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A Review of the Effectiveness Study of Botanical Components That Improves Air Filtration

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A Review of the Effectiveness Study of Botanical Components That Improves Air Filtration

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Abstract. This paper focus on the review of green filtration system that incorporated with evaporative cooling that used to enhance indoor air quality. This system was invented in attempt to thrive a clean environment that becomes a solution for certain places. Indoor air quality (IAQ) and public health risk connected to each other, it is due to the percentage of city population that stays indoors rather than go for outdoors. Indoor air contamination are originated from mixed origin such as volatile organic compounds (VOCs) and indoor airborne particulate matter (PM). There are two (2) methods will be discussed in this review paper. First is the modular green wall and VOCs removal. All trial PM factions are effectively reduced by all plant species in method one (1) which helps in improving indoor air quality (IAQ). The same goes for VOCs removal in method two (2). Our centre of attention is assessing the present condition of study and the prospective research needs.

1. Introduction

Indoor air quality (IAQ) and public health risk connected to each other, it is due to the percentage of city population that stays indoors rather than go for outdoors which is around 85 – 90 % [1]. Data collected from B.F. Yu et al in their research titled “Review of research on air-conditioning and indoor air quality control for human health” in 2009. United States Environmental Protection Agency classify indoor air quality as one of the five national health threat [2] which stated in the Classification by United States Environmental Protection Agency (EPA) in their book “Residential Air Cleaners – 2nd Edition” in 2009. Mediocre air quality seems to be a crucial contributors toward human health which generates unpleasantness, severe and continual diseases such as “Sick Building Syndrome (SBS)”. Building occupants encounter ocular, nasal cutaneous irritations, allergies, respiratory dysfunction, headache and even fatigue connected to spending time indoor is used to describe the term sick building syndrome (SBS) [3]. Indoor air contamination are originated from mixed origin such as volatile organic compounds (VOCs) and indoor airborne particulate matter (PM).

Transmit of outside generated particles to indoor raises the indoor particulate matter (PM) concentrations. PM_{10} which incorporated particles smaller than or equivalent to 10 µm in diameter are the most studied done focused on airborne PM range in size. This is because it can infiltrate easily through our breathing and respiratory system [4]. While lung can be penetrated by smaller fine PM fractions, PM2.5 accompanied 2.5 µm aerodynamic diameter. L. C. Ng, et. al in their research in 2015 found that nowadays, modern buildings incorporate with air conditioning system, as well as air tightness assisted in lowering amount of large infiltration particulates outdoor sources [5]. Only some segment of PM from affected air can be filtered due to the incompetent of heating, ventilating and air conditioning (HVAC) systems which already become today’s trending. B. Stephens, et. al found that

Minimum Efficiency Reporting Value (MERV) 4, 6, 10 and 11 filters capable in removing a range of particle sizes approximately 0 to 20% efficiencies [6]. Although there are many more high efficiency filters are available in the market today, it created other problems such as exceed usage and energy, costly maintenance and depleted sustainability, forbye inability in capturing gaseous pollutants [7].
According P. Irga et al. in their several studies done, potted plants is proven to phytoremediate various indoor air contaminants comprises of VOCs and carbon dioxide (CO_2) that able to remove along the plants bacterial community and photosynthesis process [8]. One of the main research that had been done in this field showed that 50–70% of VOCs can be reduced using potted plants [9]. Based on Lohr and Pearsons Mims [10], it was found that across foliar confront plus recommended plants accompanied rugged leaf construction such as trichomes efficient in accumulate PM.
This paper presents the effectiveness of botanical components as air filtration media of indoor environment focusing on PM levels and gaseous pollutants alleviation. And overview of the plant species, bio-system arrangement, progress along the years, method of conducting experiment and result is presented. Figure 1 displays the comparison of PM sizes and Figure 2 demonstrates the indoor contaminants resources.

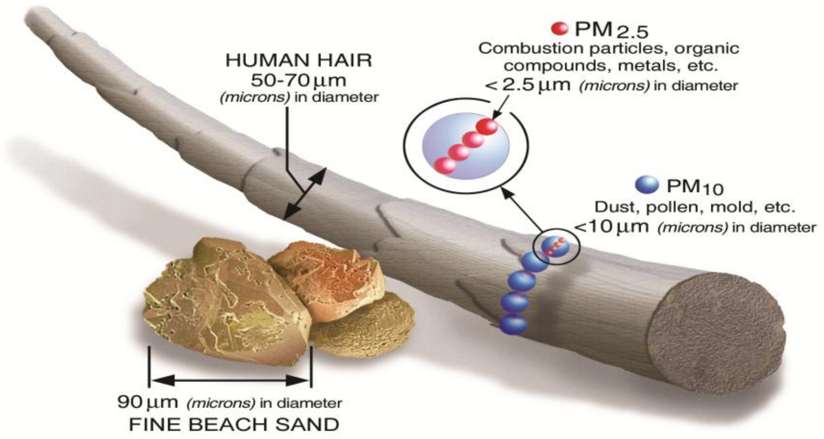

Figure 1. Size comparison for PM particles

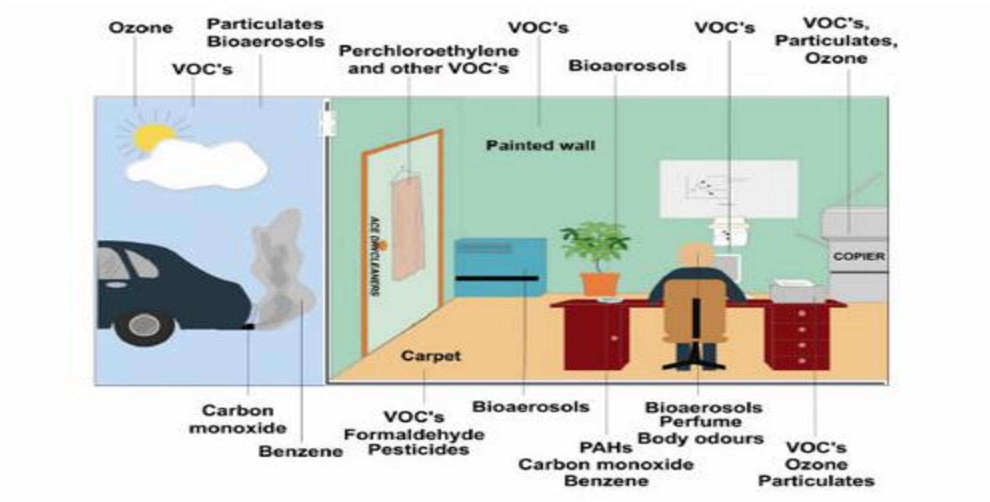

Figure 2. Primary sources of indoor air pollution

2. Botanical Bio-filtration History

For the purpose of this study, bio-filtration and phytoremediation are describes as a hybrid called botanical bio-filtration. Polluted air or water outflow move past a section with intense biological movement where it is being nullify are called bio-filters. Traditional technologies have been replaced to phytoremediation which deem to have non-evasive and worthwhile cost substitute for conditions cleaning up to ten times more economical [11]. T.C. Dollan et al. stated that in the past, United States include phytoremediation within arise list of technical developments [12]. In 1996 in United States, removal of chlorinated VOCs from ground water was done by using poplar trees. In 1980s, the potential of various plants in removing VOCs from indoor were demonstrated by National Aeronautics and Space Administration, US (NASA) scientists [13]. After this, the ability of plants in VOCs removal and reducing PM were tested and demonstrated repeatedly from time to time.

3. Bio-system Arrangement

3.1. Potted Plants (PPs)
In this arrangements, PPs represent the passive type of bio-filter for contaminated air. The water and nutrient must be supplied separately. It also can be placed in exposure chamber which allowing any monitoring to be done as illustrated in Figure 3.

3.2. Plant – assisted (botanical) bio-tricking filters (PBTFs)
PBTFs are called active bio-filtration for a reason. This is because, it equipped with hydroponic plants including filling material root assist and ongoing fed with contaminated air plus nutriment liquid as shown in Figure 4. For indoor air, it is more complement PBTFs rather than PPs as it enable outrageous removal performances.

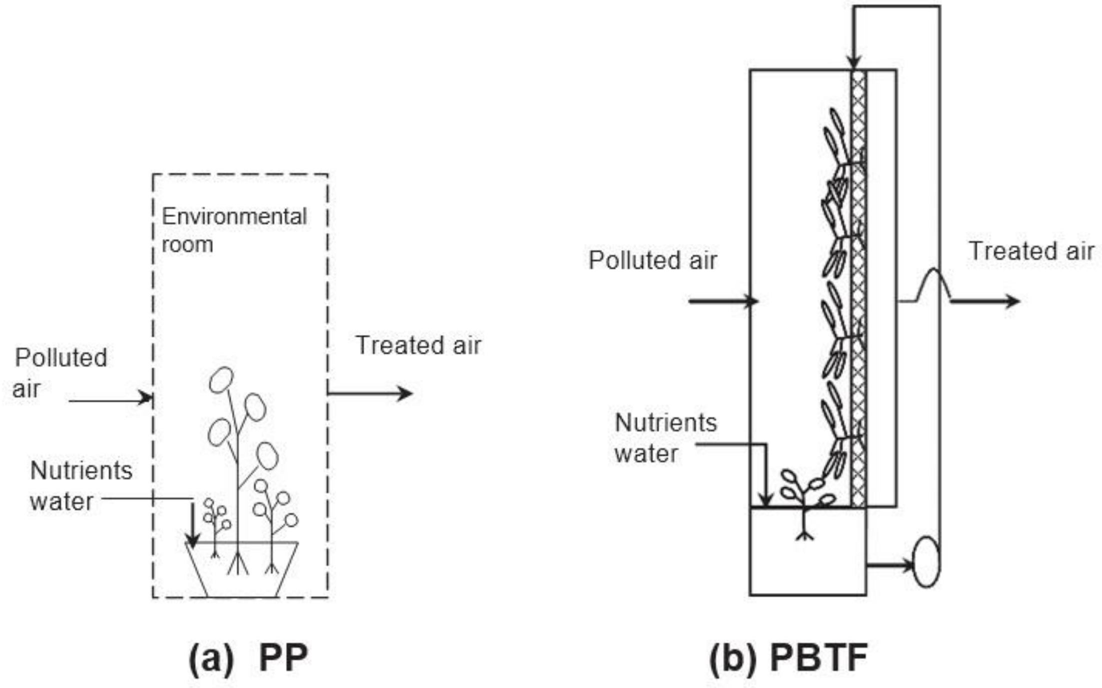

Figure 3. Schematic diagram of botanical bio-filtration systems: (a) PPs and (b) PBTFs.

There are many factors in determining botanical arrangement, such as plant species, growing rates, available funds, location and infrastructure limit.

4. Methods
There are two (2) methods will be discussed in this review paper. First is the modular green wall as suggested by Irga et al [14]. The second is the VOCs removal by W. Scriprapat et al [15].

4.1. Modular Green Wall System

4.1.1. Plant Species

There are seven (7) plant species used in trial for retrieving data of single pass removal efficiency (SPRE). The species are as follow:

i. Fire Flash *(Chlorophytum orchidastrum)*
ii. Fiddleleaf (*Ficus lyrata)*
iii. Goldfish plant (*Nematanthus glabra)*
iv. Lemon button fern (*Nephrolepis cordifolia duffii)*
v. Boston fern (*Nephropelis exaltata bostoniensis)*
vi. Umbrella tree *(Schefflera amate)*
vii. Dwarf umbrella tree *(Schefflera arboricola)*

4.1.2. System Description

It consists of polyethylene module that has 16 holes at front part with an area of 0.25 m^2. Electric powered axial impeller creates suction from rear system and go through plants before released to indoor. Selected plants grow effectively in upright position. More than a year was taken for a system establishment. The setup is shown in Figure 4.

4.1.3. Single Pass Removal Efficiency (SPRE)

Figure 4 shows experiments that were done by using sealed Perspex material chamber with dimension, 0.6m x 0.6m x 0.6m (H) with 216 L capacity. Diffusion of decontaminated airflow past chamber was assisted by the fan within it so that the throw of particles were reduced.

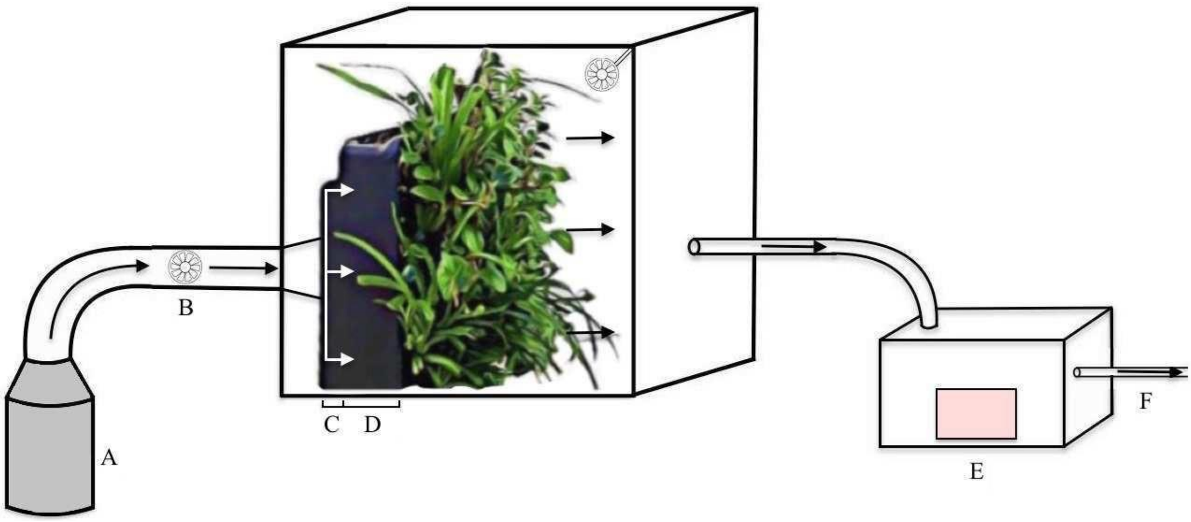

Figure 4. Single pass flow through chamber described in section 4.1.2.

Five (5) PM fractions were recorded for each replicate, $PM_{0.5-1.0}$, $PM_{1.0-2.5}$, $PM_{2.5-5.0}$, $PM_{3.0-5.0}$and $PM_{5.0-10.0}$. Equation below is used for SPRE calculation:

Equation 1:

$$\frac{([PM]control - [PM]trial)}{[PM]control} \times 100 = SPRE$$

4.1.4. Other Variables for Experiment

Along with this experiment, various data was also taken, such as plant morphological data (leaf, root and soil), pressure drop (obstruction to airflow against filter module), and data analysis (PERMANOVA used in comparing average SPRE).

4.2. VOCs removal – Toluene and Ethylbenzene

4.2.1. Plant Species

Twelve (12) plant species were chosen for this experiment:

i. Aloe Vera
ii. Sansevieria Masoniana (Snake Plant)
iii. Sansevieria Trifasciata (Viper Bowstring Hemp)
iv. Sansevieria Hyacinthoides (African Bowstring Hemp)
v. Sansevieria Ehrenbergii (Sword Plant)
vi. Kalanchoe Blossfeldiana (Flaming Katy)
vii. Dracaena Deremensis (Lemon Lime)
viii. Dracaena Sandreniana (Lucky Bamboo)
ix. Codiaeum Variegatum (Growing Crotons)
x. Chlorophytum Comosum (Spider Plant)
xi. Cordyline Fraticosa (Firebrand)
xii. Aglaonema Commutatum (Philippine Evergreen)

4.2.2. Screening Plants for VOCs Removal

All plants were tested for similar leaf's area and measured by graph paper. In order to clear soil fragments, plants were cleaned using distilled water. Use of Aluminium foil to cover pot in order to prevent pot absorption.

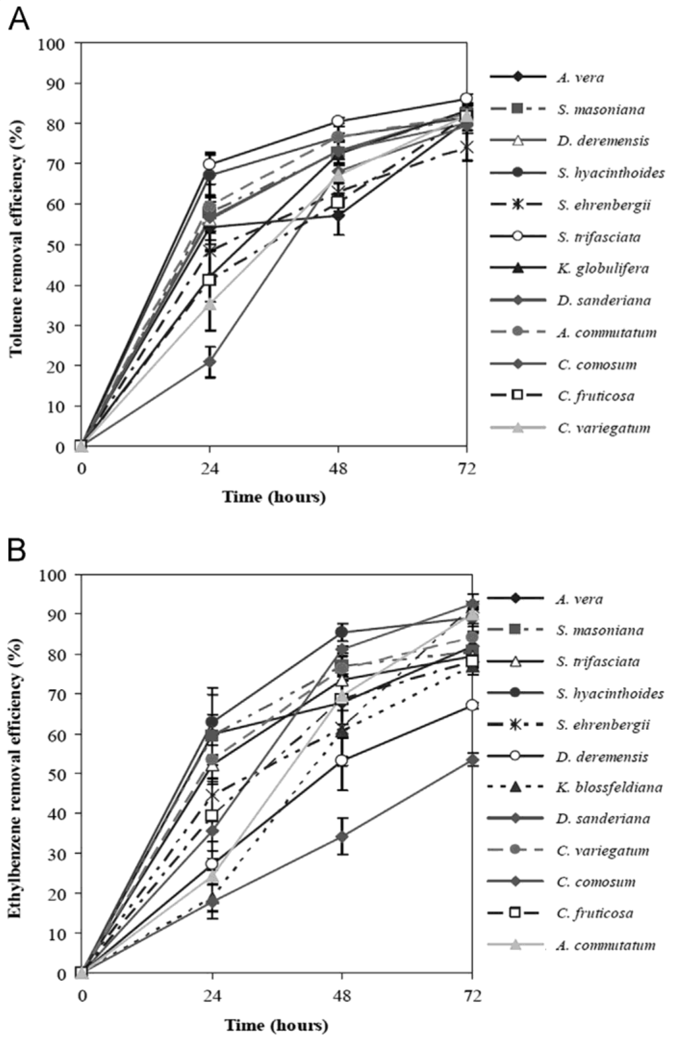

Figure 5. Toluene (A) and Ethylbenzene (B) removal efficiency of plants at 24, 48 and 72 h.

4.2.3. Fumigation
Plant fumigation was experimented by using the glass chamber (Volume 15.6L). Each treatment required three (3) replicate chambers.

4.2.4. Analysis of Gas
Gas chromatography flame ionization detector was used to analyse the concentration of Toluene and Ethylbenzene.

4.2.5. Analysis of Number of Stomata, Cuticle and Phytoxic
Nail varnish was used to duplicate leaf stomata design for stomata figures analyzation. Analytical balance was used to analyse cuticle weight. Plant leaves were measured for photosynthesis and at the same time observe the amount of toxicity.

4.2.6. VOCs Removal Efficiency
From decontaminate chamber, after 72 hours, a gas indication was taken for analyzation purpose as illustrated in Figure 5.

4.2.7. Cuticular Wax Composition Analysis
After 24 hours, in order to remove the waxes, the leaves of designated plants were submerged into hexane.

4.2.8. Analysis in Statistical Form
For complete random design experiment, Analysis of Variance (ANOVA) was used to analyse data statistically.

5. Results and Discussion
According to these two (2) methods, there are many variables to be considered and experimented. To simplify the result gained, both experiments results were separated into different factors:

5.1. Particulate Matters (PM)
All trial PM factions were effectively reduced by all plant species in method one (1) which helped in improving indoor air quality (IAQ). The plant capability as PM filter (SPRE value) also included on their morphological attributes such as roots, structure and leaves.

5.2. Pressure Drop
Escalate filtration capacity also caused by intensifying the pressure drop across root intervention as presented in method one (1). Air that passes through the plant will undergo a resistance to the flow rate and ending up elevated the time taken within plants. It can be said that increased pressure drop relates to SPRE elevated value in mechanical ventilation system.

5.3. VOCs (Toulene and Ethylbenzene) Removal in Plant Screening.
In method two (2), dismissal of Toluene and Ethylbenzene over 12 species had indicated an interesting tendency. Toluene final dismissal was average around 77%, while Ethylbenzene dismissal is more than 70%.

5.4. Cuticular Absorption of VOCs
In absorption between cuticular layer and species, it was found that there was no consequential divergent. As a result, Toluene and Ethylbenzene dismissal and amount of cuticle showed an uncertain relationship.

5.5. Toulene and Ethylbenzene Exposure on Fv/Fm Proportion
Chlorophyll flourescense or Fv/Fm proportion linking difference. Health and purpose of photosynthesis operation and VOCs uptake of plants showed some correlation between them.

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6. Conclusion

This review paper emphasizes of botanical bio-filtration in improving indoor air quality (IAQ). Various characteristics such as IAQ issues, bio-system arrangement, methods in conducting experiment and result performance are presented. Based on the methods presented, there are certain variables that can be used in implementing our green filtration system. Technology of botanical has revealed its promising potential in removing VOCs and PM based on the result reviewed. In the next future, the usage of botanical filtration can be focused more on particular places and conditions in improving air quality (indoors or outdoors).

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