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Improvement of microclimatic working conditions for miners in deep mines

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Abstract

The purpose of the paper is to substantiate possible ways to improve microclimatic conditions at workplaces in deep coal mines by controlling air moisture content. To improve the microclimatic conditions at underground workplaces, the authors propose a unit for dehumidification of air in a blind mine working, which is designed to remove moisture contained in mine air in the form of steam. The results of the calculations showed that by air dehumidification in a blind working, which is supplied by a local ventilation unit at a temperature of 24°C, and then cooled below the dew point and supplied to the face at a temperature of 20°C, the microclimatic index Humidex decreases from a dangerous level of 37.66 to a comfortable level of 12.5. The proposed method of normalising the working conditions of miners in deep mines, with an integrated approach that includes temperature conditioning with simultaneous extraction of high-quality water, as well as facilitating the ventilation regime in mine workings, provides significant benefits in terms of industrial sanitation, technology, and economics.

Keywords:

Humidex; deep mine; air moisture content; dehumidification of air

1. Introduction

In the context of rapid development of society and intensive industrialisation, the demand for energy raw materials in the world is growing every year (**OECD, 2019**). At the same time, the increase in coal production has led to various environmental and safety issues (**Kostenko et al., 2018**). These problems include endogenous fires (**Kostenko et al., 2022**), methane emissions (**Kostenko et al., 2023**), water pollution by mine wastewater, surface subsidence, biodiversity loss (**Abramowicz et al., 2021**) and soil degradation.

The gradual depletion of shallow mineral resources requires an increase in the depth of mining operations, which in turn leads to a deterioration in the microclimatic conditions of the mining environment (**Nguyen et al., 2021; Wang et al., 2021; Szlązak et al., 2018**) and intense pollution associated with the accumulation of substantial amounts of mining waste on the surface (**Bohomaz et al., 2023**).

Today, coal mining at Ukrainian Donbas mines takes place at rather deep horizons, exceeding 600-800 m, and at some mines reaching 1200-1500 m. At such depths, the temperature of the rock mass is 25-40°C and more, and the air humidity is 70-100%.

Modern Ukrainian microclimate standards at workplaces (**DSN, 1999**) provide for maintaining, when performing heavy and medium-duty work, a temperature not exceeding 28-29°C, relative humidity not exceeding 70-75% (at a temperature of 24-25°C) and a movement speed of 0.2-0.6 m/s. Exceeding the above limits of air temperature and relative humidity leads to a reduction in heat removal from the skin surface and the danger of body heating above the critical level called "climate hazard" (**Szlązak et al., 2019**).

According to Ukrainian regulations, the following restrictions are set for underground mine workings: maximum permissible temperature +26°C; air velocity 0.25-0.6 m/s (**NPAOP, 2010**). The absence of restrictions on air humidity in mine workings contradicts the national approach. High air temperatures in mine workings, combined with an equally high level of humidity, cause a serious deterioration in microclimatic conditions, which

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leads to difficult working conditions for miners (**Kocsis et al., 2017**). Studies have shown that at 80% humidity of mine air and a temperature of +35°C, it is advisable to stop all heavy work (**Zhang et al., 2015a**), due to the decrease in the comfort of miners; the critical temperature at such humidity is +37°C (**Zhang et al., 2015b**).

It is known that in relatively 'dry' workings, homeostasis indicators are much better than in 'humid' ones at equal temperatures. The productivity and safety of shaft men and face workers in the conditions of a heating microclimate is sharply reduced. Increasing the speed of humid air passing through the body, which has a temperature approximately equal to or higher than human skin temperature, slows down the heat removal from the human body and accelerates the accumulation of heat in the body. This, for example, is clearly felt by electric locomotive drivers working in the air stream coming out of the faces. The movement of locomotives contributes to the appearance of forced convection, that is, the process of transferring heat from the air to the human body. Based on the actual thermal and humidity indicators in the workings, it can be argued that the problem of ensuring comfortable and safe working conditions for miners becomes more urgent with increasing depth of mining.

Based on the above, the authors have defined the objective of the paper: To substantiate possible ways to improve microclimatic conditions at workplaces in deep coal mines by controlling air humidity.

The method of research is theoretical and computational, based on the fundamental principles of gas thermodynamics.

2. Analysis of recent research and publications

Experiments have been conducted on air cooling in underground workings by spraying cooled water using nozzles or ejectors (**Lapshyn et al., 2015**), which made it possible to reduce the air temperature in the cooling chamber from 26-32°C to 17-24°C (cooling efficiency was 21-34%), but the humidity increased from 55-78% to 75-80%. The increase in air humidity could have led to a deterioration in microclimatic conditions after the air was heated on the way to workplaces or mixed with warm air flows.

There are known estimates of human conditions based on a combination of factors, such as temperature and humidity, e.g., *Humidex*, a dimensionless value that takes into account the dew point (**Milosevic et al., 2020**). The value of this criterion is calculated by the following formula, which was proposed in 1979 by Canadian researchers Masterton and Richardson (**Masterton, et al., 1979**):

$$Humidex = T + 0,5555 \cdot (6,11 \cdot e^{5417,7530 \cdot \left(\frac{1}{273,15} - \frac{1}{273,15 + T_d}\right)} - 10) \quad (1)$$

Where are:

T – air temperature (°C),

T_d – dew point (K).

The psychometric method for determining dew point, which is widely used in mines, is not very accurate, but is quite reliable because it is quickly determined at the place where the measurement is taken

It has been established that *Humidex* values above 30 cause some discomfort, above 40 – great discomfort, and values above 45 are dangerous; if *Humidex* reaches 54, heat stroke is inevitable.

The results of the calculated *Humidex* values show that air humidity significantly affects the size of the safe index (*Humidex* ≤30); at an air temperature of 20°C, it is achievable at any humidity, and at 25°C it is possible only at a humidity of no more than 50% (**Table 1, Figure 1**).

Table 1: Calculated *Humidex* values in the ranges of humidity (*φ*, %) and temperature (T, °C) typical for underground conditions

T, °C / φ, %	Humidex				
	20	**25**	**30**	**35**	**40**
40	20.85	28.13	36.11	44.95	54.87
60	24.07	32.52	42.04	52.88	65.38
80	27.32	36.96	48.04	60.92	76.04
100	30.59	41.44	54.10	69.04	86.83

In modern production conditions, at workplaces in mine workings, due to technological requirements or economic inexpediency, it is impossible to use blowing, spot cooling, water-air cooling, and therefore in most workings it is impossible to provide regulated intensities of thermal exposure of workers. The analysis of the data obtained indicates that there is a significant potential for managing the state of microclimatic conditions at workplaces by a joint change in temperature and water vapour content in the air. The possibility of ensuring the relative comfort of miners' work (*Humidex* ≤30-40) with an increase in air temperature and a parallel decrease in its humidity is theoretically substantiated.

Most modern technical solutions for underground atmosphere conditioning are aimed at lowering the air temperature in mine workings (**Quan et al., 2019; Xue et al., 2024**) by means of heat exchange between air and a cooling medium, which can be water, ice, ammonia, various hydrocarbon low-boiling compounds, etc. These are complex material-intensive structures that consume a significant amount of electricity (**Bhukya et al., 2024; Dao et al., 2021**). Underground and surface cooling plants usually consist of pipeline compressors, heat exchangers, regulating and automatic devices. In the process of operation, they must reduce the temperature of significant air flows heading to the face, approximately 10-25 m^3/s, which requires significant energy consumption, while the moisture content in the air is not limited.

In our opinion, the process of reducing the moisture content in the air along with its cooling may be promising. This would make it possible to bring the assessment of working conditions underground closer to the require-

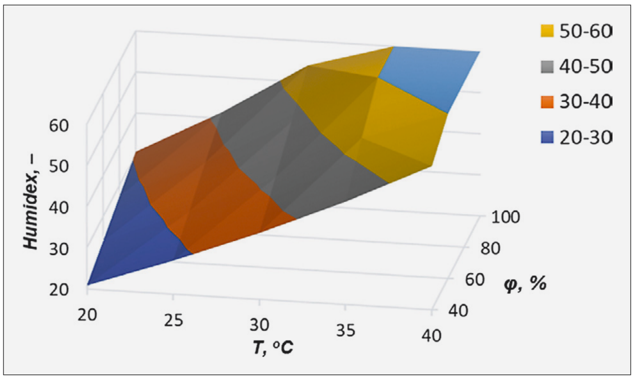

Figure 1: Influence of temperature *T, °C* and humidity *φ, %* of air at workplace on the value of the microclimate index *Humidex*

ments that exist on the surface (**DSN, 1999**). Let us consider modern methods of reducing the moisture content in the air environment.

Recently, the world has been intensively conducting research on the extraction of moisture from the atmosphere to produce drinking water. All research and experimental set-ups are based on the fundamental law of water vapour in the air to change to a liquid state and condense when it reaches the so-called 'dew point.'

Indian scientists have tested an atmospheric water extraction device operating on a vapour-compression refrigeration cycle (**Ahamed et al., 2023**). In this cycle, the temperature at the inlet to the evaporator is maintained below the dew point of the atmospheric air entering the device. Thus, the moisture contained in the air condenses on the coil and is collected. The amount of condensation depends on the psychrometric conditions of the incoming air. The air temperature was around 32°C, and when it entered the evaporator coil, its temperature dropped to 10°C (the dew point temperature of the device). Since the dew point temperature of the device (10°C) was significantly lower than that of the unsaturated incoming air (18°C), the water vapour present in the air condensed and was collected for further processing. Atmospheric water recovery devices are most effective in hot and humid regions. When the humidity level is 56%, 8.3 *mL/min* of water is extracted, and when the humidity level is 36%, 1.7 *mL/min* is extracted.

In a direct air-cooled system, the compressor circulates the coolant through the condenser and the evaporator coil in series cools the air around it (**Almrid et al., 2021**). This causes the vapour to condense by lowering the air temperature to the dew point. A variable speed fan blows the filtered air through the coil into the insulated duct. Once the temperature of the air entering the evaporator drops to the dew point, the droplets condense on the walls of the water duct and flow into the tray.

In the closed-loop pilot system, the humid air is driven by a fan that can be used to control the flow rate (**Zheng et al., 2020**). Droplet condensation occurs when hot, humid air passes along a cold substrate with a plastic film on it, which promotes droplet condensation. The polyethylene foil has a static contact angle of approximately 90°, with contact angles of about 111° and 74° at droplet advance and retreat, respectively.

A transparent experimental set-up using a composite moisture-sorbing material placed on a wire mesh tray is of interest (**Kumar et al., 2017**). During the adsorption process, the side windows are opened in the evening and the process starts due to the difference in vapour pressure between the surface of the composite absorbent and the atmospheric air (lower for the composite absorbent). This process is continued until late at night to reach equilibrium conditions, i.e. when the vapour pressure on the surface of the absorbent becomes the same as that of the atmospheric air. In the morning, the side windows are closed, and the set-up is exposed to sunlight for the regeneration process. As the temperature of the composite absorbent filler rises, the vapour pressure difference between the surface of the moisture-absorbing composite material and the air in the box increases. Due to the inclination of the water collection tray, water flows into the water measuring tank through the connecting pipe. The maximum recovery temperature depends on the amount of available solar heat.

An autonomous complex for the extraction of water from atmospheric air (**Chernov et al., 2010**) contains a transparent dome housing equipped with a vertical exhaust pipe, a heat accumulator inside the dome, a heat exchanger in contact with a cold source, an air duct to the heat exchanger, and a tank for precipitated water. An underground cooling pool is used as the cold source. In the daytime, air heated to 40-45°C with a moisture content of 38-45% is additionally heated under the dome to 50-55°C and enters the heat exchanger, where it is cooled to below the dew point. Water enters the tank through the pipeline system, and dehumidified atmospheric air enters the exhaust pipe.

The operation of an experimental unit for the extraction of drinking water using atmospheric steam was studied (**Teku et al., 2021**). The system consists of a compressor, a condenser, an expansion valve, and an evaporator through which water is collected. The coolant used in this study is R-22, and a forced-air exhaust fan is installed to cool the condenser. The water was collected daily for seven months, and its purity was tested experimentally. The results of this work showed that water production averaged 20 litres per day, and the average cost of its production per litre was 14-12 Indian rupees, which is less than one US dollar.

The device for extracting water from atmospheric vapours (**Konyakhin et al., 2010**) contains condensing elements installed in pairs, made in the form of corrugated sheets of metal, on the outer surface of which a layer of hydrophilic substance is applied. Natural wind flows are used as a source of air movement. The heat released during condensation passes almost freely through the thin layer of hydrophilic substance and is transferred to

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the outside through the thermal conductivity of the metal element. The stacked arrangement of the condensing elements makes the system efficient regardless of the direction of wind speed and vapour condensation on all surfaces of the condensing elements. The accumulated liquid flows into the water collection trough.

The results of water production with a minimum temperature of 10°C at air cooling 8°C below the dew point, an average air flow rate of 400 m^3/h, and a compressor power of 1000 *W* were analysed (**Inbar et al., 2020**). The water formed as a result of water vapour condensation was analysed for heavy metals, inorganic ions, NH^{4+} and a number of other substances. The results were compared with the recommendations for drinking water standards. A total of 64 water samples were collected in different climatic conditions, at different times of the day and over several seasons. None of the measured chemicals (except for nickel and benzo[a]pyrene in liquid samples) exceeded the drinking water standards. The chemical elements that were the main part of the device, such as iron, chromium, molybdenum, and aluminium, were not detected in the liquefied water at all or in very small amounts (less than 5 $\mu g/L$).

In order to justify the commercial use of the method of water extraction from air, a comprehensive study of the quality of water produced by the AWG type apparatus was carried out (**Kaplan et al., 2023**). The experiments were conducted in a highly polluted industrial environment. 83 water samples from the AWG were analysed for 99 different quality parameters, including organic, inorganic, and microbial contaminants. Two parameters, nickel (15 samples) and dichloromethane (2 samples), sporadically exceeded drinking water standards. Ammonia was the only parameter that consistently exceeded the standard limit of 0.5 mg/L (61% of samples from 47 countries) and even exceeded 1.5 mg/L. The results show that even in areas that are considered to be excessively polluted compared to the natural environment, air-extracted water using AWG can be considered suitable for drinking, provided that very specific contaminants are closely monitored.

A summary of the above data shows that several different design solutions for obtaining water from air have been implemented in experimental and commercial installations, all of which use the phase transition of moisture from gaseous to liquid state, condensation or sorption using the physical effect of the 'dew point'. The resulting condensate has chemical properties similar to drinking water and a relatively low cost. No studies have been conducted in terms of providing comfortable microclimatic working conditions by dehumidifying the air. A review of known designs indicates that the applied technical solutions are not adapted for use in mine workings.

3. Research results

As an example, the possibility of complex provision of thermal and humidity conditions for miner near the face of blind mine workings was considered. To ventilate this type of mine workings, local ventilation units are equipped with ventilation systems. They consist of a fan installed in the main working, which supplies air to a cylindrical flexible duct made of artificial leather. The air duct is laid to the face of the blind mine working. The air flow rate in the unit is controlled by means of fan guide vanes, as well as by changing the motor speed or installing additional flow regulators in the air duct. After ventilating the workplaces located near the face, the outgoing air stream is supplied in the opposite direction through the blind working to the main face.

To solve the task of air dehumidification and cooling, it is proposed to use the processes of the following thermodynamic system. The local ventilation unit, which contains a fan and an air duct to extract water from the air, is additionally equipped with an insulated housing mounted in the air duct, in which a tubular heat exchanger is installed, with a throttle connected to the inlet of the pipes, and a compressor at the outlet, which, in turn, is connected to a radiator, and the latter to a throttle. Furthermore, there is a trough in the lower part of the housing connected by a pipe to a valve to the condensed water tank.

The elements of the tubular heat exchanger – compressor – radiator – throttle circuit form a hermetically sealed system filled with a coolant that has a boiling point significantly lower than the air temperature in the working. The coolant is circulated by the compressor to a radiator installed in the mine air stream and then to a throttle installed at the inlet to the heat exchanger pipes.

The heat exchanger is cooled by circulating liquid coolant in its tubes, which has a low boiling point compared to the air temperature in the duct, so it boils in the tubes and absorbs heat from the air. The gaseous coolant is sucked out of the evaporator by the compressor. The compressor compresses the coolant to a high pressure and pumps it into the radiator. The compressed vapours condense, and the heat from the radiator is transferred to the surrounding mine air and dissipates into the environment. Under high pressure, the liquid coolant flows through a throttle into the evaporator to reduce pressure and regulate the flow. In the evaporator, the liquid coolant absorbs heat from the internal volume of the heat exchanger at low pressure and turns into a low-pressure gas. The compressor sucks in the coolant again, and the cycle repeats.

Dehumidification of air is achieved by passing air through the heat exchanger, which is installed in an insulated housing. The thermal insulation of the housing limits the heat from the outside to the heat exchanger and improves the heat extraction from the air moving through the duct. As the air cools below the dew point, water droplets condense and precipitate on the walls of the housing and heat exchanger tubes, with large droplets flowing down the trough under gravity. The accumulated water flows into the tank with the valve open and is used from there by consumers.

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The cooling rate of the air in the heat exchanger is controlled by changing the pressure or flow rate of refrigerant in compressor. As a result, the temperature of the heat exchanger tubes changes and, accordingly, the rate of condensation of water from the air.

Structurally, the unit for dehumidification of air in the face of a blind mine working and the main processes in it are as follows (**Figure 2**). The unit includes fan 1 connected to air duct 2 consisting of 20-metre sections of flexible ventilation pipe. Metal housing 3 covered with foam insulation is installed between the two sections. In casing 3, tubular heat exchanger 4 is installed, consisting of a bundle of copper tubes connected in a parallel system, for the movement and evaporation of coolant. The liquid coolant is supplied to heat exchanger 4 from expansion valve 5, which reduced the pressure of the liquid condensing in condenser 6 under the action of compressor 7. Compressor 7 compressed the gaseous coolant coming from heat exchanger 4 to the state required for condensation. The latent heat of condensation from radiator 6 is absorbed by air of mine working 8 and dissipated in the external space. A trough is created in the lower part of housing 3 to which the condensed water flowed, and from the trough the condensate flowed to pipe 9 with a valve. After opening the valve, the water flowed from pipe 9 to tank 10, from where it was consumed by users.

The low temperature in the heat exchanger was maintained by circulation with a change in the phase state of the coolant in the circuit: heat exchanger 4 – compressor 7 – radiator 6 – throttle 5. The coolant used was a fire and explosion-proof, non-toxic, environmentally friendly low-temperature liquid of the R-507a type. It was successively transferred from a low-pressure liquid state in heat exchanger 4 to a high-pressure liquid state in radiator 6. The excess heat of condensation dissipated in the air space of mine working 8.

To regulate the rate of air dehumidification and water extraction from it, we used such techniques as changing the flow rate of fan 1 up or down. The pressure in the heat exchanger 4 – compressor 7 – radiator 6 – throttle 5 circuit was also controlled, which determined the temperature of the pipes in heat exchanger 4 and, accordingly, the degree of air dehumidification. Condensed moisture from the bottom of housing 3 was removed through pipe 9 with a valve to tank 10 which must be as tight as possible to prevent water evaporation again.

The results of the approximate calculations (**Chepurnyy**, **2011**) showed that when fan 1 with a flow rate of 500 m^3/min was supplied with air at a temperature of 24°C and a relative humidity of 93%, the *Humidex* value was 37.66, which is dangerous. Through air duct 2, this air entered insulated housing 3, where, under the influence of heat exchanger 4 with a temperature of +2°C, the air was cooled to 12°C. Therefore, the humidity of air remaining in air duct 2 decreased to 55%. As a result, the absolute content of vaporous moisture decreased from

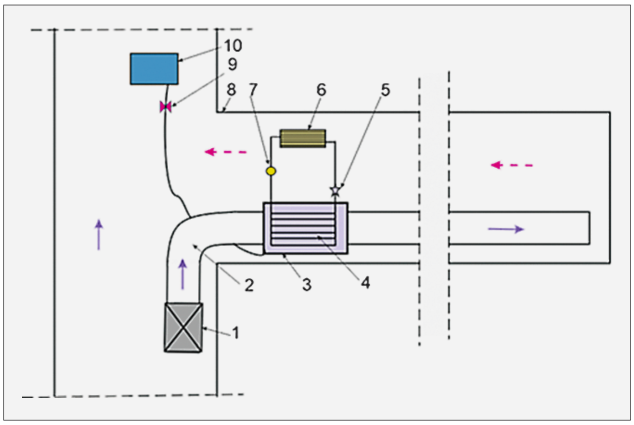

Figure 2: Schematic of the unit for dehumidification of air in a blind mine working: 1 – fan; 2 – air duct; 3 – insulated housing; 4 – tubular heat exchanger; 5 – expansion valve; 6 – condenser 7 – compressor; 8 – mine working; 9 – pipe with a valve; 10 – water tank

20 g/m^3 to 11 g/m^3. The rest of the moisture was condensed and flowed to the trough in the lower part of housing 3. The mass flow rate of condensate was 4,500 *g/min* or 330 *kg/h*. The cooled air was heated on the way to the face due to heat exchange with air surrounding the duct, but its moisture content did not increase. The air temperature in the bottomhole space was 20°C, and *Humidex* was 12.5. This ensured comfortable microclimatic conditions for the shaft men.

4. Discussion of the results

This example demonstrated the technical feasibility of controlling the environment at workplaces of shaft men by changing the moisture content in the air flow supplied to the faces. By controlling not only the air temperature, but also its humidity, the labour comfort indicators (*Humidex* from 37.66 to 12.5) in the area near the face were significantly improved, almost threefold. This approach to conditioning the working environment makes it possible to bring the working conditions of miners closer to those on the surface.

In the future, technological schemes for improving the microclimate in the workings based on the same physical principle of moisture management.

The implementation of such technical solutions requires the use of additional equipment and energy consumption, which leads to a rise in the cost of mining products. However, extracting water from mine air can provide certain economic benefits.

According to statistics, a medium-sized deep coal mine consumes more than 350 m^3/s of air to ventilate its workings. The energy of the main ventilation fans is used to move not only dehumidified air but also water vapour through the workings. The atmosphere of long mine workings has an almost stable temperature throughout the year and a significant relative humidity of about 80%, and in the ventilation horizons it is close to

100%. The content of water in the form of vapour in such air is about 17 *g/m³* at an air temperature of 20°C; with an increase in air temperature to 30°C, this figure increases to 30 *g/m³*. It is important to note that these data are representative of normal surface conditions. However, the water vapor content in the production air is a function of its barometric pressure. This means that for workings that have different locations relative to sea level, the barometric pressure can decrease or increase, so it is advisable to adjust the humid air indicators depending on the altitude location of the workings.

Considering the average cross-sectional area of mine workings of about 12 m^2 and their total length of about 150,000 *m*, the total mass of moisture contained in the volume of the mine ventilation network, at a moisture content of 20 g/m^3, can be estimated at 36,000 kg. Using technologies for extracting moisture from the air, it is possible to reduce the ballast mass in the air by at least half and eliminate the need to move this additional mass through the workings. This will reduce energy consumption for mine ventilation by switching the fan operation mode to more efficient performance. Furthermore, the reduction in moisture content and the associated reduction in the density of the dehumidified air in the outgoing stream improves the ventilation conditions of the mine by improving the natural draft that drives the fans.

Water used for drilling, flooding, dust suppression during excavation and transportation of rock mass, firefighting and other technological processes must meet the current standards. The price of water, which enterprises have to buy from external suppliers, has been rising rapidly in recent years. It is becoming a significant component of the cost structure of mines' products. The world experience of moisture extraction from air (**Inbar et al., 2020; Kaplan et al., 2023**) shows high quality indicators of the resulting condensed solutions, which are close to drinking water. Therefore, reliable extraction of good quality water from the air will be much cheaper than purchased water. As the above calculations show, water production can be sufficient to meet the process needs of the mine, and there is a prospect of using it as a commercial product.

5. Conclusions

As the depth of mineral deposits increases, the temperature of the rock mass increases and the thermal and humidity conditions in the workings deteriorate significantly. The problem of ensuring comfortable and safe working conditions for miners is becoming increasingly important. The existing temperature-based microclimate standards for underground workplaces differ negatively from those for surface workplaces due to technical and economic reasons.

The authors propose to improve microclimatic conditions at underground workplaces by removing moisture contained in mine air in the form of steam. The paper considers the option of air dehumidification in a blind mine working. The results of the calculations showed that by air dehumidification, which is supplied by a local ventilation unit at a temperature of 24°C, and then cooled below the dew point and supplied to the face at a temperature of 20°C, the microclimatic index *Humidex* decreases from a dangerous level of 37.66 to a comfortable level of 12.5.

An additional advantage of the proposed method of normalising the situation at workplaces is the production of a fairly high-quality water resource in the mine. The air of a medium-sized deep mine can contain several tens of tonnes of water in the form of vapour. Extracting part of this resource will reduce the cost of purchasing water from water utilities for process needs and firefighting. Water that is extracted from the mine air should be remove through a system of sealed containers and pipelines to prevent it from evaporating again.

The extraction of moisture from mine air reduces its density and, consequently, the cost of ventilation of the mine network by main ventilation fans. This reduces the cost of ventilation of the mine network of workings and provides a certain environmental effect.

The generalisation of the study results allowed us to conclude that the proposed method of normalising the working conditions of miners in deep mines, with an integrated approach that includes temperature conditioning with simultaneous extraction of water, as well as facilitating the ventilation regime in mine workings, provides significant benefits in terms of industrial sanitation, technology, and economics.

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SAŽETAK

Poboljšanje mikroklimatskih uvjeta rada u dubokim rudnicima

Svrha je članka obrazložiti moguće načine poboljšanja mikroklimatskih uvjeta na radnim mjestima u dubokim rudnicima ugljena pomoću kontrole sadržaja vlage u zraku. Za poboljšanje mikroklimatskih uvjeta u podzemnim radnim mjestima autori predlažu uređaj za odvlaživanje zraka u slijepim hodnicima rudničke eksploatacije, koji je namijenjen uklanjanju vlage sadržane u rudničkome zraku. Rezultati proračuna pokazali su kako se odvlaživanjem zraka u slijepome hodniku koji se opskrbljuje lokalnom ventilacijskom jedinicom na temperaturi od 24 °C, a potom hladi ispod točke rosišta i dovodi na radilište s temperaturom od 20 °C, mikroklimatski humideks indeks smanjuje s opasne razine od 37,66 na ugodnu razinu od 12,5. Predložena metoda normalizacije radnih uvjeta u dubokim rudnicima uz integrirani pristup koji uključuje temperaturno kondicioniranje uz istovremeno izdvajanje visokokvalitetne vode te olakšavanje režima ventilacije u rudarskim radovima daje znatne prednosti u smislu industrijske higijene, tehnologije i ekonomije.

Ključne riječi:
humideks indeks, duboki rudnik, sadržaj vlage u zraku, odvlaživanje zraka

Author's contribution

Viktor Kostenko (1) (doctor of technical sciences, professor) initialized the idea of extracting water from mine air, developed a methodological approach, managed the whole process and supervised it from the beginning to the end; **Olha Bohomaz (2)** (PhD, associate professor) review of literary sources, calculation and analysis Humidex; **Tetiana Kostenko (3)** (doctor of technical sciences, professor) participated in the completion of the literature review, creating graphs and figures; **Oleksii Kutniashenko (4)** (PhD, associate professor) processing and analysis of results.