https://doi.org/10.1051/e3sconf/202131901076

Electrophoretic Effects for Environmental Safety Technologies: Evacuation of Micro-Particle Conglomerations from the Surfaces

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***Abstract*—The actuality of the problem of contamination of objects by macro-molecular compounds is a growing problem today (especially given the terrible consequences of the pandemic). In fact, macromolecular complexes are mostly located on the surface layers of the surface covered with fine dust. Therefore, the development of technology for the removal of macromolecular components is actually a problem of fine (so we will call it) dust removal. This problem cannot be effectively solved by traditional mechanical removal methods alone, as contaminated objects have a rather complex, not even Euclidian, surface morphology. Therefore, it is important to develop effective technologies based on the use of properties of special configurations of external inhomogeneous electric field and removable components by means of a specially configured inhomogeneous electric field. The paper 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 decontamination of the surface-distributed macromolecular contaminants such as coronaviruses.**

***Index Terms*—dust pollution, dust cleaning, levitation, electrophoresis, macromolecular pollution, coronavirus**

I. 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. We will adhere to the concept that decontamination, which is implied in the tasks of protection against macro-molecular compounds (including viruses, can be brought to the dust removal from the surface. Of course, the model we consider for this purpose can be applied to parameterization removal of macromolecular components from the infected surface.

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. Research in this area, recently also focused on systems that are in special conditions (say, low gravity), which allow their effective manipulation using configured external electric fields of different voltages [1]–[6].

Consider the possibilities theoretical modeling of the process of combining the phenomena of levitation and electrophoresis in order to gradually manipulate the dynamics of fine dust. The relevance of the development and use of such technologies, for example for the space research program is discussed in detail in [7], [8]. A comparative analysis of the various existing technological methods of dust removal given in [1]–[6] provides an opportunity to identify the advantages and disadvantages of their use for effective dust cleaning.

Thus, in particular, the existing common mechanical methods of dust cleaning have significant limitations, in particular, because mechanical filtration and removal of dust do not allow for the complete evacuation of fine dust, especially from surfaces with complex morphology. Therefore, the task arises to use an electric field that has a high penetrating ability and, in particular, can, by manipulation, form the motion of micro-mechanical particles (in a heterogeneous electric field), group dust particles into clusters of the levitating layer and create further conditions electrophoretic motion of particles from this layer for the subsequent evacuation (removal) of dust conglomerations.

A theoretical model that can be used as a basis for the above technology and should allow modeling the kinetic stages of the whole process of manipulating the dynamics of micromechanical systems is strongly required.

In this way, it is proposed to analyze a combined levitation-electrophoretic model, which describes the manipulation of mechanical dust conglomerations in order to create a conceptual basis for technologies to protect the environment not only from dust pollution, but also from adsorbed compounds, including macromolecular and viral origin. The main technologies of fine dust cleaning from fine dust include those that operate due to the applied external manipulated electric field (under the action of electric forces), namely - electric dust collectors and electrostatic precipitators. The use of such technologies usually requires significant electrical costs. Therefore, identifying ways to reduce the operating energy stresses that accompany the proposed levitation-electrophoretic technology is an essential element (such conditions can probably be created due to the natural conditions of the space environment, where fine dust cleaning is a significant problem that needs to be solved).

We will propose a theoretical concept and model of technology that should work on a scale in which an external electric field is created, which implies deterministic manipulation. Voltages under which the motion of micro-mechanical dust particles in external gravitational and electric fields are several kilovolts. Thus, the improvement of appropriate technologies first of all requires finding ways (or conditions) to reduce the voltages required to generate electrophoretic motion.

II. General information about electrical dust cleaning technologies

The need to remove dust is due to harmful effects on human health or technological processes.

The structure and composition of dust depends on the characteristics of the process of its occurrence and the properties of the substances of which it is composed. One of the important characteristics of dust, which affects the ability to manipulate it, is its dispersion composition. According to the dispersion intervals, the dust is divided into coarse, in the range of up to 10 µm; medium in the range from 0.25 to 10 µm, and fine in the range of more than 0.25 µm.

Depending on the type of dispersion, the most optimal method of dust removal is selected. It is inefficient to use mechanical cleaners to remove fine dust. Therefore, the removal of fine dust requires special, as they say, fine cleaning methods. This is because a whole complex of forces acts on the particles of such dust. Fineness causes special forms of dust behavior under the conditions of acting forces that retain dust on the composition of contaminated surfaces, which may even have a non-Euclidean spatial morphology. Fine dust penetrates and lingers in hard-to-reach places. The process of lifting and freezing in a stationary state of dust particles in the direction opposite to the final direction of action of the complex of acting forces is called levitating motion effects of levitation and electrophoresis. To do this, the corresponding model must contain parameters that determine the criteria of levitation and electrophoretic modes of motion of dust particles. Levitation, associated with the rise of dust from the surface and the formation of a quasi-stationary dust conglomeration that evaporates over the surface of any complex morphology.

Electrophoretic, involves a stage of polarization in the case of the dielectric nature of dust particles (dielectrophoresis). In the case of charged particles, the movement of particles (electrophoresis) is stimulated by an external electric field.

Inhomogeneous electric field, due to hierarchical manipulation, is able to stimulate both levitation and electrophoretic effects.

Hybrid technology that combines conditions for levitating blankets and directed electrophoretic motion should use a single source of the field with smooth manipulation of the voltage sufficient to consistently stimulate levitation and electrophoretic processes.

In the first stage, the field is applied to the surface to be cleaned. Due to the influence of the field, fine dust is formed in the levitating layer. The field source remains the only one. Assuming that the adsorbed macromolecular compounds are otherwise bound to dust particles, we have a scenario of expected deactivation.

Experimental studies of the dynamics of electrophoretic currents formation is based on experimental observations on the removal of dust conglomerations from the horizontal surface in the form of a vertical current of microparticles (clusters) excited by an external electric field. In the experiment [1]–[6] there is a specific dynamics of the jet (Fig. 1),

 https://doi.org/10.1051/e3sconf/202131901076

which is characterized by significant heterogeneity of current (cluster current). This phenomenon demonstrates the complex inhomogeneous nature of the particle flow, which is created by an external (inhomogeneous) electric field and complicates and reduces the quality of purification (decontamination). At the same time, it proves the possibility of modeling this process using the idea of dynamically effective parameters of clusters of several particles (including effective radii, particle masses).

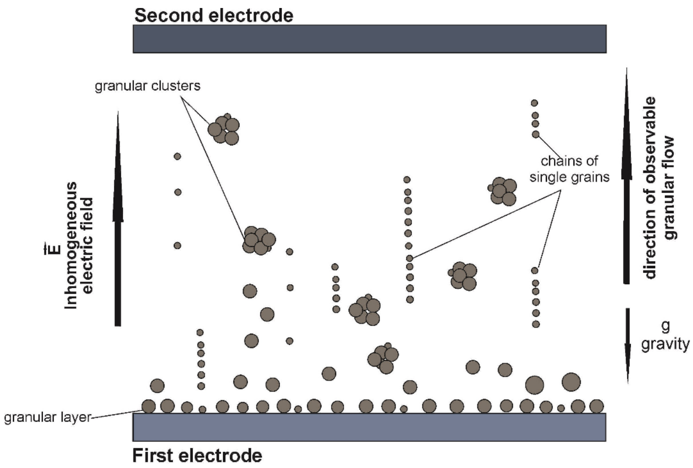

Fig. 1. A sketch of the formation of the electrophoretic effect of current in an experiment to observe stimulated motion of granular particles.

Dispersed particles from surfaces of any morphological complexity, including hard-to-reach places. The disadvantage is the need to use a force field of high voltage (approximately 20 kilovolts).

The technology of dust removal using an electric field in different environmental conditions was studied in [1]–[6]. It is shown that this method can lift and transport charged and uncharged particles especially efficiently under conditions of reduced gravity, using electrostatic and dielectrophoretic forces [9]–[12]. A typical dust protection design consists of a series of parallel electrodes connected to an AC source that generate a moving wave, so to speak, in the contactless conveyor mode.

Particles are repelled by electrodes, which are used to create a field, and move along or against the direction of wave motion, depending on their polarity. The electrodes of the protective screen can be excited by a single-phase or multi-phase AC voltage. In single-phase electrical protection, parallel cylindrical electrodes connected to an AC source generate an electric field, the direction of which changes with the change of polarity of the electrodes. This creates a standing wave, which in turn generates a force that will act on any charged particle in the field. Because the lattice of the electrodes is usually covered with a thin insulating layer to increase the breakdown voltage, uncharged particles distributed on the surface before the inclusion of the field can. A multiphase electrical protection system generates a traveling wave because the potential at each electrode changes due to phase shift. The charged particle in this region will move with or against this wave, depending on its polarity.

Let us now consider the possibility of excitation of the levitation stage. According to the definition, the force acting on particles levitating above the surface in quasi-stationary mode can be written as a combination of electrodynamic force, viscous force and gravity (Langevin equation of motion):

$$m\frac{d^2z}{dt^2} = -mgz - 6\pi\eta a\frac{dz}{dt} + F(z) + f(t), \qquad (1)$$

where m is the average (or effective) mass of the particles, z is the position of the particle (along the vertically raised axis), η is the viscosity of the medium in which the particles move, g is the acceleration in the gravitational field, $F(z)$ is the force characteristic of the external field acting on the particles, f is the force acting on the isolated particle by the surrounding due to interparticle collisions. Due to the complex nature of the interaction of particles with the field, the motion of particles is essentially nonlinear. The corresponding equation of motion, which takes into account in general all types of interaction, in the general case cannot be solved analytically.

In [11], solutions of the equation of motion in the linear approximation were proposed, and solutions in the form of small particle oscillations were obtained. In addition, numerical solutions simulated the trajectories of the particles, which corresponded fairly well to the actual measurements.

Numerical tests were performed on transparent dust shields under high vacuum to understand their capabilities and limitations.

The cleaning efficiency was determined qualitatively using visual assessment methods for each test. It has been found that dust removal ceases shortly after activation. As soon as the macroscopic movement of dust was no longer observed, the measuring system was turned off and the effectiveness of protection was evaluated. Although this method of determining efficiency is very approximate (and even inaccurate), within $\pm 5\%$ it is possible to evaluate the effectiveness of the described technology.

Its advantages are that it works satisfactorily to compare data from a number of tests and significantly reduces testing time (as opposed to those that require hundreds of measurements. In particular, it is effective for cleaning solar panels, especially in space research, which operate on particles of the order of 1 μm, which interfere with the operation of optical systems such as telescopes and pickups. For example, the answer to the simple question of how the humidity of the environment affects the processes occurring on the surface of particles, such as the presence and magnitude of capillary forces, requires prior and preferably detailed clarification.

III. Model of hybrid levitation-electrophoretic dynamics

Thus, the corresponding technology we propose is to create physical conditions for levitation-electrophoretic processes for fine dust-cleaning using an external field, with 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 dielectrophoretic dynamics [9]–[12]. 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. 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 restrictions in terms of the 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. The system is affected by a force that can be determined by the formula [9]–[12]:

$$\vec{F} = Q\vec{E} + (\vec{p}\,\nabla)\vec{E}, \tag{2}$$

where Q is a charge, $\vec{p}$ - is a dipole moment of the particle. If the external field is high-frequency (ω exceeds 1 kHz), the electrophoretic effects are mainly due to its gradient. In addition, the magnitude of the force and parameters of motion are influenced by the size, weight, conductivity and morphology of the particles. This force causes the particle to move in the direction of the gradient or against it, depending on whether the particle is more polarized than the medium in which it is located.

A typical way to create an inhomogeneous field that stimulates the phenomenon of dielectrophoresis is to use a system of electrodes with different geometry. Modern microelectronic circuitry allows you to create any contact geometry to the desired scale. For example, a system combination of flat and sharp electrodes.

A gradient field is created between them, which can be programmed to change according to the needs of the technology.

The construction which described upper corresponds to the condition when the dielectrophoretic force resulting from the interaction of the induced dipole moment of the particle with the external field is sufficient to create conditions for the directional motion of polarized particles. It follows that the field-stimulated motion of micromechanical particles does not consist of individual particles, but rather of clusters that move almost in a ballistic mode. Accordingly, the equation of motion (1), of charged dust particles (electrophoresis), taking into account the simplifications, has the following form:

$$m\frac{d^2z}{dt^2} = -mgz - 6\pi\eta a\frac{dz}{dt} + F(z). \tag{3}$$

The force with which the field affects the dielectric particles is proportional to the gradient of the square of the intensity. In the case of charged particles, it is proportional to the intensity. Consider the following configurations (linear and nonlinear) of an external inhomogeneous electric field: where α, α', α'', Γ, z_0 are particular constants which characterize relevant steady-state models, and $\theta(z)$ is a Heaviside step function

$$F_e(z) = \begin{cases} \alpha(1 - e^{-\Gamma z}), \\ \alpha'[z\theta(z_0 - z) + 1], \\ \alpha''[z^2\theta(z_0 - z) + 1]. \end{cases} \tag{4}$$

From the experiments [1]–[6], schematically presented by Fig.1 it follows that the field-stimulated motion of micromechanical particles does not consist of colliding individual particles, but rather of clusters that move almost in a ballistic mode. Therefore, we can neglect by Fokker-Plank contribution to our master equation. Accordingly, the equation of motion (1) of charged dust particles (electrophoresis), taking into account the simplifications, takes the following form:

$$m\frac{d^2z}{dt^2} = -mgz - 6\pi\eta a\frac{dz}{dt} + F_e(z), \tag{5}$$

https://doi.org/10.1051/e3sconf/202131901076

where the last term represents electrophoretic force. We do one more step to simplify our analytical model, being within the constructions given by (4). Namely, let select linear configuration of external electrical field. As a result we have the following equation for the further consideration

$$m\frac{d^2z}{dt^2} + mgz + 6\pi\eta a\frac{dz}{dt} = \alpha\Gamma z. \tag{6}$$

The analytical solution of equation (6) has the following form:

$$z(t) = \begin{cases} \exp\left(-\frac{3\pi\eta a}{m}t\right)\{c_1\cos xt + c_2\sin xt\}, & x^2 > 0, \\ \exp\left(-\frac{3\pi\eta a}{m}t\right)\{c_1\cosh xt + c_2\sinh xt\}, & x^2 < 0, \end{cases} \tag{7}$$

where $x^2 = g - \frac{\alpha\Gamma}{m} - \frac{9\pi^2\eta^2a^2}{m^2}$

Under the condition, when $g \geq \frac{\alpha\Gamma}{m} + \frac{9\pi^2\eta^2a^2}{m^2}$ it is obvious that the change of modes in the dynamics of motion is regulated by a multi-parameter whose choice in the range of values leads to the stationary solution of the equation of motion. The latter indicates the possibility of the levitation stage of electrophoretic dynamics.

The choice of a nonlinear model for an electric field, as can be shown, leads to an equation of motion in the form of Abel, which is not integrated in quadrature's, and here we will not consider this case in detail. But note that, like any nonlinear scenario, such configurations provide even greater opportunities to manipulate the type of dynamics by changing the controlled parameters.

In summary, we can expect that the solutions of the control equation of the model for arbitrary configurations of the applied electric field with variable parameters and even variable (say by the harmonic law) in time make it possible to describe different stages of levitation-electrophoretic dynamics.

The above results analytically describe the possibility of the expected stage of levitation with a gradual transition of the hierarchical type to controlled electrophoretic motion, followed by collection and disposal.

IV. Electrical properties of viruses, their identification and neutralization. Microelement volume blockade and electrophoretic removal from surfaces

Taking into account the detected electrical properties of coronavirus ([13]–[16]), 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 $1.60217662 \times 10^{-19}$ 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. This will be represented in a graphical model, where each shell reflects the continuous nature of the electric field generated by either electronegative or electropositive areas of the virus surface.

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. The electrical model of the coronavirus will provide a deeper understanding of the role and place of Coulomb forces in the processes of adsorption and fusion of viruses with the cell and to identify potentially vulnerable sites of the coronavirus. 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: oronavirus 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 ([13], [16]), inside the envelope of the virus is positively charged RNA, electric charges on the surface are distributed in a certain, strictly fixed way ([13], [16]). 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 ([17]). The electrical model of the SARS-CoV-2 coronavirus presented reflects only one of the essential properties of the coronavirus - its electrical properties and, of course, is a simplified reflection of the reaction.

The electrical properties of viruses are not partial manifestations of their morphological structure, but a fundamental principle of their organization. The electrical model of the coronavirus allows them to detect new vulnerabilities. It is proposed to consider as targets for antiviral drugs electrically charged proteins on the surface of the virus. This makes it possible to choose the right virus control strategy and suggests which electrically charged substances can be used to inactivate viruses and to reduce their adsorption activity. Here, it is difficult to overestimate the role of micronutrients, as many sites on the surface of the coronavirus are potential targets that are easily accessible to micronutrients and inaccessible to large molecules ([16]). Trace elements are the most effective electrically charged substances that affect the activity of the virus, as they very well combine the electrical properties inherent in viruses, and the electrical capabilities of trace elements, including trace elements in low oxidation. Compared to large molecules, such as electrically charged oligopeptides (oligopeptide is an organic molecule consisting of a small number of amino acid residues connected by amide (peptide) bonds), they are smaller, more mobile, able to penetrate hard-to-reach places on the surface of the virus and are not foreign substances to the body. The uniqueness of trace elements in the low degree of oxidation is that they can be both antioxidants and antiviral substances, and catalysts of biochemical processes. This combination of three functions makes them indispensable components of substances for the production of drugs for medical and veterinary purposes.

The mechanism of antiviral action of trace elements is based on counteracting the electrostatic Coulomb interaction of the virus with the cell by compensating, neutralizing and changing the electric charge on the surface of the virus. The action of microelements is not aimed at destroying the virus, but their electric charges do not allow viruses to realize their most threatening natural functions of adsorption and fusion with the cell. Micronutrient-based antiseptics can be used as prophylactics to protect the body from COVID-19 infection. Identification of viruses is still based on the morphology of viral particles, viral protein and / or detection of nucleic acids. The electrical model of the virus allows the development of electrical rapid methods for the detection and identification of viruses. Different types of virus can be matched to their ”signatures” in the form of a set of their electrical parameters, for example, based on electrical capacity and dielectric constant. Based on the geometric features of the structure of the coronavirus SARS-CoV-2, we can assume that the magnitude of its electrical capacity can be of the order of $(2 - 8) \times 10^{-10}$ μF. To determine the value of dielectric constant and conductivity (electrical resistance) it is necessary to conduct special studies. The capacity depends on the geometric features of the structure of the virus. Therefore, any difference in viral electrical capacity is primarily due to differences in the structure of the viral particle. Dielectric permeability is directly related to the protein composition of viral particles. Each type of virus is unique in its structure and in its own composition of proteins and nucleic acids, which is reflected in the value of its capacity and dielectric constant. Additional electrical parameters for the ”signature” of the virus are the number of electrically charged shells and the magnitude of the electric charges of its shells. Thus, electrical characteristics can be used to detect and identify the type of virus ([18]).

Measurement of electrical parameters of the virus allows the use of modern electronic methods for the detection and quantification of viruses. Electrical measurements allow you to quickly (within minutes) quantify and determine the type of virus tested. It is proposed to use modern biosensors to detect and identify viruses. When an electrically charged virus nanoparticle binds to the surface of a biosensor, it changes the charge of the biosensor channel with its electric field, which allows electrical detection of viruses [19]. A method has been developed that allows direct electrical detection of single viral particles in real time with high selectivity. The mechanism of virus detection is based on the field effect - on the detection and registration of electric charges of virus proteins ([20]).

The electrical properties of viruses are not particular manifestations of their morphological structure, but a fundamental principle of their organization. An electrical model of the coronavirus allows the detection of new vulnerabilities in the coronavirus. Electrically charged proteins on the surface of the virus can be used as targets for antiviral drugs. This makes it possible to choose the right virus control strategy and suggests which electrically charged substances can be used to inactivate viruses and to reduce their adsorption activity. Micronutrients can play an important role here, as many sites on the surface of the coronavirus are potential targets, readily available for micronutrients and inaccessible to large molecules ([16]). Trace elements are effective electrically charged substances that affect the activity of the virus, because they successfully combine the electrical features inherent in viruses, and the electrical capabilities of trace elements, including trace elements in low oxidation. Compared to large molecules, such as electrically charged oligopeptides, they are smaller, more mobile, able to penetrate hard-to-reach places on the surface of the virus and are not foreign substances to the body. The uniqueness of trace elements in the low degree of oxidation is that they can be both antioxidants and antiviral substances, and catalysts of biochemical processes. This combination of three functions makes them indispensable components of substances for the production of drugs for medical and veterinary purposes. The mechanism of antiviral action of trace elements is based on counteracting the electrostatic Coulomb interaction neutralizing and changing the electric charge on the surface of the virus. The action of trace elements is not aimed at destroying the virus, but their electrical charges do not allow viruses to realize their most important natural functions of adsorption and fusion with the cell. Micronutrient antiseptics can be used as prophylactics to protect the body from COVID-19 infection.

The identified electrical properties allow the use of electrophoretic technologies, described in detail in the previous sections.

V. Conclusions

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.

Acknowledgment

The authors appreciate Francesco Aliotta for providing the results of related experiments.

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