

This paper reports a substantiated method and a designed device for controlling the concentrations of air ions in premises in accordance with the European standards SBM 2015. The use of an ultrasonic humidifier with a capacity of 25 W for two hours increases the concentration of negative ions around the device from 240 to 560 cm^{-3} , positive ones – from 260 to 410 cm^{-3} . The intensity of the electrostatic field of a polymeric coating decreases from 5.1 to 0.2 kV/m. The disadvantage of the humidifier is a small radius of influence (1.0–1.5 m) and the inability to control the polarity of ions. It has been experimentally established that air cooling systems (split systems) deionize the air of the premises. Degrees of deionization and dominating polarity are unpredictable and different for devices of different manufacturers and brands. To control the ion composition of the air simultaneously with the maintenance of normative relative humidity and stresses of static fields, the structure was proposed and the effectiveness of a bipolar ultrasonic air ionizer with adjusted performance and dominating polarity has been tested. The maximum productivity of the ionizer is 4,000–5,000 cm^{-3} . The radius of exposure is 5 m (reducing the concentration of ions with a distance to 500 cm^{-3}). To pass the ionized air through an air capacitor, the number and predominant polarity of air ions are regulated by the polarity and voltage on the covers of the capacitor. It was established that in order to service a room with an area of 50 m^2 , an ultrasonic emitter with a capacity of 25 W would suffice. The adjustability of the device performance makes it possible to reduce or increase the service area. The ability to purify air from suspended particles is shown. During the two hours of operation of the ionizer, the dust content decreased from 4.3–4.4 mg/m^3 to 1.4–1.6 mg/m^3 .

Keywords: microclimate, air ionization, electrostatic charge, ultrasonic humidifier, triboelectric effect, air purification

UDC 628.5/8:614.7
DOI: 10.15587/1729-4061.2022.253110

MONITORING AND MANAGEMENT ION CONCENTRATIONS IN THE AIR OF INDUSTRIAL AND PUBLIC PREMISES

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Received date 03.01.2022

Accepted date 03.02.2022

Published date 25.02.2022

How to Cite: Bolibrukh, B., Glyva, V., Kasatkina, N., Levchenko, L., Tykhenko, O., Panova, O., Bogatov, O., Petrunok, T., Aznaurian, I., Zozulya, S. (2022). Monitoring and management ion concentrations in the air of industrial and public premises. *Eastern-European Journal of Enterprise Technologies*, 1 (10 (115)), 24–30. doi: <https://doi.org/10.15587/1729-4061.2022.253110>

1. Introduction

The physical and chemical properties of air are one of the main indicators of the quality of the industrial and household

environment. The presence in the air of chemical compounds of man-made origin is considered at enterprises of a certain profile or in areas of their location. In most industrial and household conditions, air quality is assessed by microclimatic

indicators such as temperature, relative humidity, and the speed of directed air movement. These parameters affect the heat exchange of humans with the environment. At the same time, such important indicators as air ionization and static electricity remain out of sight. These indicators are considered climatic and are quantitatively regulated by the European construction standard SBM-2015 [1]. The concentrations of ions of both signs should be greater than 500 cm^{-3} while the intensity of the electrostatic field – less than 0.5 kV/m . However, the concentration of ions in the air depends on the intensity of electrostatic fields. The concentrations of ions and fine dust and aerosols are mutually dependent. Suspended particles deionize air to values lower than normative ones [2]. These factors and dependences must be taken into consideration when assessing and adjusting the parameters of the air environment. Even modern automated climate control systems do not solve these problems. At the same time, the ion composition of the air is influenced even by the materials from which the ducts of ventilation systems, fan blades, etc. are made. And deionized air negatively affects the health, biological age, and performance of people [3].

Given the ambiguous impact of the ventilation system, the electrification of polymer surfaces, the different air quality outside the premises used for ventilation, it is a relevant task to devise common principles for controlling air quality in rooms for various purposes. This requires experimental studies into the dynamics of microclimatic parameters, subject to the functioning of cooling and humidification systems, artificial ionization, etc. That would make it possible to work out organizational and technical measures for the normalization and maintenance at the regulatory level of all critical parameters that affect the air quality of industrial and public premises.

2. Literature review and problem statement

The problems associated with maintaining the normative values of the main microclimatic parameters such as temperature, relative humidity, and directed air movement speed have been almost solved technically. Most current studies into the quality of the air environment relate to its ionization, the content of dust and aerosols. In work [4], it is shown that the presence of a dominating number of negative ions in the air contributes to an increase in human performance and improves well-being. Study [5] proves that with the help of artificial air ionization, it is possible to remove fine dust and aerosols from the air, which reduces the likelihood of spreading COVID-19, which is transmitted by drip. However, no technical solutions have been provided. Work [6] shows the possibility of using an air ionizer for partial cleaning from fine dust. However, the use of air ionization due to crown discharges has significant side effects – the generation of ozone and nitrogen oxides, which have a toxic effect on the human body. With the high productivity of the ionizer, exceeding the maximum permissible levels of these chemical compounds is possible. In addition, the deposition of dust on electric plates requires its periodic removal. The mathematical apparatus that makes it possible to evaluate the relationship of concentrations of ions of both signs and suspended particles in the air is given in [7]. With some improvement, it can be used to calculate the desired performance of the ionizer. In study [8], the modeling of the spread of ions from sources of artificial ionization of air was carried out. However, the spread of ions without their settling on dust and aerosols is considered, so the patterns of distribution of ionized air should

be specified experimentally. Modeling the distribution of ions in work [9] is geometric, that is, the recombination of ions in the process of their distribution is not taken into consideration. Article [10] shows the possibility of using ultrasonic emitters for air ionization due to the baloelectric effect. It assesses the quantitative characteristics of ionization using water of various chemical composition. However, these experiments indicate the impossibility of controlling the number of ions of each polarity, which is inconvenient.

Ultrasonic humidifiers are produced industrially and are fundamentally indistinguishable from those given in [10]. Therefore, it is advisable to use such a humidifier to investigate the change in the ion composition of air in an isolated room along with changes in temperature and relative humidity. At the same time, it is also possible to determine the mutual impact of the electrification of surfaces and air ionization. This will provide actual data on the dynamics of interdependent factors and materials for designing the device to create the necessary concentrations of ions and ensure the most achievable air quality.

3. The aim and objectives of the study

The aim of this work is to devise a method for controlling the concentrations of ions in the air of premises for various purposes, which would ensure the normalization of ion concentrations, the intensity of electrostatic fields of the developed ultrasonic device.

To accomplish the aim, the following tasks have been set:

- to investigate the influence of the source of artificial humidification of air on the concentration of ions of both signs and on the intensity of the electric field of the electrified polymer surface;
- to investigate the influence of the air-cooling system (split-system) on the concentration of ions of both signs;
- to design an ultrasonic air ionization device with controlled dominating polarity.

4. The study materials and methods

The measurements were carried out in a test room with an area of 20 m^2 and a volume of 60 m^3 . The entire floor is covered with a coating of synthetic material produced industrially. The surface electrostatic charge was created due to the triboelectric effect. The temperature in the room was set using a standard split system. There was no air exchange with external space during the measurements. The research was conducted on the fifth floor of a standard office building in the summer. There is no forced ventilation system.

To change the humidity and ionization of the air, the standard ultrasonic humidifier SaturnST-AH2107 (Ukraine) with a capacity of 25 W with a water consumption of 0.28 kg/h was used.

Relative humidity and air temperature were measured by the calibrated combined device CX 601 D (China).

The background radiation was measured by the calibrated device SRP-68-01 (Russian Federation).

During the experiments, the background was stable: $0.18\text{--}0.20 \text{ }\mu\text{Sv/h}$. The concentrations of ions of both signs were measured by the calibrated ion counter Sapphire-3K (Russian Federation) according to the operating instructions. The maximum basic measurement error was 20% . Each measurement consisted of three series. Each series includ-

ed 24 readouts from the device in both polarities. The results of measurements were treated according to the procedure given in [11]. The result was entered in the table (n^- , n^+). Measuring instruments were located at a distance of 1 m from the humidifier at a height of 0.5 m from the floor level. The measurement of the intensity of the electric field was measured by the calibrated portable meter VEZ-P (Republic of Moldova). The maximum basic measurement error did not exceed 10 %. Measurements were carried out at 10 points within a radius of 1 m around the humidifier, and were processed according to the instructions for operation of the device; we entered them in tables.

5. Results of studying air ionization, as well as designing and testing a bipolar air ionizer

5.1. Investigating the dynamics of concentrations of ions of both signs depending on the time of operation of the humidifier

Taking into consideration the dependence of air ionization on its condition outside the room, depending on the time of day, the time of measurements was registered. The first series of measurements began at 12:00 Kyiv time. The time $T=0$ corresponds to the data measured before turning on the humidifier. The results of measurements are given in Table 1.

Table 1

Change in air ionization (n), relative humidity (ϕ), and electric field (E) intensity of polymer surface electrostatic charges depending on the time of operation (T) of the ultrasonic humidifier in the daytime

T, h	$t, ^\circ C$	$\phi, \%$	$E, kV/m$	n, cm^{-3}	
				n^-	n^+
0.0	24.0	37	5.1	240	260
0.5	23.5	39	4.8	480	410
1.0	22.5	44	4.0	720	530
1.5	22.5	44	2.1	430	380
2.0	22.5	45	0.2	560	410

The dynamics of concentrations of ions of the relative humidity and intensity of the electrostatic field are shown in Fig. 1–3.

Concentrations of ions are approaching the minimum permissible values over two hours of operation of the humidifier. At the same time, the relative humidity rises to the values regulated for most industrial and household conditions (40–60 %), and the temperature is within the regulatory limits (20–24 °C) [1]. This process is accompanied by neutralization of electrostatic charges, as evidenced by a sharp decrease in the intensity of the electric field.

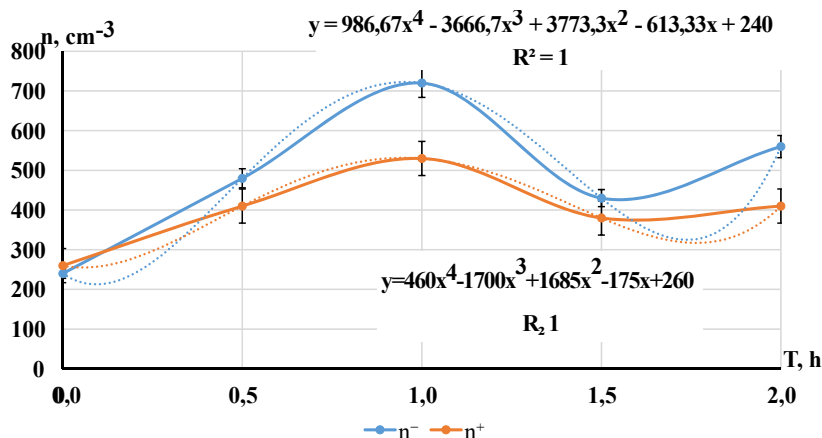


Fig. 1. Change in ion concentrations depending on the time of operation of the humidifier at a distance of 1 m from the device

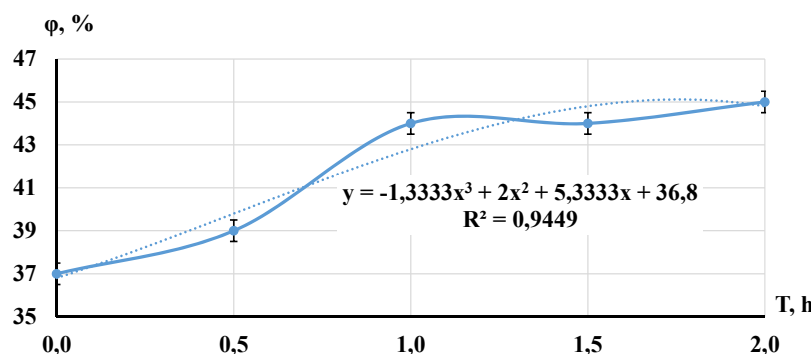


Fig. 2. Dependence of relative humidity on the time of operation of the humidifier at a distance of 1 m from the device

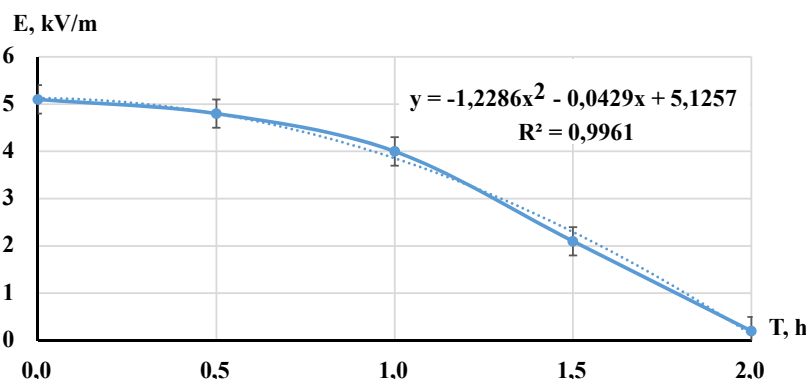


Fig. 3. Dependence of electrostatic field intensity on the time of operation of the humidifier at a distance of 1 m from the device

Similar measurements, but in increments of 1 hour, were performed in the morning (beginning – 6:00 am Kyiv time, Table 2).

The data in Tables 1, 2 indicate that the initial parameters in the room (concentration of ions, intensity of the electrostatic field) differ depending on the time of day, despite the close values of temperature and relative humidity. The concentrations of ions in the morning are higher (with dominating negative ionization), and the intensity of electrostatic fields is less. That can be a consequence of the different composition of the air that comes from the outside, as well as other reasons. For example, it is known that the Earth's electrical charge is negative. Therefore, in the absence of

air movement (including convection, under the influence of sunlight), mainly positive ions accumulate in the near-surface layer. This proportion in Table 2 at the beginning of measurements may be a consequence of this phenomenon. Subsequently, with the work of the humidifier and mixing the air, this phenomenon becomes insignificant. However, the above data show that with the help of a standard device with unregulated generation of ions of each sign, it is impossible to achieve the desired (predicted) result. In addition, this is complicated by the presence of other factors influencing the concentration of ions, for example, air cooling and ventilation systems.

Table 2

Change in air ionization, relative humidity, and intensity of the electric field of electrostatic charges of the polymer surface depending on the time of operation of the ultrasonic humidifier in the morning

T, h	t, °C	φ, %	E, kV/m	n, cm ⁻³	
				n ⁻	n ⁺
0	24.0	40	1.2	300	490
1	23.5	44	0.8	810	710
2	23.0	52	0.5	1,700	960
3	22.5	51	0.1	1,540	1,150

5. 2. Investigating the effect of the air-cooling system on the concentration of ions of both signs

Ventilation and cooling systems can significantly affect the concentrations of ions and their predominant polarity [11]. This is especially true of split systems. Therefore, a study was conducted on their impact on air ionization. The room was previously ventilated. The time T=0 corresponds to the parameters before the air cooling is turned on. The humidifier was not used. The measurements start at 6:00 – Kyiv time.

The results given in Tables 1–3 were obtained using a single split system.

Table 3

The effect of the air-cooling system on the concentration of ions of both signs

T, h	t, °C	φ, %	n, cm ⁻³	
			n ⁻	n ⁺
0	26.0	52	180	430
1	23.0	45	130	450
2	22.5	47	120	410
3	22.5	46	110	320

Table 3 shows that as a result of exposure to the air-cooling system, partial deionization of air occurs, while it is disproportionate to ions of various signs.

We investigated the change in the concentrations of ions in three premises with different brands of split systems (trademarks are not accepted to advertise for ethical reasons).

The results of measurements are given in Table 4.

As seen from the data in Table 4, there is no clear tendency to change the ion composition of the air. It should be borne in mind that significant differences in data can be due to the service life of the devices (for example, the layering of dust on the blades). This may be due to design features, for example, various electrification of polymers, from which ducts and fan blades are made.

Table 4

Degrees of air deionization by air cooling systems of different brands

Room	T=0 h		T=3 h	
	n, cm ⁻³		n, cm ⁻³	
	n ⁻	n ⁺	n ⁻	n ⁺
No. 1	630	740	420	480
No. 2	620	740	600	390
No. 3	480	690	120	100

The above predetermines the relevance of designing an ultrasonic air ionizer with adjustable polarity of ion generation.

5. 3. Design of an ultrasonic air ionization device with controlled performance and dominating polarity of ions

The data provided in Tables 1, 2 were obtained at a distance of 1 m from the humidifier. At greater distances, the concentration of ions decreases rapidly due to natural processes (for example, recombination of ions). In the absence of a sufficient number of ions, surface electrostatic charges are not neutralized. Overcoming these defects is possible by the forced spread of air jet ions. In addition, the generation of ions by a standard device is not regulated. It is necessary to ensure the control of the polarities of ions, depending on the parameters of the factors of deionization of air in the room, signs of electrostatic charges on polymer surfaces, indicators of external air.

Based on this, the main requirements for an air ionizer should be as follows:

- sufficient performance in generating ions of both signs at least for normalization and maintenance at the normative level of their concentrations and neutralization of surface electrostatic charges;
- the regulation of the generation of ions of each sign depending on the sign of static surface charges and the actual polarity coefficient of air ionization in a given room;
- the absence of side effects regarding the generation of potentially dangerous substances (ozone, nitrogen oxides, etc.).

Such requirements are met by an ionizer using an ultrasonic emitter as a working unit that ionizes water molecules due to the baloelectric effect. The generation of ions is always even, and the difference in concentrations is due only to the geophysical factor and the absorption of ions of one sign by surfaces or objects charged opposite. To obtain the desired result, a large generation of ions of both signs and partial absorption of ions of one sign by a special node of the device would suffice.

The schematic diagram of the bipolar air ionizer is shown in Fig. 4.

The ionizer works as follows. From the ultrasonic generator 1, the electrical signals of the ultrasonic frequency are fed to emitter 2. From tank 3, tube 4 feeds water to the emitter, which is ionized under the influence of ultrasonic vibrations. Fan 5 is used for the ionized air to blow between the covers of the air capacitor 6. Key 7 switches on the covers of the capacitor voltage of the desired sign from source 8. Ions of the opposite sign are deposited on the covers of the capacitor and their number is regulated by rheostat 9.

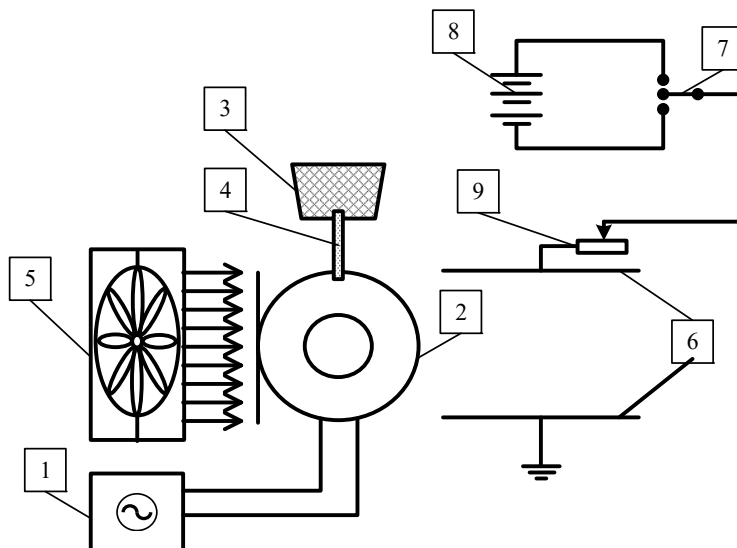


Fig. 4. Schematic showing a bipolar ultrasonic air generator: 1 – ultrasonic generator; 2 – ultrasonic emitter; 3 – water tank; 4 – water supply tube; 5 – fan; 6 – capacitor covers; 7 – capacitor polarity switch key; 8 – constant voltage source; 9 – rheostat

It is easy to calculate the necessary parameters of the device. For all aspiration systems, to determine ion concentrations, the following ratio is used:

$$K = \frac{V_1}{4\pi CU}, \tag{1}$$

where K is the mobility of ions, $\text{cm}^2/\text{V}\cdot\text{s}$;

V_1 is the volume of air that passes through the capacitor per unit of time, cm^3/s ;

C is the capacitor capacity, cm ;

U is the voltage on the cover of the capacitor, V .

All standards consider that ions of mobility $\text{cm}^2/\text{V}\cdot\text{s}$ are light. That is, it is possible to determine the parameters of the capacitor, fan, and voltage of the battery with the known mobility of ions.

By adjusting the voltage with resistance 9, the concentration of ions that settle on a capacitor over 1 s is determined from the ratio:

$$U = IR = Rn'eV_1, \tag{2}$$

where I is the electric current in the circuit;

R – resistance 9 at a given time, Ω ;

n' is the concentration of ions that settle over 1 s, $\text{cm}^3/\text{s}^{-1}$;

e is a single charge of the ion ($1.6 \cdot 10^{-19} \text{ C}$).

Therefore, with the known performance of the ionizer, the device absorbs the necessary part of the ions of the desired sign to maintain the concentrations of ions at regulatory levels and polarities in the room.

Laboratory studies of the bipolar ionizer layout have proved that to regulate the ion composition of air and neu-

tralize static charges in a room with an area of up to 50 m^2 , a generator with a capacity of 25 W with an amplitude of oscillations of $18\text{--}20 \mu\text{m}$ at frequencies of $23\text{--}25 \text{ kHz}$ is enough. Air capacitor can be both flat and cylindrical in shape. The battery voltage of 12 V is enough.

The adjustability of ion concentrations by this device ranges from the background to $4,000\text{--}5,000^3 \text{ cm}^{-3}$ ions of each sign throughout the test room area. A comparative analysis of the distribution of ions of both polarities from the designed bipolar air ionizer and humidifier is shown in Fig. 5. The measurement was carried out after two hours of operation of the device.

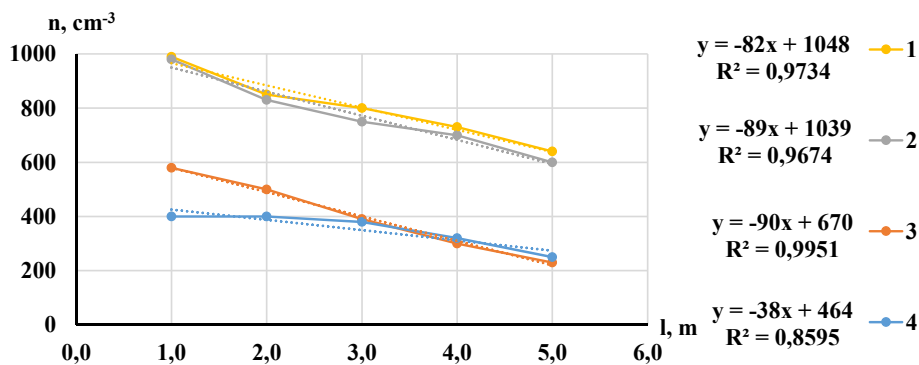


Fig. 5. Propagation of ions from the source of air ionization: 1 – change in the concentrations of negative ions with a distance from the air ionizer; 2 – change in the concentrations of positive ions from bipolar air ionizer; 3 – change in the concentrations of negative ions from humidifier; 4 – change in the concentrations of positive ions from humidifier

The decrease in concentrations of ions with a distance from the ionizer occurs almost linearly and depends on the fan speed and the amount of water supplied to the emitter.

All industrial air ionizers generate ions with high-voltage crown discharges and are varieties of the well-known Chizhevsky chandelier. Such ionizers do not provide for the forced spread of regulated polarity ions and have a funda-

mental drawback – the generation, as a result of discharges, of ozone and nitrogen oxides harmful to humans.

6. Discussion of results of studying the dynamics of the ion composition of air and testing the bipolar ionizer

Our experimental data (Tables 1, 2) show that after one two hours of operation of the ionizer and an increase in ion concentrations, their decrease occurs. The explanation for this is a sharp decrease in the levels of electrostatic fields. The ionizer is located close enough from the floor, there begins a steady drift of ions to the charged surface. After neutralizing the surface potential, the concentration of ions begins to increase again. The prolongation of this process in the continuous operation of the ionizer makes the process of air purification from fine dust and aerosols promising. In the presence of indoor ion generation or high natural air ionization, finely dispersed suspended particles become heavy ions small-dispersed suspended particles become heavy ions. Basically, this is the process of attaching light ions to particles. It is described by equations:

$$\frac{dn^-}{dt} = q - \alpha n^- n^+ - \beta^- n^- N^+ - \beta_0^- n^- N, \quad (3)$$

$$\frac{dn^+}{dt} = q - \alpha n^- n^+ - \beta^+ n^+ N^- - \beta_0^+ n^+ N, \quad (4)$$

where n^- , n^+ – concentrations of negative and positive light ions, cm^{-3} ;

q – the level of generation of pairs of light ions, cm^{-3} ;

α – coefficient of recombination of light ions;

β^- , β^+ – coefficients of deposition of negative and positive light ions onto heavy ones;

N^- , N^+ – concentrations of heavy negative and positive ions, cm^{-3} ;

β_0^- , β_0^+ – deposition coefficients of negative and positive light ions on neutral particles;

N – concentration of neutral particles, cm^{-3} .

This balance is true for space far from charged surfaces, near which at distances of several centimeters the balance is different [2]. The required coefficients are mostly known from reference sources [7, 8]. The values of coefficients: $\alpha = 1.6 \cdot 10^{-6} \text{ cm}^3/\text{s}$; $\beta^- = 4 \cdot 10^{-6} \text{ cm}^3/\text{s}$; $\beta^+ = 3.97 \cdot 10^{-6} \text{ cm}^3/\text{s}$; $\beta_0^- = 1.67 \cdot 10^{-6} \text{ cm}^3/\text{s}$; $\beta_0^+ = 1.2 \cdot 10^{-6} \text{ cm}^3/\text{s}$. Therefore, for the introduction of air purification, one can evaluate the desired generation of light ions with an ionizer. In this case, the process of interaction with the electrified surface would have a certain sequence. Light ions settle on suspended particles, under the influence of air movement and electrostatic forces, they drift to the opposite-charged surface on which they settle. To check the possibility of air purification from fine dust, the dust content in the air of the room with a volume of 60 m^3 was measured before the ionizer started operation and after two hours of its operation. The measurements were carried out by aspiration method – pumping a fixed volume of air using the EF-2C electric device through a container with water. Weighing of the container with water was carried out before and after pumping air. It was found that the initial content of suspended particles in the room was $4.3\text{--}4.4 \text{ mg}/\text{m}^3$. After two hours of ionizer operation, the particle content was $1.4\text{--}1.6 \text{ mg}/\text{m}^3$. Thus, the dust content in the air decreased almost three times.

In this case, the surface electrostatic charge is neutralized. The main condition is the remoteness of the ionizer from charged surfaces in order to avoid the predominant process of rapid sedimentation of ions on an electrified surface after one hour of operation of the ionizer (Fig. 1).

The results given in Tables 3, 4 indicate that the degrees of air deionization and the predominant polarity by split systems have no patterns and are unpredictable. Therefore, before the introduction of organizational and technical measures for managing air quality in the room of any purpose, it is necessary to monitor the levels and dynamics of the necessary physical factors. It excludes the control of air ionization in the room; this indicator is for outdoor air entering the room; degrees of air deionization by cooling and ventilation systems; the value and polarity of static charges accumulated on polymer surfaces. This information could make it possible with less time and resources to manage air quality even in rooms with complex dynamics of microclimatic indicators under an automatic mode.

Our truly original research indicates the possibility of using a standard air-cooling system and a bipolar air ionizer to control all microclimatic parameters, at least those normalized by international standards [1]. Unlike traditional serial air ionization devices that, due to crown discharges, generate ozone and nitrogen oxides, the designed device is completely safe. High-voltage devices as ultrasonic humidifiers have a limited radius of influence ($1.0\text{--}1.5 \text{ m}$), which is due to the lack of systems for the forced propagation of ions and the danger in the case of increased power. The designed device, even in the layout version, has a guaranteed service area of up to 5 m , on which the concentration of ions of both signs of 500 cm^{-3} is achieved. The advantage of the ionizer in comparison with analogs is the simultaneous increase in air humidity to normative values of 40% or more, as well as the possibility of air purification. This is important due to the fact that according to the standard [1] for residential premises, the concentration of suspended particles should not exceed $50 \mu\text{m}/\text{m}^3$ (for particles less than $10 \mu\text{m}$). Therefore, it is advisable for them to use a device that has no harmful side effects in the form of chemical compounds and performs several functions – ionization and purification of air, as well as neutralization of static charges.

The limitations of the current research is that the normalization of parameters that affect air quality is considered. It is advisable to consider the possibility of managing the entire complex of physical factors of the industrial and household environment. The tasks of protecting people from the effects of man-made electromagnetic and acoustic fields using a risk-oriented approach based on modeling the spread of physical factors are relevant [12, 13]. Such issues can be resolved in conjunction with those discussed in this paper. Thus, work [14] designed and investigated the protective properties of the composite electromagnetic and noise protection screen. This material is made of cheap materials – iron ore dust and latex. Such components, if necessary, can be used for facing surfaces of large areas for shielding electromagnetic fields and noise of wide frequency bands. The advantage of the main component (latex – by weight up to $85\text{--}90 \%$) is that it is not electrified under any physical influence. That is, in this case, the task of avoiding air deionization is simplified. The process of air purification from suspended particles that can be deposited on charged plates, similar to the covers of the bipolar ultrasonic air ionizer capacitor, is also simplified.

The copy paste area of research is considered promising as it could create a holistic system for managing the levels of physical factors of production and domestic environments.

7. Conclusions

1. Our original studies into the dynamics of the ion composition of the air of industrial and household premises have proved that the means of normalizing the concentrations of ions of both signs, relative humidity and temperature is the use of air-cooling devices (split systems) and ultrasonic humidifiers. In addition, it makes it possible to almost completely neutralize the electrostatic charges formed on polymer surfaces. It makes it possible to increase the concentration of ions to the minimum permissible levels within a few hours and almost completely neutralize the surface electrostatic charge. The disadvantage of the technique is the uncontrollability of the dominating polarity of ions depending on the conditions of use of the equipment (background ionization values, electrostatic charge signs) and a small radius of efficiency (1.0–1.5 m).

2. It was found that the split air-cooling system in the test room deionizes it. In the process of reducing the temperature from 26.0 °C to 22.2 °C and relative humidity from 52 % to

46 %, the concentration of negative ions in the air decreases from 180 cm⁻³ to 110 cm⁻³, positive – from 430 cm⁻³ to 320 cm⁻³. It is established that this phenomenon is systemic in nature. Air cooling means with the same principles of action deionize the air in an unpredictable way, with different predominant polarities of deionization. Three different split systems under the same modes of operation showed that the concentration of negative ions decreased by 33 %, 3 %, and 75 %, and positive – by 35 %, 41 %, and 72 %. Such data should be obtained for all specific conditions and taken into consideration when using artificial air ionization.

3. The designed bipolar air ionizer makes it possible to regulate the predominant polarity of the generated ions depending on background air concentrations and the properties of deionization sources. The device makes it possible to maintain the normative concentrations of ions within a radius of 5 m. Due to the directed movement of air, the decrease in ion concentrations occurs almost linearly. The maximum performance of the ionizer is 4,000–5,000 cm⁻³ of both signs. Measurements showed that in the test room, over the work of the ionizer for two hours, the content of suspended particles in the air decreased from 4.3–4.4 μm/m³ to 1.4–1.6 μm/m³ within a room volume of 60 m³. The advantage of the bipolar ionizer compared to serial high-voltage ionizers is a large radius of exposure and the absence of generation of harmful substances.

References

1. Standard of Building Biology Testing Methods SBM. Germany: Institut für Baubiologie + Nachhaltigkeit IBN. URL: <https://buildingbiology.com/building-biology-standard/>
2. Glyva, V., Nikolaiev, K., Tykhenko, O., Tymoshenko, O. (2019). The study of physical factors levels in the control tower service premises of civil aviation airport. *Control, Navigation and Communication Systems*, 1 (53), 32–35. doi: <https://doi.org/10.26906/sunz.2019.1.032>
3. Nazarenko, V. I., Cherednichenko, I. M., Nykyforuk, O. I., Martirosova, V. G., Tikhonova, N. S., Beseda, A. Yu., Paliychuk, S. P. (2017). Physiolo-hygienic evaluation of work conditions in bank workers. *Ukrainian Journal of Occupational Health*, 4, 35–41. doi: <https://doi.org/10.33573/ujoh2017.04.035>
4. Jiang, S.-Y., Ma, A., Ramachandran, S. (2018). Negative Air Ions and Their Effects on Human Health and Air Quality Improvement. *International Journal of Molecular Sciences*, 19 (10), 2966. doi: <https://doi.org/10.3390/ijms19102966>
5. Suwardi, A., Ooi, C. C., Daniel, D., Tan, C. K. I., Li, H., Liang, O. Y. Z. et. al. (2021). The Efficacy of Plant-Based Ionizers in Removing Aerosol for COVID-19 Mitigation. *Research*, 2021, 1–11. doi: <https://doi.org/10.34133/2021/2173642>
6. Sidorov, A. V. (2014). The technique of small air ions concentration measurement at the PC operator working place. *Engineering industry and life safety*, 1, 36–41. URL: http://www.mbsd.ru/1_2014-36eng/
7. Fletcher, L. A., Noakes, C. J., Sleigh, P. A., Beggs, C. B., Shepherd, S. J. (2008). Air Ion Behavior in Ventilated Rooms. *Indoor and Built Environment*, 17 (2), 173–182. doi: <https://doi.org/10.1177/1420326x08089622>
8. Belyaev, N. N., Tsygankova, S. G. (2015). Otsenka aeroionnogo rezhima v rabochey zone pri isskustvennoy ionizatsii vozduha v pomeschenii. *Naukovyi visnyk budivnytstva*, 3 (81), 158–161.
9. Tolkunov, I. O., Popov, I. I. (2011). Vplyv pryrodnykh dzherel aeroionizatsiyi na protses formuvannia poliv kontsentratsiyi aeroioniv u povitriianomu seredovyschchi prymishchen. *Zbirnyk naukovykh prats Kharkivskoho universytetu Povitrianykh Syl*, 1 (27), 243–246.
10. Sukach, S., Kozlovs'ka, T., Serhiienko, I., Khodakovskyy, O., Liashok, I., Kipko, O. (2018). Studying and substantiation of the method for normalization of airionic regime at industrial premises at the ultrasonic ionization of air. *Eastern-European Journal of Enterprise Technologies*, 4 (10 (94)), 36–45. doi: <https://doi.org/10.15587/1729-4061.2018.141060>
11. Sukach, S. V., Sydorov, O. V. (2016). Metodolohichni zasady pidvyshchennia yakosti kontroliu aeroionnoho skladu povitria vyrobnychoho seredovyschcha. *Problemy okhorony pratsi v Ukraini*, 32, 127–133.
12. Glyva, V., Lyashok, J., Matvieieva, I., Frolov, V., Levchenko, L., Tykhenko, O. et. al. (2018). Development and investigation of protective properties of the electromagnetic and soundproofing screen. *Eastern-European Journal of Enterprise Technologies*, 6 (5 (96)), 54–61. doi: <https://doi.org/10.15587/1729-4061.2018.150778>
13. Zaporozhets, O., Levchenko, L., Synylo, K. (2019). Risk and exposure control of aviation impact on environment. *Advanced Information Systems*, 3 (3), 17–24. doi: <https://doi.org/10.20998/2522-9052.2019.3.02>
14. Khodakovskiy, O., Levchenko, L., Kolumbet, V., Kozachuk, A., Kuzhavskiy, D. (2021). Calculation apparatus for modeling the distribution of electromagnetic fields of different sources. *Advanced Information Systems*, 5 (1), 34–38. doi: <https://doi.org/10.20998/2522-9052.2021.1.04>