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ELECTROPHORETIC EFFECTS FOR ENVIRONMENTAL SAFETY TECHNOLOGIES: EVACUATION OF MICRO-PARTICLE CONGLOMERATIONS FROM THE SURFACES

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Анотація

У роботі проаналізовано сучасні технології тонкого очищення від пилу як механічно, так і за допомогою зовнішніх електричних полів за певних умов та створення левітації та електрофоретичного руху. Знайдено точні рішення моделі, які свідчать на користь теоретичної обґрунтованості технології знезараження з використанням електричного поля з маніпулятивними властивостями; умови найбільш ефективного використання левітаційно-електрофоретичних технологій у задачах очищення та знезараження пилу, включаючи дезактивацію поверхнево-розповсюджених макромолекулярних забруднювачів, таких як коронавірус.

Ключові слова: пилове забруднення, очищення від пилу, левітація, електрофорез, високомолекулярне забруднення, коронавірус.

Abstract

The work analyzes modern technologies of fine dust cleaning both mechanically and with the help of external electrical fields under the particular conditions and creation of levitation and electrophoretic motion. It has been found exact solutions of the model, which indicate in favor of the theoretical validity of decontamination technology using electric field with manipulative properties; the conditions of the most effective use of levitation-electrophoretic technology in the tasks of dust cleaning and decontamination, including the surface-distributed macromolecular contaminants such as coronaviruses.

Keywords: dust pollution, dust cleaning, levitation, electrophoresis, macromolecular pollution, coronavirus

Introduction

Cleaning of surfaces from pollution by macro-molecular components is an urgent task of technologies of protection of elements of environment. The dynamics of macromolecular contaminants is formed, including with the involvement as carriers of dust micro-particles, which can be both neutral and charged. The problem of dust removal (dust collection and cleaning) with the development of modern technologies and their impact on the environment has become widespread and is currently relevant and requires the development and implementation of fundamentally new technological solutions. The development of technological means for removing fine micromechanical dust particles from the space of industrial (domestic), sanitary (and even space) premises is an urgent task of the relevant field of environmental protection technologies, as well as the various devices that accompany human activity.

Results

The technology we propose is to create physical conditions for levitation and electrophoretic processes for the purpose of fine dust cleaning using an external field, providing conditions for the formation of levitation distributions and induced electrophoretic flows. One of the requirements for the levitation-electrophoretic model is the possibility of superposition of the gravitational field and the electric field. The stage of creation of a levitating layer, i.e. formation of levitating conglomerations of the removed fine dust for the purpose of creation of conditions of its further complex removal from surfaces with difficult morphology also plays a significant role in the considered technology. It is known that polarized dielectric particles can form dielectro-phoretic dynamics [1-6]. Since neutral particles contain almost equal amounts of positive and negative charges, the electric field induces a dipole moment in them. The interaction of a certain moment with an electric field leads to the appearance of a corresponding force. Similarly, particles with their own electric dipole moments (such as water) will also feel the force in an external field.

Electrophoresis conditions are that the particles have a dielectric constant different from its value in the environment. The time-averaged force acting on a given or permanent electric dipole in an electric field causes, respectively, the controlled motion of particles (clusters).

The action of this force, which is determined, determines the possibility of effectively manipulating the parameters of the corresponding motion of microparticles, changing the parameters of influence (electromagnetic fields). The described processes play an important role in the design of filters that perform the division of the system into its constituent components. It is for the needs of this engineering that the method of electrophoresis is widely used (for example, in microbiology, for the manipulation of bacteria and cells). When using mechanical methods, there are significant quality limitations associated with the polydisperse nature of the system. Filtration technology based on the use of electric degrees of freedom and manipulated externally field do not have these limitations, and can be effectively applied by changing the controlled parameters for the division into constituent components of complex polydisperse systems.

Therefore the proposed technology is based on use manipulated external inhomogeneous electric field, which affects the dust particles and causes the first-rise of dust over the surface on which it is initially distributed, and then the formation of current, which is formed under the influence of forces of electrophoretic origin. The hierarchical division of these stages of dynamics can be carried out, as the criteria for their occurrence in practice do not match. The advantages of this technology are the ability to create conditions for the formation of the levitation layer above the surface with any topological complexity. The method also has no limitations in terms of polydisperse composition of the blanket of micro-mechanical particles, because the purely phenomenon of levitation occurs primarily due to the balance of forces that shape the dynamics of the system. It is significant that both stages of the dynamics of the dust output are regulated by the same factor, namely the external electric field, which acts on both charged particles (electrophoresis) and dielectric, which are polarized and receive the given dipole moment. Formally, the theoretical basis of the proposed technology is based on the idea of conglomeration of discrete dipoles (permanent or induced), which are affected by an external inhomogeneous electric field.

It is interesting to note that developed upper approach can be applied to deactivation of infected by coronavirus surfaces. Namely, taking into account the detected electrical properties of coronavirus ([7-10]), the electrical model of coronavirus SARS-CoV-2 can be imagined as a symmetric multilayer spheres with three electrically charged shells and a nucleus that has a positive charge. The shells have different signs of charge and magnitude of electric charges. The first (outer) shell is negatively charged. The second (inner) shell is positively charged. It displays the electrical charges of proteins on the RBD. The third (inner) shell is positively charged and is located at a distance of 10 nm from the outer shell.

The first (outer) shell has a total negative electric charge equal to $-21Ne$, Where: e is the charge of the electron, equal to 1.60217662×10^{-19} C; N is the number of peplomers. The third (inner) shell has a total positive electric charge, probably equal to $+9Ne$. Electric charges are located on the surface of the virus discrete in accordance with the geometric location of the peplomers on the surface. Electric charge fields are continuous due to the overlap of adjacent electrostatic charge fields. The model reflects the presence of electrostatic fields of groups of electric charges on the surface of the virus. As a result, a multilayer field shell is formed around the nucleus (around + RNA). In such a field electrostatic outfit, the virus interacts with the cell. SARS-CoV-2 has additional electropositive shells that reflect the electric charges of the proteins of the cleavage group and the presence of electropositive areas of the surface on the RBD domain. Taking into account their influence allows to find out what electric currents will flow through the membrane when the virus merges with the cell, to obtain the energy characteristics of the virus, its energy potential and to determine what changes this potential undergoes when the virus merges with the cell. Of particular interest are those vulnerabilities in the virus that can be affected by electrically charged substances or an electric field. Among the electrically charged substances of the greatest interest in this regard are trace elements in the low degree of oxidation: coronavirus SARS-CoV-2 is an electrically charged biological nanoparticle with a size of approximately 120 nm. The virus has a spike length of about 20 nm, the surface of the virus, branched due to the spikes on it, on the spikes are electrically charged areas ([7], [10]), inside the envelope of the virus is positively charged RNA, electric charges on the surface are distributed in a certain, strictly fixed way ([7], [10]). Additionally, in addition to the sign of the electric charges, it is necessary to know the magnitude of the electric charges of the proteins on the surface of the virus and the charge of the nucleus. It is necessary to find out how the picture of distribution of electric charges of a virus at adsorption of a virus and interaction with ACE2, CD147 and NRP1 (neuropilin-1) changes. It is very important to find out what changes the picture of the distribution of electric charges on the surface of the virus when it merges with the cell. For a more detailed electrical model of the virus, it is necessary to know the magnitude of the electrical capacity of the viral particle, dielectric constant and conductivity. Their accounting requires additional research. It is known that the dielectric properties of capsid proteins and shell glycoproteins significantly affect the dielectric constants of viruses and, ultimately, their electrical capacity, which allows the method of scanning probe microscopy (SPM - scanning). This method is already used to detect and identify viruses, using their different spectra of electrical capacity as unique identification features ([11]).

Conclusion

The concept of decontamination from macromolecular contaminants is proposed, which is based on the position of adsorption of contaminants on the micro-mechanical system of surrounding dust conglomerations, of homogeneous and inhomogeneous electric fields with manipulative parameters and its analytical solutions are obtained, dynamics of an external inhomogeneous electric field. The parameters, both internal and external, that affect the conditions and criteria of the corresponding dynamic processes are defined. The ways of optimization (reduction of standard voltages) of parameters of levitation-electrophoretic technologies are analyzed and their application for fine dust-cleaning in the conditions of reduced gravity is offered. A comparative analysis of the efficiency of the proposed technology in comparison with traditional electrostatic precipitators is conducted. Applications of the developed approach to cleaning of surfaces from the adsorbed macro-molecular complexes. including the coronavirus of SARS-CoV-2 (which possesses a cover electric structure) are discussed in detail.

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