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INDOOR ECOSYSTEM SERVICES: IMPACTS OF PLANTS ON AIR QUALITY

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SUMMARY

Ecosystem services have been the focus of recent research on ecology, biodiversity and human health. As most of this research has placed emphasis on natural ecosystems, there is a lack of data on the effect of indoor and urban ecosystems on both human health and the quality of human life. One of the most common health issues associated with urban and indoor spaces is the quality of air. Considering that humans spend most of their time indoors, accompanied by a lack of fresh air due to industry growth and environmental degradation, there is an obvious need for a non-invasive and non-obtrusive air purification system. This paper presents the results of the indoor air quality monitoring under non-controlled conditions, i.e. the changes in air quality induced by the common indoor ornamental plant Sansevieria trifasciata 'Laurentii'. The following air quality parameters were observed: the relative humidity and temperature of air, as well as the concentrations of carbon-dioxide, methane and overall VOCs. Measurements were performed using the commercial CO_2 *data logger Extech SD800 and the in-house developed Arduino Uno-based measuring device with different sensors. The results obtained show the changes in the indoor air quality relative to the presence or absence of the selected plants. A sudden increase in the overall VOC (*NH_3*,* NO_x*, benzene and smoke), methane and carbon-dioxide concentrations was recorded after the plants were removed from the indoor space. The purpose of this research is to form a basis for designing a biological purification system as a low-cost and environment-friendly method for the monitoring and purification of indoor air.*

Key words: *ecosystem services, Sansevieria trifasciata, indoor air quality, biological purification system, quality of life*

INTRODUCTION

Ever since the Industrial Revolution, people seem to have been losing that special connection with nature, which used to be constant in the earlier stages of our personal and social development. As a result, the so-called Western style of living has cost us dearly, leading to a decrease in the overall quality of human life and health (Husti et al., 2016). Considering the social and economic effects of human health, the role of nature as a non-obtrusive method for improving human health and the quality of human life should be defined as soon as possible. In recent years, a number of studies on ecosystem services have been published, focusing mainly on natural environments in the wilderness (Martin et al., 2010) while disregarding the fact that people spend most of their time indoors (Shwartz, 2018). Therefore, there is a limited body of data on urban and indoor ecosystems, as well as on the appropriate methods of their assessment and practical implementation for human purposes (Lyytimäki, 2012). The quality of indoor air is an important factor for determining the level of human wellbeing and exerts a major impact on human health. Indoor air contamination is a complex problem which, according to the World Health Organization (2010), involves the negative effect of particles (namely dust and smoke), biological agents (molds and spores), radon, asbestos, and gaseous contaminants (namely CO, CO_2, NOx, SOx, aldehydes and VOCs (Volatile Organic Compounds)). Different volatile organic compounds found in indoor air are defined as air pollutants which are associated with various health issues. The long-term exposure to harmful particles such as formaldehyde, xylene, toluene, benzene, methane and NOx can lead to the deterioration of chronic diseases and the occurrence of allergy- and flu-like symptoms, whereas some of these compounds (namely formaldehyde and benzene) are carcinogenic (Jones, 1999; Kostiainen, 1995; Xu et al., 2013). On the basis of the data obtained by comparing the existing methods for indoor air purification, Guieysse et al. (2008) argued that only devices comprising biological components (plants and/or microorganisms) were capable of significantly removing VOCs from the indoor air. As people are exposed to different pollutants such as VOCs on a daily basis, there is a need for air purification systems that could reduce the concentration of pollutants without adverse effects on the environment and human health. Certain ornamental plants commonly used in indoor spaces (such as the mother-in-law‘s tongue (Sansevieria trifasciata)) can improve the quality of air (Kim et al., 2008; Yoo et al., 2006; Begum & Gopinath, 2017; Wolverton & Wolverton, 1993; Kays, 2011). As a common indoor ornamental plant, Sansevieria trifasciata has low maintenance requirements, featuring good general aesthetic qualities. This plant is commonly called the ‘bedroom plant’ because it releases higher concentrations of oxygen at night as opposed to most other plants. The purpose of our research is to promote indoor ecosystem services and the role of plants in human lives, as well as to develop a system for monitoring, assessment and potential improvement of air quality.

MATERIAL AND METHODS

To examine To examine the potential impact of non-obtrusive botanical purification system on the indoor air quality under real conditions, a total of eight pots with Sansevieria trifasciata ‘Laurentii’ were placed in a small single bedroom. The plant selection process was based on the literature overview. Sansevieria trifasciata 'Laurentii' (Fig. 1) was selected for its ability to remove certain indoor air pollutants and release larger amounts of oxygen at night (because most people spend the night sleeping in a bedroom). For this purpose, we developed a low-cost approach to monitor the following air quality parameters: air temperature (°C), relative air humidity (%RH) and the concentrations (ppm) of carbon-dioxide (CO_2), VOCs and methane. The self-designed biological air purification system features two components: Sansevieria trifasciata ‘Laurentii’ plants and monitoring devices. The plants with an average height of 45 cm were potted in a standard substrate mix for ornamental plants and allocated in two groups of 3 and 5.

Figure 1. *Sansevieria trifasciata* ‘Laurentii’

Figure 2: Extech SD800

Figure 3: Arduino Uno-based measuring device fitted with low-cost sensors

Air quality Air quality parameters were continuously measured for 23 days using the commercial CO_2 data logger Extech SD800 (Fig. 2) and the Arduino Uno-based measuring device fitted with low-cost sensors: DHT11 (a temperature and relative humidity sensor), MQ-135 (a poisonous VOCs sensor) and MQ-4 (a methane sensor) (Fig. 3). According to the manufacturer, MQ-135 reacts to the presence of NH_3, NOx, benzene and smoke. The present low-cost approach was based on the use of uncalibrated VOCs and methane sensors. The precise ppm calculations

for MQ-135 and MQ-4 sensors require one step prior to the measurement-determination of sensor‘s resistance (Ro) at 100ppm of NH3 in the clean air. After Ro is determined, ppm calculations are based on the comparison of Ro and the measured sensor‘s resistance (Rs) at a specific gas level using the following equation: ppm = a*(Rs/Ro)^b (where a and b are the specific gas constants). This paper presents the results of ppm calculations based on Ro = 5 kΩ, which is accordance with the distributor’s recommendations (https://www.mikroe.com/air-quality-click). As we are aware that the actual ppm values can be different from those obtained in this study, we only analyzed trends of change in the values measured.
The research was conducted in Banja Luka, Bosnia and Herzegovina, during December 2017. The experiment was divided into three stages (Fig. 4).

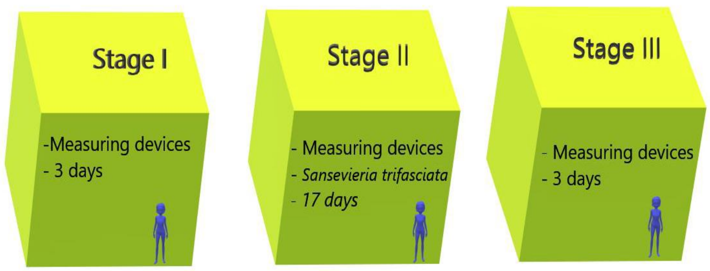

Figure 4. Three stages of air quality monitoring

During the first stage of the indoor air quality parameter monitoring, the devices were placed in the bedroom and measurements were performed under these conditions for three days. During the second stage, which lasted 17 days, the plants were introduced in the indoor space, followed by continuous parameter measurements. During the final third stage of the research, the plants were removed from the bedroom and the air quality parameters were monitored for another three days. Other than the introduction of eight Sansevieria trifasciata ‘Laurentii‘ plants in the bedroom, no changes were made that could affect the results obtained.

RESULTS AND DISCUSSION

The changes recorded in the air temperature (°C), relative air humidity (%RH), carbon-dioxide (ppm), VOC (NH3, NOx, benzene and smoke) (ppm) and methane (ppm) values in the bedroom are shown in Fig. 1. Each graph consists of three experimental stages: Stage I (black lines) marks the period before the plants were introduced in the bedroom, Stage II (green lines) indicates the presence of the plants and Stage III (black lines) marks the period after the plants were removed from the bedroom. The data obtained show changes in the parameters measured at different stages of the monitoring process. The air temperature parameter was found not to be affected by the presence of the plants. As the experiment was conducted in the winter while the heating was on, the temperature values ranged constantly between 20-24°C. A decrease in the relative air humidity was recorded at the end of Stage II, which is probably the consequence of a longer period of high temperatures. Furthermore, there was no clear and measurable evidence that the plants exerted any impact whatsoever on the concentrations of carbon-dioxide (CO2) and the overall VOC values during Stage II. After the plants were removed from the room in Stage III, a sudden increase in the concentrations of these compounds was recorded, which can be attributed to the absence of the plants as no other change was made in the bedroom.
These changes are highly noticeable in the methane (CH4) monitoring graph. There is an evident decrease in the methane concentration at the end of Stage II, compared to a sudden increase in the methane concentration at the beginning of Stage III. Moreover, a larger number of peaks were recorded in the CO2 and VOCs values during Stage III compared to these values recorded during Stage II.

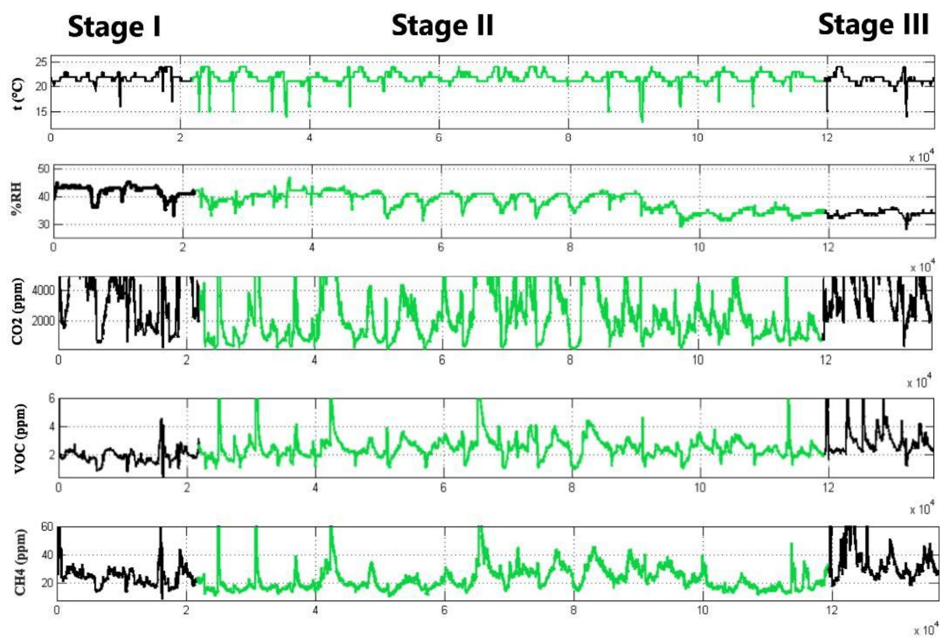

Figure 4. Three stages of the experiment: Stage I (black lines), Stage II (green lines) and Stage III (black lines)

Indoor air quality is one of the major factors contributing to the health and overall wellbeing of each individual (Duflo et al., 2008). The majority of people spend most of their lives in indoor spaces, which feature different sources of pollution. Even indoor air in our homes is polluted from building materials, human activities (Hänninen at al., 1999) and outdoor air pollutants. We are fully aware that the results obtained in this study do not unequivocally argue that Sansevieria trifasciata 'Laurentii' has a positive impact on carbon-dioxide, methane and VOCs concentrations in the indoor air. However, these results unequivocally indicate a sudden increase in carbon-dioxide, methane and VOCs concentrations after the plants were removed from the room. Therefore, this research has shown that inexpensive custom-designed botanical purification system for indoor air quality monitoring and improvement can provide data on the indoor air quality and the positive impact of plants on indoor air pollutants. Although some authors claim that previously conducted studies have failed to confirm the positive impact of plants on the air quality in indoor spaces (Apte & Apte 2010), others sources claim that there is an evident positive impact of certain ornamental plants such as Ficus elastica, Dracaena deremensis and Sansevieria trifasciata (Husti et al., 2016) on indoor air pollutants. These contrary reports confirm that there is a constant need for a functional and economically affordable botanical system for air purification.

CONCLUSION

As satisfactory methods for the monitoring and removal of indoor air pollutants have not been fully developed and employed yet, this research was conducted in order to develop a preliminary low-cost method for the non-obtrusive natural improvement and monitoring of indoor air quality using ornamental plants and microcomputer-based measuring devices. Moreover, this biological purification system can easily be adjusted to the specific indoor space or user's preferences with regard to the device modifications (i.e. fitting the device with other sensors) and the use of different plant species. The present study poses a series of multidisciplinary questions for future research such as the design and adaptation of calibrated sensors for air quality monitoring and the selection of most favorable plant species and genotypes for the improvement of indoor air. Further research on adequate plant species and the number of plant individuals in a certain indoor space relative to the type and concentration of indoor air pollutants would definitely increase the efficiency of ornamental plants in improving the quality of indoor air.

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