable dusts:

- at SP1 reference point, from 9.66 to 5.25 mg/m^3, i.e., by 45.7%

- at SP2 reference point, from 2.2 to 0.9 mg/m^3, i.e., by 59.1%. At SP1 reference point, a decrease in the concentration of respirable dusts by 45.7% was observed (improvement in working conditions.) Exposure limits for respirable dust fractions were exceeded both before and after the application of a water solution of the ZWILKOP ZW-10 preparation.

At reference point SP2, exposure limits for respirable dust fractions were not exceeded after applying a water solution of the ZWILKOP ZW-10 preparation.

- preparation use in the water mist sprinkler systems resulted in decreased concentrations of inhalable dusts:

- at SP1 reference point, from 34.3 to 17.16 mg/m^3, i.e., by 6.7%

- at SP2 reference point, from 9.4 to 9.4 mg/m^3, i.e., by 0%. At SP1 and SP2 reference points, exposure limits for inhalable dust fractions were exceeded after applying a water solution of the ZWILKOP ZW-10 preparation. The use of the preparation had no major decreasing effect (improvement in working conditions) on the concentration of inhalable fraction dusts [16-23].

The assessment of the efficiency of the ZWILKOP ZW-10 agent to reduce inhalation exposure to coal dust in Halemba Hard Coal Mine

The assessment of the concentrations of dusts containing crystalline silica present in the mine air was conducted in Halemba Hard Coal Mine, wall 5, seam 507/H, where hard coal type 34.2 was extracted (PN-68/G-97002).

Tests and measurements were performed at material loading points and in the areas where the mining personnel were operating, and where the mist systems were used.

The excavation parameters in wall 5, seam 507/H in which measurements were performed were respectively:

- excavation height: 2.68 meters
- excavation width: 135 meters

Measurement point	Ventilated air parameters	ZWILKOP ZW-10 preparation concentration ‰	**Dust concentration, mg/m³**				Permissible dust concentrations as per the Ordinance of the Minister of Labour and Social Policy of 29 November 2002 on the maximum allowable concentrations and maximum allowable intensity of agents harmful to health in the workplace (Journal of Laws 02.217.1833 as amended)	
			respirable fraction		inhalable fraction		respirable fraction	inhalable fraction
			before preparation use	after preparation use	before preparation use	after preparation use	**EL**	**EL**
SP1-20 m from the water curtain and from the longall inlet	V=5.2 m/s t=24.6°C p=1013 hPa	20	9.66	5.25	34.3	17.1	**1**	**4**
SP2-20 m from the water curtain and from the longall outlet	V=5.2 m/s t=24.6°C p=1013 hPa	20	2.2	0.9	9.4	9.4		

Description of denotations contained in Table 3:

• V-air flow speed in the gallery

• t-air temperature in the gallery

• t-air pressure in the gallery

• SP1, SP2-reference measurement points

• EL (exposure limit): average weighted value of concentration which, when having an effect on a worker within an 8-hour working day and for an average weekly working time specified in the Labour Code, for the duration of such worker's working life, should not have an adverse impact on their health or the health of their future generations

• STEL (short-term exposure limit): average value of concentration which should not cause adverse changes in a worker's health if it is present in the workplace for no more than 20 minutes and not more frequently than 2 times during a work shift, at a time interval of not less than 1 hour.

Table 3: Measured concentrations of respirable and inhalable fraction of dusts present in the mine air at the measurement points in wall 219, seam 502 in Pokój Hard Coal Mine.

- excavation cross section (F): 361.8 square meters
- average speed of air flowing through the excavation: 5.3 m/s
- air flow rate to $V_{nom\ dia}$=1917.5 m³/s

The Figure 5 shows a schematic diagram of measurement point's location and ventilated air flow directions in wall 5, seam 507/H.

The mist system equipment was mounted to the gallery lining at a point indicated in Figure 5.

The mist system equipment provided for the tests had the following characteristics:

- Single nozzle capacity: 1 dm³/min
- Number of nozzles provided: 6
- Water per curtain: 5 dm³/min.

The tests were performed at the two selected reference points (Figure 4):

- Reference point no. SP1 located 12 meters from the longwall inlet and from the mist system device
- Reference point no. SP2 located 20 meters from the longwall outlet and from the mist system device

An optimum ZWILKOP ZW-10 concentration of 20‰ vol in a water solution was used for the tests.

Mine air samples were taken at selected reference points as per the applicable standards (PN-Z-04008-7-2002, PN-91/Z-04030.04, PN-91/Z-04030.05, PN-91/Z-04030.06, PN-EN 482:2002, PN-EN 689:2002) during normal working hours of the mining personnel.

The concentration level assessment results for dusts containing crystalline silica contained in the mine air before and after the use of the ZWILKOP ZW-10 preparation are presented in Table 4.

In Halemba Hard Coal Mine, where hard coal type 34.2 was extracted, the test results presented in Table 4 indicated the following:

• preparation use in the water mist sprinkler systems resulted in decreased concentrations of respirable dusts:

- at SP1 reference point, from 4.3 to 3.5 mg/m³, i.e., by 18.6%

- at SP2 reference point, from 1.8 to 0.6 mg/m³, i.e., by 66.7%

At SP1 reference point, a decrease in the concentration of respirable dust fraction by 18.6% was observed (improvement in working conditions.) Exposure limits for respirable dust fractions were exceeded both before and after the application of a water solution of the ZWILKOP ZW-10 preparation.

At reference point SP2, exposure limits for respirable dust fractions were not exceeded after applying a water solution of the ZWILKOP ZW-10 preparation

• preparation use in the water mist sprinkler systems resulted in decreased concentrations of inhalable dusts:

- at SP1 reference point, from 31.9 to 28.9 mg/m³, i.e., by 9.4%

- at SP2 reference point, from 4.8 to 1.5 mg/m³, i.e., by 68.8%

At SP1 reference point, exposure limits for inhalable dusts were exceeded both before and after the application of a water solution of the ZWILKOP ZW-10 preparation. The use of the preparation had no major decreasing effect (improvement in working conditions) on the concentration of inhalable dusts.

At SP2 reference point, exposure limits for inhalable dust fraction were not exceeded after applying a water solution of the ZWILKOP ZW-10 preparation

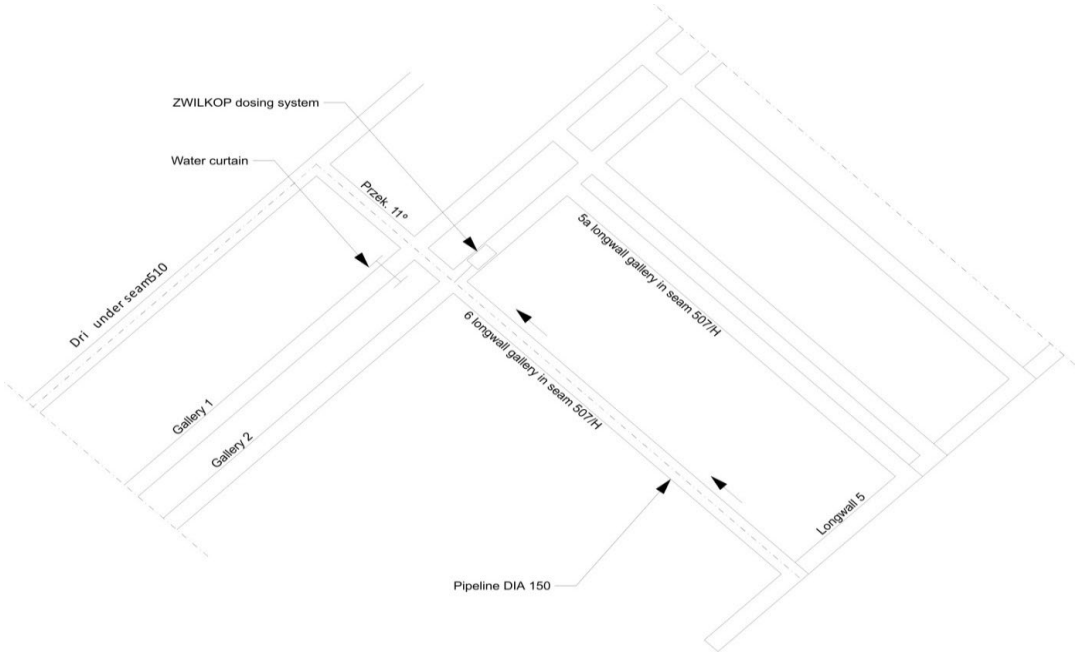

Figure 5: Shows a schematic diagram of measurement points location and ventilated air flow directions in wall 5, seam 507/H in Halemba Hard Coal Mine.

Measurement point	Ventilated air parameters	ZWILKOP ZW-10preparation concentration °/₀₀	**Dust concentration, mg/m³**				Permissible dust concentrations as per the Ordinance of the Minister of Labour and Social Policy of 29 November 2002 on the maximum allowable concentrations and maximum allowable intensity of agents harmful to health in the workplace (Journal of Laws 02.217.1833 as amended)	
			respirable fraction		inhalable fraction		respirable fraction	inhalable fraction
			before preparation use	after preparation use	before preparation use	after preparation use	**EL**	**EL**
SP1-12 m from the water curtain and from the longall inlet	V=5.3 m/s t=20.6°C p=1013 hPa	20	4.3	3.5	31.9	28.9	**1**	**4**
SP2-20 m from the water curtain and from the longall outlet	V=5.3 m/s t=20.6°C p=1013 hPa	20	1.8	0.6	4.8	1.5		

Description of denotations contained in Table 4:

• V-air flow speed in the gallery

• t-air temperature in the gallery

• t-air pressure in the gallery

• SP1, SP2-reference measurement points

• EL (exposure limit): average weighted value of concentration which, when having an effect on a worker within an 8-hour working day and for an average weekly working time specified in the Labour Code, for the duration of such worker's working life, should not have an adverse impact on their health or the health of their future generations

• STEL (short-term exposure limit): average value of concentration which should not cause adverse changes in a worker's health if it is present in the workplace for no more than 20 minutes and not more frequently than 2 times during a work shift, at a time interval of not less than 1 hour.

Table 4: Measured concentrations of respirable and inhalable fraction of dusts present in the mine air at the measurement points in wall 507/H, wall 5 in Halemba Hard Coal Mine.

Conclusion

• The aim of the tests conducted in:

Budryk Hard Coal Mine, seam 341, wall Dz-1, Pokój Hard Coal Mine, wall 219, seam 502 and Halemba Hard Coal Mine, wall 5, seam 507/H was to assess the inhalation exposure of the mining personnel to respirable and inhalable dust fractions and to chemical agents after the use of the ZWILKOP ZW-10 preparation.

• The tests were performed to assess the efficiency of the ZWILKOP ZW-10 preparation to reduce the concentrations of respirable and inhalable dust fractions for hard coals type 32, 34 and 35 (PN-68/G-97002), and its chemical effect.

• The following post-test observations were made for hard coal type 35.2:

- the concentration of respirable dust fraction was decreased by 6.7%, but permissible exposure limits after applying a water solution of the ZWILKOP ZW-10 preparation were not reached;

- the concentration of inhalable dusts was decreased by 12.1% and values below the permissible exposure limits were obtained after applying a water solution of the ZWILKOP ZW-10 preparation. The efficiency of the ZWILKOP ZW-10 preparation to reduce the concentrations of respirable and inhalable dust fractions is shown in Figure 6.

• The following post-test observations were made for hard coal type 34.1:

- the concentration of respirable dust fractions was decreased by 52.4% and the permissible exposure limits were reached after applying a water solution of the ZWILKOP ZW-10 preparation

- the concentration of inhalable dust fractions was decreased by 0.0% and values below the permissible exposure limits were not obtained after applying a water solution of the ZWILKOP ZW-10 preparation. The efficiency of the ZWILKOP ZW-10 preparation to reduce the concentrations of respirable and inhalable dust fractions is shown in Figure 7.

• The following post-test observations were made for hard coal type 34.2:

- the concentration of respirable dust fractions was decreased by 42.7% and permissible exposure limits were reached after applying a water solution of the ZWILKOP ZW-10 preparation.

- the concentration of inhalable dust fraction was decreased by 39.1% and values below the permissible exposure limits were obtained after applying a water solution of the ZWILKOP ZW-10 preparation. The efficiency of the ZWILKOP ZW-1 preparation to reduce the concentrations of respirable and inhalabledust fractions is shown in Figure 8.

• The application of the ZWILKOP ZW-10 preparation in the air and water sprinkler systems for preventing dust hazards at mining facilities is not determined by the coal type (PN-68/G-97002).

• The application of the ZWILKOP ZW-10 preparation with a concentration of 20‰ vol does not cause permissible exposure limits and short-term exposure limits of airborne 2-(2-butoxyethoxy)ethanol and 2-ethylhexan-1-ol contained in ZWILKOP ZW-10 to be exceeded in the mine air.

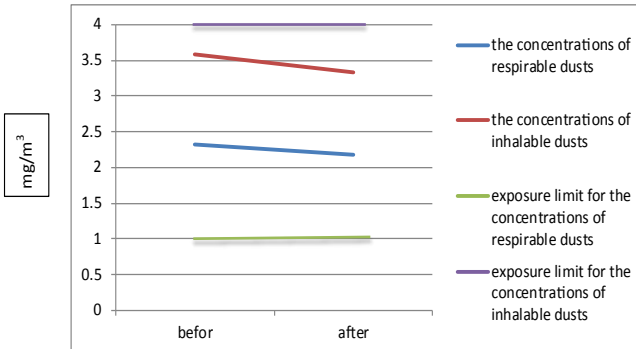

Figure 6: The efficiency of the ZWILKOP ZW-10 preparation to reduce the concentrations of respirable and inhalable dusts for hard coal is shown in Figure 35.2.

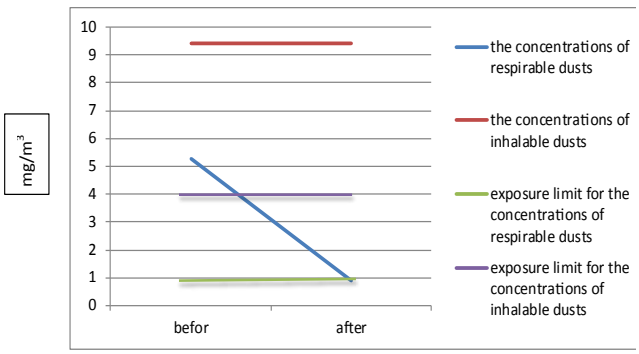

Figure 7: The efficiency of the ZWILKOP ZW-10 preparation to reduce the concentrations of respirable and inhalable dust fractions for hard coal is shown in Figure 32.1.

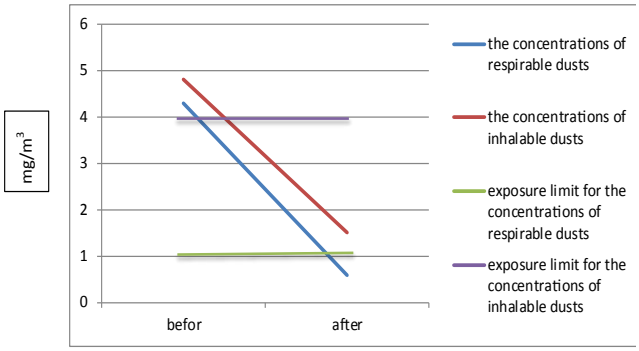

Figure 8: The efficiency of the ZWILKOP ZW-10 preparation to reduce the concentrations of respirable and inhalable dust fractions for hard coal is shown in Figure 34.2.

• The tests performed after applying the ZWILKOP ZW-10 preparation to assess the concentrations of hazardous substances, i.e., (2-butoxyethoxy)ethanol and 2-ethylhexan-1-ol contained in the mine air, and the respirable and inhalable dust fractions, confirmed that permissible concentration levels can be achieved with the preparation (Ordinance ... 2002).

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