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PM 2.5 Reduction by Installation of Façade with Broad Leaf and Narrow Leaf Plant

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Abstract

PM 2.5 has been an important issue for living in a city due to its negative health impact. PM 2.5 reduction by green facade was studied in this experiment. The steel facade with 3.70 x 2.50 m was installed at the front of the model room which located near the 4 lanes road. Broad leaf and narrow leaf plant as *Epipremnum aureum* and *Chlorophytum comosum* were attached to the facade for 2 weeks. The inside and outside air quality of the model room as PM 2.5, temperature, relative humidity were hourly observed. The result showed that the installation of a facade or green facade could significantly reduce PM 2.5 and heat through the model room via shading and plant evapotranspiration. Both *Epipremnum aureum* and *Chlorophytum comosum* gave better PM 2.5 reduction than steel facade which corresponding to the leaf area index (LAI) during the experiment.

Keywords: Façade, PM 2.5, Broad leaf plant, Narrow leaf plant, Green façade

1. Introduction

The worse air quality has affected people's health all over the world, causing 3.7 million deaths worldwide in 2012 due to particulate matter small than 10 µm, ozone, nitrogen oxide, and sulfur dioxide (World Health Organization [WHO], 2014). The European Environment Agency estimated that during 2012-2014, 50-63% of the Europeans would be exposed to the particle matter (PM) with a particle size of 10 µm and 85-91% to 2.5 µm. This is higher than the level informed by the World Health Organization that the concentration should not higher than 20 µg/cm^3 and 10 µg/ cm^3 for PM 10 and 2. 5 µm. These small particles can cause respiratory irritation via inhalation. Moreover, some types of chemicals can be contaminated with PM 10 and 2.5 and also be passed into the body, for example, polycyclic aromatic hydrocarbon (PAH) and heavy metals (Kleeman et al., 2009). The particulate matter can also get into the circulation system triggering inflammation or blood coagulation (Seaton, Godden, MacNee, & Donaldson, 1995). The larger particulate matter originated from natural sources and human activities, while the smaller particulate matter is generated by the emission of the combustion engine (benzene and diesel) (Chow et al., 2006). Some chemical reactions are stimulated by light (Photochemical reaction) can cause even smaller dust particles and be very toxic as it can emit some heavy metals such as Polyaromatic Hydrocarbon (PAHS, Polychlorinated dibenzo-p dioxide/Dibenzofuran (PCDD/FS) Polychlorinated Biphenyl, PCB) which is a carcinogen (Dzierzanowski, Popek, Gawronska, Saebo, & Gawronski, 2011) . Planting some plants on the wall, a Green wall, could minimize the planting area, insulate a building from heat, noises and increase biodiversity in the urban area (Alexandri & Jones, 2007; Chiquet, Dover, & Mitchell, 2013; Dover, 2015; Jepson, 2016; Johnston & Newton, 2004) . A method of dust measuring has been developed by concerning factors that impact the diffusion of the dust, such as temperature, humidity, rainfall and wind speed. An ability to purify the air of each plant is different because of the different physical characteristics of each plant (shape and size) . The most ideal air-purifying plants would be the ones in the evergreen plant which do not shed their leaves in autumn (Bache, 1979; Beckett, Freer-Smith, & Taylor, 2000; Dochinger, 1980; Feer-Smith, Beckett, & Taylor, 2005; Ram et al., 2012)

This research has studied the effect of green façade installation with golden pothos (*Epipremnum aureum*) and spider plant (*Chlorophytum comosum*) were used as the broad leave and narrow leave plant for PM 2.5 passing in the building and insulation was the other advantage. Roadside room of 8 m^2 was conducted

Suan Sunandha Science and Technology Journal

and the data of dust concentration, temperature and humidity were collected.

2. Materials and Methods

2.1 Preparation the model room

The model room area 8 m^2 (2.15 x 3.70 m) was built with double layers of 12 mm thick gypsum board using a zinc structure. The door size was 0.90 x 2.0 m, the size window was 1.10 x 1.50 m and floor-ceiling was 2.50 m. This room was closed to 4 lanes road (2.00 m) and settled nearby the traffic lights.

2.2 Setting the facade

The facade was installed with steel box pipe line (25 x 25 mm), size 3.7 x 2.5 m. (length x width) and space between each pipe line was 6 x 6 cm. Installed facade was set at 0.50 m away from the room wall (Figure 1).

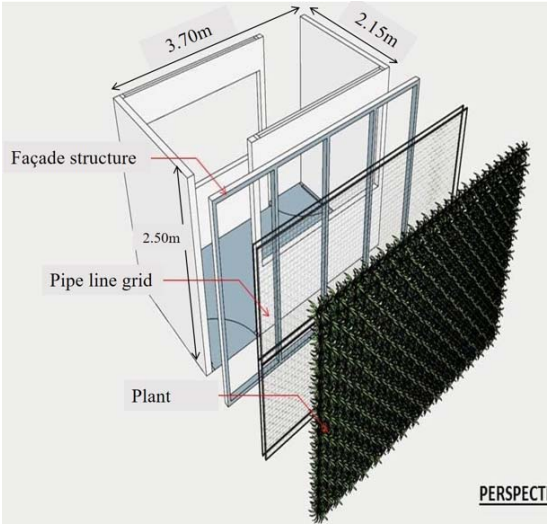

Figure 1. Show 3D model room and its dimension.

2.3 Temperature, relative humidity and PM 2.5 measurement

Thermometer/hygrometer (IBUTTON DATA LOGGER, DS-ds1921G) and particulate matter meter (SNDWAY SW-625B) were installed inside and outside the model room, 0.30 m next to the wall and 1.50 m above the room floor (inside) or pavement (outside). Hourly data were collected for each condition as 1) without façade, 2) with façade, 3) with golden pothos façade and 4) with spider plant façade. Each condition was conducted for 14 days.

2.4 Installation of green facade

The selected plants, Spider plant (*Chlorophytum comosum)* and golden pothos (*Epipremnum oureum*) were used as the representative of narrow-leaf and broadleaf plant. The Spider plant with a density leaf of 25-30 leaf/ pot and golden pothos with a density leaf of 10-15 leaf/pot were tied with the pipe line structure with 240 pots in each experiment. The planting material was a combination of soil, chopped coconut husk and monkeypod tree dry leaf, which was contained in the pot with the size of 8 x 11 x 8 cm. Water was showered on the plant pot twice a day. The experiment was conducted for 2 weeks for each condition.

2.5 Statistics data analysis

Comparability of the PM 2.5, temperature and relative humidity, in each condition in an experiment by one-way ANOVA and Least Square Difference in SPSS V. 17 program at 95% confidence level.

3. Results

3.1 Comparison of the air quality in each period

PM 2.5, temperature and relative humidity were collected hourly for 5 days (Monday-Friday) and the data were compared between outside and inside model room. These parameters were collected for 5 time periods refer to temperature grouping in Panrare, Sohsalam, and Tondee (2015). The result showed the difference of 5 time periods which are (1) 6.30-10.30 AM, (2) 10.30 AM-03.30 PM, (3) 03.30-07.30 PM, (4) 07.30 PM-00.30 AM and (5) 0.30-6.30 AM, respectively (fig 2). The car number of each period was also observed and the high amount of car period (6.30-10.30 AM, 10.30 AM-03.30 PM) resulted to a high concentration of PM 2.5 which the low temperature was the co-factor (Currie & Bass, 2008; Dzierzanowski et al., 2011). A high concentration of PM 2.5 was frequently found at low temperature and emission from car combustion was major source in urban area (Chow et al., 2006) . Low PM 2.5 was obtained at the evening (3.30-7.30 pm) due to high temperature enhances PM 2.5 dispersion to the upper atmosphere even at high car density. Low car density at night time was clearly showed low PM 2.5. The relative humidity inside the model room was high at 10.30 AM-03.30 PM because of low ventilation in the model room. According to this result, the effect of façade installation was observed during 6.30 AM-03.30 PM.

Suan Sunandha Science and Technology Journal

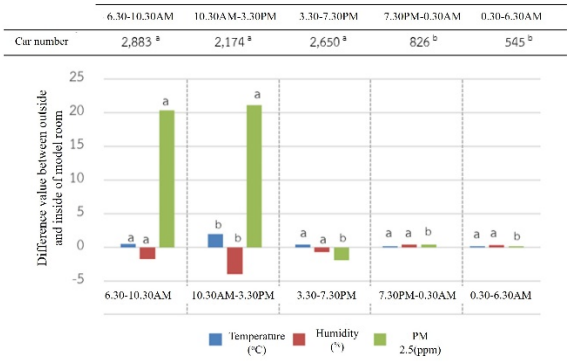

Figure 2. The differences of PM 2.5, temperature and relative humidity outside and inside model room compare with the mean number of car for 5 days (Monday-Friday) in each period.

3.2 The effect of installation façade and green facade on air quality

The PM 2. 5 concentration, temperature and relative humidity were compared during 6.30-10.30AM and 10.30 AM-03.30 PM, the difference between the outside and inside the model room (Table 1). The installation façade and green facade could reduce the amount of PM 2.5 which enters the model room significantly. The % humidity inside the model room was higher than outside due to low ventilation in the model room in 6.30-10.30 AM and resulted from plant photosynthesis in 10.30 AM-3.30 PM.

Table 1. The differences of PM 2.5 concentration, temperature and relative humidity inside and outside of the model room between 6.30-10.30 AM and 10.30 AM-03.30 PM.

Condition	6.30-10.30AM		
	Temp.	Humidity	PM2.5
No facade	0.49[a]	-1.80[a]	17.30[a]
Façade	1.24[b]	-1.22[a]	28.30[b]
Façade+Golden pothos	1.49[c]	-2.13[b]	35.63[c]
Façade+Spider plant	1.66[c]	-2.71[b]	32.40[c]
Condition	10.30AM-3.30PM		
	Temp.	Humidity	PM2.5
No facade	1.99[a]	-4.04[a]	11.09[a]
Façade	2.14[b]	-4.22[a]	14.09[a]
Façade+Golden pothos	3.09[c]	-8.00[b]	18.38[b]
Façade+Spider plant	3.66[c]	-6.11[c]	17.06[b]

Remark: The difference superscript letter in each column showed the difference between conditions at 95% confidence level.

But there may be particles matter return into the atmosphere due to wind and rain. Which the amount of heavy rain will cause the particle matter to come out of the leaves plant. (Weerakkody, Dover, Mitchell, & Reiling, 2018) The large particle matters were easily fall out of the plant leaves, while the wax which covered the plant leaf surface trapped particles matter better than smooth leaf plant. When installing the facade, the temperature inside the model room was reduced significantly ($p<0.05$) because the facade provided shade to the building. Facade with plants or green facade reduced the inside model room temperature than facades ($p<0.05$). The different plant type did not result in different temperature in both time periods. Higher difference temperature was found in 10.30 AM-3.30 PM because the high-density material outside the model room such as sidewalks and public roads accumulate heat during day time. The humidity difference between the outside and inside the building is negative. The inside of the building has humidity accumulation because ventilation is lower in the model room. Green façade installation gave a higher humidity difference ($p <0.05$). The increased humidity was caused by the photosynthesis of plants and the transpiration in the daytime and the amount of photosynthesis varied directly with the amount of solar radiation. The high difference of humidity was observed during 10.30 AM-3.30 PM because broad leaf plant (Golden pothos) gave more transpiration than narrow-leaf plants (Spider plant). This might depend on the leave areas which larger areas could give higher photosynthesis (Figure 3). While the different of plant leaves did not show the difference in PM 2.5 reduction.

a b

Figure 3. The leaf characteristics of narrow-leaf plants (a) and broad-leaf plants (b) used in the experiment.

4. Conclusion

The factors that affect the diffusion of particle matter such as temperature, humidity, rainfall, wind speed and each plant have the potential to reduce particle matter was different, especially non-deciduous plants (Bache, 1979; Beckett et al., 2000; Dochinger, 1980; Freer-Smith et al., 2005; Ram et

Suan Sunandha Science and Technology Journal

al., 2012). In the experimental area was the traffic light intersection with heavy traffic and there was high particulate matter diffusion (PM 2.5). During morning until 3.30 PM showed the highest PM 2.5 due to a large number of cars and low temperature in the morning which resulted to low dispersion of PM 2.5. But during 3.30-7.30 was the highest temperature period (Panrare et al., 2015), PM 2.5 was low because high temperature air rises up and PM 2.5 was also raised to the upper atmosphere (Beckett et al., 2000; Chow et al., 2006; Freer-Smith et al., 2005). The nearby model room could reduce PM 2.5 transfer by using a façade or green façade which could reduce PM 2.5 and temperature inside the model room. Installation of green façade, biofilter, reduced more PM 2.5 and temperature than the façade significantly ($p<0.05$). The plant could reduce wind speed, plant leave could trap particulate matter and hairy leave or wax leave could better trap particulate matter (Beckett et al., 2000; Currie & Bass, 2008; Freer-Smith et al., 2005). The broad leave (Gloden pothos) and narrow leave (Spider plant) in this study did not give the difference performance in PM 2.5 reduction. Extension of this experiment may give the difference between broad leave (Gloden pothos) and narrow leave (Spider plant) because the new plant leave will be produced and the LAI (Leave Area Index) should be further discussed.

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6. Reference

Alexandri, E., & Jones, P. (2007). Developing a one-dimensional heat and mass transfer algorithm for describing the effect of green roofs on the built environment: Comparison with experimental results. *Building and Environment*, *42*, 2835-2849.

Bache, D. H. (1979). Particle transport within plant canopies - I. A framework for analysis. *Atmospheric Environment*, *13*(9), 1257-1262.

Beckett, K. P., Freer-Smith, P. H., & Taylor, G. (2000). Particulate pollution capture by urban trees: Effect of species and windspeed. *Global Change Biology*, *6*, 995-1003.

Chiquet, C., Dover, J. W., & Mitchell, P. (2013). Birds and the urban environment: The value of green walls. *Urban Ecosystems*, *16*, 453-462.

Chow, J. C., Watson, J. G., Mauderly, J. L., Costa, D. L., Wyzga, R. E., Vedal, S., … Dockery, D. W. (2006). Health effects of fine particulate air pollution: lines that connect. *Journal of the Air & Waste Management Association*, *56*(10), 1368-1380.

Currie, B. A., & Bass, B. (2008). Estimates of air pollution mitigation with green plants and green roofs using the UFORE model. *Urban Ecosystems*, *11*, 409-422.

Dochinger, L. S. (1980). Interception of airborne particles by tree plantings. *Journal of Environmental Quality*, *9*(2), 265-268.

Dover, J. W. (2015). *Green infrastructure: Incorporating plants and enhancing biodiversity in buildings and urban environments*. London: Routledge.

Dzierzanowski, K., Popek, R., Gawronska, H., Saebo, A., & Gawronski, S. W. (2011). Deposition of particulate matter of different size fractions on leaf surfaces and in waxes of urban forest species. *International Journal of Phytoremediation*, *13*, 1037-1046.

Freer-Smith, P. H., Beckett, K. P., & Taylor, G. (2005). Deposition velocities to *Sorbus aria, Acer campestre, Populus deltoides* x *trichocarpa* Beaupre, *Pinus nigra* and x *Cupressocyparis leylandii* for coarse, fine and ultra-fine particles in the urban environment. *Environmental Pollution*, *133*(1), 157-167.

Jepson, P. (2016). A rewilding agenda for Europe: Creating a network of experimental reserves. *Ecography*, *39*, 117-124.

Johnston, J., & Newton, J. (2004). *Building green: A guide to using plants on roofs, walls and pavements*. London: Greater London Authority.

Kleeman, M. J., Riddle, S. G., Robert, M. A., Jakober, C. A., Fine, P. M., Hays, M. D., … Hannigan, M. P. (2009). Source apportionment of fine ($PM_{1.8}$) and ultrafine ($PM_{0.1}$) airborne particulate matter during a severe winter pollution episode. *Environmental Science and Technology*, *43*(2), 272-279.

Panrare, A., Sohsalam, P., & Tondee, T. (2015). Constructed wetland for sewage treatment and thermal transfer reduction. *Energy Procedia*, *79*, 567-575.

Ram, S. S., Majumder, S., Chaudhuri, P., Chanda, S., Santra, S. C., Maiti, P. K., … Chakraborty, A. (2012). Plant canopies: Bio-monitor and trap for re-suspended dust particulates contaminated with heavy metals. *Mitigation and Adaptation Strategies for Global Change*, *19*, 499-508.

Seaton, A., Godden, D. , MacNee, W. , & Donaldson, K. (1995). Particulate air pollution and acute health effects. *The Lancet*, *345*, 176-178.

Suan Sunandha Science and Technology Journal

Weerakkody, U., Dover, J. W., Mitchell, P., & Reiling, K. (2018). Quantification of the traffic-generated particulate matter capture by plant species in a living wall and evaluation of the important leaf characteristics. *The Science of the Total Environment*, *635*, 1012-1024.

World Health Organization. (2014). *WHO's Ambient Air Pollution database: Data summary of the AAP database*. Retrieved from http://www.who.int/phe/health_topics/outdoorair/databases/cities/en/