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REDUCING THE RISK OF AIR POLLUTION IN WORKING AREAS BY CONSTRUCTION DUST USING A COMBINED DUST COLLECTOR

The object of research is methods for reducing the level of air pollution in working areas with industrial dust. The problem of reducing the impact of dustiness of production premises on the workers' health is solved by improving the aspiration air purification system.

A new approach is proposed that provides the blower (fan) with an additional purification function by attaching a dust collector to its housing. By organizing the circulation movement of the dust-gas flow, part of the dust settles in the dust collector before it enters the main dust collector. Such a combined dust collector can be used as an independent device in closed aspiration systems or as part of complex dust removal systems, reducing the load on the main device. A methodology for calculating purification indicators has been developed, which is based on the discretization of the differential dust mass distribution curve by particle size. The method allows to assess the efficiency of the process, determine the dimensions of the dust collection container and the frequency of dust discharge from it. The technology was used for the air aspiration system of the working area of the building materials processing facility to reduce the risk to workers' health from air pollution. The calculations have established the conditions of acceptable non-carcinogenic risk at the level of construction dust concentration not higher than 61.42 mg/m^3, and with the introduction of the proposed combined dust collector, it is possible to increase the dust level to 99.1 mg/m^3 without exceeding the risk threshold.

The proposed technology is cost-effective, requires minimal design changes and can be implemented at most industrial facilities, especially in conditions of high dustiness of production premises.

Keywords: *air purification, combined dust collector, differential distribution curve, non-carcinogenic risk, dust removal systems.*

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1. Introduction

Urbanization and globalization of the world economy in recent years have caused aggravation of environmental problems, primarily due to air pollution, which affects human health, worsens the quality and shortens life expectancy Among the non-carcinogenic air pollutants in industrial areas and industrial premises, dust is the most widespread and dangerous due to its ability to penetrate into the deepest structures of the human body and cause a wide range of acute and chronic diseases. Polydisperse dust includes particles of various sizes that may contain chemically active, toxic, and carcinogenic substances. These substances can cause serious respiratory and cardiovascular diseases in humans, trigger allergic reactions and increases carcinogenic risks [1, 2]. In many countries, the construction industry is a significant source of air pollution, and workers are at increased risk due to proximity to dust sources [3, 4]. The highest levels of respiratory exposure are associated with cement mixing, concrete demolition and manual demolition. Such conditions contribute to the growth of cardiovascular, respiratory and skin diseases. According to [3], the total geometric mean value of the inhaled dust concentration is 0.314 [mg·m^{-3}] (geometric standard deviation – 3.929) and 0.003 [mg·m^{-3}] (geometric standard deviation – 5.105) for the quartz concentration in such processes occurring in open space.

In Ukraine, as in most other countries, wet and dry inertial precipitators (scrubbers and cyclones), electrostatic precipitators and fabric filters are traditionally used to purify gases from solid particles. Gravity precipitators are used in certain industries. These devices are elements of conventional direct-flow gas purification schemes. For thermal power plants, more complex (hybrid) systems are currently under development. Given the current state of the Ukrainian thermal power industry, it is difficult to talk about the prospects and timing of their implementation [5, 6]. Despite the moral obsolescence of inertial devices, research is currently underway to increase their efficiency and improve the capture of the fine fraction of the dust mass. Constructive methods of solving this problem have already been practically exhausted, so a certain part of research is devoted to finding ways to influence the fractional composition of dust, in particular by acoustic coagulation [7, 8], (including the using ultrasound [9, 10]). These methods are effective, but require the use of additional equipment, the cost of which can be several times higher than the cost of the treatment equipment itself [11].

Almost all types of dust collectors are used in the construction industry, either independently or as part of various dust collection technologies. However, in the production of building materials such as cement, concrete, aerated concrete, dry inertial collectors (for example, cyclones) are mainly used [12]. They are distinguished by their design simplicity, reliability, low energy and operating costs, and do not require highly qualified personnel. Their main disadvantage is the low efficiency of gas flow purification, especially from fine solid particles. Electrostatic precipitators are almost devoid of this disadvantage, but their use is limited by their high cost and rather strict requirements for the electromagnetic properties of dust [13, 14]. Modern construction industry enterprises employ inertial dust collectors with opposing swirling airflows, which provide higher dust collection efficiency than conventional cyclones [15], due to the extraction from the hopper and the introduction of air streams with different dust concentrations at the lower and upper inlets. Their implementation in various configuration schemes, including recirculation systems, allows for a significant improvement in the overall dust collection efficiency, as noted by the authors of the study [16].

Thus, the development of combined systems appears to be the most promising approach for removing fine particulate matter from gas streams. As shown in studies [17, 18], a two-stage scheme has been substantiated. Its first element is an acoustic coagulator, followed by a collector, such as an electrostatic precipitator or a bag filter [17]. In [19], the authors proposed a two- or three-stage scheme that combines cyclones and electrostatic precipitators. However, these configurations remain essentially direct-flow systems. A truly combined dust collection system is described in [20] where a significant increase in separation efficiency is achieved through the recirculation of the dusty flow through the collector. This principle, albeit with a different design solution, forms the basis of the combined dust collector, considered in this study. The practical application of the device will allow solving the current problems of reducing environmental and industrial risks associated with air dust-pollution.

The aim of research is to determine the dust collection efficiency of a combined dust collector, that implements the principle of cyclic separation. The use of a simple and cost-effective device in aspiration systems will allow reducing the levels of health risks for workers exposed to construction dust pollution.

2. Materials and Methods

2.1. Determination of the fractional composition of dust and expansion of the functionality of the aspiration system fan

This work investigates a method for purification the air of working areas from industrial dust. Dust samples were collected in a building material grinding shop that was formed as a result of dismantling old or destroyed buildings.

The density of the collected samples was determined by the pycnometric method, using a conventional pycnometer (a glass flask with measuring marks) and electronic laboratory scales according to the generally accepted procedure. The fractional composition was determined by sieve analysis, i. e. by successively sieving the collected dust mass through sieves with weighing the resulting residues with electronic laboratory scales (Table 1).

Table 1

Fractional composition of dust

Dust particle size, μm	0–25	25–50	50–63	63–100	100–160
Dust fraction, %	16	40	21	22	1

The choice of these methods is due to their relative simplicity, sufficient accuracy of the results obtained and the actual lack of an alternative.

The problem of increasing the efficiency of aspiration systems used in industry was solved using several methods. First, the study used the method of constructive modification of the fan, which is part of the dust collection systems in order to increase the efficiency of air purification. The method involves modifying the design of the blower so that, in addition to its primary function of transferring energy to the airflow, it also performs a purification function, thereby improving the overall efficiency of the aspiration system. The method of discretization of the differential distribution curve is used to determine the main parameters of the combined dust collector and its efficiency. This method enables the representation of the mass fraction of dust in individual fractions, therefore it was chosen due to its high informativeness in analyzing the behavior of aerosol particles of various diameters within the airflow.

2.2. Method for assessing the risk to workers' health from air pollution

The calculation of hazard quotient (*HQ*) for workers is performed using the following algorithm according to [21]:

$$HQ = \frac{ADD}{RfC}, \quad (1)$$

where *ADD* (Average Daily Dose) – the average daily dose of the pollutant received by the worker; *RfC* (Reference Concentration) – the reference concentration at which no harmful effects are expected.

The average daily dose (*ADD*) of the pollutant for the production premises is calculated according to the formula:

$$ADD = \frac{C \cdot IR \cdot ET \cdot EF \cdot ED}{BW \cdot AT}, \quad (2)$$

where *C* – the average dust concentration in the workplace (mg/m^3); *IR* – the breathing rate in the workplace (m^3/h), equal to 1.2 m^3/h for an adult in an active state; *ET* – the daily exposure duration, $ET = 8$ h/day; *EF* – the exposure frequency, days/year, $EF = 260$ days/year for a 40-hour work week; *ED* – the total exposure duration, $ED = 30$ years of work experience; *BW* – the body weight, $BW = 70$ kg for an adult [21]; *AT* – the averaging period, $AT = 30$ years×365 days/year = 10950 days for chronic exposure.

The advantage of this risk assessment method is its ease of practical use and adaptability to industrial conditions, as well as its wide application in the world practice of hygienic assessment of the air environment [22].

The Python 3.11 programming language [23] was used for numerical modeling and plotting of graphs using the Pandas and Matplotlib libraries [24]. The use of Python provided high accuracy of numerical integration and convenience of visualization of results, and also allowed to implement an adaptive approach to risk assessment depending on variable input data. The program code consists of:

– constants: all physiological parameters of the worker and working conditions;
– concentration array: given dust concentrations in the working area;
– calculation: calculation of *ADD* and *HQ* for each concentration;
– visualization for plotting the dependence of dust concentration *C* on *HQ*.

3. Results and Discussion

3.1. Scheme of a combined dust collector

The key element of any purification scheme is an industrial fan (blower or exhauster), which ensures the transport of contaminated air through the system's ducts to dust collectors. The design modification involves attaching a dust collection container to the blower body, as shown in Fig. 1, *a*, while the rotary and flow parts of the blower remain unchanged, which guarantees the invariability of its energy characteristics.

The diagram of the dust-gas flow in a combined dust collector (CDC) is shown in Fig. 1, *b*. The dust-gas mixture is directed through the inlet pipe 1 into the impeller of the fan (exhauster), from which it enters its flow part. Within this section the flow follows a curvilinear trajectory. Due to the influence of centrifugal forces, solid particles are concentrated on the periphery of the blower body 7. These particles together with a small amount of gas (10–15 % of the total supply), are discharged through the gap 3 into the dust collector hopper 4.

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The remaining gas is discharged from the blower through the outlet 6. In the hopper, a certain part of the solid particles settles under the action of gravity, and the rest, together with the purified gas, returns to the flow part of the blower through the gap 5. The main (but not the only) application of the CDC is to perform the function of pre-purification. In this case, the air that has passed through the fan outlet is fed to the main collector, after which it is discharged into the atmosphere or returned to the workspace if the CDC is an element of a closed aspiration air purification system.

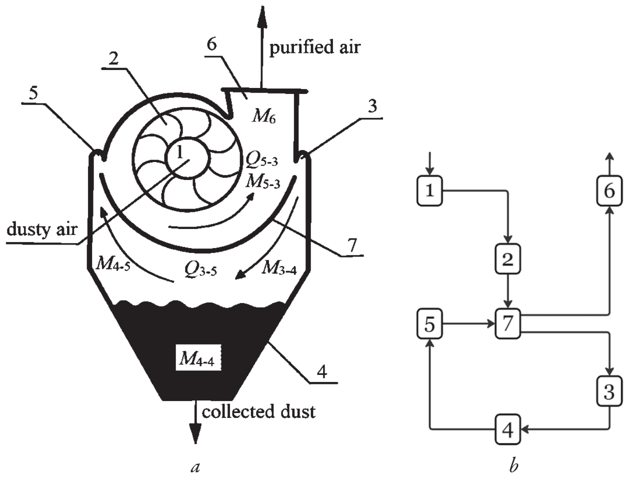

Fig. 1. Combined dust collector: *a* – CDC design; *b* – diagram of the movement of the gas-dust mixture; 1 – inlet pipe; 2 –supercharger impeller; 3 – slot for the removal of dusty gas flow; 4 – dust collection container; 5 – slot for the removal of dust-free gas flow; 6 – outlet pipe; 7 – supercharger body

When the hopper is filled with dust, a diffuser-confusor curved channel is formed between the free surface of the dust mass and the curved surface of the blower housing. This means that there are zones with a low carrier gas velocity in the hopper, and therefore zones with favorable conditions for deposition. Gradually, due to the accumulation of dust, the channel of variable cross-section turns into a curved channel of approximately constant cross-section. At the same time, the gas velocity in this channel increases, which leads to a decrease in the sedimentation mass and an increase in the secondary entrainment of dust particles that have already settled. Thus, at a certain point, a balance is established between the settling and transport processes, which means that the CDC stops working as a catchment device. Therefore, the issue of determining the optimal size of the dust container and the frequency of its cleaning is of fundamental importance.

Based on the considered principle of CDC operation, it can be concluded that the removal of solid particles from the dusty flow takes place in two stages. In the first, solid particles are carried by centrifugal force toward the outer wall of the blower's flow section and enter the dust collection container. In the second, particles settle under the action of gravity. The effectiveness of this stage depends on the proper selection of the container's (hopper's) geometric dimensions and the desired (preset) cleaning frequency. The main stage of designing the hopper is determining its minimum volume, which is reduced to determining the amount of dust collected per unit of time. As with other types of collectors, the amount of captured dust in the CDC depends on the physical and mechanical properties of the dust mass and the technological parameters of the carrier gas.

3.2. Analysis of the efficiency of a combined dust collector

The main physical and mechanical properties of the dust mass are its density and fractional composition. The technological parameter of the carrier gas is its volumetric flow rate. The volumetric flow rate, as a rule, is a known value for an already operating aspiration system, and in the conditions of its design – a given one. The fractional composition of dust is conveniently represented in the form of a differential distribution curve (DDC). DDC demonstrates the density of the distribution of the dust mass by particle size. The fact that the size of a dust particle will acquire any value is a reliable event, that is, the normalization condition is met:

$$\int_0^\infty N(\Delta)\mathrm{d}\Delta = 1, \tag{3}$$

where Δ – the size of a solid particle, μm; N – the mass fraction of solid particles with a size Δ, %.

If the entire size range of a given dust mass D is divided into k segments, that is, using the discretization method, the normalization condition takes the following form:

$$\sum_{i=1}^{k} N_0^i(\Delta)\frac{D}{k} = 100\ \%. \tag{4}$$

The CDC, according to the diagram of the dust-gas flow in Fig. 1, *b*, includes the volumetric flow rate of the carrier gas Q_0, m^3/s, with the dust mass M_0, kg/s, and the fractional composition, which is characterized by the differential distribution curve, $N_0=f(\Delta)$. The volume that passed the dust collection container with the flow rate Q_{3-5}, the dust mass M_{4-5} and the differential distribution curve $N_{3-5}=f(\Delta)$ is added to this flow.

Thus, dusty air enters the air sampling point in the circulating circuit (zone 3 in Fig. 1) with a flow rate:

$$Q = Q_0 + Q_{3-5}, \tag{5}$$

and a dust mass:

$$M_{5-3} = M_0 + M_{4-5}, \tag{6}$$

its DDC is determined by the following equation:

$$N_{5-3}^i(\Delta) = \frac{D\left(M_0^i + M_{4-5}^i\right)}{k\left(M_0 + M_{4-5}\right)}, \tag{7}$$

where M^i_0 – the mass of the i-th dust fraction entering the CDC; M^i_{4-5} – the mass of the i-th dust fraction entering the supercharger housing from the CDC hopper.

Air enters the CDC hopper with a flow rate:

$$Q_{3-5} = Q_{5-3}\cdot q_{sep}, \tag{8}$$

where q_{sep} – the fraction of air entering the supercharger housing into the hopper, the value of which depends on the width of the gap.

The mass of dust entering the CDC hopper:

$$M_{3-4} = M_{5-3}\cdot \eta_{sep}, \tag{9}$$

where η_{sep} – the fraction of dust entering the hopper from the supercharger body, which according to [20] is determined by the following equation:

$$\eta_{sep} = \sum_{i=1}^{k} \eta_{sep}^i \cdot N_{5-3}^i \cdot \frac{k}{D}. \tag{10}$$

Differential distribution curve of dust entering the CDC hopper:

$$N_{3-4}^i(\Delta) = N_{5-3}^i(\Delta)\eta_{sep}^i \frac{M_{5-3}}{M_{3-4}}. \tag{11}$$

Dust is collected in the hopper with a mass of:

$$M_{4-4} = M_{3-4} \cdot \eta_c, \tag{12}$$

where η_c – the fraction of dust deposited in the hopper, determined by the equation:

$$\eta_c = \sum_{i=1}^{k} \eta_c^i \cdot N_{3-4}^i \cdot \frac{k}{D}. \tag{13}$$

Dust with the following mass:

$$M_{4-5} = M_{3-4} \cdot (1-\eta_c), \tag{14}$$

and the following DDC:

$$N_{4-5}^i(\Delta) = N_{3-4}^i(\Delta)(1-\eta_c)\frac{M_{3-4}}{M_{4-5}}, \tag{15}$$

returns to the supercharger body in transit.

Air with the following dust mass and DDC is sent to the CDC outlet:

$$M_6 = M_0 - M_{4-4}, \tag{16}$$

$$N_6^i(\Delta) = N_{5-3}^i(\Delta)(1-\eta_{sep})\frac{M_{4-5}}{M_6}. \tag{17}$$

According to the given ratios, calculations of the CDC efficiency indicators, intended for air purification of the aspiration system of the room for crushing building materials – elements of dismantling old or destroyed buildings, were carried out.

For the convenience of analysis, the one-second mass of dust M_0 was assumed to be equal to one, and all subsequent mass calculations were carried out as fractions of M_0. At the beginning of the operation of the combined dust collector (zero cycle), dust with a differential distribution curve N_0 enters its body. The purification cycle in the CDC is the time during which the air-dust mixture makes a full circle through the bunker 4 (Fig. 1). Dusty air with a dust mass M_{5-3} and a differential distribution curve N_{5-3} enters the circulating circuit at the air intake point. The mass of dust that captured in the CDC hopper is M_{3-4} with a corresponding distribution N_{3-4}. The fraction of dust captured in the hopper is M_{4-4}. Dust with a mass M_{4-5} and a differential distribution curve N_{4-5} is returned to the blower housing. For the zero cycle, the mass M_{4-5} is 0, therefore, according to equation (6), $M^0_{5-3} = M_0$. Air with a mass of dust M_6 is directed to the outlet of the air handling unit.

This completes the calculation of the first cycle. The calculation results are given in Table 2 and are graphically presented in Fig. 2, provided that in equation (4) $D = 100$ μm, $k = 10$.

In the subsequent cycle, the bypassed dust mass M_{4-5} is added to the mass of dust that enters the CDC from the dust emission source, meaning that M_{5-3} increases relative to the previous cycle by M_{4-5}. Further calculations are carried out similarly to the zero cycle.

For dust collection devices or systems that operate on the principle of cyclic purification, two operating modes can be distinguished:

1) the main mode, when dusty gas enters the device or system where it is cleaned;

2) the idle mode, when $M_0 = 0$, and the system continues to purify the circulating gas from the dust accumulated during the main mode.

The calculations show that the purification indicators for each subsequent cycle differ from the previous one and with each subsequent cycle asymptotically approach constant values. The number of required calculation cycles is determined by the desired accuracy of determining the constant values characterizing the CDC operation. For the case under consideration, 30 cycles for the main mode and the same number for the idle mode (self-cleaning) were found to be sufficient. However, given the current level of computational capabilities, the number of cycles is not a limiting factor.

Since the mass flow rate of the *i*-th dust fraction remains constant under steady-state conditions, the following relationship can be written:

$$M_{5-3}^i = M_0^i + M_{5-3}^i \eta_{sep}^i (1-\eta_c^i). \tag{18}$$

Hence, the mass flow rate of the *i*-th dust fraction under steady-state conditions is determined as follows:

$$M_{5-3}^i = \frac{M_0^i}{1-\eta_{sep}^i(1-\eta_c^i)}. \tag{19}$$

Fig. 3 shows the results of calculations for two modes: cycles $n = 0 \div 30$ correspond to the main mode, and $n = 31 \div 60$ to the self-cleaning mode. It is obvious that at the beginning of the main mode there is an acceleration period, the duration of which will differ for CDC of different sizes, but in general in time it will be no more than one minute.

The nature of the change in the main indicator of CDC efficiency – the capture coefficient η_c is presented in Fig. 4.

During the acceleration period, it decreases and eventually reaches a value of 38 %. The change in η_c occurs due to changes in the fractional composition of the dust mass. Since coarse particles predominantly settle in the hopper, the DCC of the remaining dust mass shifts towards fine fractions. Also, although to a lesser extent, the change in DCC occurs during the self-cleaning mode.

Table 2

Initial results of differential distribution calculations

Δ, μm	N_0, %	M^0_{5-3}	N_{5-3}, %	N_{sep}, %	M_{3-4}	N_{3-4}, %	η_c	M_{4-4}	M_{4-5}	N_{4-5}, %	M_{5-3}
5	0.34	0.034	0.34	0.1	0.003	0.039	0	0	0.003	0.137	0.037
15	0.77	0.077	0.77	0.3	0.023	0.263	0	0	0.023	0.929	0.100
25	1.19	0.119	1.19	0.74	0.088	1.001	0	0	0.088	3.542	0.207
35	1.53	0.153	1.53	0.98	0.149	1.704	0.14	0.021	0.128	5.186	0.282
45	1.73	0.173	1.73	0.99	0.171	1.947	0.97	0.166	0.005	0.207	0.178
55	1.65	0.165	1.65	1	0.165	1.876	1	0.165	0	0	0.165
65	1.29	0.129	1.29	1	0.129	1.466	1	0.129	0	0	0.129
75	0.89	0.089	0.89	1	0.089	1.012	1	0.089	0	0	0.089
85	0.47	0.047	0.47	1	0.047	0.534	1	0.047	0	0	0.047
95	0.14	0.014	0.14	1	0.014	0.159	1	0.014	0	0	0.014
Σ	–	1	–	–	0.879	–	–	0.631	0.249	–	1.249

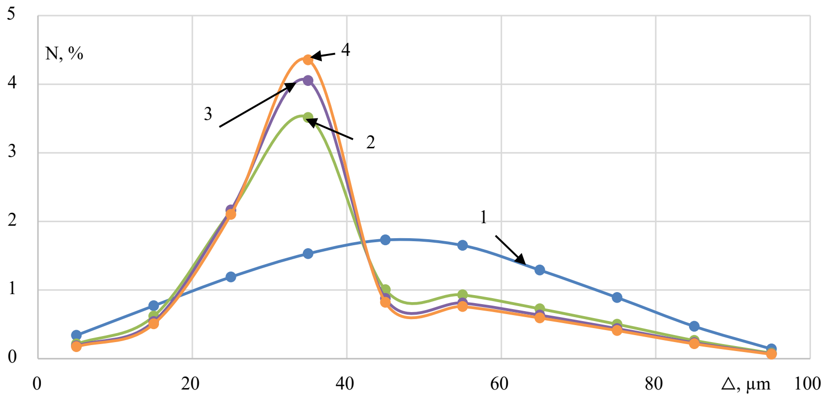

Fig. 2. Differential curves of the mass distribution of the circulating circuit M_{5-3} during the CDC operation in the purification mode for n cycles: 1 – DDC M_0 (n=0), 2 – n=5, 3 – n=10, 4 – n=20, 5 – n=30

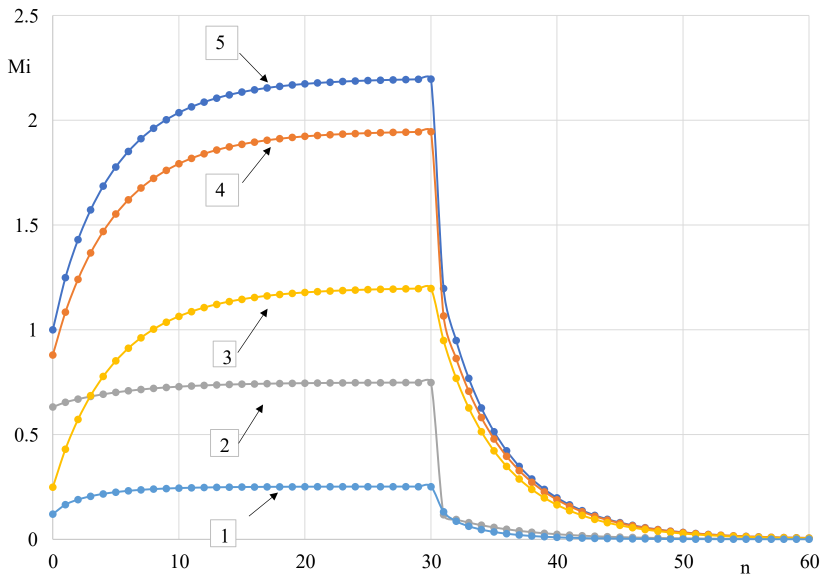

Fig. 3. Change in dust mass values in the main mode and self-cleaning mode of the CDC: 1 – M_6, 2 – M_{4-4}, 3 – M_{4-5}, 4 – M_{3-4}, 5 – M_{5-3}

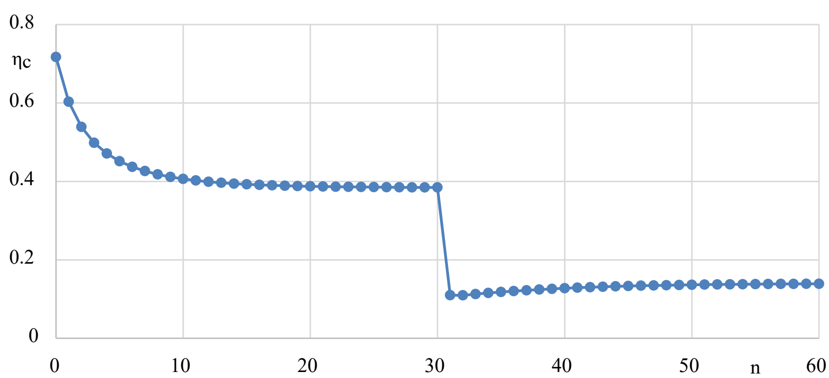

Fig. 4. Dependence of the capture coefficient η_c depending on the number of cycles

At a given value of M_0, the calculation of the captured mass M_{4-4} (kg/s) makes it possible to easily predict the time of filling the hopper, and therefore to free it from captured dust in a timely manner.

The proposed CDC can be used in two configurations:

1) as a means of preliminary purification of the dusty flow, when a certain part of the dust is captured in it, and the main separation occurs after the CDC;

2) as the primary collector in a closed-loop system for purifying aspirated air in industrial facilities.

3.3. Assessment of the risk of dust exposure to human health

The health risk indicator associated with dust exposure was calculated for the conditions of the building materials grinding workshop described above considering the use of the CDC for purifying the aspiration air.

Dust generated from the processing of construction materials is classified as non-carcinogenic, therefore, the assessment of worker health risks due to construction dust exposure in the workplace was carried out using the non-carcinogenic risk indicator – Hazard Quotient (*HQ*), which quantifies the extent to which exposure exceeds the safe level. The reference concentration (*RfC*) of dust depends on its type, composition and impact on human health. Key benchmarks are based on particle types, which are determined by their size and chemical composition. Construction dust is polydisperse in terms of particle size, with the majority of particles larger than 10 µm. Therefore, the impact of fine particles (PM_{10}, $PM_{5-2.5}$) can be considered insignificant, and the reference concentration may be taken as the maximum allowable concentration in workplace air for dust containing free silicon dioxide (e. g., cement, olivine, apatite, forsterite, clay, kaolinitic chamotte) at the level of 6 mg/m^3 [25].

The criteria for evaluating non-carcinogenic risk are as follows:

– $HQ<1$ – negligibly small risk of harmful effects;
– $HQ\sim1$ – threshold risk;
– $HQ>1$ – unacceptable risk value, the probability of harmful effects increases in proportion to the value of *HQ*.

The results of calculations of the dependence of the risk to the workers' health due to air pollution in the working area on the initial dust concentration are presented in Fig. 5.

The graph simultaneously shows the safe levels of construction dust concentrations for conditions of acceptable risk, $HQ\leq1.0$:

– $HQ=0.5$; $C=30.71$ mg/m^3;
– $HQ=0.75$; $C=46.06$ mg/m^3;
– $HQ=1.0$; $C=61.42$ mg/m^3.

So, the limiting dust concentration is 61.42 mg/m^3, or 0.06142 g/m^3, which is difficult to ensure in the conditions of the real production process. The CDC use, provided that the efficiency of dust pollution capture is 38 %, allows to increase the maximum acceptable dust concentration without increasing *HQ* to 99.1 mg/m^3, or 0.0991 ~ 0.1 mg/m^3.

With certain restrictions related to the physiological parameters of the person and working conditions adopted in the calculations, the specified concentration can be recommended as a safe level of impact of construction dust on the workers' health. Therefore, the calculations can serve as a guideline for any industrial premises of the specified industry. For example, specific determinations of dust concentration from grinding building materials at the enterprise show average values at the level of 0.1 g/m^3 at a height of 2–3 m from the floor level. This means that safe conditions for working personnel can be fully ensured by a closed system of aspiration air purification with a CDC.

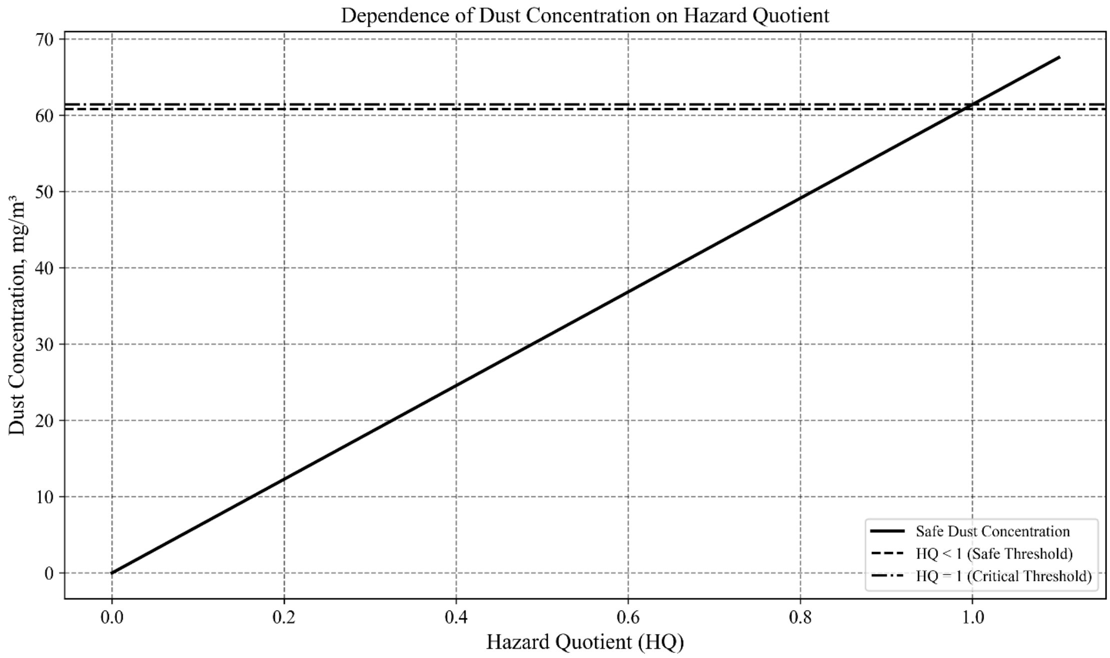

Fig. 5. Dependence of risk to the health of the worker due to pollution with construction dust in the working area

The limitations of this research are related, firstly, to the fact that the efficiency of the combined dust collector was determined in controlled conditions, which may differ from real operation at enterprises with unstable dust load parameters. Similarly, the assessment of the risk of dust contamination of the working area for the workers' health was carried out on the basis of generalized human physiological parameters that do not take into account the individual characteristics of the personnel.

Martial law in Ukraine has significantly limited the ability to conduct more detailed tests of CDC in specific production conditions. The economic instability of the enterprise has complicated both experimental investigations and the implementation of the proposed technology. On the other hand, Russian aggression has caused large-scale destruction of industrial facilities and residential buildings. They will need to be dismantled and processed into rubble and building materials. Therefore, research into effective and cost-effective technologies for dust removal from industrial premises is of critical importance for protecting the health of both workers in the restoration industry and residents of cities that have been destroyed.

Prospects for further research. The research is planned to be continued using numerical modeling to predict the behavior of dust particles of various properties in the CDC. Developing such models will make it possible to forecast the device's efficiency in removing dust particles of specific materials, such as ceramic or silicate bricks, foam concrete, or slag concrete.

4. Conclusions

The proposed combined dust collector is intended mainly for preliminary purification of gas-dust flows from polydisperse dust. On the one hand, this unloads the main dust collector, and on the other hand, it allows to increase the overall purifying efficiency. The CDC is built by relatively simple structural changes to the fan of the aspiration system and therefore does not require significant material costs. The operation principle of the device is to repeatedly clean the circulating dusty flow through the built-in gravity sedimentation hopper.

It is shown that the CDC operating time can be divided into a purified period, in which a short-term acceleration period and a period of constant operating parameters can be distinguished, and a short-term idle mode (self-cleaning).

The work proposes a simple method for calculating purification indicators, which allows to evaluate the efficiency of the process and determine the dimensions of the dust collector container and the frequency of dust discharge from it. The scheme can be used for systems with any main dust collectors.

Using the main indicator of the CDC efficiency – the capture coefficient η_c, a risk assessment was carried out for workers exposed to construction dust, assuming that the reference concentration of dust generated during the processing of building materials corresponds to the maximum allowable concentration in the workplace air. The limit concentration of dust was established to achieve acceptable risk conditions ($HQ \leq 1$) at the level of 61.42 mg/m^3. With certain limitations related to the physiological parameters of a person and working conditions adopted in the calculations, the determined concentration can be recommended as a safe exposure level of for worker health protection. The developed technical solutions can be integrated into modern industrial filtration systems, which will help reduce occupational risks for workers in the construction industry.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

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The study was performed without financial support.

Data availability

Manuscript has no associated data.

Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies when creating the current work.

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