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Characterization and performance evaluation of a full-scale activated carbon-based dynamic botanical air filtration system for improving indoor air quality

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ABSTRACT

A dynamic botanical air filtration system (DBAF) was developed for evaluating the short and long-term performance of botanical air cleaning technology under realistic indoor conditions. It was a fan-assisted with controlled airflow, activated-carbon/hydroculture based potted plant unit. The DBAF was first tested using a full-scale stainless chamber to evaluate its short-term performance. It was then integrated in the HVAC system of a new office space (96.8 m^2) to study the effects of moisture content in the root bed on the removal efficiency, and the long-term performance. The results indicated that 5% outdoor air plus botanical filtration lead to the similar indoor formaldehyde/toluene concentration level as 25% outdoor air without filtration, which means that the filtration system was equivalent to 20% outdoor air (476 m^3/h). The DBAF was effective for removing both formaldehyde and toluene under 5–32% volumetric water content of the root bed. It also performed consistently well over the relatively long testing period of 300 days while running continuously. The reduction in outdoor ventilation rate while using the botanical filtration system to maintain acceptable air quality would lead to 10–15% energy saving for the cold climate (Syracuse, NY), based on simulation analysis using EnergyPlus. For winter condition, the filter was also found to increase the supply air RH by 20%, which would decrease the dryness of air. For summer condition, the increase of RH in summer would be within 15% of the RH condition when no botanical air filtration is present.

1. Introduction

Indoor air quality (IAQ) remains a very important issue today because it can significantly affect people's health, comfort, satisfaction and productivity. U.S. Environmental Protection Agency (EPA) studies of human exposure to air pollutants indicated that indoor air levels of many pollutants may be two to five times, and occasionally, more than 100 times higher than outdoor level [1]. In recent years, comparative risk studies performed by the EPA and Science Advisory Board (SAB) have consistently ranked indoor air pollution among the top five environmental risks to public health. The importance of indoor air quality is also due to the absolute amount of time that people spend indoors. Most Americans spend up to 90% of their time indoors and many spend most of their working hours in an office environment [2]. It has been estimated that the potential productivity gain by providing better indoor environmental quality are over $40 billion to $200 billion per year in the U.S [3].

Indoor air quality can be improved by three ways: controlling source, designing ventilation systems to dilute and exhaust contaminated air, and cleaning air [4]. Nowadays, there is no single fully satisfactory method for volatile organic compounds (VOCs) removal from indoor air due to the difficulties associated with the diversity and variability at which VOCs are typically found in the indoor environment. Several studies have demonstrated the potential of biological methods to remove indoor VOCs [5–14]. Common indoor plants may provide a valuable weapon in fight against rising level of indoor air pollution. Those plants in your office or home are not only decorative, but NASA scientist found them to be surprisingly useful in absorbing potentially harmful gases and cleaning the air inside modern buildings [6,7]. However, there are very limited data demonstrating the effectiveness of botanical air filtration under realistic and full-scale ventilation conditions and inadequate understanding of the true removal mechanisms in these systems [15].

How well do houseplants perform when they are used as cleaner for improving indoor air quality? In 1990s, a published research indicated that potted plant can remove 9.2–90% formaldehyde, benzene or xylene in a small sealed-chamber [7]. The pollutant

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