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EQUIPMENT TO PREVENT THE SPREAD OF CORONAVIRUS SARS-COV-2. RESEARC OF SEPARATION ELEMENTS

Abstract. *The aim of the work is to develop separation elements for photocatalytic and ultrasonic equipment for air purification for infectious safety of buildings from coronavirus SARS-COV-2. The equipment is designed for air volume G = 50… 150 m3 / hour, should reduce the degree of microbial contamination of the air to the required level (capture particles of 0.1 μm) and help reduce the risk of airborne diseases. Project considers solving an important scientific and technical problem of creating and development of photocatalytic and ultrasonic heat and mass transfer separation equipment for air clean from dust and viruses (coronavirus SARS-COV-2). The separation technologies and the devices employing them are able to perform purification from particles with the size exceeding 0.10 μm with the efficiency up to 99 %. Combination of this methods will help to develop photocatalytic and ultrasonic heat and mass transfer separation equipment for air clean from dust, viruses and to prevent coronavirus SARS-COV-2 spread.*

Keywords: aerosol gradient technologies; separation equipment; gradient field; resource and environmental safety

Problem statement

The aim of the work is to develop photocatalytic and ultrasonic equipment for air purification for infectious safety of buildings from coronavirus SARS-COV-2.

The equipment is designed for air volume G = 50… 150 m^3 / hour, should reduce the degree of microbial contamination of the air to the required level (capture particles of 0.1 μm) and help reduce the risk of airborne diseases.

Science project considers solving an important scientific and technical problem of creating and development of photocatalytic and ultrasonic heat and mass transfer separation equipment for air clean from dust and viruses (coronavirus SARS-COV-2).

The separation technologies and the devices employing them are able to perform purification from particles with the size exceeding 0.10 μm with the efficiency up to 99 %.

Dust and liquid drops are the important medium for microorganisms and viruses to spread.

It is necessary to termly clean the components that are easy to be infected in air-conditioning systems (e.g., filter, heat exchanger and muffler) and to replace them in time in order to avoid the aggradations of pollutants. Moreover, the condensing water should be eliminated in time in air-conditioning systems to prevent bacteria from propagating.

Filtration is a quite economical and efficient method of improving air-conditioning system, the air filtration systems represent a good solution for the improvement of Indoor Air Quality (IAQ), and the Antimicrobial treatments (coronavirus SARS-COV-2 prevention) of filters may be a solution to these problems.

It is possible to prevent the accumulation and dispersion of microorganisms by adding anti-microbial agents on the surfaces of filter, which contributes to the improvement of air quality.

Purification from dust and viruses and liquid media smaller than 1 μm requires development of air-purifying separation equipment able to capture particles of this size with implementation of resource-saving features base on photocatalytic and ultrasonic equipment.

Development of photocatalytic and ultrasonic heat and mass transfer separation equipment for air clean from dust and viruses (coronavirus SARS-COV-2 prevention) is based on multilevel gradient aerosol technologies, as well as research of methods of their control, is their joint use in the presence of substantial gradients of the hydrodynamic and thermophysical parameters (temperature, pressure, velocity, density, etc.).

All the conditions are met at purification of aerosol media in the gradient fields of temperature, acoustic oscillations, concentrations and pulsations when they pass through multifunctional surfaces able to separate and coagulate and to prevent coronavirus SARS-COV-2 spread.

Latest research and publications analysis

Over the last years some progress in the creation of technologies and production of purification equipment has been achieved. In this area there are some widely known studies by V. Strauss [1] S. Calvert and G. M. Inglund [2; 3], researchers of IAMSTI (Nikolaev), as well as by foreign researchers [4; 5].

These studies show the developed and used types of separation equipment. The presented analysis of the composition and aerosols characteristics [1 – 4], which is supplemented with new data, indicates that the particles have polydisperse composition (from less than 1 micrometer to large ones – more than 100 micrometers) and vapours.

This allows defining new methods of particle settling intensification on account of hydrodynamic forces. It also advantageous for the use of intensification of processes of particles transport to the deposition surfaces due to the velocity gradient fields, pulsation, pressure, temperature, acoustic vibrations for creating a compact separation equipment.

THE ARTICLE AIM is to develop aerosol gradient technologies (AGT) for separation equipment to present infectious safety of buildings from coronavirus SARS-COV-2. AGT is expected to use the gradient fields of speed, pulsation, temperature, pressure, acoustic vibrations.

Basic material

Basic mechanisms and physical processes of particles deposition in the aerosol technologies and quantitative need to analyze to develop photocatalytic and ultrasonic equipment for air purification for infectious safety of buildings from coronavirus SARS-COV-2.

Physical processes of the above presented AGT can be characterized by the following processes of movement of medium that flows around the deposition surface: highly turbulent jets, turbophoretic, turbulent-diffusion, thermophoretic, acoustic, eddy and tear.

In addition, with the possible phases of the movement processes the processes of their interaction are possible – coagulation, grinding, heat and mass transfer.

Different variants of the sequences of these processes and their quantitative trait indicators allow to obtain various physical models and variants of design solutions for the equipment.

The solution is carried out on the basis of a systematic approach. This allowed to explore the complex aerodynamic system in the form of a polydisperse medium stage by stage, from individual processes in their totality, and thus to determine the conditions of intensification of comprehensive treatment, and to form technology and equipment construction based on them.

The mathematical model of the process. Used mathematical model of the processes of particle transport in the channel is based on the transport equation of Reyolds stress with individual stress analysis ($u_i' \, u_j'$) and has the form:

$$\frac{\partial}{\partial t}\left(\rho \overline{u_i' u_j'}\right) + \frac{\partial}{\partial x_k}\left(\rho u_k \overline{u_i' u_j'}\right) =$$

$$= \frac{\partial}{\partial x_k}\left[\frac{\mu_T}{\sigma_T} \frac{\partial \overline{u_i' u_j'}}{\partial \overline{x_k}}\right] + \frac{\partial}{\partial x_k}\left[\mu_L \frac{\partial}{\partial x_k}\left(\overline{u_i' u_j'}\right)\right] -$$

$$-\rho\left[\overline{u_i' u_k'} \frac{\partial u_j}{\partial x_k} + \overline{u_i' u_k'} \frac{\partial u_i}{\partial x_k}\right] - 2\mu_L \frac{\overline{\partial u_i'}}{\partial x_k} \frac{\overline{\partial u_j'}}{\partial x_k},$$

where t – the temperature; u' – fluctuating velocity component; x – coordinate; μ – viscosity; u – speed; P – the density; i, j, k – the coordinates of the indices and vector quantities of 1 and 2; indices: T – turbulent; L – molecular.

By analogy with the transport equation of Reynolds stress to account for non-isothermal process parameters convective heat transfer by means of the energy equation has been calculated:

$$\frac{\partial}{\partial t}(\rho E) + \frac{\partial}{\partial x_i}\left[u_i(\rho E + P)\right] =$$

$$= \frac{\partial}{\partial x_i}\left[\left(k + \frac{C_P \mu_T}{\Pr_T}\right)\frac{\partial T}{\partial x_i} + u_i\left(\tau_{ij}\right)_{eff}\right],$$

where τ is calculated as:

$$\tau = \mu_{eff}\left(\frac{\partial u_j}{\partial x_i} + \frac{\partial u_i}{\partial x_j}\right) - \frac{2}{3}\mu_{eff}\frac{\partial u_i}{\partial x_i}\delta_{ij},$$

where $\mu_{eff} = \mu_T + \mu_L$; E – energy; τ – stress tensor; k – kinetic energy of turbulence; P – generated voltages; C – coefficient; indices: p – particle, L – molecular.

To simulate the trajectories of dispersed two-phase medium particles there was solved the equation of motion [1], which takes into account the particles inertia force and other basic forces acting on it. In Cartesian coordinates, this equation can be written as follows:

$$\frac{\partial u_P}{\partial t} = F_D + \frac{g_x(\rho_P - \rho)}{\rho_P} + F_i,$$

where F_D – resistance force for unit mass of the particles:

$$F_D = \frac{18\mu}{p_p d_p^2} \frac{C_D}{24} \mathrm{Re}, \qquad \mathrm{Re} = \rho d_p \frac{|u_p - u|}{\mu},$$

where Fi – the additional forces exerted on the particle; d – diameter particles; m – mass of the particle. The drag coefficient CD is calculated as follows:

$$C_D = \frac{24}{\mathrm{Re}}\left(1 + b_1 \mathrm{Re}^{b_2}\right) + \frac{b_3 \mathrm{Re}}{b_4 + \mathrm{Re}},$$

where b_i – asked polynomial coefficients.

The equation takes into account the additional forces that act on the particle. To account for the settling of the particles under the influence of forces of inertia, acceleration should be considered when flowing around the particle. The force of inertia is determined by:

$$F_1 = \frac{1}{2} \frac{\rho}{\rho_k} \frac{\partial}{\partial t}\left(u - u_k\right).$$

Lateral displacement of the particles can be caused not only by the gradient of the averaged velocity of the gas, but the heterogeneity of the field of his fluctuating speeds. The unevenness of the velocity profile leads to the direction of displacement of a particle in the direction of reducing the pulsation intensity. This effect, commonly referred to as the turbulent migration or turbophoresis, is calculated as follows:

$$F_2 = -0{,}5 m_k \frac{\partial \overline{u_k'^2}}{\partial y}.$$

Additional force of particle transport occurs in the event of a pressure drop and is called difusiophoretic force, which can be found:

$$F_3 = \left(\frac{P}{P_w}\right) u_k \frac{\partial u}{\partial x}.$$

The calculation of the flow of the separation equipment for AGT

On the basis of a mathematical model the calculation of photocatalytic and ultrasonic equipment for air purification for infectious safety of buildings from coronavirus SARS-COV-2 was carried out, applying the possibilities for intensification of precipitation AGT.

The initial and boundary conditions were set according to the parameters of operation buildings ventilation and cleaning system.

The main objectives of the study are the following:

– analyze particle transfer processes in dispersed multiphase streams of power plants and identify promising ways to intensify purification processes due to inertia, acousticophoresis, turbophoresis, photocatalytic effects, non-isothermal gradient separation, etc. to prevent the spread of coronavirus SARS-COV-2;

– to develop a generalized mathematical model of separation processes of gradient aerosol technologies and to substantiate research methods;

– to develop circuit solutions of generalized multilevel gradient separation aerosol technologies;

– 3D-modeling on the basis of modern software packages and numerical calculation methods to investigate the patterns of particle transfer processes in dispersed multiphase streams and separation equipment;

– scientifically substantiate the creation of innovative cleaning technologies and devices that implement them for modern technologies for cleaning the air from dust and viruses to prevent the spread of coronavirus SARSCOV-2;

– prove the validity of the obtained scientific provisions for the intensification of air purification processes from dust and viruses to prevent the spread of coronavirus SARS-COV-2.

The study of photocatalytic and acoustic-phoretic levels of gradient aerosol technologies and obtaining circuit solutions for multifunctional deposition surfaces is planned. The structure of the flow will be investigated by thermogram filming. Increasing the flow rate at the inlet to the coagulator intensifies the deposition due to turbophoresis and inertia, and the thermal effect of nonisothermal gradient technology and diffusiophoresis decreases, and vice versa. Thus, the allowance due to the thermal effect to capture particles with a diameter of 0.1…1 µm at $u_{вх}$ = 9.5 m/s is about 40 %, and at $u_{вх}$ = 13 m / s only 10 %. No influence of nonisothermality on the hydrodynamic characteristics of the flow in the grid coagulator and it is determined that the distribution of the main hydrodynamic characteristics of the flow (velocity, turbulence intensity, kinetic energy of turbulence, static pressure) is almost the same for the temperature difference 20… 50 ° C and flow velocity 0.5… 7.0 m / s.

Calculation of multi-jet separator with AGT

The results of the calculation of the distribution of the longitudinal and transverse velocity component, static pressure, turbulent kinetic energy and the degree of turbulent energy dissipation in the separator are analysed.

The calculations confirmed the separation of the boundary layer to form the reverse currents (the field of negative values of the longitudinal velocity) and large amounts of vortex above the surface turbulent with significant energy potential.

Has been offered Variant 1 (Figure 1) and Variant 2 (Figure 2) of separation stages for photocatalytic and ultrasonic equipment for air purification for infectious safety of buildings from coronavirus SARS-COV-2.

The equipment is designed for air volume G = 50… 150 m^3/hour, should reduce the degree of microbial contamination of the air to the required level (capture particles of 0.1 µm) and help reduce the risk of airborne diseases.

The separation technologies and the devices employing them are able to perform purification from particles with the size exceeding 0.10 μm with the efficiency up to 99 %.

The measurements of venting system work flow area and proposed decision of its placement allows next geometrical dimensional parameters for Air Separator Turboimpact Filter:

– **length=665 mm;**
– **height=200 mm;**
– **depth= 85 mm.**

Further designing process of photocatalytic and ultrasonic equipment for air purification for infectious safety of buildings from coronavirus SARS-COV-2 needs usage of Multilevel complex scheme of intensification of separation processes using gradient turboimpact technologies.

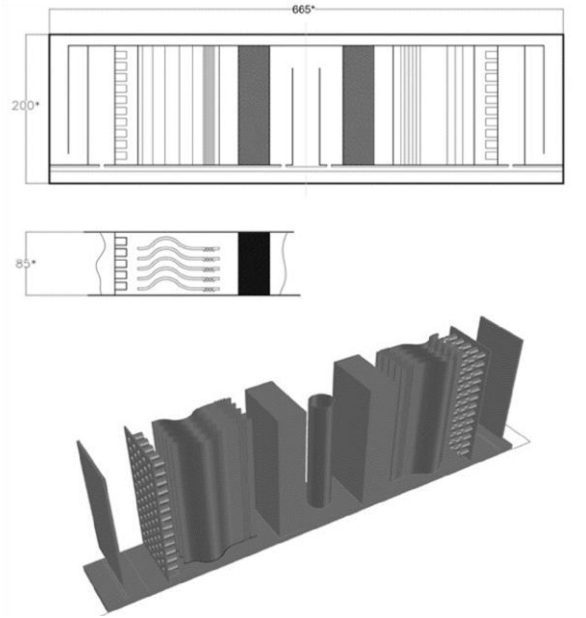


Figure 1 – Variant 1 of separation stages for photocatalytic and ultrasonic equipment for air purification for infectious safety of buildings from coronavirus SARS-COV-2

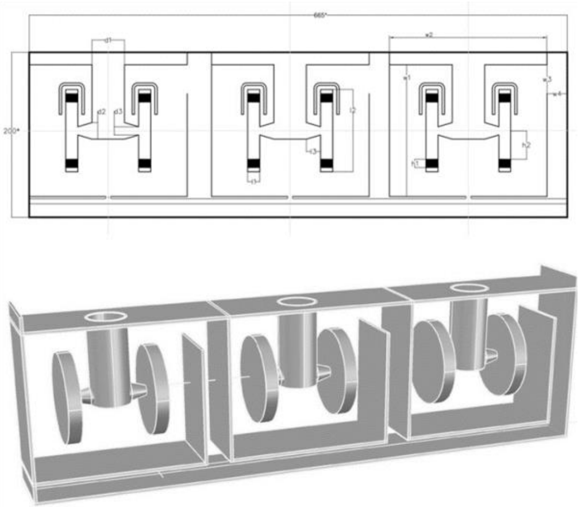
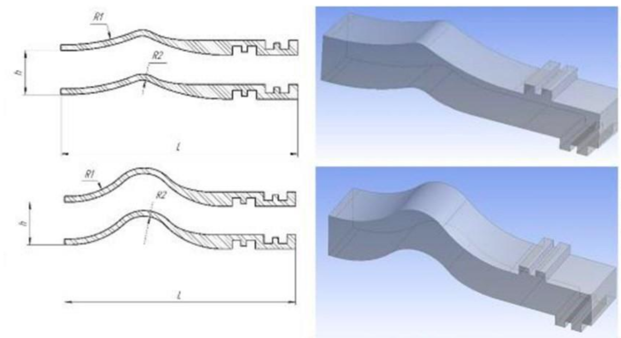


Figure 2 – Variant 2 of separation stages for photocatalytic and ultrasonic equipment for air purification for infectious safety of buildings from coronavirus SARS-COV-2

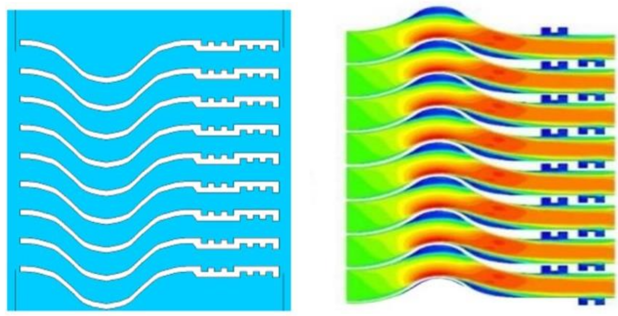
Research of hydrodynamic characteristics of Variant 1 of separation stages for photocatalytic and ultrasonic equipment for air purification for infectious safety of buildings from coronavirus SARS-COV-2 has been preformed Figure 3.

Geometrical parameters of Variant 1 and theoretical-precalculations of work flow hydro dynamical characteristics showed not optimal use of this geometry.

Research of hydrodynamic characteristics of Variant 2 of separation stages for photocatalytic and ultrasonic equipment for air purification for infectious safety of buildings from coronavirus SARS-COV-2 has been preformed Figure 4, 5. Geometrical parameters of Variant 2 and theoretical-precalculations of work flow hydro dynamical characteristics showed optimal use of this geometry.



a



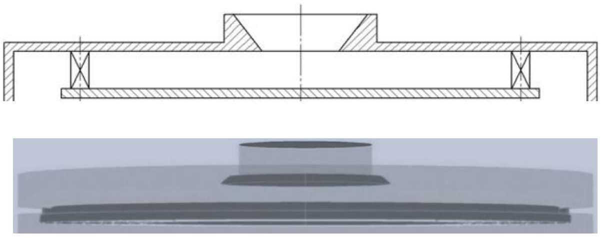
b *c*

Figure 3 – Research of hydrodynamic characteristics of Variant 1 of separation stages for photocatalytic and ultrasonic equipment for air purification for infectious safety of buildings from coronavirus SARS-COV-2:
a – geometry of working channel; b – calculation geometry; c – research of flow hydrodynamic

To study the separation characteristics of photocatalytic and acoustic phoretic technology in the multifunctional surfaces of the channels, a number of calculation grids in the three-dimensional formulation of the problem will be constructed.

Preliminary studies and calculations show that the transverse ripples significantly increase the value of the total capture coefficient in the speed range of 0.5 ... 5.0 m/s: from 15.0 to 46.3 % at an initial flow rate of 0.5 m/s and from 48.7 to 66.7 % at an initial flow rate of 5 m/s. Ultrasound is ineffective against highly dispersed aerosols and increases the value of the total capture coefficient (from 48.1 to 68.0 %) with a particle diameter greater than 5 μm.

When particles of different sizes are deposited, which occurs at different oscillation frequencies, a higher frequency is required for smaller particles. The results of calculations show that at the frequency of ultrasonic oscillations at the level of 10 kHz, the sizes of the captured aerosol particles are in the range of 0.1 ... 5 µm. With increasing dispersion of aerosols, the use of ultrasonic waves in the separation cleaner is impractical.



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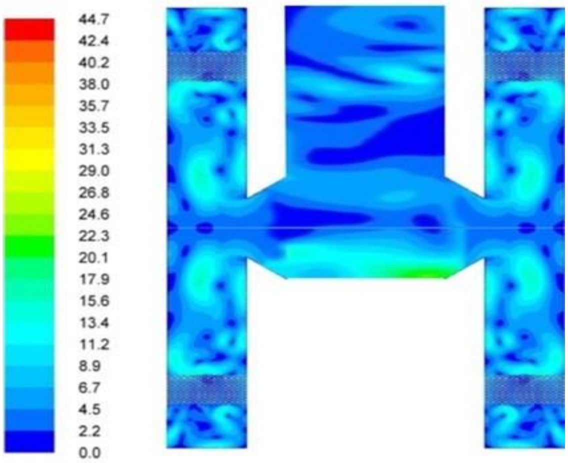

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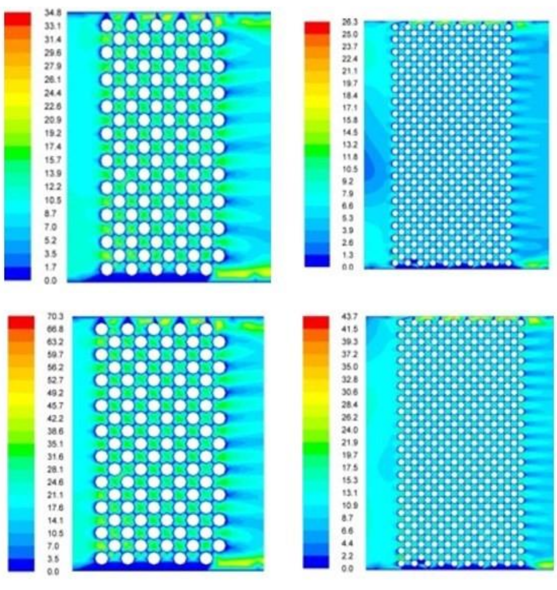

c

Figure 4 – Research of hydrodynamic characteristics of Variant 2 of separation stages for photocatalytic and ultrasonic equipment for air purification for infectious safety of buildings from coronavirus SARS-COV-2:
a – geometry of working channel, b – calculation geometry, c –research of flow hydrodynamic

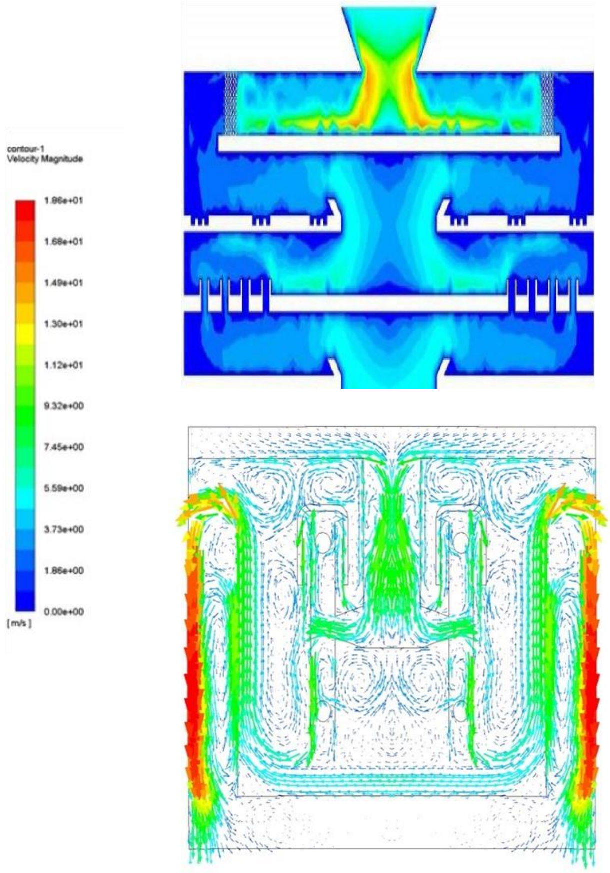

Figure 5 – Research of velocity parameters of Variant 2 of separation stages for photocatalytic and ultrasonic equipment for air purification for infectious safety of buildings from coronavirus SARS-COV-2

Improving the efficiency of air purification from dust particles and viruses with the help of photocatalytic and ultrasonic equipment and integrated performance separation equipment is achieved by multilevel purification of aerosol media by combining different levels of gradient separation technologies with sequential or combined use of energy potential. separation) and external sources (non-isothermal and acoustic phoretic separation, photocatalytic separation).

The required level of air purification efficiency from dust particles and viruses depending on their operating modes is achieved by joint application of different levels of gradient separation technologies: inertial, turbophoretic, nonisothermal, acoustic phoretic and photocatalytic at gas velocities up to 20 m/s, particle sizes 0.1… 10 m also cleaning efficiency not less than 99 %.

Conclusions

Separation elements of photocatalytic and ultrasonic equipment (G = 50… 150 m3/hour) has been analyzed and proposed for use . It is designed to disinfect the air in a small area. Destruction of microorganisms in the air is carried out by repeated recirculation of air through a system of filters.

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ОБЛАДНАННЯ ДЛЯ ЗАПОБІГАННЯ ПОШИРЕННЮ КОРОНАВІРУСУ SARS-COV-2. ДОСЛІДЖЕННЯ РОЗДІЛОВИХ ЕЛЕМЕНТІВ

Анотація. *Поєднання пропонованих методів допоможе розробити фотокаталітичне й ультразвукове обладнання для розділення тепла та маси для очищення повітря від пилу, вірусів, запобігти поширенню коронавірусу SARS-COV-2. Обладнання розраховане на об'єм повітря G = 50... 150 $м^3$/год, має зменшити ступінь мікробного забруднення повітря до необхідного рівня (захоплення частинок 0,1 мкм) та сприяти зменшенню ризику захворювань, що передаються повітрям. Проєкт розглядає вирішення важливої науково-технічної проблеми створення та розвитку фотокаталітичного й ультразвукового обладнання для розділення тепла та маси для очищення повітря від пилу та вірусів (коронавірус SARS-COV-2). Технології поділу та пристрої, що їх використовують, здатні проводити очищення від частинок розміром понад 0,10 мкм з ефективністю до 99%.*

Ключові слова: аерозольні градієнтні технології; обладнання для розділення; градієнтне поле; ресурсна та екологічна безпека

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