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RECOMMENDATIONS CONCERNING PREVENTION OF OCCUPATIONAL HAZARDS RESULTING FROM THE MISTAKEN SELECTION AND USE OF FILTRATION DUST RESPIRATORS

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Objective *is to determine occupational hazards connected with contraction of diseases of respiratory organs, and to elaborate recommendations concerning the improvement of staff protection level.*

Methods. *Following research have been carried out to identify the hazards resulting from failure in respirator service: review of publications in scientific sources; analysis of studies in the field carried out lately by hygiene institutions; discussions with scientists from industrial medicine institutes, and work safety officers from coal industry enterprises as for the improved conditions of respirator use; and analysis of the current techniques intended to identify hazards of professional disease contraction.*

Results. *Decrease in the number of contraction of diseases of respiratory organs at workers during performance of their professional duties is possible if only effective respirator is used which can be implemented on the basis of:*

– *preliminary validation test for anthropometric parameters of faces of users as well as for production environment;*
– *training for correct control and adequate use in the process of performance of professional duties.*

Practical value. *The process of respirator selection it is possible to ask manufacturers for the information concerning characteristics of the respirator and their efficient use. Proper service involves engagement of the manufacturers to train staff as for the gaining skills of efficient use of the facilities. Adequate service involves appropriate tests of operational characteristics of the respirator in cooperation with their manufacturer.*

Key words: *respirator, protection, dust disease, health of workers, aerosol, operational conditions, risk, selection, errors.*

Чеберячко Сергій, Яворська Олена, Яворський Андрій, Іконніков Максим. Рекомендації щодо запобігання професійним ризикам, пов'язаним із неправильним вибором та використанням протипилових респіраторів

Мета *– визначити професійні ризики, пов'язані з виникненням захворювань органів дихання, та розробити рекомендації щодо підвищення рівня захисту персоналу.*

Методи. *Для виявлення небезпек, пов'язаних з порушеннями в роботі респіраторів, були проведені такі дослідження: огляд публікацій у наукових джерелах; аналіз останніх відповідних досліджень, проведених установами гігієнічного профілю; обговорення з науковцями інститутів промислової медицини та спеціалістами з охорони праці підприємств вугільної промисловості щодо покращення умов використання респіраторів; аналіз наявних методик, призначених для виявлення небезпек розвитку професійних захворювань.*

Результати. *Зменшення кількості захворювань органів дихання у працівників під час виконання їхніх професійних обов'язків можливе за умови використання лише ефективного респіратора, що може бути реалізована завдяки:*

– попередньому валідаційному тестуванню антропометричних параметрів обличчя користувачів, а також виробничих умов;

– навчанню правильного контролю та використання у процесі виконання професійних обов'язків.

Практична цінність. *У процесі вибору респіратора можна запитати у виробника інформацію про характеристики респіратора та його ефективне використання. Належне обслуговування передбачає залучення виробників до навчання персоналу з метою набуття навичок ефективного використання обладнання. Належне обслуговування передбачає проведення відповідних випробувань експлуатаційних характеристик респіраторів у співпраці з їх виробником.*

Ключові слова: *респіратор, захист, пилова хвороба, здоров'я працівників, аерозоль, умови експлуатації, ризик, вибір, помилки.*

Introduction. Despite the requirements of legislation to apply personal respirator equipment (PRE) only if it is impossible to reduce concentration of hazardous aerosols down to safety indices by means of organizational and technological measures, they are still popular industrially. It has been calculated that industrial companies of the USA spend annually almost $5 mln to equip workers with PRE only [2]. Moreover, the sum increases significantly taking into consideration processes of service, conformance inspection, and staff training. If selection and use are incorrect then substantial sum of money is wasted and workers will have no adequate protection which may result even in fatal cases. Thus, it is necessary to be careful with a procedure of PRE selection which involves several steps: determination of emission concentration in the working air; climatic conditions; working schedule; estimation of professional risks connected with PRE use; substantiation in terms of functionality and operation conditions; staff training as for application skills; and provision of correct storage and service [3].

However, the problem, which should be studied thoroughly, is to estimate occupational risks connected with PRE use since the majority of scientists, researchers, and labour safety experts believe it will favour its conscious application [4–6]. It should be noted that the procedure is required by several International Standards [7; 8]. Moreover, every country has its own legal system duplicating requirements of the abovementioned norms. Without going into details, we mention that the listed documents do not cover explanations concerning origin, weight evaluation, and recommendations concerning either elimination or minimization of occupational hazard of PRE users. Nevertheless, estimation of any occupational risk should also include the hazardous factors favouring the undesired event rise under the certain conditions. According to [7], the hazardous factors, connected with the use of PRE, can be divided into two basic groups: one depends upon mistakes resulting from PRE selection; another one depends upon amateurship or its irresponsible application.

However, before discussion of the problem, try to gain insight into numerous and diversified phenomena which should be taken into consideration while analyzing effect of aerosols on a human body. Since aerosol is a disperse system, consisting of the airborne particles of solid substance or liquid substance and characterized by differences in their chemical nature, their after-effects will differ as well. Thus, it is impossible to generalize the occupational risk estimation since retaining solid particles in lungs results in traumatizing of the latter and further progress of such occupational diseases as pneumoconiosis; in addition, getting of various toxicants (i.e. liquid aerosols) results in the body intoxication followed by progress of various occupational diseases. Relying upon the abovementioned, consider the effect of solid aerosols only.

Purpose of the analysis is to estimate qualitatively the risks of occupational diseases of the employees' respiratory organs while selecting and using filtering respirators.

Methods. The research has been carried out to identify the hazardous factors, which may deteriorate significantly the protection degree of workers using PRE to be defended against solid aerosols for effective implementation of respiratory protection as the part of measures to save their health.

Basing upon the open-source information, the analysis has gathered information on factors favouring or preventing from correct selection and use of PRE [9–18]. First, scientific sources estimating risks of contraction of occupational diseases while using PRE have been analyzed. Then, scientists, researchers, and employees of Institute of Hygiene have been interviewed as for the progress of occupational diseases in terms of staff during performance of their professional duties, and possible ways to reduce them taking into consideration use of PRE. Lastly, when the information was gathered, a meeting was held attended

by labour protection experts being representatives of different manufacturing companies who shared their opinions concerning the efficiency of workforce respiratory protection.

Results. While considering the problem of professional risk determination in the process of PREs, it is necessary to mention the lack of the unified approach to its solution. Moreover, even the idea of the risk does not have any common definition. Thus, certain experts believe that industrial risk is a potential injury to employee health during performance of his/her professional duties stipulated by hazard level and/or hazard of labour conditions, and scientific and technological conditions of enterprises which can be evaluated quantitavely as mathematical expectation of a harmful event occurrence [19; 20]. Paper [8] determines occupational risk as a combination of the occurrence of such a harmful event up to the injury severity or health deterioration as a result of the event which involves identification of each industrial risk as well as understanding of its health hazard. Papers [21; 22] supplement the occupational risk with the concepts of damage and severity of the damage. In other words, recently a concept of hazard has been complemented with the associated damage. Unfortunately, there is no explanation concerning the evaluation units. Moreover, neither of norms proposes distinct indices characterizing the damage. By the way, according to [23], risk is the empiric scientific "activity" connected with the determination of hazard likelihood as well as the damage amount being a result of effect of labour conditions. Since the situation with risk interpretation is not defined uniquely, we will follow its classic definition as a likelihood of health damage onset. In our case, after-effect is the progress of occupational disease resulting in partial or complete disability of a worker or even his/her death due to solid aerosol inhaling in the process of performance of his/her professional duties.

Determination of any occupation risk involves the detailed data concerning labour conditions, hazard, protection means, control means, competence of the staff etc. Its value may be estimated with the help of different techniques described in [24]. For instance, if "Risk score" technique is applied [25] (Fig. 1) then risk (R) is evaluated by means of scores using formula

$$R = S \times P, \quad (1)$$

where S is severity of after-effects; and P is event likelihood.

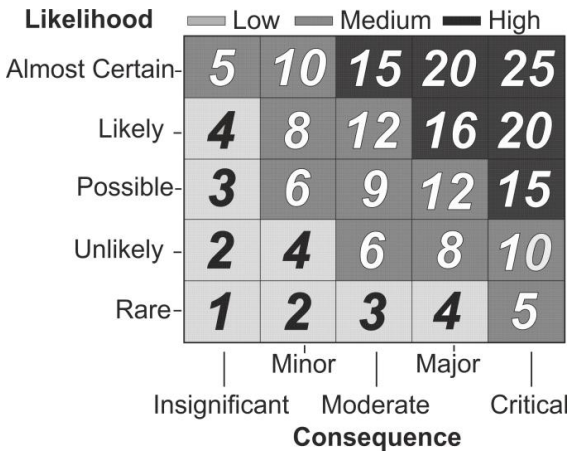

Fig. 1. Table to determine risk using "Risk score" technique

Table 1 demonstrates an example how a risk of such occupational mining disease as anthracosis is determined.

Moreover, occupational risk can also be evaluated with the help of more complicated technique "HAZID" most commonly used at the initial stages of the development of any projects. The technique complies with the requirements in the field of HSE (i.e. health, safety, and environment). The calculations should involve knowledge of infrastructure, operations, hazards for the staff health, potential emergency etc. The risk level is also identified taking into consideration "likelihood – severity of after-effects" matrix in terms of the determined rating. Table 2 shows a fragment of risk evaluation worksheet in terms of the described technique.

The factors, effecting correct selection of PRE and its use, are complex and inhomogeneous even at one workplace. If various factors are emphasized, it does not always mirror what can be expected for the branch or for the respirator [26]. However, understanding of the gathered

Table 1

Risk of occupational respiratory disease contraction in the context of miners working at 30 mg/m3 gas content

Occupation	Hazard	After- effects	Basis risk			Risk category
			Severity of the after-effects	Event likelihood	Risk	
Miner	Coal dust	Anthracosis	5	5	25	Critical

Table 2

A fragment of a worksheet to calculate risks using "HAZID" technique

№	Hazardous factor (keyword)	After-effects of the hazardous factor	Hazards	Prevention	Risk	Remarks
Health hazards						
1.	Insufficient oxygen	Breathlessness, heart beating, dizziness, death	Staff	Airing, control of oxygen concentration, developing of routs in the fresh air flow	2	–
2.	Coal dust	Contraction of respiratory diseases (i.e. silicosis, and lung cancer).	Staff	Airing, implementation of dedusting systems, systems of collective protection, development of respiratory protection program	1	High hazard level since the staff is within the hazard zone constantly where concentration exceeds limit concentration

information can help comprehend the following: inadequacy of functionality, when the selected PRE corresponds neither to toxicant type nor to protection class, which is one of the most important mistakes in the process of filtering PRE and may result in a fatality. In that case, an employee remains vulnerable due to major violations of the related instructions or negligence of authority. The mask mismatching anthropometric measurements of a face, which can be determined by insulation characteristics of half-masks, is another mistake which also results in the deterioration of protective characteristics while favouring the increased occupational risk. That is why after determining the required protection level and making decision concerning its type, the stage of PRE selection should provide test for the density contact between the mask and worker's face without exceeding limits of its specific pressure exerted on the face (4–6 N).

PRE selection process often neglects operating conditions: potential decrease in oxygen concentration (for instance, operations in the restricted premises); varied contamination level of hazardous aerosols (i.e. day-night concentration is taken into consideration when there is the likelihood of instant intolerable one due to explosion or another emergency situation); and climatic conditions (i.e. temperature and air humidity) will aggravate health of workers due to insufficient oxygen, weakening of protective characteristics resulting from toxicants getting to undermask space, loss of ergonomic properties stipulated by the increased breath resistance, face perspiration, and water falling on the filter. Table 3 demonstrates recommendations concerning the decrease in the effect of the reasons deteriorating protective characteristics of respirators in the process of their selection.

The most common mistakes of PRE application are as follows: misuse by the unqualified workers misunderstanding operating principle of the protective device, its structure, and the restricted use depending upon the work pace, communication need, and engagement of other PRE. Moreover, they have no idea how to put on/take off the device correctly; to recognize potential damages, and how to make necessary tests before use. Moreover, it is necessary to provide the required service after its use as well as cleaning and disinfection. If workers do not have essential knowledge and skills, the abovementioned increases chances of occupational risk due to deterioration of protective and ergonomic indices. Thus, employers should provide appropriate procedures to train their staff, to check PRE performance at work places, and to identify the damaged components with their further replacement.

Table 4 demonstrates recommendations concerning the decreased risks of occupational diseases caused by the mistakes during the respirator use.

Analysis of the information from Tables 3 and 4 shows that it is possible to reduce some of the listed risks using high-quality PRE with proper data concerning identification, service, and replacement period. The above needs cooperation with fair PRE manufacturers controlling constantly the production process starting from raw material purchase and finishing by the end product. It should be noted that according to [8], either manufacturer of PRE or its supplier has to provide information on the risks to coordinate activities with a consumer. The requirement involves greater integration of partner companies which will help provide mutual control over the operating procedures (i.e. PRE use) thus improving the product quality as well as safety of employees using it.

It stands to reason that in addition to the correct PRE selection by experts (for instance, those representing the Institute of Industrial Labour Hygiene and understanding PRE specifications) and a procedure determining occupational risks, it is important to solve managerial problems. Motivation of employees to apply the facilities correctly is the key problem since the solution has an effect

Table 3

Recommendations concerning decrease in occupational disease risks resulting from the mistaken selection of PRE

Mistakes		Recommendations concerning decrease in occupational disease risks
Name	**After-effects**	
1. The selected respirator mismatches its functions.	The specified protection of respiratory organs is not provided.	Select respirator of proper type and protective level.
2. The selected respirator matches its functions but anthropological properties of the user's face are not determined.	The specified protection of respiratory organs is not provided due to obturator-face incompatibility, i.e. toxicants get to undermask space.	Use a head strap to press the obturator against the face not exceeding specific pressure exerted on the face (4–6 H), or apply a respirator with the varied geometry of obturation line.
3. The selected respirator corresponds to the requirements listed in points 1 and 2 but its operating conditions are not taken into consideration, i.e.:	First, dizziness, weakness, and tachycardia arise; critical oxygen concentration (<< 18%) results in convulsions and death.	Ventilate the working area or use insulating PRE instead of the respirator.
– air concentration within the working area air is < 18 %;		
– toxicant pollution of the working area air exceeds safety limit of the respirator use; and	The specified protection of respiratory organs is not provided due to toxicant getting into the undermask space.	Apply a respirator of adequate protective level.
– heightened temperature and air humidity.	Perspiration of a face and increase in the breath resistance due to the filter watering.	Apply a respirator equipped with the exhalation valve and water-absorbing element.

Table 4

Recommendations concerning the decreased risks of occupational diseases caused by the mistakes during the respirator use

Mistakes		Recommendations concerning the decreased risks of occupational diseases
Name	**After-effects**	
The respirator is used by unqualified (unskilled) employees	The specified protection of respiratory organs is not provided.	Mandatory staff training as for the adequate PRE use
The respirator is used by the skilled employees; however, its preparation for use and service is not satisfactory	The specified protection of respiratory organs is not provided due to toxicant getting into the undermask space through the damaged components of the respirator	Routine control of operating characteristics identification of the damaged components, and their replacement.
The selected respirator corresponds to the requirements listed in points 1 and 2 but its operating conditions are not taken into consideration, i.e.: work pace, and the increased mobility; and	Ergonomic factors deteriorate due to the increased breath resistance and origination of extra load	Use a respirator with low breath resistance, or with the forced air supply
	The specified protection of respiratory organs is not provided due to toxicants getting into the undermask space because of the necessity to take off the respirator	Use a respirator equipped with intercommunication systems
– communication need	The specified protection of respiratory organs is not provided due to the worsened PRE performance because of its incompatibility with other respiratory protective devices	Use respiratory protective device manufactured by one and the same company. Provide control of protective characteristics of PRE as for its compatibility with other respiratory protective devices
– use of other PRE – period of use	Discomfort; the necessity to take off the half-mask to have rest	Prolong breaks while operating using PRE. Use respirators with the forced air supply

on the implementation of the program of respiratory protection. Any PRE is the extra load on a worker. Its value depends greatly upon occupational hazards as well as upon other implemented common protection devices. If the necessity to apply PRE arises then the employees should take responsibility for refusal of using the facilities, development of occupational disease, deterioration of life quality, and economic loss connected with the disease treatment. It is also important for them to understand the nature of the hazard and apprehend it recognizing that the caused inconveniences are nothing to compare with the disease. That will stipulate responsibility for both PRE selection and its use.

The heavy role in the process of such an approach is played by enterprise authorities as well as by introduction and implementation of the respiratory protection programme; manufacturers of respiratory facilities should be involved in the elaboration of the key points of such programmes. Responsible attitude towards high-quality product manufacturing at each stage from raw material to the end product is the element of reliable protection of workers as well.

Conclusions. Summing up the research results, we will note that each employer should evaluate proper risks in the of PRE selection. Minimization of hazards is possible if only high-quality PRE is selected, serviced, and applied correctly. The employers may share the responsibility to provide their workers with high-quality and relevant RPD involving the producers in the process of worker's protection process [1] stipulates such a possibility. Adequate selection involves participation of workers to obtain necessary information concerning operating characteristics of the PRE; adequate use involves manufacturers to train operating skills; and adequate service involves corresponding tests of operating characteristics of the PRE in cooperation with its manufacturer or according to his/her instructions.

Moreover, while arranging the respiratory protection programme, training workers to use PRE correctly involving its manufacturers, and demanding the enforcement of proper procedures, described in [8], the employer delegates them certain share of his/her responsibility; what is more important, those measures protect health of the employees.

To make PRE able to decrease a pollution degree of the inhaled air down to the acceptable level, following three conditions should be met.

1. Protection coefficient of respirators should exceed pollution coefficient of a working area, i.e.:

$$K_{PR\ min} > K_{POL}, \quad (2)$$

where K_{PRmin} is minimum required protection coefficient of PRE; $K_{POL} = C / BAC$ is pollution coefficient of the working area; and C is the pollutant concentration, mg/m^3; BAC – boundary admissible concentration.

2. The PRE protection coefficient should be determined at the workplace individually. The idea is to identify the ratio of the external test-aerosol concentration to the undermask space with the help of specific measuring devices.

3. PRE half-mask should correspond to the worker's face anthropometry. To provide the requirement, operating department needs implementation of a procedure intended to test PRE half-mask – face contact along obturation line while determining areas where pollutants in the form of aerosols (i.e. aerodisperse particles, gases, vapours etc.) inflow into the PRE undermask space. There are two types of such a test: qualitative and quantitative. Qualitative technique is based upon subjective reaction of sense organs on the penetrating odour of airborne safe aerosols (i.e. saccharine, bitrex, isoamyl acetate etc.). Quantitative techniques rely upon instrumental test using corresponding facilities (e.g. fittest, quantifit test, and thermal mapping).

4. PRE should be applied timely and correctly. It is important for adequate and suitable PRE use to inform employees about health risks if the equipment is applied incorrectly, and to train them adequately. The training involves studies of the protective device components, its correct putting on, preliminary wearing to get used to it and to evaluate comfort as well as familiarizing with activities during the emergency. Such training should be regular; moreover, its programme has to be updated annually.

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