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Performance of *Epipremnum aureum* (Lind. and Andre) Bunting to Remove Toluene

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Abstract: This research aimed to remove toluene vapor contaminated in the ambient environment by *Epipremnum aureum* (Lind. and Andre) bunting. About 5 L of glass chamber were set to close experiment system. The leaf area index of the experimental plant was approximately 150 cm^2. Initial toluene concentrations were examined separately; 0.87, 1.73, 3.46, 6.92, 10.38, 13.84 and 17.30 mg L^{-1}. The results showed that the concentration equilibrium time rise within 120 min. The equilibrium concentrations were 0.33, 0.45, 0.90 1.80, 2.70, 3.60 and 4.50 mg L^{-1} and the removal capacity of toluene absorption of the leaves were 13.60, 32.00, 45.80, 107.30, 182.00, 235.10 and 295.10 μg cm^{-2}, respectively. The toluene removal efficiency of almost initial concentrations was equal on average 74% indicating that the amount of toluene absorptions greatly depended on the amount of the initial toluene concentrations.

Key words: Toluene, *Epipremnum aureum*, phytoremediation, diffusion, absorption, glass chamber, Thialand

INTRODUCTION

Volatile Organic Compounds (VOCs) are the Hazardous Air Pollutants (HAPs), commonly released to air in the workplaces (Silva *et al*., 2008; Guo *et al*., 2004) such as offset printing (Ghittori *et al*., 2003) and electronic industries (Aoki *et al*., 2009). VOCs emission sources are primarily generated by consumption of several commercial products like printing supplies, adhesives, clothes, furnishings, building materials, combustion products as well as electronic appliances (Reyna, 2008). One of the major VOCs associated with printing industries was toluene, an important solvent to dissolve paint and paint thinners, chemical reactants, rubber, printing ink, adhesives (glues), lacquers, leather tanning and disinfectants (Reyna, 2008). Dangerous toluene found in the air during the printing process could be measured from 141-328 mg m^{-3} (Hammer, 2002). Inhalation of toluene 188-375 mg m^{-3} can result in slight headache and fatigue. Exposure to 1,500 mg m^{-3} of toluene also causes irritation of eye and throat, mental confusion. According to Foxall (2007), many harmful effects of toluene 1,875-2,250 mg m^{-3} include anorexia, stagger, nausea, nervousness, momentary loss of memory and reduction of reaction time.

Techniques used for controlling the VOC emission could be classified to destruction, oxidation, bio-filtration, absorption, adsorption, condensation and membrane separation (Khan and Ghoshal, 2000). Another technique for controlling the emission of toluene in the air is known as Phytoremediation that comprises >50 plant species listed by the National Aeronautics and Space Administration (NASA). For instance, *Epipremnum aureum* helps in eliminating and cleaning certain toxic chemicals commonly released to the air such as hydrogen sulfide, ammonia, methyl mercaptan (Oyabu *et al*., 2003) benzene, Tri-chloroethylene (TCE) and toluene (Cornejo *et al*., 1999). The technique of using *E. aureum* (Lind. and Andre) bunting to reduce air pollutants has many advantages such as its availability, tolerance, rapid growth and feasible use.

In this experiment, *E. aureum* was chosen as a removal of toluene commonly vaporized in the air. The efficiency of toluene removal and adsorption capacity of the selected plant's leaves would be determined by the varied amounts of toluene concentrations added into the closed experimental chamber without being dispersed by the room air.

MATERIALS AND METHODS

Plant species and plant preparation: *E. aureum* (Lind. and Andre) Bunting was chosen to be the experimental plant. In the plant preparation stage, the selected plant with a 1 leaf and 2 or 3 bud was chosen to cut into 4 cm long. It had been left to naturally grow for 6 weeks without any controls of the light, temperature or moisture. Then a newly-grown plant (length; 4-5 cm, leaves; 4-5 and average Leaf Area Index (LAI); 150 cm^2) would be used for further experiment.

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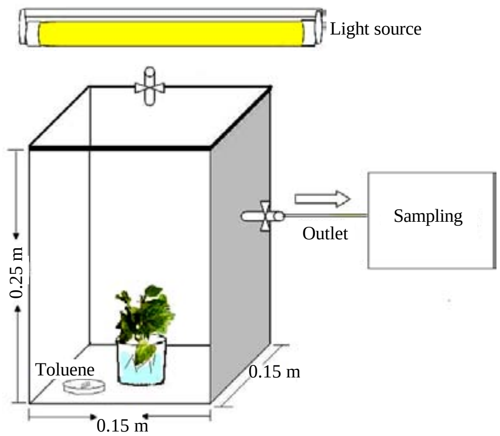

Fig. 1: Schematic diagram of reactor

Experimental chamber: Closed system bench-top chamber (size 0.15×0.15×0.25 m (internal volume 5 m^3) with a removable lid was sealed with a rubber tape (Orwell *et al*., 2004).

Each chamber had a gas valve to direct the sample air. The light was supplied to the plant being studied generated from Oslam fluorescent lamp 20 W (Sylivania product inc.) which was about 395 lux which hung 0.50 m above showed in Fig. 1. The chamber was later placed in another new room where moisture and temperature were precisely controlled.

Studies of toluene removal efficiency: The desired LAI of the experimental plant, *E. aureum* (Lind. and Andre) Bunting was 150 cm^2 as readily to be put into a 100 mL beaker that contained 10 mL of distilled water. The top of the beaker was covered with a paraffin tape. Later the plant was placed into a 5 L chamber. Toluene solution was poured into Petri dish at the bottom of the chamber which had to be immediately closed with a rubber seal lid after that with toluene concentration 0.87-17.30 mg L^{-1} together with air ranging from 30 min to 6 h.

An analysis of toluene by Photo-Ionization Detector (PID): The toluene concentration was observed less by the reaction between the amount of toluene and the plant. Toluene concentration was analyzed by real-time monitoring volatile organic compound (Schiffman *et al*., 2002; MiniRAE, 2000 portable VOC monitor PGM-7600, RAE systems inc).

The sample was directly analyzed by the tube that was pumped up from the air outlet valve of the glass chamber. The flow rate of sample air was 450-550 cc min^{-1}. Based on this equation:

$$E_f = \frac{(C_0 - C_{air})}{C_0} \times 100$$

Where:

E_f = Efficiency of toluene removal (%)
C_0 = Initial toluene concentration (μg L^{-1}) at 25°C 1 atm
C_{air} = Concentration remaining in air (μg L^{-1}) at 25°C 1 atm

The capacity of plant for the toluene removal was based on this equation:

$$q = \frac{(C_0 - C_{air})}{LAI} \times V$$

Where:

q = Capacity of toluene removal by *E. aureum* (μg cm^{-2})
LAI = Leaf area (cm^2)
V = Inner volume of chamber (5 L)

RESULTS AND DISCUSSION

Equilibrium times and concentrations of toluene removal: The result showed that amount of each initial toluene concentration decreased first and then rose up to the equilibrium in the 120th min (Fig. 2). The effects of the initial concentrations as 0.87, 1.73, 3.46, 6.92, 10.38, 13.84 and 17.3 mg L^{-1}. The equilibrium concentrations were 0.33, 0.45, 0.90, 1.80, 2.70, 3.60 and 4.50 mg L^{-1}, respectively. The results indicated that *E. aureum* (Lind. and Andre) Bunting had capabilities of absorbing toluene on the leaf structure in wax cutin and permeability via stomata. Adsorption of toluene compounds mainly occurred at the leaf surface and then changed some volatile pollutant to become non-volatile at last (Kvesitadze *et al*., 2009). Initial concentration of toluene relating to a variety of times provided had a certain effect on the ability of the plant to remove toluene substance in the air; the results of this study was also consistent with the research by Kondo. Regarding the ability of removing phenol in the plant leaf (Beattie and Seibel, 2007), it was found that the concentration of toluene increased and so did the rate of diffusion onto the leaf.

Effect of initial concentrations yielding to toluene removal efficiency: The results indicated that the quantity of toluene removal in the air depended on the initial concentrations whereas toluene removal efficiencies were about 74% of almost individual initial toluene concentrations as can be shown in Fig. 3. The results were similar with an experiment of the potted plant conducted to remove offensive odors in goden pothos

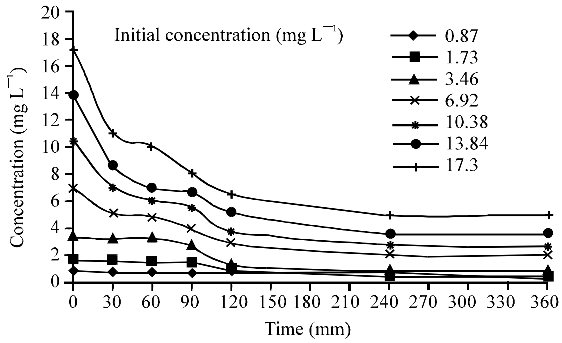

Fig. 2: Toluene concentrates in chamber with time

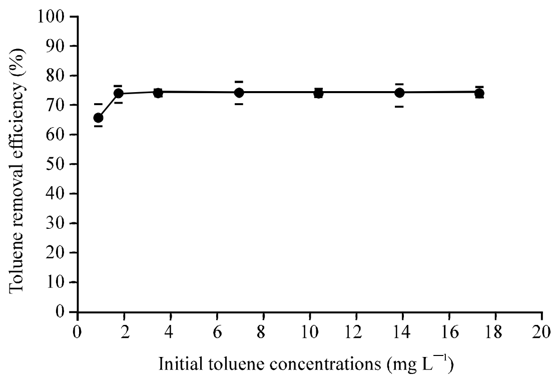

Fig. 3: Toluene removal efficiency with various concentrations

(*Epipremnum aureum*) which had maximum air pollution removal capacity of plant. So, VOCs removal in air using by the plant could not completely be able to remove all kind of toxic gases.

That is the plant still had a limited ability to detoxify hazardous volatile or semi-volatile organics such as coenzymes NADH elimination. For removing VOCs by plants, it can change a structure of VOCs to be a xenobiotics or amino acid. It showed that the plant had capability to elimination many types of VOCs such as benzene, pentane and Tri-chloromethane but could not remove toluene at all (Cornejo *et al*., 1999).

Accumulation capability of toluene into *E. aureum* leaf: The result showed that the amount of toluene adsorption on the leaf was diverse due to initial concentrations; 0.865, 1.73, 3.46, 6.92, 10.38, 13.84 and 17.3 mg L^{-1} of toluene concentrations had adsorption capacity on the leaf after the 4 h experiment 0.58, 1.24, 2.32, 4.78, 7.50, 9.83 and 12.41 mg L^{-1}, respectively. It was found that if the concentration of toluene increased, the rate of diffusion into leaf would also increase because Passive dispersion mechanism suggested different capacities of adsorption (Kume *et al.*, 2008) as shown in Fig. 4. Kondo model was

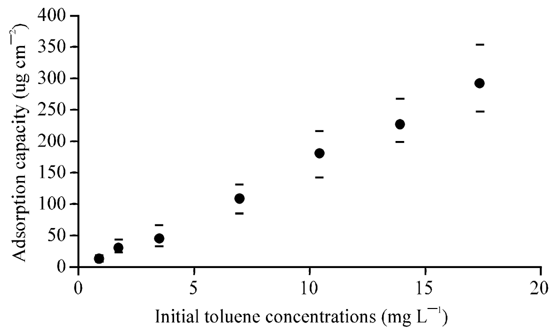

Fig. 4: Capability of toluene adsorption in leaf plant

sugguset to determine the VOCs capacity by plant that was depend on an initial VOCs concentration and amount LAI (Beattie and Seibel, 2007).

CONCLUSION

The different initial toluene concentrations and different times recognized as the influential elements of the given treatment to eliminate pollutants by using the plant leaf in passive diffusion airborne toluene had somewhat limited abilities to remove certain pollutants although there was added more time or even enhanced toluene concentrations. The wax cutin on the plant's leaf and passive diffusion in the plant tissue was important mechanism in absorption on the leaf area.

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REFERENCES

Aoki, F., K. Iizuka, M. Wakae and A. Higashiura, 2009. Development of low VOC-emission products and analyses of emitted VOCs and aldehyde. J. Furukawa Rev., 35: 23-30.

Beattie, G.A. and J.R. Seibel, 2007. Uptake and localization of gaseous phenol and p-cresol in plant leaves. Chemosphere, 68: 528-536.

Cornejo, J.J., F.G. Munoz, C.Y. Ma and A.J. Stewart, 1999. Studies on the decontamination of air by plants. Ecotoxicology, 8: 311-320.

Foxall, K., 2007. Toluene Toxicological Overview. Version 1, Health Protection Agency, USA.

Ghittori, S., A. Alessio, S. Negri, L. Maestri, P. Zadra and M. Imbriani, 2003. A field method for sampling toluene in end-exhaled air, as a biomarker of occupational exposure: Correlation with other exposure indices. Ind. Health, 42: 226-234.

Guo, H., S.C. Lee, L.Y. Chan and W.M. Li, 2004. Risk assessment of exposure to volatile organic compounds in different indoor environments. Environ. Res., 94: 57-66.

Hammer, D.H., 2002. Metabolite ratio of toluene-exposed rotogravure printing plant worker reflect individual mutagenic risk by sister chromatid exchanges. Mutation Res./Genet. Toxicol. Environ. Mutagen., 519: 171-177.

Khan, F.I. and A.K.Ghoshal, 2000. Removal of volatile organic compounds from polluted air. J. Loss Prev. Process Ind., 13: 527-545.

Kume, K., T. Ohura, T. Amagai and M. Fusaya, 2008. Field monitoring of volatile organic compounds using passive air samplers in an industrial city in Japan. Environ. Pollut., 153: 649-657.

Kvesitadze, E., T. Sadunishvili and G. Kvesitadze, 2009. Mechanisms of organic contaminant uptake and degradation in plants. World Acad. Sci. Eng. Technol., 55: 458-468.

Orwell, R.L., R.L. Wood, J. Tarran, F. Torpy and M.D. Burchett, 2004. Removal of benzene by the indoor plant/substrate microcosm and implications for air quality. J. Water Air Soil Pollut., 157: 193-207.

Oyabu, T., A. Sawada, T. Onodera, K. Takenaka and B. Wolverton, 2003. Characteristics of potted plant for removing offensive odor. Sens. Actuator B: Chem., 89: 131-136.

Reyna, M., 2008. Toluene. CAS Registry No. 108-88-3, Texas Commission on Environmental Quality, USA., pp: 1-14. http://www.tceq.state.tx.us/assets/public/implementation/tox/dsd/final/toluene_108-88-3_final_4-15-08.pdf.

Schiffman, S.S., R. Gutierrez-Osuna and H.T. Nagle, 2002. Measuring odor Intensity with E-noses and other sensor types. Proceedings of the 9th International Symposium on Olfaction and Electronic Nose, Sept. 29-Oct 2, Rome, Italy, pp: 1-5.

Silva, L.I.B., T.A.P. Rocha-Santos and A.C. Duarte, 2008. Sensing of volatile organic compounds in indoor atmosphere and confined areas of industrial environments. Global NEST J., 10: 217-225.