Results of investigations of usage the environmental friendly technology for the air purification in non-industrial buildings

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Abstract. Ability of plants to purify contaminated indoor air using vertical hardware-biological complex of recirculating type was studied. Laboratory experiments were made for assessing capability to purify indoor air against different particle size of contaminated air by cigarettes. Comparative analysis of the data obtained with the use of Tradescantia fluminensis Vell and Sansevieria trifasciata was shown. According to the results of laboratory tests and diagnostic status of the air, making the following options by location of vertical hardware-biological complex of recirculating type.

1 Introduction

Nowadays, air pollution has become one of the most important environmental problems of megacities [1]. Air pollution has serious impacts on public health, causes urban and regional haze, and has the potential to contribute significantly to climate change [1]. Moreover, in 1983, the working group of the world health organization in its report identified the main and integral cause of "sick building syndrome" [2].

All contaminations observed not only in outdoor air, but it is presented in indoor air. Moreover, indoor air contains some particular pollutant elements. The relationships between indoor, outdoor and personal levels are complex [3]. However, green plants have a capability to air purification that is applicable for indoor conditions [4].

Different species of plants can reduce contamination of the air due to its biological possibilities [5]. One of alternative approach to maintaining indoor air quality may be the biofiltration of air circulated within the space [6].

Saint-Petersburg is one of the biggest cities in Russia with approximately 5 million people inhabitants and developed industrial and transport clusters, emitting different types of contamination into the atmosphere. Moreover, usage different types of materials for indoor design [7, 8], human activity and peculiarities of climate bring to accumulation of contaminations and developing sick building syndrome [9]. In recent years, an environmental friendly technology for air purification has been started to develop.

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In St. Petersburg State Politechnical University vertical hardware-biological complex of recirculating type was design [8]. This complex allows to effective purify the indoor air of non-industrial buildings against various kind of pollutant agents. The results of applying the complex are presented.

1.1 Indoor and outdoor air pollutants

The air pollution path of the urban atmosphere consists of emission and transmission of air pollutants resulting in the ambient air pollution [10]. Each part of the path is influenced by different factors [10]. According to literature review, the following parameters are the most important for the air quality: quantity of emissions into the atmosphere, chemical composition, height of a source of air pollution, climatic conditions [11] and dependent physical parameters of the atmosphere. Moreover, suspended particulate matter is complex with respect to particle size distributions, the chemical composition and its sources [3].

There are a lot of pollutant in the air of cities, including Saint-Petersburg. All of the cities contain high concentrations of PM; O3; sulfur dioxide (SO2); nitric oxide (NO) and nitrogen dioxide (NO2), the sum of which is known as nitrogen oxides (NOx) [3, 12]; carbon monoxide (CO); volatile organic compounds (VOCs), and hydrocarbons (HC, a VOC subset) [1]. PM is often reported as mass concentration in the total suspended particulates (TSP), PM10, and PM2.5 (particles with aerodynamic diameters of less than 40, 10, and 2.5 μm, respectively). The major PM chemical components are sulfate (SO42-), nitrate (NO3-), ammonium (NH4+), organic carbon (OC), elemental carbon, and soil (a weighted sum of mineral elements such as aluminum (Al), silicon (Si), calcium (Ca), titanium (Ti), and iron (Fe)). Long-lived greenhouse gases (GHG) such as carbon dioxide (CO2), methane (CH4), and chlorofluorocarbons are important on global scales [12, 13].

Moreover, changes in building design devised to improve energy efficiency have meant that modern homes and offices are frequently more airtight than older structures. Furthermore, advances in construction technology have caused a much greater use of synthetic building materials. Whilst these improvements have led to more comfortable buildings with lower running costs, they also provide indoor environments in which contaminants are readily produced and may build up to much higher concentrations than are found outside [7].

The health effects of inhaled biological particles can be significant, as a large variety of biological materials are present in indoor environments [7]. Sources of indoor particles are from outdoors and some specific indoor sources such as smoking and cooking [7, 14] for fine particles or moving of people (resuspension of dust) for coarse particles [3]. Baek S.-O. et. al. (1999) shown that heating practices, coupled with generally inadequate ventilation has an influence to indoor air quality. Of particular importance might be substances known as volatile organic compounds (VOCs), which arise from sources including paints, varnishes, solvents, and preservatives [7].

That indoor plants are very essential to us human beings has been widely recognized. They can reduce dust fall, carbon dioxide and VOCs for enhancement of indoor air quality. They can also restrain micro-organisms, maintain humidity and make our daily activity space more comfortable and healthy to improve work performance [15].

1.2 Recirculating type of vertical hardware-biological complex

Functional scheme of hardware-biological complex is presented on the Fig. 1.

Contaminated air by the fan (2) enters into the complex with plants, installed at different tiers. The complex is equipped with a supporting structure of vertical design with shelves-planter flats. Boxes with plants installed in the planter flats. It design allows the lower watering plants. Hypoallergenic mineral soils used as the soils, essentially eliminates the development of micro-organisms on the surface. Plants with advanced transpiration function intensively illuminate energy saving lamps or LED illuminators (10), resulting in dramatically increased yield of the surface leaves the moisture and biologically active substances, including volatile.

There is a hardware module in the upper part of the complex. It provides the generator operation to produce bipolar ions and its removal in the air of the indoor area. Control and monitoring modules process the information data, coming from sensors and tracking the availability of water in the reservoir (13) and in one of the planter flats, and generate a command to the next watering of the plants. In the lower part of a complex set reservoir for water storage.

Air flows inside of the complex formed thereby to aerosol clusters passing through the leaves of plants settled on them. Wet leaves are well kept aerosols and volatile inactivate microorganisms.

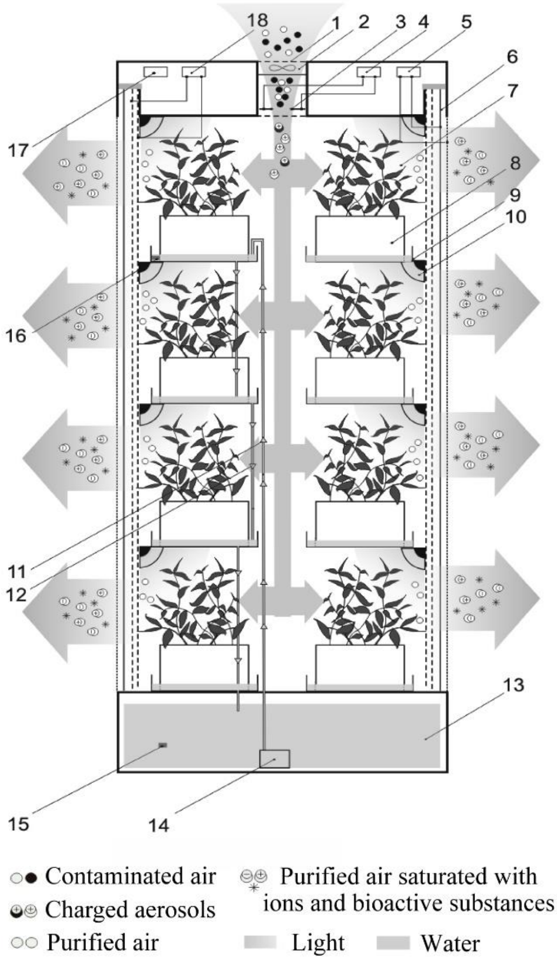

Fig. 1. Functional scheme of hardware-biological complex, where: 1 – air intake; 2 – fan; 3 – electrodes of unipolar ionizer; 4 – power supply of unipolar ionizer; 5 – constant-voltage source; 6 – electrode of bipolar ionizer; 7 – plants; 8 – flower pots; 9 – planter flats; 10 – light-emitting diodes (LED); 11, 12 – water supply; 13 – water reservoir; 14 – pump; 15, 16 – water-level receiver; 17 – sensor; 18 – confining potential

The presence of a confining potential (18) on the perforated grilles exclude yield of charged aerosol clusters of the enclosure. As a result purified air against of aerosol and microbial contaminations and humidified air, rich in biologically active substances come out of complex. Passing grilles, the air is saturated with light ions at concentrations according to Russian standards SanPin 2.2.4.1294-03, and distributed into the room.

2 Materials and methods

2.1 Assessment of green plants cleaning degre

Cleaning degree of plants was assessed during experiment. Investigation of possibilities air cleaning by plant was made during laboratory experiments. Laboratory experiments were provided on the model of hardware-biological complex of recirculating type and its construction presented in this paper

The research methodology includes determining possibilities of green plants to air purification by aerosols for indoor “standard” air and contaminated air by aerosols in a test chamber plants. Modelling air contamination into the camera used tar aeroform from cigarettes. Tobacco smoke contains 4000 components approximately. It consist from both fractions aeroform and aerosol and contain different chemical elements as carbonous oxide, ammonium, formaldehyde, etc.

The investigation were made with two groups of plants, which are characterized by a considerable area of leaf mosaic, high density of thin scarfskin containing substances with high level of adhesive capacity due to the presence on the leaf surface of fatty acids and waxes (first group) or developed transpiration capacity (second group). The first group presented by *Sansevieria trifasciata* (bowstring hemp) and the second group included *Tradescantia fluminensis Vell* (spiderwort).

2.2 Coefficient of the air cleaning efficiency by the plants

Efficiency coefficient of the air cleaning by the plants depends on the time. It calculates by the next equation (1):

$$K_{ef}=((N_{in}-N_{out})/N_{in})*100\%, \quad (1)$$

where N_{in} and N_{out} are aerosol concentration of corresponding dispersivity on input and output of complex.

Results of calculation the efficiency of air purification are presented below.

3 Results and discussion

Laboratory experiments were made for assessing capability to purify indoor air against different particle size of contaminated air by cigarettes. The results of investigation purification capability of Tradescantia fluminensis Vell presented on the Fig. 2 and Fig. 3.

The analysis of the graphs show the concentration of aerosol particles at the output of the complex have low values, almost tending to zero, which clearly underlines the effectiveness of the hardware-biological complex.

Calculations show that for all the experiments purification efficiency of the plants was approximately at the difference level, depending on the particle size of contamination agents. The rate for particle with size 0.3-0.4 µm presents on the level of 80-90%, for coarse particles it consist of 85-88%. This experiments show that use of mechanical facilities with biological methods of purification is significantly enhances cleaning properties of the complex and thus reduces the load on the plant communities.

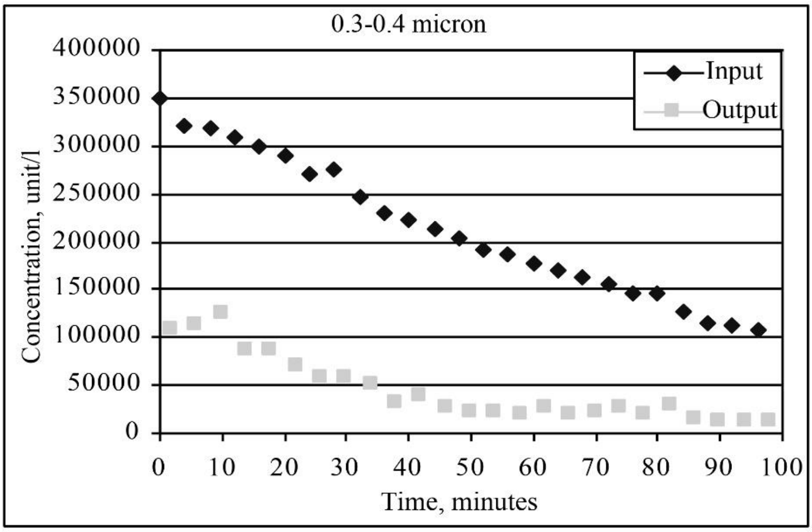

Fig. 2. Changing the concentration of tobacco aerosols with particle sizes 0.3-0.4 micron in a room of 130 m^3 when pumping contaminated air at a flow rate of 100 m^3/h through the complex with *Tradescantia fluminensis Vell*, unipolar ionizer and confining potential

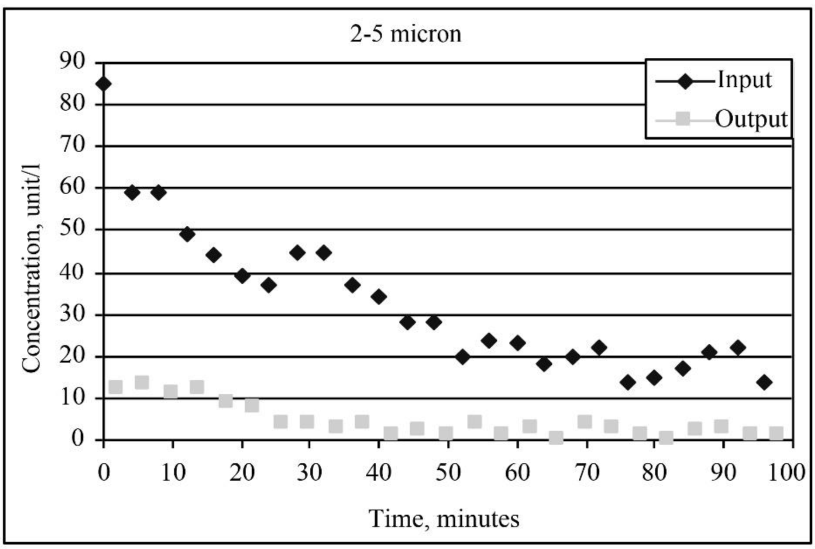

Fig. 3. Changing the concentration of tobacco aerosols with particle sizes 2-5 micron in a room of 130 m3 when pumping contaminated air at a flow rate of 100 m3/h through the complex with Tradescantia fluminensis Vell, unipolar ionizer and confining potential.

Comparative analysis of the data obtained with the use of *Tradescantia fluminensis Vell* and *Sansevieria trifasciata* generally reveals similar patterns. However, *Sansevieria trifasciata* provides more stable purification features of the air for a long time. Probably it depends on different structure of the leaves of the plants. *Sansevieria trifasciata* is a plant from arid semi-desert regions has high content of fat-soluble substances on the surface of a leaves. It provides much higher capacity to attachment of the aerosol particles. However *Tradescantia fluminensis Vell* has on its surface a more water-soluble compounds which provide a sufficiently effective attachment of aerosol particles, but weaker anchor, and during water evaporation the particles can again be provided in the environment.

4 Conclusions

In the residential and office buildings located along major urban highways or industrial areas contaminated air enters. In terms of quality of life this air has poor quality for life and health. It should be noted that indoor air is also exposed to a variety of contamination agents emitted during combustion of products (carbon dioxide, tobacco smoke, nitrogen dioxide), biological sources (dust mites, mold, Legionella) and other organic and inorganic contaminants. Thus, purification of the indoor air is very important tasks for modern engineering technologies.

Vertical hardware-biological complex of recirculating type is environmental friendly technology that shown during experiments.

According to the results of laboratory tests and diagnostic status of the air, making the following options by location of vertical hardware-biological complex of recirculating type:

1) in case of domination in the air of rooms indoor contaminants it is possible to place the complex in the area of the source of pollution;

2) in case of external sources of contamination it is possible to connect the complex to ventilation system.

Moreover different species of plants have various capabilities to air purification from pollutants. Thus special composition of plants into the vertical hardware-biological complex of recirculating type will provide to more effective purification air.

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