INDOOR AIR QUALITY (IAQ) IMPROVEMENTS USING BIOFILTRATION IN A HIGHLY EFFICIENT RESIDENTIAL HOME

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INTRODUCTION

Americans spend the majority of their time indoors where levels of pollutants may run two to five times—and occasionally more than 100 times—higher than outdoor levels [1]. Many of these pollutants can cause adverse health reactions in building occupants, which can contribute to lower worker productivity and increased sick leave. Traditional methods of indoor pollutant control in sealed buildings involve the use of outdoor ventilation. Outdoor ventilation requires the intake of outdoor air, which must be heated or cooled to meet indoor temperature and humidity requirements. This represents between 10–20% of the total energy consumption of a building [2].

Even though past research has touched on incorporating actual biofiltration into building systems, there is little to no research on the incorporation of biofilters into energy-efficient residential dwellings. One of the first applications of biofiltration for energy-efficient homes was conceived close to 30 years ago [3]. Figure 1 shows an example of a particular design that could be piloted in a building system.

Biofiltration research has gone through numerous stages over the past 30 years, including: focusing on plant research to determine which plants are the most efficient at filtering contaminants; refinements to the construction of biofiltration systems; and the air quality impact that biowalls have on buildings [4-15]. While significant time and effort has been spent on identifying the best plant combinations to filter the air in biofiltration systems, little effort has been made on analyzing the potential energy savings of these systems. If it is also shown that a particular biowall system has the potential to significantly reduce the energy consumption in residential and commercial buildings, which jointly represents more than 60% of the electric energy consumption in the United States [1], their subsequent installation in buildings will have more validity and merit. The purpose of this paper is to elucidate a novel application to be piloted using biofiltration as a means to manage indoor air quality in buildings, as well as to potentially reduce overall energy consumption.

KEYWORDS

biofiltration, indoor air quality, biowall, energy efficient residential home

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METHODS

The main purpose of the biofiltration system is to filter the air in the home. In addition, the expectation would be to realize a certain level of energy savings by using a biowall over traditional dilution ventilation techniques to control indoor air quality in a highly efficient residential home. In order to make an assessment on both accounts, a number of different airborne contaminants or indoor air quality surrogates will be monitored for the pilot study. Initially, these included carbon dioxide, volatile organic compounds (VOCs), relative humidity, and temperature.

The testing environment for this research is a newly constructed facility, built for an international design competition. The 984 square foot building is a solar powered, highly efficient home that is fully operational and habitable. The biowall was designed as an integrated component of the HVAC system of the home. Design of the building began in the fall of 2010, with completion realized in the summer of 2011. It was the goal of the researcher to collect data during the testing phase of the house. The building was designed so that the HVAC system could operate with or without the biowall to provide air filtration capability. If the facility is not utilizing the biowall, then it will use traditional dilution ventilation and an energy recovery ventilator to lower indoor air contaminants. The fully-installed biowall used in this study is shown in Figure 2 below.

FIGURE 1. Example of an original biofilter design for indoor applications (Permission: LeAnn Hurst).

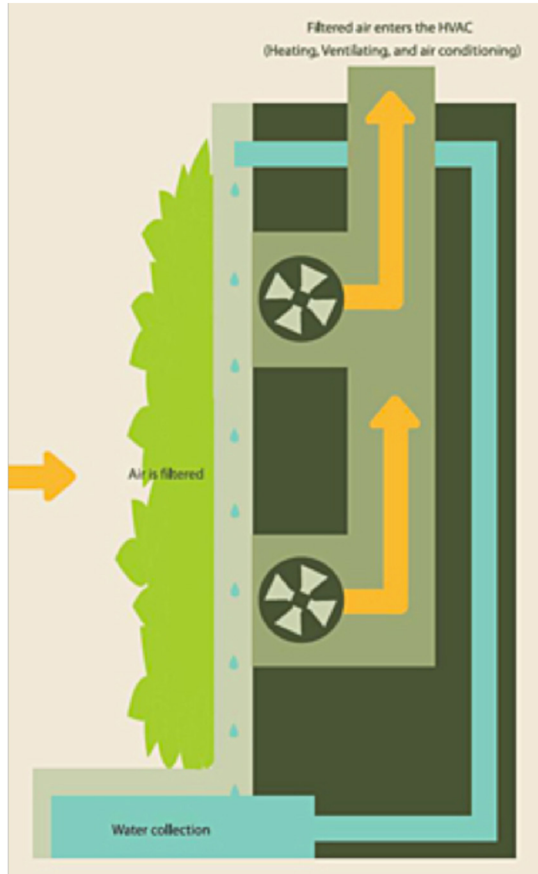


FIGURE 2. Novel biofilter unit installed in home for pilot study.

For this pilot study, testing involved operating the home with and without the biowall in operation, and monitoring various sensors to determine energy usage. Temperature monitoring was required upstream and downstream of both the biowall and also the energy recovery ventilator. Sensors were selected for each contaminant/surrogate of concern and a data acquisition system was designed and installed into the home to collect the relevant data.

The following section provides the data and results from an initial pilot study focusing on proving the effectiveness of the biowall system on enhancing overall indoor air quality. The contaminants/surrogates measured included carbon dioxide, VOCs, relative humidity, and temperature.

DATA AND RESULTS

The results from a pilot run conducted in the competition residential home are shown graphically in Figures 3–6 below. The pilot run was from approximately nine days of operation during the months of August and September of 2011. Figures 3 and 4 show a significant reduction in the levels of carbon dioxide and VOCs realized with the unit in operation while Figures 5 and 6 provide evidence of enhancements in the relative humidity and temperature conditions during biofiltration.

Over the duration of the pilot study, the average reduction in VOCs downstream from the biowall was calculated to be approximately 250% when compared to the upstream values. In addition, the average reduction in carbon dioxide concentrations in the air after the biofiltration was approximately 35%, while the average relative humidity increase downstream was nearly 7%. During the study, the overall carbon dioxide levels in the air ranged from 550–1975 ppm before running through the biowall. In contrast, the carbon dioxide levels ranged from 360–1370 ppm in the air downstream of the biowall. The range of values measured for VOCs was from 3–76 ppm of CO_2 equivalent units upstream but ranged from 3–41 ppm of

FIGURE 3. CO_2 reduction in residential test building using biowall.

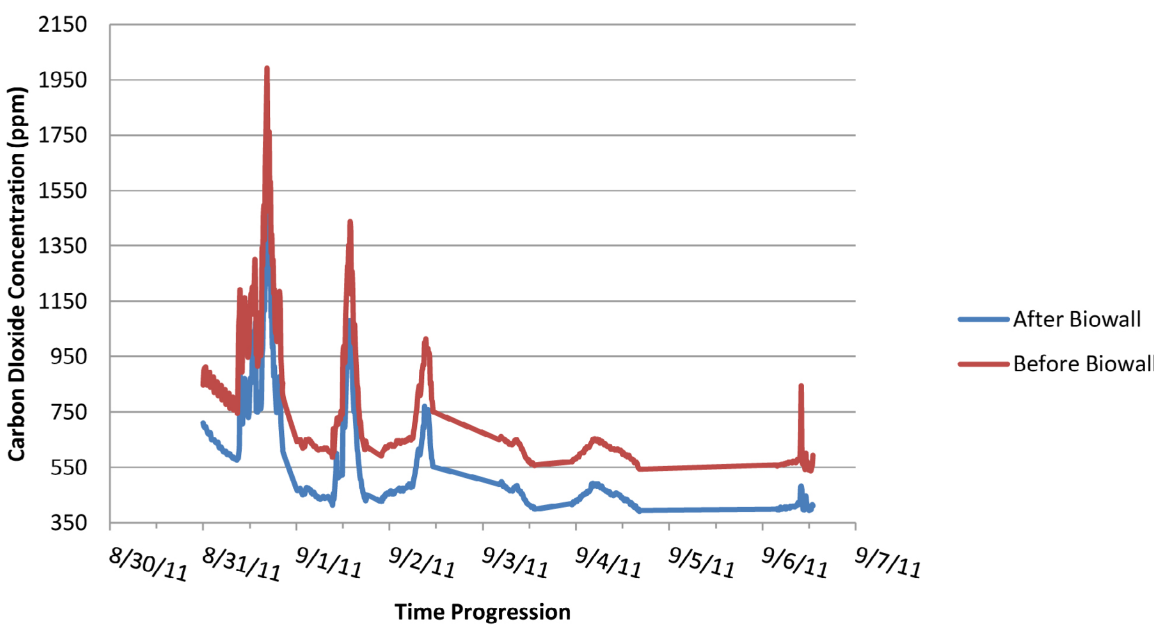


FIGURE 4. VOC reduction in residential test building using biowall.

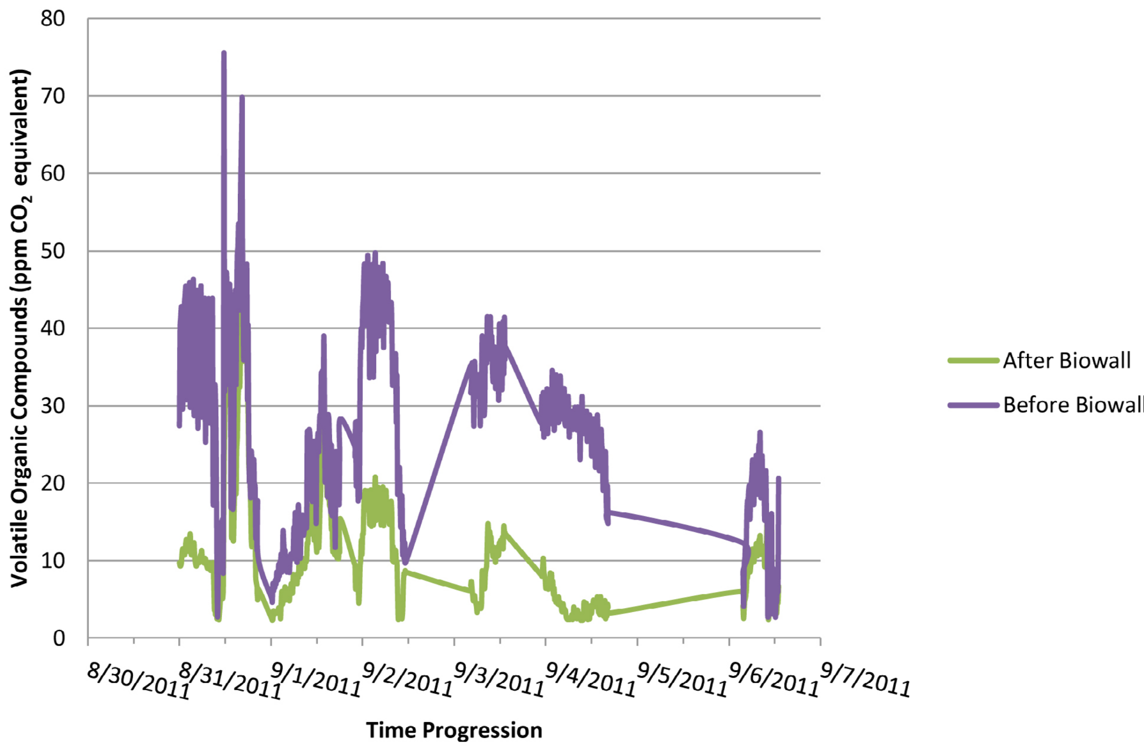


FIGURE 5. Relative humidity increase in residential test building using biowall.

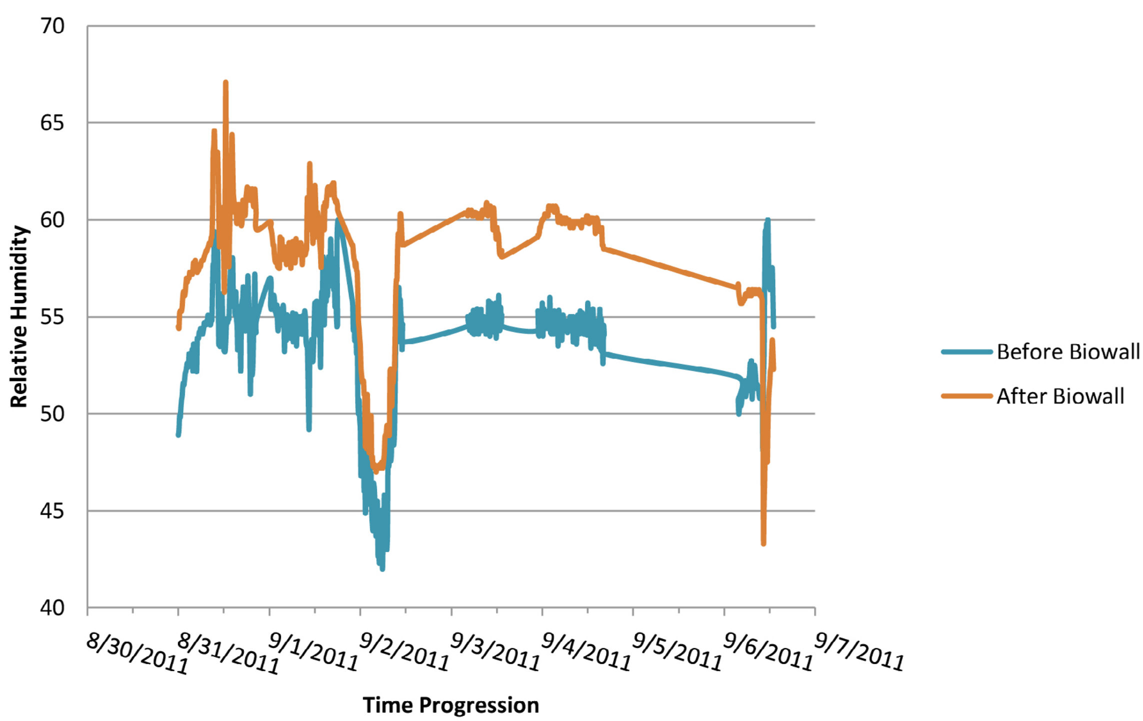
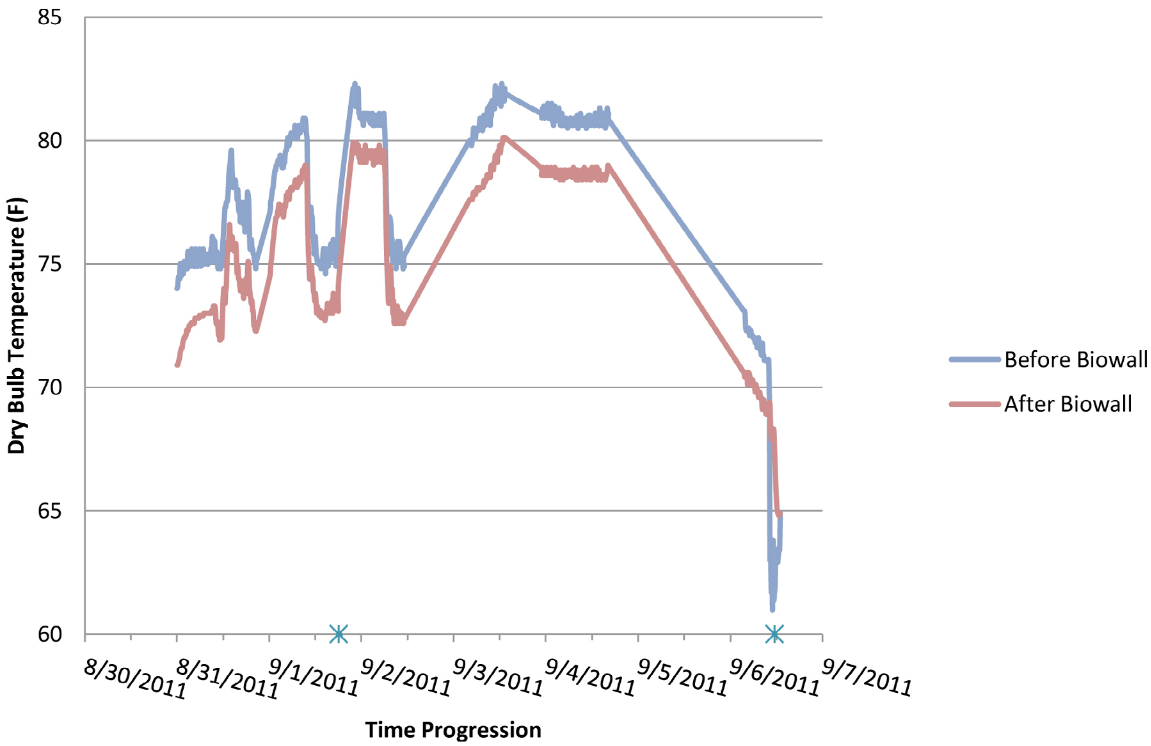


FIGURE 6. Temperature decrease in residential test building using biowall.



CO_2 equivalent units in the downstream air. Relative humidity values measured from 43–67% upstream, while those found downstream from the biofilter were from 42–60%. Typically, temperature values varied from 3–5 degrees F before and after the biofiltration activity, with the temperature values going down in each case in the air after passing through the biowall. Thus, the data from this pilot run suggests the expectation of significant energy savings from operating the biowall for HVAC cooling cycles during warmer weather conditions.

SUMMARY AND CONCLUSIONS

A review of the literature involving biofiltration and its potential use in residential buildings was presented. In addition, a novel approach for using biofiltration as a means for improving building indoor air quality and improving energy efficiency was presented and assessed on its merit. A technique was elucidated for testing the particular unit and determining the potential energy savings due to its implementation.

Results from the pilot test run conducted in the competition residential building showed promise. With the biowall unit in operation, VOC and CO_2 levels were appreciably reduced while overall temperature decreased and relative humidity increased. Future work will include a more extensive field study of the effectiveness of the biowall in reducing environmental contaminants and energy usage.

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