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S. I. Cheberiachko,
orcid.org/0000-0003-3281-7157,
O. O. Yavorska,
orcid.org/0000-0001-5516-5310,
A. V. Yavorskyi,
orcid.org/0000-0003-4484-3723,
M. Yu. Ikonnikov,
orcid.org/0000-0003-2977-2007

Dnipro University of Technology, Dnipro, Ukraine, e-mail: elenayavorska80@gmail.com

A RISK OF PULMONARY DISEASES IN MINERS WHILE USING DUST RESPIRATORS

Purpose. To determine magnitudes of the occupational risks of respiratory disease (pneumoconiosis) occurrence in miners while using filter respirators on the basis of an exposure dust dose with the consideration of work experience.

Methodology. To assess occupational risks, a new approach proposed by the Research Institute of Complex Hygiene and Occupational Diseases is used. The approach is based on determining an exposure dose of a hazardous substance entering the worker's lungs during their professional contact with it taking into account the volume of pulmonary ventilation, the number of shifts, and work experience.

Findings. Use of dust respirators reduces the risk of occupational respiratory diseases but does not eliminate it completely. It has been established that with more than three-year work experience and coal dust concentrations of more than 50 mg/m^3, use of dust filter respirators does not ensure a minimal degree of the occupational disease risks. At the same time, it has been identified that if work experience is less than 3 years with the use of filter respirators, the risk of occupational diseases will be minimal. It has been proved that the risk assessment should involve using the minimal value of a protection factor of a respirator, which is fixed in the production environment. It has been shown that working within the areas with dust concentrations higher than 100 mg/m^3 is dangerous for miners; over time, with the accumulation of sufficient dust in the lungs it will lead to the development of silicosis.

Originality. It consists in scientific substantiation of the magnitude of occupational risk of respiratory diseases in miners, taking into account a real protection factor of respirators, which is determined at the workplace based on the calculation of an exposure dose and time of professional contact with hazardous substances.

Practical value. The experience of safe operation in mine workings with and without using filter respirators has been substantiated, basing on a safe value of coal dust concentration, at which a low level of occupational risk of respiratory diseases is recorded. Recommendations for determining the dust load taking into account a protection factor of respirators at the workplace have been developed.

Keywords: *mine, dust, occupational diseases, pneumoconiosis, risk magnitude, specific dust release, dedusting means*

Introduction. It is a well-known fact that the occupational diseases of miners working in underground mines include pneumoconiosis, dust bronchitis, sensorineural deafness, arthritis, radiculitis and others. According to the data by the Centre for Disease Control and Prevention (CDC), the most often occurred disease is pneumoconiosis – a serious lung trouble developed due to inhaling fine-dispersed dust particles with their further absorption by alveolar macrophages with the following emission of cytokines, which stipulates inflammation near bronchioles and alveoli (coal macules), whose further development results in fibrosis (due to accumulated collagen and dilatation of bronchiole walls) with the resulting malignant tumours. As we can see, the consequences of coal dust getting into the workers' lungs are rather drastic anyway. That is confirmed by the number of studies as for the occurrence of lung diseases caused by entrance of hazardous aerosols [1–5]. For instance, paper [2] indicates that within the period of 1970–2004, 69,277 miners died in the USA while in China up to 5,000 cases of respiratory diseases had been recorded annually up to 2010. Such a situation made the USA Mine Safety and Health Administration, MSHA develop a set of requirements for employers to reduce dust concentration in mine workings down to 2 mg/m^3. Nevertheless, within the period of 2000–2006, a growth of dust-factor diseases in miners with more than twenty-year work experience was recorded, which was a significant issue requiring implementation of new hardline approaches to solve that problem [2]. At the same time, in Germany after gradual reduction of a maximum admissible dose from 10 mg/m^3 (defined in 1974) down to 4.0 mg/m^3 at silicon dioxide content above 5 % in 1991, there arose again the necessity in reconsideration of safe dust doses with specific toxicity to 0.3 mg/m^3, provoked by titanium dioxide, whose inhalation results in lung cancer [3].

In terms of Ukrainian mine workings, there are so-called residual dustiness levels that can exceed the maximum admissible ones by ten folds. The latter, by the way, are higher than in the USA and depend on the silicon dioxide content. Such a situation requires implementation of risk control in the system of labour protection management on the basis of international standards like ISO 45001:2018 – Occupational health and safety management systems – A practical guide for small organizations that stipulates the necessity in hazard identification, evaluation of professional risks, and implementation of preventive measures as for their hierarchy to eliminate or reduce accident probability at the workplace. Moreover, the main requirement of the mentioned standard is a process of constant updating of the labour protection management system on the basis of Deming Cycle.

Basing on the aforementioned, we consider the study aimed at reducing a level of risks of the occupational respiratory disease (pneumoconiosis) development to be rather topical.

Statement of the problem. European legislation stipulates the priority of the use of collective protective devices over the individual ones. However, the first ones are used by employers depending on the degree of their awareness and finances, which prevents from the reduction of occupational disease risks down to a proper level according to the legislation requirements (e.g. DSTU 2293:2014 in Ukraine). In such cases, legislation determines the use of respiratory protective equipment (RPE). Taking into consideration the fact that implementation of the latter is much cheaper comparing with the collective equipment, the RPE wide use is rather obvious. At the same time, it is essential for RPE selection to assess the risks for identifying the efficiency for the proposed protective devices. Hence, a topical task arises concerning the availability of a simple but accurate method to assess professional risks of the occupational disease occurrence in workers while using protective equipment including the specification of safe period of their use.

Literature review. Analysis of publications concerning the risks of occupational dust-related diseases showed that there are two contradicting ideas. The first one states that the RPE use reduces their development considerably [4–6]. Thus, paper [4] studies a model of virus transmission by droplet spread due to a contact with infection particles contained in small (<5 mcm) air aerosols that can stay in the air for hours and spread over large distances that helped define high protective efficiency of respirators at about 90 %. Similar conclusions are obtained in paper [5], where calculation of the probability of miners' occupational diseases involves direct statement that the use of filter respirators reduces the anthracosis probability down to the admissible value being less than 10–5 [6]. Similar conclusions can be found in specialized medical literature as well [7], where clinical tests of respiratory protection efficiency carried out in the laboratory of biological material sampling are used to determine the probability of occupational respiratory diseases.

National normative documents (such as DNAOP (State Normative Acts on Labour Protection) 0.00-1.04-07) "Rules of selection and use of respiratory protective equipment" also give examples of high RPE efficiency. Another group of scientific papers indicates that a level of workers' protection by respirators is rather low; therefore, they should be used as additional protective devices [8, 9]. This conclusion is based on numerous results obtained under production conditions [8] showing that the main way of harmful aerosol entering through a half-mask is the leakage along the obturation line formed during the production activities. Paper [9] points out that the average dust dose reduction by a respirator is from 1.7 up to 3 times contrary to the mentioned 12 MAC (maximum admissible concentration). Paper [10] emphasizes a series of problems concerning the determination of real RPE protective efficiency. The key problems include an unstable protection factor of even one worker, which prevents from accurate determination of the aerosol amount entered the lungs; that requires further studies and explanations to determine the risk magnitude.

According to the data by the National Institute for Occupational Safety and Health (the USA), the amount of aerosol inhaled while using half-masks is rather unstable in terms of different workers using the same respirators under similar working conditions. It can differ by tens or even hundreds times. Thus, the ranges of assigned protection factors (APF) OK_3 were determined to indicate the minimal multipleness of the inhaled air contamination that could be provided by respirators of the specific design in terms of their correct and timely application by the trained workers after individual selection of a half-mask according to face geometry [11]. However, the indicated coefficient in the NIOSH Guidance on Respirator Selection published in 2004 is not connected with the calculation of workers' dust load, i.e. the amount of respirable dust having entered the lungs is the basis for making a solution whether to suspend workers or transfer them to other operations. M. Nicas, a famous specialist in filter respirators, tried to correct this gap [12]. Nevertheless, his papers focus mostly on the identification of a subgroup of workers, whose coefficient of RPE protection will be lower than the minimal required one; that needs corresponding managerial decisions. The developed mathematical model helped him calculate the amount of dust entering the lungs though his calculations were not connected with risk assessment being the compulsory condition while selecting protective devices.

Purpose of the paper is to identify occupational risks of the respiratory disease occurrence in workers while using filter respirators on the basis of an exposure dose, time of contact with a hazardous substance, and work experience in a dusty working zone.

Research methods. To define the risks, a methodology proposed by the Research Institute of Occupational Health and Occupational Diseases is used. In this context, a professional risk is defined as a combination of the probability of occurrence of a hazardous event before the injury severity or health deterioration as a result of that event that requires identifying all hazards at production and understanding their health impact degree. Here, the harmful effect of dust aerosol on a human organism was determined in terms of "dose-response".

The procedure algorithm consists of the following:

1. A risk magnitude is calculated according to the formula *Algorithm of the risk assessment procedure* [13]

$$R = D_e \cdot R_r \cdot 100\ \%,$$

where R is risk magnitude, %; D_e is exposure dose during the time of professional contact with a hazardous substance in (mg · shift)/kg; R_r is relative risk in kg/(mg · shift).

Here $P < 0.05$ is insignificant risk;
$0.05 > P > 0.08$ is low risk;
$0.08 > P > 0.1$ is moderate risk;
$P > 0.1$ is high risk.

2. Exposure dose is determined as follows

$$D_e = \frac{C \cdot Q \cdot N \cdot X}{M \cdot 230 \cdot 25},$$

where C is average concentration per shift, mg/m^3; Q is pulmonary ventilation per shift, m^3; N is the number of working shifts per year; X is a period of professional contact with a hazardous substance, years; M is body mass, kg.

While determining a total exposure dose, average shift concentration is calculated according to the methodology represented in [7]; in this context, the coefficient of RPE protection (K_3) against gaseous substances and solid aerosol particles can be introduced.

3. Relative risk (R_r) is the risk per substance dose. Its calculation requires applying the methodology from the practice of identification of chemical substance standards in the environment by the Environmental Protection Agency (the USA) where a specific risk is calculated by the formula

$$R_r = \frac{R_a \cdot M}{N \cdot Q \cdot MAC},$$

where R_a is admissible risk ($1 \cdot 10^{-3}$) [14]; M is body mass, kg; MAC is maximum admissible concentration mg/m^3.

4. To determine a safe working period with hazardous substances provoking occupational chronic intoxications, one

should use the data on the admissible and factual exposure doses involving the formula proposed in paper [15].

$$H_a = MAC \cdot Q \cdot 230 \cdot 3600,$$

while a factual exposure dose should be calculated as follows

$$H_f = C \cdot Q \cdot N \cdot 3600,$$

where C is average concentration per shift (mg/m^3).

Safe operating period is determined from the ratio H_a/H_f.

Research results. The initial stage of the occupational risk assessment involves identifying a hazard for the workers' health basing on the work specifics and production conditions. The information concerning these factors can be collected from different sources: attestation of workplaces in terms of labour conditions; results of inspections; reports on the workplace control by the health protection authorities etc. However, before determining any results, we should gain insight into numerous factors that are to be considered while studying the aerosol effect on a human organism. Since aerosol is a disperse system consisting of suspended small particles of solid or liquid substances in the air and characterized by different chemical nature, then the consequences from aerosol actions will differ as well. That prevents from generalizing the assessment of occupational risks as retaining of hard particles in lungs results in their injuries and further development of occupational diseases – pneumoconiosis, while entrance of various toxicants (liquid aerosols) causes additional intoxication of the organism systems with the following development of different occupational diseases. Relying on the aforementioned, we are going to limit ourselves by evaluating the effect of hard aerosol particles only.

Coal dust is the most widespread hazard for miners' health. That is confirmed by a structure of occupational diseases by the State Statistics Service of Ukraine, where dust-etiology diseases rank first. Analysis of the studies demonstrated that a value of dust aerosol concentration in mine workings fluctuates within the range from 10 to 200 mg/m^3; sometimes the values can be even higher [3, 14, 15].

The next stage involves evaluating the risk of respiratory occupational disease occurrence. For instance, consider the workers with work experience from 5 to 15 years having 200–230 working shifts in mines per year with dustiness from 50 up to 300 mg/m^3. The represented data do not contradict the information from the papers by famous researchers Medvedieva, Ye. N., Krutenko, S. A., Basanets, A. V., Kundiiev, Yu. I., and others.

Assume that the individual miners' protection applies filter respirators with the second-class protection filters P2, which consists of an elastomeric half-mask, inhale and exhale valves, headband, and two filtering boxes with corrugated filters made from a polypropylene filtering material. According to NAOP 0.00-1.04-07 "Rules of selection and use of respiratory protective equipment", such devices for individual protection are recommended to be used at dustiness up to 400 mg/m^3. At the same time, the guidance for such filter respirators indicates that the application range is limited by 12 MAC (for RPE of second-class protection, Appendix 3 of the Rules), i.e. it is capable of effective reduction of dust concentration by 12 times. If we consider that maximum coal dust concentration is 10 mg/m^3 in terms of free silicon dioxide content up to 5 % (according to the Safety Rules in Coal Mines), then the coal dust concentration within a working area, at which the use of filter respirators may guarantee safe protection, is not more than 120 mg/m^3. However, in reality the represented value can be by several times higher. That depends on a lot of components described in the national standard DSTU EN 529:2006. In particular, each respiratory protection device can be evaluated according to several indices: the determined coefficient of penetration under laboratory conditions on a specially trained and prepared testees with the preliminary tested correspondence of their facial parameters to the half-mask sizes; the nominal protection factor of filter respirators that is related to the coefficient of penetration as a reversed value and protection factor at the workplace, which shows how RPE reduces real concentration within a working zone. It is the latter value that allows evaluating the under-mask concentration of a hazardous substance. It is no doubt that the obtained index should be lower than MAC. However, due to certain reasons it is quite hard to meet the mentioned condition, especially while using a filter respirator in terms of boundary limits of a safe area (in this case, it is 110–120 mg/m^3). The greatest deterioration of protective properties of filtering RPE is observed due to appearing gaps along the obturation line (a place of half-mask contact with a face). Their origin also caused by the half-mask incompliance with the anthropomorphic facial parameters, changing facial mimics, loosening headband fixation, and half-mask slipping because of head movements. At the same time, the main problem, due to different reasons, is still found in respirator's taking off while working. This fact nullifies the worker's protection that is substantiated below.

We cannot but mention a problem of growing resistance of filters due to accumulation of dust sedimentation. The greater the difference between pressure differential on a filter and a respirator is, the higher the coefficient of unfiltered air suction along the obturation line is; that will result, without doubt, in general deterioration of protective properties of a respirator. If pressure differential on a respirator is lower than on filters, that indicates the formation of additional channels of air suction through the leakage points along the obturation lines. Besides, this is the principle to be the basis for testing the half-mask correspondence to a specific user (Quantifit test) that should be performed during the RPE selection according to the DSTU EN 529:2006 standard. The availability of the described fact requires determination of a breathing resistance value of a respirator in general and filters in particular that can be done in a simple way under production conditions with the help of differential electronic manometer. While determining the breathing resistance of a respirator, it is important to control the effect of pressing efforts of a headband. The greater the efforts are, the harder it is for the air to enter the under-mask space indirectly from a filter. Nevertheless, tensile force is limited by physiological limits of human endurance, being within the range of 4–6 N. Its increase will result in emerging pain on the face due to compression of soft tissues. Thus, it is possible to reduce suction only at the expense of obturator "ability" to adjust to the anthropomorphic facial parameters and provision of reliable half-mask fixation of the user's head with the uniform distribution of efforts along the obturation line. The latter is possible in case of coinciding action of a resultant force of the headband tension with the mass centre of a respirator.

Taking into account the fact that pressure differential on the P2 class filter is 80 Pa at the air consumption of 95 dm^3/min [16], and pressure differential on the RPA-DE (РПА-ДЕ) respirator selected by us is about 75–77 Pa at similar air consumption [17] as well as concerning the fact that the coefficient of penetration of the second-class filters is not more than 2 % while the respirator shows 6 % [18], this respirator can be used under conditions of dustiness not exceeding 100 mg/m^3 with sticking to its timely and constant use during operation in the polluted atmosphere. The results of the theoretical calculations of risk magnitude dependence on a dust concentration value, work experience of miners with the body mass of 75 kg, and pulmonary ventilation of 0.0013 m^3/s are represented in Fig. 1 and in Table 1.

Discussion. While analysing the obtained data, we can see that along with the growing dust concentration and work experience, the disease risk increases linearly. Wearing a respirator can improve considerably this situation. However, in terms of high dustiness of a working zone being more than 200 mg/m^3, it does not provide the minimal risk anymore. The exception here is the situation with short work experience up to three years. Nevertheless, it should be noted that risk reduction re-

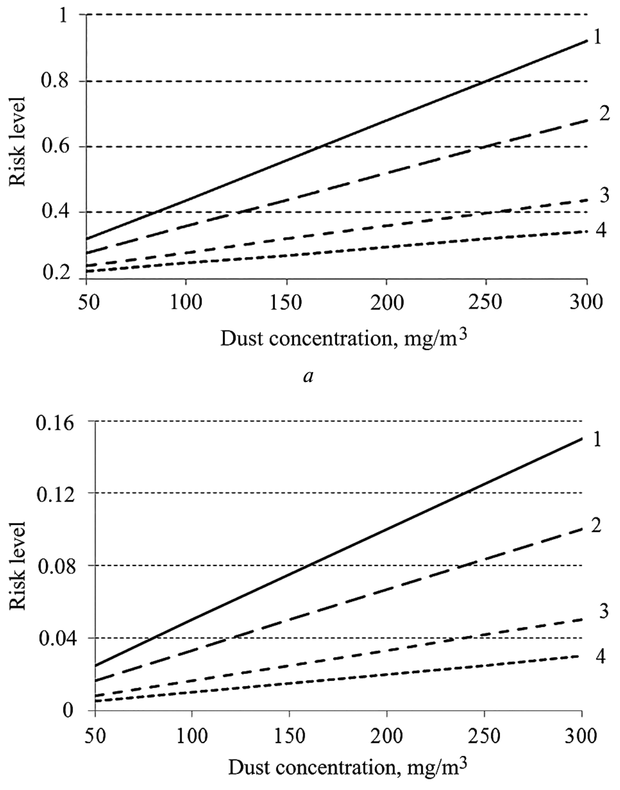

Fig. 1. Theoretical dependence of the level of occupational dust-etiology disease occurrence on the content of average dust concentration per shift in the working zone atmosphere in terms of miners' work experience without protective equipment (a) and while using filter respirators of second class of protection (b): years 15(1), 10(2), 5(3), 3(4)

Table 1

Calculation of safe work experience within a dusty working zone

Dust concentration, mg/m^3	Admissible exposure dose of dust, H_a, g, for coal dust with free silicon dioxide content from 5 to 10 %	Factual exposure dose of dust, H_f, g		Safe work experience within a dusty zone, years	
		without RPE	wearing PRE of second class of protection	without RPE	wearing PRE of second class of protection
50	≈ 248 g	1,242	103.5	0.2	2.4
100		2,484	207	0.1	1.2
150		3,726	310.5	0.06	0.8
200		4,968	414	0.05	0.6
250		6,210	517.5	0.04	0.5
300		7,452	621	0.03	0.4

quires solution of organizational problems – the key ones here involve encouraging the workers to use respirators properly. Any RPE is the additional load on a worker. If there is a necessity to use RPE, workers should be aware of their complete responsibility in case of refusal of its wearing, development of an occupational disease and deteriorating health quality along with economic losses due to medical treatment. One should also realize the hazards and the fact that any inconveniences worth nothing comparing to diseases. That will stipulate responsible attitude to both RPE selection and use. Nevertheless, the obtained result confirms that use of respirators helps both reduce risks of disease development and prolong safe workers' employment. However, as it has been mentioned earlier, it is hard to implement due to untimely and inconstant use of protective equipment.

For instance, we consider that the coefficient of respiratory protection is 12 MAC; in this context, dust concentration during a shift is constant being 100 mg/m^3. Assume that a worker uses PRE for only 5 min per six-hour working shift. Real protection factor will be equal to

$$K_{p.real.} = \frac{t_s}{\frac{t_1}{K_p} + \frac{t_2}{1}} = \frac{360}{\frac{355}{12} + \frac{5}{1}} = 10.4,$$

where K_p is protection factor indicated by a manufacturer; t_s is time of a working shift, min; t_1 is overall time of the respirator use; t_2 is time of the respirator non-use.

We can see that only five-minute non-use of a respirator within a dusty zone has reduced a protection factor by 1.4 units resulting in this case in risk growth by 8 % as the exposure dose of dust entering the lungs will increase.

Relying on studies [19, 20], we can state that a share of use of filter respirators is only 60–70 % per shift. Thus, real RPE efficiency reaches not more than 3–5 MAC, which increases the disease risk while RPE using by 4 times (Table 2).

While analysing the results of assessment of respiratory occupational disease occurrence represented in Table 2, it should be emphasized that the reduction of the respirator's protection factor takes place due to incompliance of a half-mask to the facial anthropomorphic features as well, which can be determined at the selection stage, e.g. by applying a fittest. Despite the fact that this test is used mostly for corresponding selection of the best half-mask for a particular worker with a minimal suction coefficient, the identified indices can be also used for calculating a protection factor at the workplace. To do that, a procedure is organized to test tight contact of the RPE half-mask with a face along the obturation line by identifying the points of suction (penetration) of hazardous substances in the form of aerosols (aerodisperse particles, gases, vapours etc.) into the RPE under-mask space.

The abovementioned calculations do not consider variations in dustiness that can influence greatly the coefficient of respirator protection at the workplace per shift. The latter is the determining one for the dust load evaluation.

Assume that the air contamination is about 50 mg/m^3, consumption of inhaled air is 0.03 m^3/min, and total time of being within the dusty space is 360 min. Then, the amount of dust entering the lungs without the respirator use will be of the value according to NPAOP 10.0-5.08-04 "Instructions on measuring dust concentration in mines and consideration of dust loads"

$$A_d = 0.001 C_0 Q_0 t = 0.001 \cdot 50 \cdot 0.03 \cdot .60 = 0.54,$$

where C_0 is dust concentration in the working zone air, mg/m^3; Q_0 is total air flow through a respirator, m^3/min; t is time, min.

Table 2

Calculation of occupational risks in terms of different respirator efficiency

Dust concentration, mg/m^3	Protection factor of a respirator with filters of second class of protection	Work experience, years	Exposure dose, g	Risk, %
120	12	5	$3.4 \cdot 10^{-5}$	0.008
	≈ 3*		$1.3 \cdot 10^{-4}$	0.03

* *Note* 3 is possible factor of respirator protection if workers will use a protective device for not more than 70 % of their working shift

Let a worker in these conditions use a filter respirator for six hour. In this context, a worker's protection factor within a five-hour period of constant and correct use is equal to 12 MAC, and within an hour period – 1 MAC due to mask slipping during the work or filter replacement, necessity in speaking or other reasons when the face contact tightness is violated or a mask is taken off. Then the dust load will be equal to

$$A_d = \frac{0.001}{K_{p1}} C_0 Q_0 t_1 + \frac{0.001}{K_{p2}} C_0 Q_0 t_2 = 0.03 + 0.09 = 0.12,$$

where K_{p1}, K_{p2} are coefficients of respirator protection 12 MAC and 1 MAC, respectively; t_1, t_2 are time of working wearing a filter respirator with its correct and constant use as well as with tightness violation or taking off a filter respirator, respectively.

The obtained result validates the dependence of dust load on a minimal value of the factor of respirator protection connected with the calculation of an exposure dose while assessing occupational respiratory disease risks. The represented results show that in case of correct, timely, and constant use of a filter respirator during the whole working shift, the dust amount entered the lungs would be only 0.045 mg at the dustiness of 50 mg/m^3 during a shift while in case of taking off the respirator even for five minutes, its amount would increase by almost 2.5 times.

The calculations represented in the table show that in terms of admissible exposure dose of 248 g for coal dust with free silicon dioxide content being 5–10 % per year (to compare with, according to NPAOP 10.0-5.08-04 "Instructions for coal dust measurement in mines and dust load consideration", this dose makes up 540 g at pulmonary ventilation volume of 0.03 mg/m^3), safe working period in a coal mine is not more than one month (at 50 mg/m^3 dustiness) while using RPE of second class of protection this period is 2.5 years.

Moreover, the calculations tell that the filter respirators of second class of protection are not expedient to be used at more than 100 mg/m^3 dustiness as the safe work experience shortens considerably; along with the dust concentration growth, the work experience becomes similar in both cases – either with or without a respirator. That is explained by accumulation of critical dust mass in lungs resulting in a disease. The conclusions are also confirmed by changes in the occupational risk level represented in Fig. 1. Assessment of the risks concerning respiratory disease occurrence considering the work experience is more informative than its magnitude calculated only in terms of the available hazard factor, whose factual value exceeds maximum admissible concentration, by one of the adopted methods given in the international standard ISO 31010:2019 "Risk management – Risk assessment techniques". The feature of the represented approach makes it possible to observe an increase in probability of hazard event occurrence at the expense of a growing factual exposure dose that is a peculiarity of the development of exactly occupational disease occurrences expanded in time. The known approaches to occupational risk assessment are aimed mostly at determining the probability of workers' injuries while performing their duties. Their application for defining risks of occupational diseases is complicated just due to lack of clear approach to consideration of accumulated hazardous substances in the workers' organisms and consideration of their elimination through the excretory systems. In this context, the best method is to organize periodical biomonitoring of the exposure dose value in terms of the determined indices. Undoubtedly, this control is necessary for specifying a procedure of risk assessment as the individual characteristics of organism are taken into consideration.

Thus, in this case the assessment of occupational risks while selecting respirators should rely exactly on the dust load value, whose magnitude makes it possible to identify safe work experience.

Conclusions.

1. Use of dust respirators reduces the magnitude of occupational respiratory disease risks but does not eliminate it completely. It has been defined that only in terms of working within the dusty area for not more than three years with some assumptions with the help of RPE, minimal risk can be provided.
2. It has been proved that while assessing the risks one should use a minimal value of protection factor of a respirator that is determined under production conditions in terms of half-mask compliance with the anthropomorphic parameters of the user's face.
3. Operations in the zone with dust concentration above 100 mg/m^3 is hazardous for miners; with the course of time and with sufficient dust mass accumulated in the lungs it results in pneumoconiosis. That requires development of the corresponding regulations in respiratory protection equipment, which would allow having clear specification of dust load basing on risk assessment to be under constant control.
4. Thoroughly selected high-quality dust respirators and their proper use can help reduce the risks down to a low level. The latter requires worker's shortened staying within the immediate dusty atmosphere as well as skills of correct RPE application.

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Ризик виникнення легеневих захворювань у гірників при використанні протипилових респіраторів

С. І. Чеберячко, О. О. Яворська, А. В. Яворський, М. Ю. Іконніков

Національний технічний університет «Дніпровська політехніка», м. Дніпро, Україна, e-mail: elenayavorska80@gmail.com

Мета. Визначення величини професійного ризику виникнення захворювання органів дихання на пневмоконіоз у гірників при використанні фільтрувальних респіраторів на основі експозиційної дози пилу з урахуванням стажу роботи.

Методика. Для оцінки професійних ризиків був використаний новий підхід, запропонований у НДІ комплексних проблем гігієни та професійних захворювань, що базується на визначені експозиційної дози шкідливої речовини, яка потрапить до працівника за час професійного контакту з нею з урахуванням об'єму легеневої вентиляції, кількості змін і стажу.

Результати. Використання протипилових респіраторів зменшує рівень ризику виникнення професійних захворювань органів дихання, але не ліквідує його зовсім. Встановлено, що при стажі роботи більше 3 років і концентраціях вугільного пилу більше 50 мг/м^3 використання протипилових фільтрувальних респіраторів не дозволяє забезпечити мінімальний ступінь ризику виникнення професійних захворювань. У той же час, встановлено, що при стажі роботи менше 3 років з використанням фільтрувальних респіраторів ризик виникнення професійних захворювань буде мінімальним. Доведено, що при оцінці ризику необхідно користуватись мінімальним значенням коефіцієнта захисту респіратора, що фіксується у виробничих умовах. Показано, що робота в зонах із концентрацією пилу понад 100 мг/м^3 є небезпечною для гірників і з часом при накопиченні достатньої маси пилу у легенях це призведе до розвитку силікозу.

Наукова новизна. Полягає у науковому обґрунтуванні величини професійного ризику виникнення захворювань органів дихання гірників з урахуванням реального коефіцієнту захисту респіраторів, що визначається на робочому місці на основі розрахунку експозиційної дози й часу професійного контакту зі шкідливою речовиною.

Практична значимість. Обґрунтовано стаж безпечної роботи у гірничих виробках як із використанням, так і без використання фільтрувальних респіраторів, виходячи з безпечної величини концентрації вугільного пилу, за якої фіксується низький рівень професійного ризику захворювання органів дихання. Розроблені рекомендації із визначення пилового навантаження з урахуванням коефіцієнта захисту респіратора на робочому місці.

Ключові слова: *шахта, пил, професійні захворювання, пневмоконіоз, величина ризику, питоме пиловиділення, засоби знепилювання*

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