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Changes in Air Ions Concentration depending on Indoor Plants Activity

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Abstract. Lack of negative ions in the air can cause deterioration of the health which is described in many scientific articles. At the same time, an air saturated with negative ions can improve the state of health and provide a comfortable indoor environment. In addition, there are considerable evidences that drowsiness, apathy, headache etc. get even worse indoors, and these health problems may be effectively eliminated with a help of moderate concentrations of negative ions. Literature sources and earlier researches state that plants may be able to produce a variety of air ions, including negative light ions. The most plants emit different types of volatile organic compounds, and the indoor plants can improve the air quality: they effectively remove organic pollution and reduce the number of microorganisms in the air by releasing phytoncides. In this article, the regularity of influence of plants on the number of ions in the room is being proved, basing on a series of experiments performed with the following plants: Spathiphyllum, Pinus mugo, Aloe arborescens, Chlorophytum comosum, Cactaceae opuntia.

Key words: air ions, plants, microclimate.

INTRODUCTION

In fact, air ions are charged air gases molecules appearing as a result of ionisation. The physical essence of the air ionisation process is connected with the influence of different physical factors on the air gasses molecules (solar radiation, space emanation, electrical field of high tension, radioactive emanation and others). It results in the molecule tearing off the electron and it becomes positively charged, but the torn off free electron, having joined the neutral molecule, imparts it the negative charge. This results in the formation of the negative air ion. Thus, both positively and negatively charged ions are formed in the atmosphere air. Their existence habitat- air determined their spread name- air ions. Under normal conditions, 1 cm^3 of air contains about 750 positive and 650 negative air ions (Ulascik, 2008).

Air ions are constantly created, but outside of the premises. Given the average air ions age in urban areas (about 10 seconds), it can be concluded that closed areas are almost devoid of charged particles. If a healthy person after work has the ability to walk in the street, to receive the necessary amount of ions, the patient is forced to spend much time in 'dead' air (Ponomarenko, 2015).

The presence of negative air ions (NAI) in the inhaled air is essential for normal functioning of human and animal organisms (Charry & Kvet, 1987). Scientific research indicates that the air within homes and other public or office buildings can be more seriously polluted than the outdoor air. Public concern about the effects of indoor air pollution on health has resulted in expanded research of the topic (Wang et al., 2005). Some countries have already elaborated legal framework for air ion concentration in work rooms. On 16 June 2003, sanitary and epidemiological rules and regulations 'Hygienic Requirements for the Air-Ion Level of Industrial and Public Facilities SanPin 2.2.4 1294-03' (Санитарно-эпидемиологические правила и нормативы 'Гигиенические требования к аэроионному составу воздуха производственных и общественных помещений СанПин 2.2.4 1294-03') entered into force in the Russian Federation. According to these Requirements, optimal concentration of light negative ions amounts to 3,000–5,000, while concentration of positive ions should be half as much. However in most cases, the concentration of favorable light, negative air ions indoors does not exceed few dozens, while the concentration of harmful positive ions is growing rapidly, especially if there are people, TVs, computer monitors and similar devices in the room.

Besides, practical field testing reveals that the somnolence, apathy, headaches, etc. ascribed to the 'dead' air in enclosed spaces can be conquered effectively by supplying moderate concentrations of negative ions (Krueger, 1985). Air ions may be healing or may harmfully affect human health. This effect depends on ion concentration in the air and on proportions of positive and negative ions. These proportions are characterized by unipolarity coefficient

$$K = \frac{n^{+}}{n^{-}} \qquad (1)$$

where n+ and n- mean concentration of positive and negative cluster ions.

Sanitary-hygienic characteristics of plants include their ability to release a special volatile organic compound called phytoncides, which kill pathogenic bacteria or delay their development. These properties become especially valuable in urban conditions where the air contains 10 times more pathogenic bacteria than the air of fields and forests.Most plants emit different types of volatile organic compounds (Bio VOCs) and even micro-amount of Bio VOCs have a great impact on formation processes of cluster ions (Duddington, 1969). This effect is reinforced when volatile compounds are emitted from the plant in ionic form, e.g., Bio VOCs emitted from the needles of conifers are ionized because of charges accumulated in the sharp tips of the needles. Ions of volatile compounds are very good condensation nuclei in the atmosphere that contribute to further formation of mist and clouds. Thus, coniferous forests can affect even the global climate (Kulmala et al., 2000). To a certain extent, most of the plants are air ion generators. Intensity of such generation depends on the daily intensity cycle of metabolic process in these plants (Cibula & Fershalova, 2000).

Despite that aeroionizers are always present in places with artificial atmosphere, in submarines, and long-term space stations. Although today the saturation of air ions of the air we breathe at work and at home, is becoming a more urgent problem (Ponomarenko, 2015).

We have tried to model the artificial air ionisation using indoor plants. For this purpose, a special experimental stand was constructed. (Fig. 1).

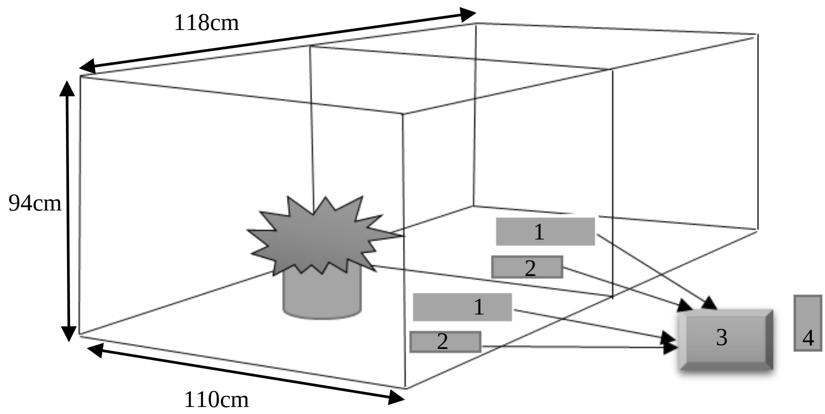

Figure 1. Schematic drawing of the experimental stand, consisting of two equal sectors: one with plants, other without plants. 1 – air ion counter, 2 – microclimate multi-meter, 3 – laptop computer, 4 – radioactivity meter.

It has been determined that the plants are able to reproduce negative air ions, flowing down the leaves into the surrounding air without any stimulation with electric impulses (as it was done by the previous researchers). The greatest ability for artificial air ions generation possess pointed leaves or sharp thorns (for example, Pinus Mugo, Aloe arborescens, Cactaceae opuntia). These plants are able to maintain medium concentration (with some spontaneous fluctuation) for a long period of time. It would be perspective to develop technology for artificial greening that would ensure air ion concentration and microclimate conditions indoors optimal for human organism. In order to develop such technology, it is necessary to find out changes in air ion concentration depending on indoor plants and microclimate.The aim of this research is to explore the impact of indoor plants and microclimate on air ion concentration in order to find opportunities to use plants for air quality improvement.

MATERIALS AND METHODS

We used the same plant species as the Tikhonov et al. (2004) article and found similar species-dependent differences in the ability to generate NAI. The data presented in this paper prove that the capacity of plants to generate NAI differs. The aim of the experiments was to find the species with the most expressed capability to generate NAI.

In order to perform this study, several plants were selected which, by their nature and taking into account the impact of external factors, can affect the air ion concentration indoors. Therefore, plants with the following characteristics were chosen: large area of leaves, leaves with a pointed tip and hair shaft; developed transpiration function (as a result of transpiration a lot of water is vaporized from plants), dust particle absorption, expressed phytoncide features (Table 1).

Table 1. Plants properties

Latin Name	Phytoncide features*	Intensity of oxygen generation*	Efficiency of air purification from gas admixtures (relative values) 0–10*	Substances absorbed efficiently *	Size, H/D, cm
Chlorophytum	*	**	7.8	Formaldehyde, carbon dioxide	35/40
Aloe arborescens	**	**	7.8	Formaldehyde, carbon dioxide	40/50
Cactaceae opuntia	**	***	6.9	Formaldehyde,	35/45
Pinus mugo	***	**	8	Formaldehyde, acetone, benzene	35/45
Spathiphyllum	*	**	7.5	Formaldehyde, acetone, benzene	50/55

***high efficiency; **efficient; *average efficiency low efficiency;*(Cibula & Fershalova, 2000).

In order to research the influence of plants on ions concentrations indoors we have constructed an experimental stand made of 10 mm thick veneer. The general dimensions of the box are 118 cm x 110 cm x 94 cm. The box is divided by the partition into two equal sectors. A plant was placed in one sector but the other stayed without any plants. Every sector contained devices for measuring microclimate parameters. The box itself was placed in the basement type premises with natural air ventilation, without any windows, the walls covering- processed concrete. In addition, outside the box the radiation background was measured. During the experiment there were no people in the premises. The premises were entered to change plants and save meters' data. Air ion concentration was measured with the portable bipolar air ion counter 'Sapfir-3м'. This device provides simultaneous measuring of positive and negative air ions with minimum resolution of 10 ions per 1 cm^{-3}. The device measures air ion concentration in the air (mobility $k \geq 0.4$ cm^2 $V^{-1}s^{-1}$). This mobility interval is close to the class of cluster ions. During the measurements, air ions, according to their polarities, are channelized to positive or negative aspiration collector in aspiration chamber and, after coming into contact with this collector, the ions are discharged. Afterwards, the charge is sent to amplifiers and then the impulses are counted and displayed. The device counts the charges of air ions, therefore if an ion has more than one charge, it is counted as several ions.

Indoor climate parameters were determined using the multi-meter 'Easy Sense Q'. Systematic measurement error of this device for temperature is ± 0.3 °C, whereas error for relative humidity is ± 5%. Error for lighting is not specified. The total amount of radioactive α, β and γ radiation was measured in μSvh^{-1} with the portable device 'Gamma-Scout' with systematic measurement error less than 5%. For all devices, the average value of each measurement point was 10 minutes. Each time the measuring devices were placed in a distance of approximately 40 cm from the plants.

The measurements were carried out in automatic mode for each species of plants individually constantly within 66 hours.

RESULTS AND DISCUSSION

The experimental data (Table 2) show that the number of positive air ions in the box is higher than the number of negative air ions: 9% (without houseplants) and 21% (with houseplants). Maximum / minimum concentration of positive air ions: 1,693 cm^{-3} 350 cm^{-3} (without houseplants) and 2,345cm^{-3} 292 cm^{-3} (with houseplants). Maximum / minimum concentration of negative air ions: 1,282 cm^{-3} 411 cm^{-3} (without houseplants) and 1,503 cm^{-3} 263 cm^{-3} (with houseplants). These data reveal that, basing on the air ion concentration and unipolarity coefficient, the box used for the experiments is not recommended for human health (if not ventilated).

Table 2. Average ions concentration and Indoor climate parameters

Conditions/ Parameters	*Spathiphyllum*		*Pinus mugo*		*Aloe arborescens*		*Chlorophytum comosum*		*Cactaceae opuntia*	
	Without plants	With plants	Without plants	With plants	Without plants	With plants	Without plants	With plants	Without plants	With plants
N^- (cm^{-3})	439	294	920	1,282	1,503	1,106	535	395	411	263
N^+(cm^{-3})	473	292	1,033	2,345	1,693	1,462	518	491	350	317
$N^{(total)}$(cm^{-3})	912	586	1,953	3,627	3,196	2,568	1,053	886	761	580
K	1.01	1.05	1.14	1.74	1.13	1.40	1.08	1.34	0.79	1.25
T (°C)	21.78	21.99	22.61	21.57	21.91	21.57	22.66	22.39	22.05	22.38
RH(%)	27	36	45	50	30	34	28	36	31	33
Sv(μSvh^{-1})	0.38	0.38	0.38	0.38	0.39	0.39	0.39	0.39	0.39	0.39

The box has very low concentration of positive and negative air ions and inadequate unipolarity coefficient, because, basing on the SanPin 2.2.4 1294-03, minimal admissible concentration of positive air ions is 400 cm^{-3}, negative air ions 600 cm^{-3}, admissible values of unipolarity coefficient $0.4 < K < 1.0$. During the experiment, the temperature and relative humidity in the box increases. The measured average ambient temperature in the room with plants is about 0.5 °C higher than in the room without plants. The average humidity is up to 15% higher in the room with plants than in the room without plants. It means that plants increase the air humidity (the water is evaporated through leaf pores). As the natural radiation level fluctuates chaotically around the average value 0.39 μSvh^{-1} and the amplitude of these fluctuations is less than 10%, the level of radiation can be considered as constant; fluctuations of radioactive background do not affect daily changes of air ion concentration.

The indicated concentration of negative ions in air in the presence of plants (Fig. 2) allow us to conclude that fluctuations in the number of ions depends on the time of day. These changes are well seen on the example of Aloe arborescens and Chlorophytum comosum. The maximum number of ions was observed during the day (9:00–10:00 a.m.), at the same time the decline of the ions occurred in the evening hours (5:00–10:00 p.m.). Although the experiment was conducted in complete darkness, i.e. without the influence of daylight or artificial light.

Plants used in the experiments are producers and absorbers of positive and negative air ions. During the night, the process of plant's metabolism and ion emission into the air slows down; during the night, the plants mainly adsorb air ions. Therefore, during the night a significant decrease in air ion concentration can be observed in the room with plants. During the day metabolic processes in plants are activated; plants emit positive and negative ions into the air and simultaneously adsorb these ions. These electrons increase the amount of negative air ions. At the same time the surfaces of plants are charged positively; it increases the adsorption of negative air ions and decreases the absorption of positive ones. As a result, during the day the room with plants has increased concentration of air ions (especially positive ones).

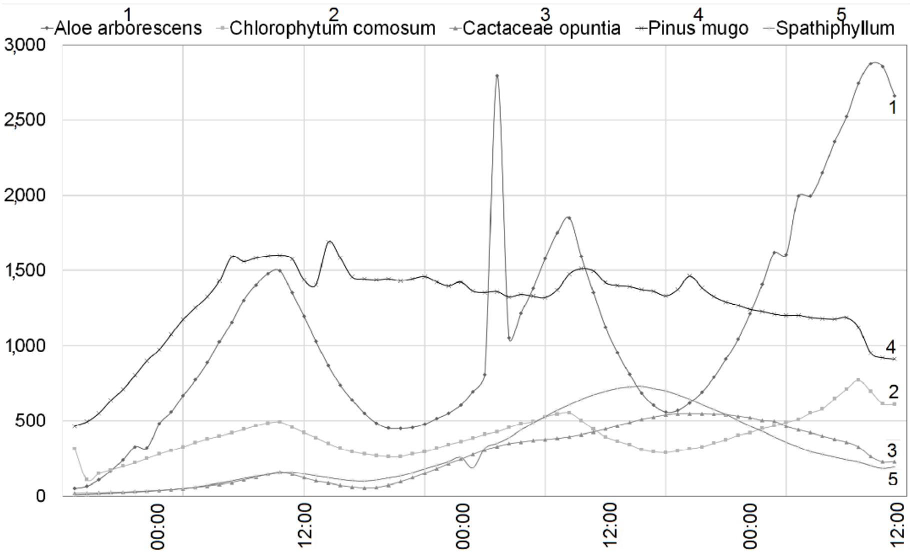

Figure 2. Concentration of negative ions in the air in box with plants, cm^{-3}.

The room has good ventilation. Air ions from the outside infiltrate into the experiment room. The measurements in the box without plants show on the quantity of the ion outside air. If in the room completely close ventilation, it is possible that there would not be the cyclical changes in the graphs. Comparing the graphs with the plants and without the plants can make conclusions how the plants change the ion number in the diurnal period.

Presence of plants in the room can significantly stabilize uncontrolled fluctuations of ion concentration, however the necessary level of ionization was not reached. As indicators for the generation of negative ions by plants depend on the time of day it is important to know in what areas you plan to use them.

For example, according to the results of experiment Aloe arborescens is recommended for use in office where work is during the day. In order to maintain the level of negative ions while sleeping (at night) above mentioned plants are not suitable.

CONCLUSIONS

The positive and negative air ions concentration indoors (with plants and without plants) varies periodically during twenty-four hours - Aloe arborescens (Fig. 3, A) and Chlorophytum comosum (Fig. 3, B): in day time - increases, in night time – decreases.

In some cases, there are identified deviations from the periodicity. It is possibly related of the changes of Solar radiation activity.

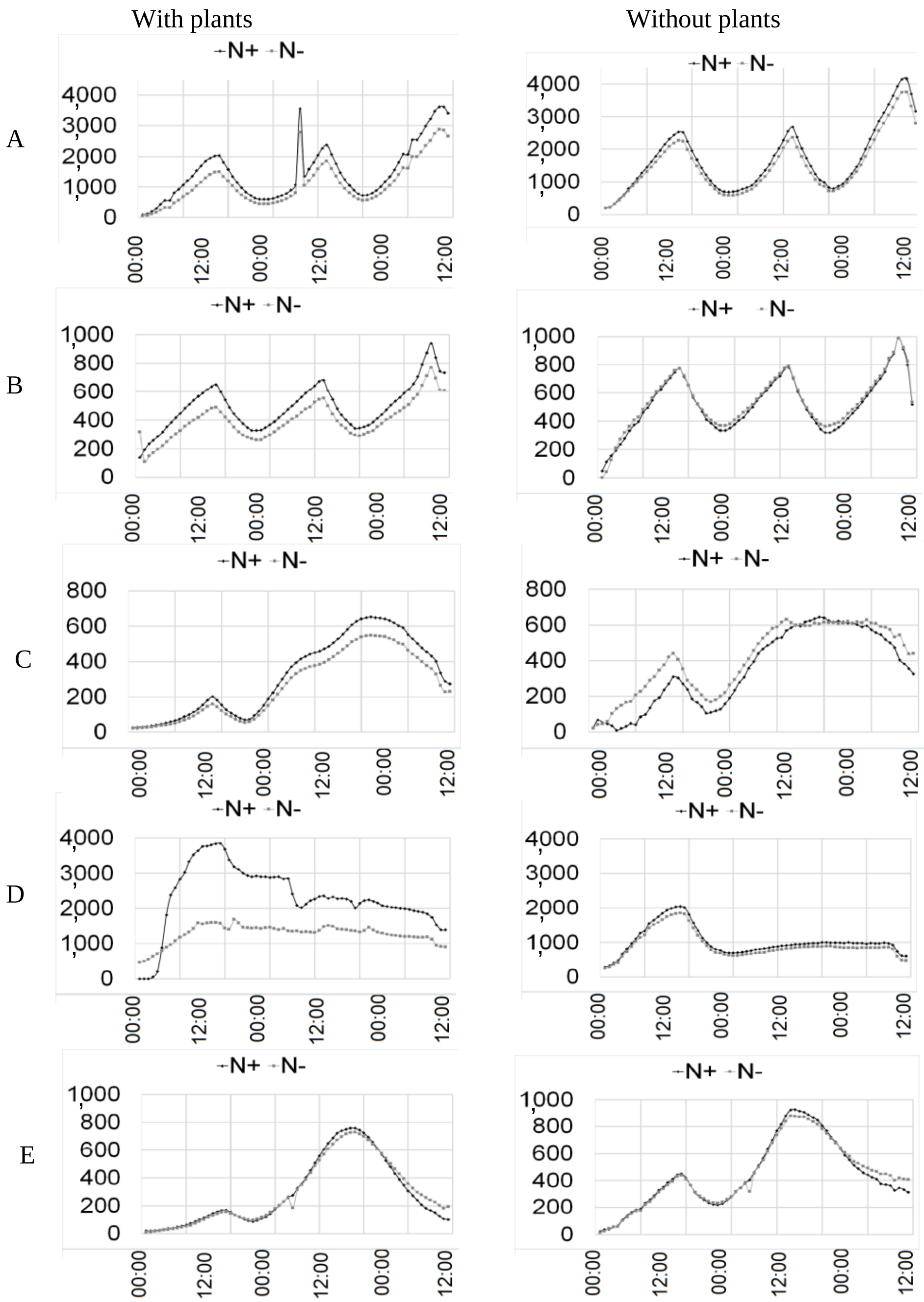

Figure 3. Concentration of negative and positive ions in the air in box without and with plants, cm^{-3}: A – Aloe arborescens; B – Chlorophytum comosum; C – Cactaceae opuntia; D – Pinus mugo; E-Spathiphyllum.

After conducting a series of experiments with five species of plants, it was concluded that the best among them is the ability to generate negative ions has Pinus mugo (Table 2, Fig. 2). If in the room are plants, the positive and negative air ions concentration decreases. Pinus Mugo is exception - about 2 times more the positive and 1.4 times more negative ions. In the room with Pinus Mugo negative ions concentration during the twenty-four hours remains constant. This means that the Pinus Mugo could be used as a source of negative air ion.

Further experiments could be related to changes in air ion concentration depending on electrization of soil by high voltage pulses, thus providing for the high level of air ion.

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