Risk of pathologies when exposed to fine dust in the construction industry

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Abstract. Problem urgency. According to the World Heart Federation prolonged exposure to pollutants of the air environment has negative effect on the cardiovascular system. Up to the present moment the question of the negative impact of fine dust on the cardiovascular system is studied insufficiently, there is no enough data about the risk to the health of workers in the construction industry during long contact with it.

Purpose. To assess the risk of occurrence and development of the cardiovascular system disease under the impact of fine dust in the construction industry.

Object of research: constructions of ground and underground types, undergoing reconstruction.

Subject of research: impact of working zone air fine dust on the cardiovascular system of the worker in the construction industry.

Methods. Sampling of air was carried out by automatic measurements of concentrations of fine particles PM2.5; PM10 in the studied objects working zone air by using a combined semi-automatic dust meter OPMN-10.0: the average concentrations for each operation (working zone) and time-weighted average concentration were defined. The risk of occurrence and development of cardiovascular pathology was determined on the basis of evolutionary modeling.

Results. Based on the established exposure of fine dust there is a possibility to determine the forecast the negative impact of harmful factors on the expected period of employment duration. Determined the relationship between the risk value of occurrence and development of cardiovascular system diseases in contact with fine dust and the employment duration and the value of the maximum permissible concentration for surface and underground facilities.

Conclusions. On the basis of the results of the obtained dependence was developed the scheme of the rapid assessment of risk of occurrence and development of cardiovascular system diseases to workers of facilities of surface and underground types when exposed to fine dust.

Keywords: risk, cardiovascular system, fine dust, PM2.5, PM10, harmful factor, labor protection, construction
1. Introduction

Working conditions in the construction industry remains one of the most urgent and socially significant problems [1]. Working in the construction industry associated with the wide and diverse spectrum of harmful factors [2, 3, 4, 5]. One of them is pollutants in the air environment [6]. World Heart Federation [7] declares, that long-term exposure to pollutants of the air environment has a negative impact on the human organism.

The suspended particulate matters in the form of fine dust pose the greatest threat to health of the worker regardless of the duration of exposure, as they contain respirable particles [8].

Question about the fine dust negative impact on the human body, especially the cardiovascular system insufficiently explored till present time. Quantity of data at hand about the risk to the workers’ health in the construction industry with long contact with it is insufficient. Thus, the aim of this work is to assess the risk of cardiovascular system pathology development under the impact of fine dust in the construction industry.

Objects of study in the article are structures of surface and underground types undergoing reconstruction; and the subject of research is the impact of the fine dust in the working zone air on the worker's cardiovascular system in the construction industry.

2. Methods

Sampling of air was carried out using automatic measurements of concentrations of fine particles PM2.5; PM10 in the working zone's air of the studied objects using a combined semi-automatic dust meter OPMN-10.0. In the course of the works the average concentrations for each operation (work zone) and time-weighted average concentration were determined.

The risk of occurrence and development of cardiovascular pathology were determined on the basis of evolutionary modeling [9]. The evolutionary model of organism responses dependence from exposure is a model for evaluating the health risks accumulation taking into account the duration of exposure to harmful factors. It is a mathematical model describing the dynamic of negative changes in the body of the individual under the impact of harmful factors, taking into account natural system processes in the body.

3. Results

There is a possibility to determine the forecast the negative impact of harmful factors on the expected period of work experience Based on the duration of exposure to fine dust. Dependence of the risk and development of diseases of the cardiovascular system in contact with fine dust from the work experience and the value of excess of maximum permissible concentration for surface and underground facilities were determined. When working on the ground object, the risk of occurrence and development of diseases of the cardiovascular system passes valid border at the age of 32, on the underground – 31.

4. Discussion

There are two types of impact of fine dust on the human body: when doing work on the earth's surface and in the conduct of work in the underground complexes.

The initial concentration of fine dust on the surface, as a rule, higher than in underground facilities (impact of road-transport complex, industrial plants, periodic decrease humidity, etc.) [10, 11, 12]. However, areas on the surface have an intense mobility of air, which is typical for the lower layers of the atmosphere. It is possible to observe the passive transfer of suspended particles by flows of air masses. That leads to a dispersion concentration of fine dust and the periodic decrease of its concentration on the studied object.

Underground facilities - are specially equipped mine openings in the rock mass [13].This is man-made system that tend to be isolated. Such systems have favorable conditions for deposition of dust particles: high humidity and poor air movement – thus, such systems are able to accumulate fine dust. This property leads to an increase of health risk from exposure to fine dust. With the increase of air
movement there is a sharp increase in the concentration of suspended particles, for example in underground tunnels when there is transport movement.

The following discussion describes the state of air environment (concentration of PM-particles) of the surface object during the construction process. The study was conducted during the reconstruction of the object in period tile-cladding works at the construction site. The measurement results are given in Table 1.

Table 1. Research results of air environment state (concentration of PM-particles) of the surface facility during construction works

| Ser. No. | Factor of work environment | Unit of measurement | Maximum permissible concentration | Actual average monthly indicator |
|----------|-----------------------------|---------------------|----------------------------------|---------------------------------|
| 1        | Fine dust – PM10           | mg/m³               | 0.30                             | 1.90±0.3                        |
| 2        | Fine dust – PM2.5          | mg/m³               | 0.16                             | 1.10±0.2                        |

As the hygienic standard of the content PM-particulate in the working area air, maximum allowable one-time concentration of PM-particles in atmospheric air was used in the research [14]. This can be explained that the standard for air of the working area is missing. Scientific literary data and materials of the World Health Organization (WHO) [15] highlights that the effect on health status is significant and has very low threshold level. In addition, there is data in the literature on the possibility of using maximum allowable one-time concentration of PM-particles in atmospheric air in the absence of value of maximum permissible concentration (8-hour time weighted averages) for the work area [16].

Thus, the harmful factor of a working environment – fine dust - is beyond the boundary of hygienic practice for surface object. The excess of MPC (maximum permissible concentration) was as follows: PM10 – 6.3 times, for PM2.5 – 6.9 times.

We shall consider the condition of the air environment (concentration of PM-particles) of the underground facility - an underground transport tunnel - during the construction process. The results of the measurements are shown in Table 2.

Table 2. The results of the research of air environment conditions (concentration of PM-particles) of the underground facility during the construction process

| Ser. No. | Factor of work environment | Unit of measurement | Maximum permissible concentration | Actual average monthly indicator |
|----------|-----------------------------|---------------------|----------------------------------|---------------------------------|
| 1        | Fine dust – PM10           | mg/m³               | 0.30                             | 3.30±0.4                        |
| 2        | Fine dust – PM2.5          | mg/m³               | 0.16                             | 1.87±0.3                        |

Thus, the harmful factor of a working environment – fine dust - steps over the bounds hygienic practice for underground facilities. The excess of MPC was as follows: PM10 – 11 times, for PM2.5 – 11.9 times.

Quantification of occupational risk of occurrence of pathology of the cardiovascular system when exposed to dust fraction PM10-2.5, and was conducted by evolutionary modeling. The evolutionary model allows to calculate the risk at any given time. The evolution equation in standard form is a formula [9]:

\[
\frac{dx}{dt} = ax - bx^2
\]
\[ R_{i+1}^i = R_i^i + (\alpha_i R_t^i + \sum_j \Delta R_t^j)C, \]  
\(1\)

Where \( R_{i+1}^i \) – the risk of violations of the \( i \)-th system at time \( t+1 \);
\( R_t^i \) – the risk of violations of the \( i \)-th body system at time \( t \);
\( \alpha_i \) – multiplier that takes into account the risk evolution due to natural causes;
\( C \) – time empirical coefficient.

Multiplier that takes into account the risk evolution due to natural causes \( (\alpha_i) \) is determined based on the background incidence for this category of disease, \( \alpha_i =0.05 \). Time empirical coefficient \( (C) \) depends on the period of exposure for risk calculation. The period for the risk calculation is 1 year, \( C=1 \).

Quantitative risk assessment was carried out considering work and rest schedule, length of service – since 18 years, working day duration – 8 hours.

Paired mathematical models were used when modeling health risk. These models are shown in published scientific research, taken at international scale, as well as obtained on the basis of regional epidemiological studies [17, 18, 19].

The results are presented in Table 3.

| Risk                  | Surface facility | Underground facility |
|-----------------------|------------------|---------------------|
| Allowable (<0.05)     | 0-32 years       | 0-31 years          |
| Moderate risk (0.05-0.35) | 33-71 years       | 33-71 years         |
| High risk (0.35-0.6)  | 72 years and older | 70 years and older |

5. Conclusions

Results of the obtained dependence made it possible to develop a scheme for rapid assessment of occurrence and development cardiovascular system diseases risk of the workers of surface and underground facilities, in contact with fine dust during the construction process.

Scheme is presented in Figure 1.

**Figure 1.** Risk accumulation model of cardiovascular system's pathology when exposed to fine dust
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