



Innovative solution using ion-electronic technology to purify the air from pathogenic microflora and create comfortable living conditions for humans

Solución innovadora que utiliza tecnología electrónica iónica para purificar el aire de la microflora patógena y crear condiciones de vida cómodas para los seres humanos

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ABSTRACT

According to the Federal State Statistics Service regarding respiratory diseases in Krasnoyarsk Krai, the increase in this indicator was 6% over the five years, and the increase in oncologic diseases was 4% over the same period. Polluted air is one of the leading causes of the increased incidence. The paper aims to find ways to clean indoor air using ion-electronic technology and bring the microclimate parameters to optimal values in cold and warm seasons. Experimental and theoretical studies substantiated the possibility of developing a device capable of creating and maintaining an air environment in closed premises, close in terms of indicators to the healthy air of ecologically clean regions. The device can have different performance and can be used in domestic, industrial, and public premises. Depending on the mode of operation and purpose, this device can be both stationary and mobile. Fine dust cannot be removed from the room even if the air exchange rate is increased by 200 and 400 times. It has been experimentally proven that ion-electronic technology and volatile matter of woody plants remove dust to achieve a *clean room*. This concept formed the basis for developing a device using nanotechnology combined with the volatile matter of woody plants. The dependences of the influence of artificial ionization of air and volatile matter of woody plants on reducing the amount of fine dust and pathogenic microflora are theoretically substantiated. The air purified in this way maintains immunity and reduces the incidence of respiratory diseases, which has been proven experimentally based on a prototype of the developed device.

Keywords: Volatile matter of woody plants, Fine dust, Methods of prevention of respiratory organs, Nanotechnology, Innovations

RESUMEN

Según el Servicio Estatal Federal de Estadísticas sobre las enfermedades respiratorias en el Krai de Krasnoyarsk, el aumento en los cinco años de este indicador fue del 6%, y el aumento de las enfermedades

oncológicas fue del 4% en el mismo período. El aire contaminado es una de las principales causas del aumento de la incidencia. El documento tiene como objetivo encontrar formas de limpiar el aire interior utilizando tecnología electrónica de iones y llevar los parámetros del microclima a valores óptimos en estaciones frías y cálidas. Estudios experimentales y teóricos corroboraron la posibilidad de desarrollar un dispositivo capaz de crear y mantener un entorno de aire en locales cerrados, cercano en términos de indicadores al aire saludable de regiones ecológicamente limpias. El dispositivo puede tener un rendimiento diferente y se puede usar en locales domésticos, industriales y públicos. Dependiendo del modo de operación y el propósito, este dispositivo puede ser tanto estacionario como móvil. El polvo fino no se puede eliminar de la habitación, incluso si el tipo de cambio de aire se incrementa entre 200 y 400 veces. Se ha demostrado experimentalmente que la tecnología electrónica de iones y la materia volátil de las plantas leñosas eliminan el polvo para lograr una “sala limpia.” Este concepto formó la base para desarrollar un dispositivo que utiliza la nanotecnología combinada con la materia volátil de las plantas leñosas. Las dependencias de la influencia de la ionización artificial del aire y la materia volátil de las plantas leñosas en la reducción de la cantidad de polvo fino y microflora patógena están teóricamente justificadas. El aire purificado de esta manera mantiene la humedad y reduce la incidencia de enfermedades respiratorias, lo que se ha demostrado experimentalmente sobre la base de un prototipo del dispositivo desarrollado.

Palabras clave: materias volátiles de plantas leñosas, polvo fino, métodos de prevención de órganos respiratorios, nanotecnología, innovaciones.

1. INTRODUCTION

In Krasnoyarsk Krai, a significant amount of harmful substances that cause respiratory diseases have been identified in public and residential premises. Studies have established that the air environment is polluted with chemical substances from stationary and mobile sources. The state of the atmosphere in the urban environment is far from ecologically clean regions, which leads to an increase in disease incidence. Existing ventilation and recirculation systems, as well as air conditioning, have a sufficiently high efficiency of air purification from bacteria, viruses, and fine dust; they can refine and even clean the indoor air environment from pollutants (Roy, Mishra, Jain & Jain, 2018). Based on the results of many years of research on the natural air environment, namely, the physical and chemical properties of air in the forests of Krasnoyarsk Krai (Rogov, 2000a; Rogov, Golovina & Stepen, 1992; Rogov, 2002; Stepen & Repyakh, 2005), parameters of a *healthy* air environment for confined spaces were developed. The presence of fine dust in the air formed due to the ventilation and infiltration in industrial, public, and domestic premises is a source and a carrier of pathogenic microflora, a major cause of respiratory diseases. Therefore, the purpose of these studies is to find ways to clean indoor air using ion-electronic technology [IET] and bring the microclimate parameters to optimal values in the cold and warm seasons.

Currently, the issue of the working capacity of the population is becoming increasingly relevant. A common reason for the decline in this factor in the Russian Federation, particularly in the Siberian region, is that various viral infections lead to allergies and other diseases, which significantly affect the economy of the region.

The air in cities is filled with gases and harmful substances, such as gases of technogenic origin and fine dust, which cause acute respiratory infections, allergies, and chronic diseases. These substances exceed the threshold limit value [TLV]. The dynamics of the content of harmful substances in 2015–2019, according to the Government of Krasnoyarsk Krai (2020), are presented in Table 1.

Table 1: Dynamics of the content of harmful substances in the air of Krasnoyarsk in 2015–2019

Year	Carbon oxide	Nitrogen dioxide	Benzopyrene
2015	0.3 (2.0)	0.92 (1.05)	3.7 (18.5)
2016	0.4 (1.8)	0.85 (1.15)	5.1 (40.6)
2017	0.45 (3.0)	0.75 (1.21)	5.3 (40.1)
2018	0.47 (3.6)	0.9 (1.5)	6.5 (50.6)
2019	0.5 (3.0)	0.87 (4.23)	4.0 (22.0)

In Table 1, values without brackets are mean values of harmful substances (mg/m^3), and values in brackets are the maximum excess of the TLV of the daily average (mg/m^3).

According to statistical data (Government of the Krasnoyarsk Krai, 2020), 15 cases of benzopyrene exceeding the average daily value of 10 TLV were recorded in the atmospheric air of Krasnoyarsk in 2019. A significant excess of the daily average TLV was also recorded for carbon oxide and nitrogen dioxide.

Air pollution in a megalopolis has a considerable impact on the state of the air in preschool and educational institutions and, accordingly, leads to an increase in the incidence among children. In Krasnoyarsk Krai, 102,504.5 cases of respiratory diseases, as well as 545.4 cases of pneumonia, were recorded per 100 thousand children from 0 to 14 years of age (Federal Service for Surveillance on Consumer Rights Protection and Human Wellbeing, 2020). The main reason for this situation is a weak immune system that is influenced by an unfavorable air environment.

In the technogenic situation, exhaust gases from cars sharply worsen the air environment, polluting it with harmful substances and fine dust. Polluted air enters the room due to artificial and natural ventilation and infiltration.

Existing devices (Johnson, 2021) are effective for air purification from fine dust (less than 0.3 microns) and bacteria; however, they do not create an air environment close to an ecologically clean and natural one. Deionized (dead) air (Chizhevsky, 1989) enters, while immunity decreases, and disease prevention is not carried out. Thus, we developed an industrial prototype of a device for air purification based on nanotechnology to create an atmosphere that reduces the incidence of respiratory diseases and even stimulates the development of immunity.

2. MATERIALS AND METHODS

In order to reduce the incidence of respiratory diseases, it is necessary to influence the immune system of the inhabitants of the metropolis, bringing the indoor air closer to ecologically clean regions. One of the options for solving this problem is an original, combined device based on IET for air enrichment, which we developed.

Studies have evidenced that reducing the dust content in the air is most effective when using nanotechnology based on saturating the air with negative ions and volatile matter of woody plants. Negative ions transfer a charge to dust particles, and, because of the dipole moment, dust particles grow larger and form coagulants; as a result, they are deposited from the air environment (aerosol) with subsequent removal. The nature of the interaction between negative ions and dust particles is shown in Fig. 1. According to Fig. 1, the amount of coagulants increases with an increase in the ion flow, asymptotically approaching the maximum (Petrenko, Parshikova & Stepen, 2017).

The size of dispersed particles is one of the main parameters that determine the kinetics of aerosols and, naturally, significantly affect their coagulation. In this regard, it is of interest to consider the effect of dispersion on aerosol coagulation when exposed to an ion flow and volatile matter of woody plants. Based on the results of the semi-empirical theory of equilibrium enlargement of the condensation aerosol (Rogov, 2002), the dependence of the concentration of ions and volatile matter on aerosol coagulation was determined.

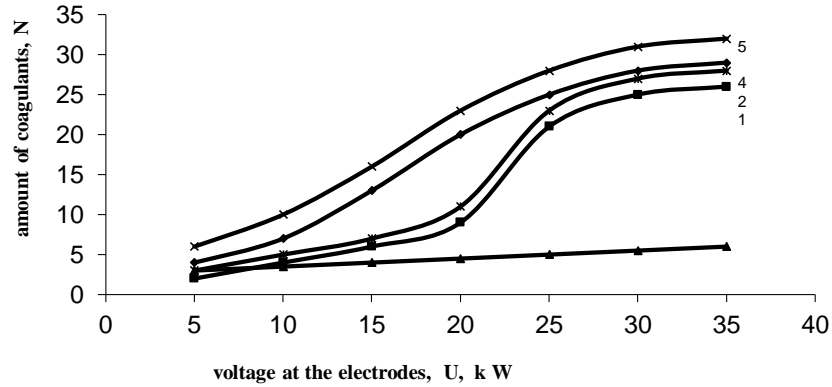


Figure 1: Dependence of aerosol coagulation on the voltage at the electrodes. *Note**: 1 – bipolar aerosol; 2 – unipolar aerosol; 3 – neutral aerosol; 4, 5 – when exposed to the ion flow and volatile matter

Equilibrium condition for aerosol particles in a humid atmosphere:

$$\ln W = \frac{B_W}{r(W)} - \frac{\Phi M_W m_T}{m_W} \quad (1)$$

where: W – air humidity, %; $r(W)$ – equilibrium particle size, μm ; B_W – Kelvin coefficient; m_w and m_T – the mass of water and volatile matter; M_w and M_T – molecular weight of water and volatile matters; Φ – osmotic coefficient.

When the condition

$$|\ln W| \gg \frac{B_W}{r(W)}, \quad (2)$$

which is true at moderate humidity up to 90%, is met, the above expression can be rewritten as follows:

$$m_p = m_T \left[1 - \frac{\Phi M_W}{M_T \ln W} \right] \quad (3)$$

where: $m_p = m_r + m_w + m_u$ – the mass of the particle.

Assuming that for spherical particles, the following is true:

$$m_p = \frac{4}{3} (\pi \rho r^3 W), \quad m_T = \frac{4}{3} (\pi \rho_T C R^3) \quad (4)$$

where: R – the initial (nonequilibrium) radius of the conglomerate formed (water and terpenoid); ρ – density of particles; ρ_T – the density of the formed conglomerate, one can get the following:

$$r(W) = c^{1/3} R \left[1 - \frac{\Phi M_W}{M_T \ln W} \right]. \quad (5)$$

Therefore, other things being equal, an increase in the concentration of volatile matter in the aerosol should lead to a proportional increase in the equilibrium size of all particles; that is, the shape of the logarithmic distribution does not change in this case.

When exposed to an ion flow, the coagulation rate increases with an increase in the number of ions, and in the case of an impact on an aerosol with an ion flow and volatile matter, this tendency is more pronounced.

The results obtained confirm the conclusion about the sensitivity of the coagulation rate (enlargement of dispersed particles) to the quantitative value of aerosol ionization and the effect of volatile matter on it. The chosen approach is substantiated, which considers the appearance of adsorbate from the dipole molecules of water, ions, and volatile matter, adsorbing onto a particle with the formation of an adhesion film, resulting in aggregates with subsequent deposition of aerosol from them (Rogov, 2000b; Rogov, Stepen & Saulova, 2000).

2.1. Using coniferous essential oils to improve the indoor air environment

The content and composition of phytoorganic compounds in the air environment under the canopy of coniferous plantations were examined 40 km north of Krasnoyarsk (Rogov, Kravchenko, Bagaeva, Guseva & Sugak, 2020; Stepen et al., 2005).

The main research objects were conifers. The concentration of their phytoorganic substances varied within a wide range depending on the species composition and age of the stands, season, temperature, and air humidity, averaging 1–5 mg/m³. There are also significant changes in the yield of essential oils, determined primarily by the composition and age of trees (Gavrilenko, Prokushkin, Stepen & Prokushkin, 2006).

For the sanitation of the air environment of institutions, gymnasiums, and other premises, the use of pine oil is effective. The use of this oil is justified by the fact that the highly volatile component (i.e., the light fraction) migrates first from the oil. Undoubtedly, it is more expedient to improve the atmosphere of the premises directly due to the volatile secretions of coniferous trees. The healing effect of volatile secretions, in this case, was significantly enhanced by the use of IET because of the formation of light negative ions. It has been shown that their combined effect significantly reduces the number of microorganisms and pathogenic microflora. Moreover, ionization is more effective against staphylococcal infections. It should also be noted that placing plants in a room and increasing bacteriostaticity enrich the air with oxygen and improve psychoemotional mood.

The mathematical description of the dust deposition process from the air, the reduction of pollution, and the saturation of air with negative ions allow one to describe the IET, based on which the device was developed. The use of this device leads to the creation of an air environment close to natural conditions. The studies conducted confirmed that as a consequence of using this device, one can preserve immunity and reduce disease incidence.

3. RESULTS

As a result of this research, an innovative device was created and tested to improve the environment in closed premises. The design of the device consists of four units. The first unit is an ionic fan, an inducer of traction, and the creator of an electrostatic filter for the destruction of pathogenic microflora. The second unit is a water filter with a silver electrode to create a sufficient amount of silver ions (at least 30 mg/m³). The third unit is a bactericidal lamp with a wavelength of 320–350 nm. The fourth unit is a corona

electrode for saturating the air with negative ions. An automatic essential oil dispenser was installed on the body of the device.

An experiment was conducted based on primary classes of a secondary school in Krasnoyarsk. The device was placed in a class where 90 children were engaged during the day, and a control group of 90 children was selected. The results are shown in Table 2.

Table 2: Evaluation of the results of using the device in an educational institution

Characteristics of groups	Outcome		Total	
	Desirable (children are healthy)	Undesirable (signs of acute respiratory disease [ARD], acute respiratory viral infection [ARVI])	Number of children	%
Application of the device	79	11	90	81.8
Without device	58	32	90	65.2

We found that the use of the device reduced the number of cases of ARVI diseases during the epidemic (1 month) in a children's institution by 16.6% (i.e., 21 children). This device is innovative, and we propose a transfer of this innovation. Since the incidence rate of children is 2.3 times higher than that of adults, the use of the device will further increase the expected health-improving effect. Earlier applications of device modifications have shown positive effects on skin diseases, allergies, and an increase in general immunity.

4. DISCUSSION

In recent decades, much attention has been paid to the effects of artificial ionization on the purification of the air environment. Effective devices for air purification from dust, bacteria, and viruses using bipolar and unipolar ionization have been developed (a review of general and modern air purification methods). The technologies obtained by the researchers were applied in the development of devices for effective air purification from dust, bacteria, and viruses.

However, the air purified according to these technologies does not possess the properties of the natural environment; it neither prevents diseases nor creates conditions for a comfortable stay. The air purification technology proposed using negative ions and volatile matter from woody plants is based on many years of research (A. Rogov, V. Rogov & Stepen, 2008; Rogov et al., 2020). The studies took into account the physico-chemical properties of air in coniferous and deciduous forests of the forest-steppe zone: the presence by year and season, the amount of negative ions, and volatile matter of woody plants. In order to develop design features, the influence of negative ions and volatile matter of woody plants on dustiness, gas pollution of the air, and operating modes was theoretically substantiated. These studies were the basis for developing an innovative device for creating an air environment close to natural conditions. At the consumer's request, the air can be made forest, mountain, or sea and still be effective in purification from pathogenic microflora. According to the proposed technology, the devices can be used in domestic, public, and industrial premises.

5. CONCLUSION

The studies have confirmed the need to create an air environment for the closed premises of educational and public institutions, close to forest air. The developed device makes it possible to create such an

environment based on nanotechnology, including a combination of ionization and volatile matter of woody plants.

The effects of negative ions and volatile matter on dust particles and bacterial contamination of the air environment have been theoretically substantiated. The obtained analytical and graphic dependences explain the influence of ionization and volatile matter on the formation of coagulants and their deposition on the surface.

The study of the chemical composition of essential oils from foliage has shown that highly volatile matter is identical in its properties to the volatile matter of woody plants under natural conditions. The technical conditions of the device include the modes of using the highly volatile matter of essential oils of woody plants, which makes it possible to create an air environment close to the forest environment in terms of its physical and chemical properties. The proposed modes of operation reduce the incidence of acute respiratory viral infections and preserve immunity.

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