

Investigation of BTEX and Ozone Concentrations in a Printing Facility in Bangkok, Thailand

K. Thanacharoenchanaphas^{1*}, A. Changsuphan², R. Nimmual³, T. Thongsri²,
S. Phetkasem² and C. Lertkanawanitchakul²

¹Naresuan University, Department of Natural Resources and Environment, Faculty of Agriculture
Natural Resources and Environment, Phitsanulok, Thailand, 65000

²Department of Science Service, Physics and Engineering Division, Rama VI Rd.,
Bangkok, Thailand, 10400

³King Mongkut's University of Technology Thonburi, Department of Printing and Packaging
Technology, Faculty of Industrial Education and Technology, Tungkrui, Bangkok, Thailand, 10140

*Corresponding Author E-mail: kanitaphas@yahoo.com

Abstract

The presence of Volatile Organic Compounds (VOCs) in ambient and indoor air is widely recognized as precursors of serious risk to human health. In addition, VOCs contribute to the production of secondary photochemical pollutants such as ozone. Many studies have shown that printing processes lead to indoor emissions of VOCs. In this study, the concentration of four VOCs namely benzene, toluene, ethylbenzene, xylene (BTEX) and ozone in a large printing facility located in Bangkok, Thailand. Air samples were collected and analyzed at the working place (sheet offset printing) during working time (8 hr) using portable ambient air analyzers and colorimetric method from June to September 2005. The concentration ranges of benzene, toluene, ethylbenzene and xylene were 63.9-126.1 ppm, 1.3-2.1 ppm, 0.8-6.5 ppm and 1.1-2.7 ppm, respectively. The four month-average concentrations of benzene, toluene, ethylbenzene and xylene species were 101.7 ± 28 ppm, 1.7 ± 0.3 ppm, 3.0 ± 2.5 ppm and 1.9 ± 0.7 ppm, respectively. The concentration of benzene, which is found as the most prevailing VOC, exceeded the recommended maximum level of 5 ppm set by the American Conference of Governmental Industrial Hygienists (ACGIH). The measured concentrations of toluene, ethylbenzene and xylene showed levels below the recommended maximum level set by ACGIH. Ozone concentration remained below 0.01 ppm over four months of measurement campaign, and hence much lower than the ACGIH standard. The observed low concentration of ozone is probably due to low concentrations of the three VOCs associated to low light intensity in the printing facility.

Key words: Volatile Organic Compounds (VOCs), BTEX, Ozone, Printing facility.

Introduction

Air pollution events are not limited to outdoor but can also affect indoor environment. Several studies demonstrated that indoor air pollutants are directly associated with human health symptoms

[1]. Currently, investigations are being conducted on indoor air pollution as increasingly number of people spend more and more time living in confined areas [2]. Many published studies reported that indoor air pollutant concentrations are higher than those observed outdoor [3]. Volatile Organic Compounds (VOCs) such as benzene, toluene, ethylbenzene, m,p-xylene and o-xylene, shortly called BTEX, are widely used in manufacturing industries, including printing and paint manufacturing units [4], and generally they are parts of the composition of the raw material. Because of their physico-chemical properties, they exert serious adverse effects on environmental air quality [4]. Wolkoff *et al.* [5] identified 61 different VOCs in photocopier toner powder and from the processed paper of six photocopier machines, three laser printers, and two matrix printers. The results showed that dry process photocopiers are contributors to VOCs emission. Regarding outdoor emissions, Na *et al.* (2004) [6] investigated emission sources of VOCs in Seoul and found that the main emission sources of VOCs in this city are motor vehicles, gasoline evaporation, natural gas and liquefied petroleum gas (LPG), and paint solvents. It is reported that toluene (63%) is the most abundant component in paint solvents, followed by m-p-xylene (19%), o-xylene (8%) and benzene (1%). Because of the toxicity related to their physico-chemical properties, many VOCs are classified as substances able to exert lung cancer. For instance, exposure to toluene emitted from Chinese-style cooking is observed to be highly correlated with risk of lung cancer in the non-smoking population of Chinese women [2].

Ozone is a pollutant of concern because it can affect both plants and human health. High ozone levels in urban and sub-urban areas during pollution episodes are able to affect human health [7]. Ozone (O_3) formation is a complex non-linear photochemical reaction driven by two major classes of precursors: nitrogen oxides (NO_x) and volatile organic compounds (VOCs) [8]. Emissions of both ozone and VOCs from photocopiers were documented in the US since the end of 1970s [9-11], but investigations in Thailand are still very scarce.

In this study, the concentrations of BTEX and ozone were measured in a printing facility during working hours, in order to investigate the level of exposure of the workers to these compounds in printing industry in Thailand, and to identify potential relationship between ozone and BTEX in this indoor environment.

Materials and methods

Study Site

Ozone and BTEX were sampled in a large printing facility in Bangkok. The sampling was conducted in the working place, including 4 colors and 5 colors sheet offset machines, and printing presses. Samples were collected for 4 times (1time/month) during 8 hours of normal working period time for in June, July, August and September 2005.

BTEX Measurements

In this research, real-time measurements of benzene, toluene, ethylbenzene and xylene concentrations were performed using portable ambient air analyzer (Miran 205B series sapphire) for 40 minutes/time at 1 m above ground. Samples were taken at a flow rate of 14 liters/minute. The detection technique used in this portable ambient air analyzers is based on a single-beam infrared spectrophotometry, involving infrared absorption properties of BTEX. The micro-controller incorporated in the analyzer automatically performs the sampling, processes the measurement signals, and converts the signals into absorbance values. A particulate filter was used at the inlet to remove dust and particulates. Before each sampling, the analyzer is set to zero using the zero gas filter to remove most infrared-absorbing components from the air. BTEX concentrations were displayed in ppm.

Ozone Measurement

Ozone was measured and analyzed following the reference KI absorption-colorimetric method No. P&CAM 153 for concentrations ranging 10 to 10000 ppb. The sampling was conducted 4 times/day at a flow rate of 1liters/minute during 40 minutes. Samples were collected at 1 m above the ground using midget impinger containing 10 ml of 1% potassium iodide in a neutral (pH 6.8) buffer composed of 0.1 M disodium hydrogen phosphate and 0.1 M potassium dihydrogen phosphate. The iodine liberated in the absorbing reagent was determined spectrophotometrically by measuring the absorption of the tri-iodide ion at 352 nm. The concentration of ozone was determined directly from the calibration curve using the standard iodine solution (0.025 M), as indicated that 1 mole of ozone liberates 1 mole of iodine.

Results

The monthly average concentrations of BTEX investigated in this study are presented in Table 1-2. The highest average concentration of benzene was observed in August at 126.1 ppm. The concentration of benzene, toluene, ethylbenzene, and xylene ranged from 63.9 to 126.1 ppm, 1.3 to 2.1 ppm, 0.8 to 6.5 ppm and 1.1 to 2.7 ppm, respectively. In order to document the average concentrations of these four compounds to which the workers of the printing facility are exposed, averages over the four months were calculated. Resulted concentrations are reported in Table 2. The over four months average concentrations of benzene, toluene, ethylbenzene and xylene were 107.8 ppm, 1.7 ppm, 3.0 ppm and 1.9 ppm, respectively.

Table 1: Monthly average concentrations of BTEX during June-September 2005.

Month (2005)	VOCs concentration(ppm) , Time (min)			
	Benzene	Xylene	Toluene	Ethylbenzene
June	119.3 ± 21.4, 48	2.7 ± 0.5, 59	1.7 ± 0.2, 42	2.7 ± 0.4, 40
July	97.3 ± 35.8, 44	1.6 ± 0.1, 47	1.8 ± 0.2, 40	6.5 ± 7.9, 48
August	126.1 ± 8.8, 47	2.3 ± 0.6, 45	2.1 ± 0.2, 41	1.8 ± 0.3, 40
September	63.9 ± 6.7, 37	1.1 ± 0.7, 40	1.3 ± 0.3, 40	0.8 ± 0.5, 37

Table 2: Four months average concentrations of BTEX (ppm) during June-September 2005 vs. TWA.

VOCs	Concentration (ppm)	TWA (ppm)*
Benzene	101.7 ± 28	0.5
Xylene	1.9 ± 0.7	100
Toluene	1.7 ± 0.3	50
Ethylbenzene	3.0 ± 2.5	100
n= 4		

*TWA=Time-Weight Average, maximum level of TWA in the work environment that are suggested by American Conference of Governmental Industrial Hygienists (ACGIH).

Regarding ozone, the measured concentrations were always lower than 10 ppb (0.01 ppm) during the four months experiment. Based on this observation, it seems that there is no correlation or direct relationship between BTEX and ozone in the printing facility.

The temporal profiles of BTEX concentrations during working hours are shown in Fig.1-4. No correlation between sampling time and concentration of specific VOC was observed. During the whole duration of the experiment, the ambient temperature measured in the working place was quite stable and ranged around 23-26°C. Therefore, it is nearly impossible that BTEX and ozone concentrations were influenced by temperature change.

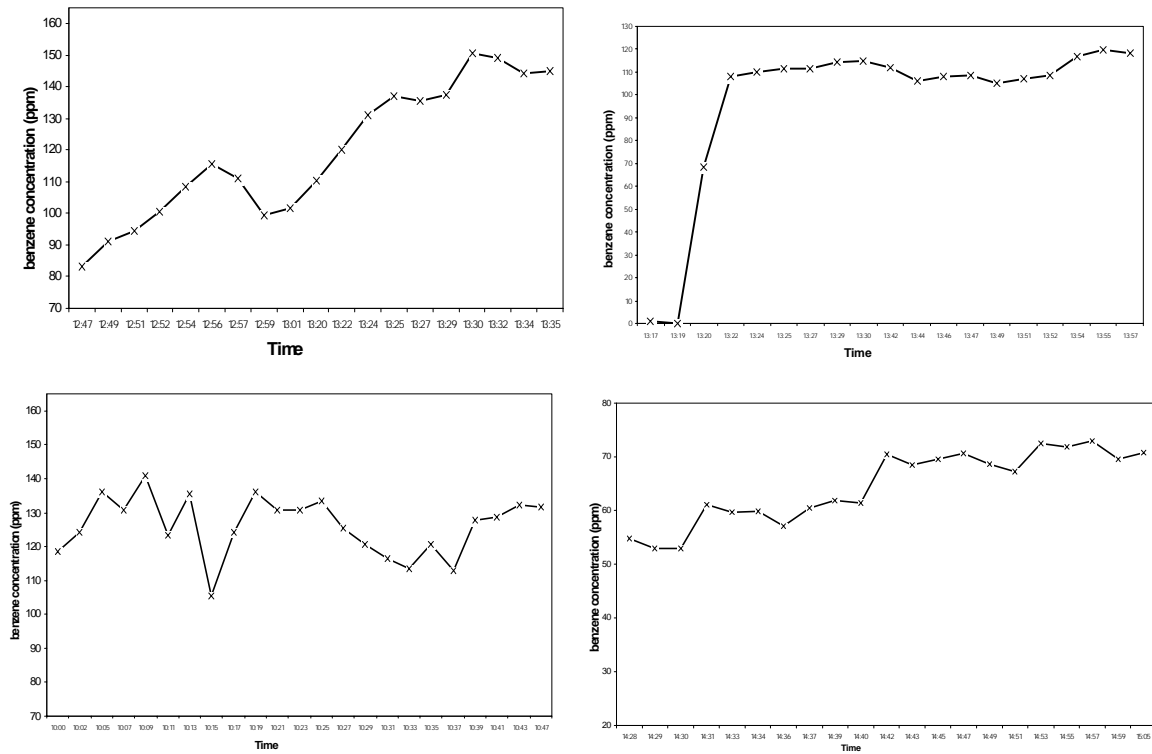
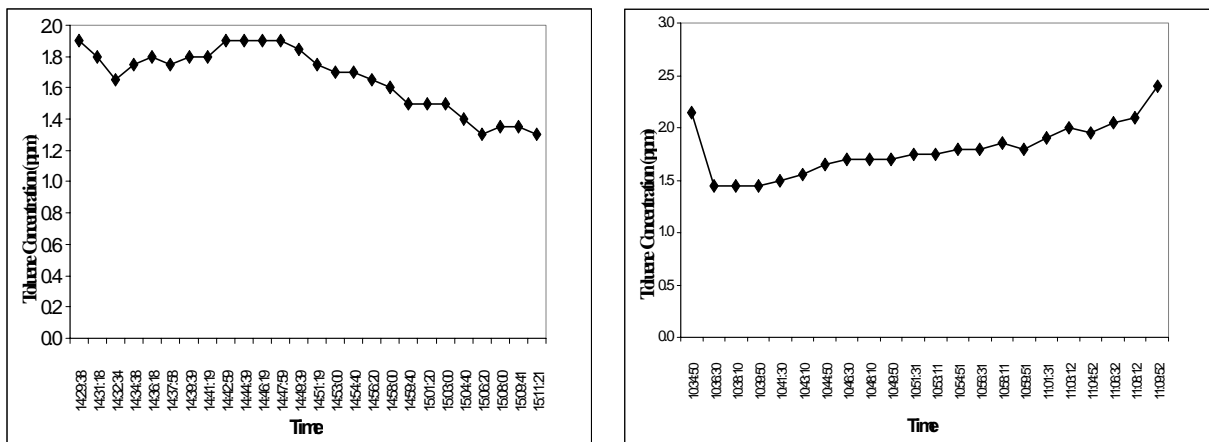


Figure 1: Benzene concentration profiles during working period.



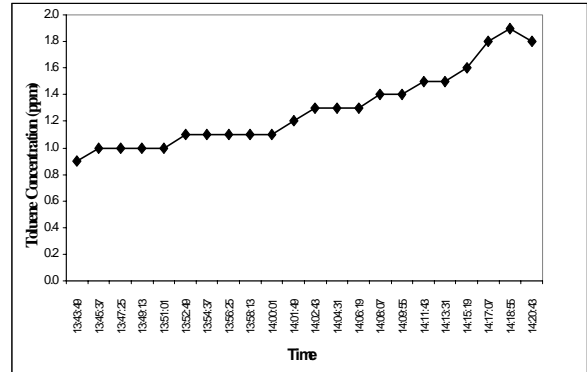
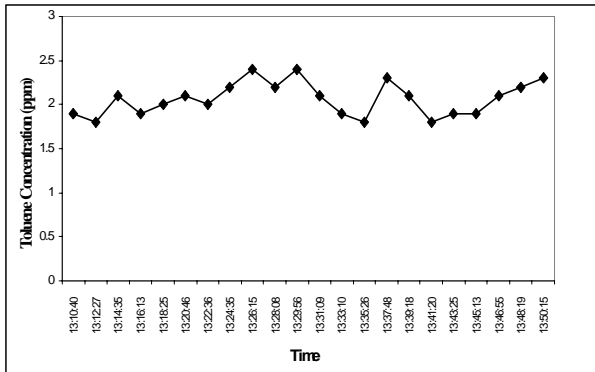


Figure 2: Toluene concentration profile during working period.

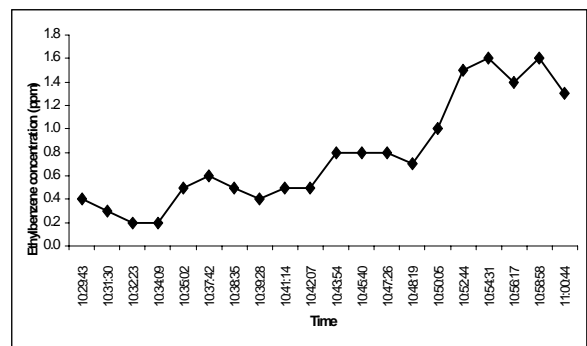
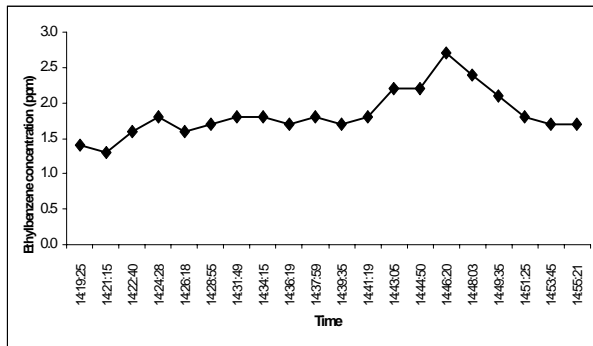
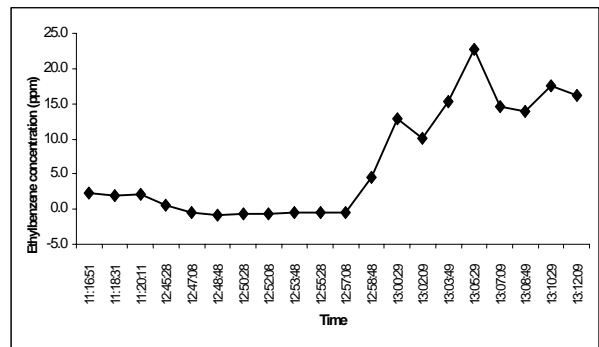
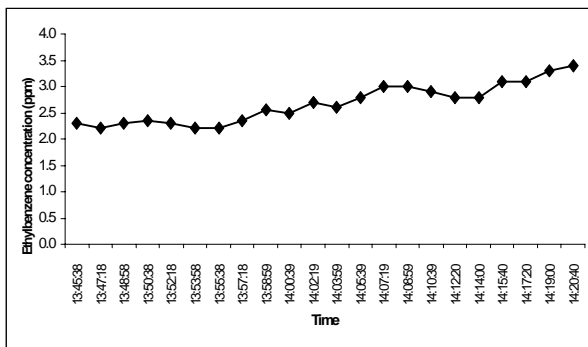
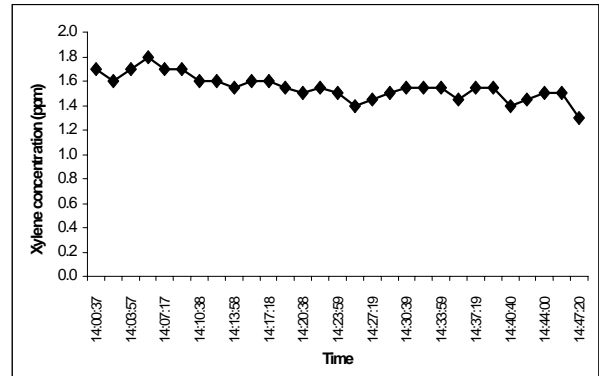
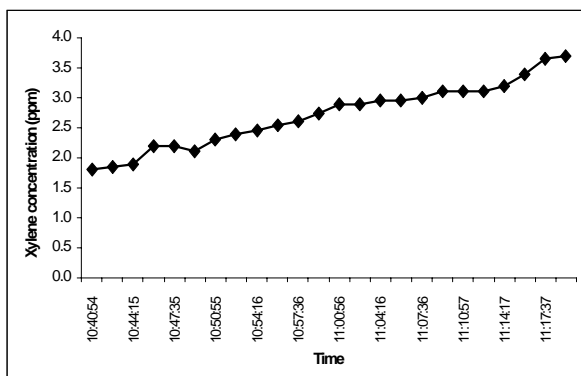


Figure 3: Ethylbenzene concentration profile during working period.



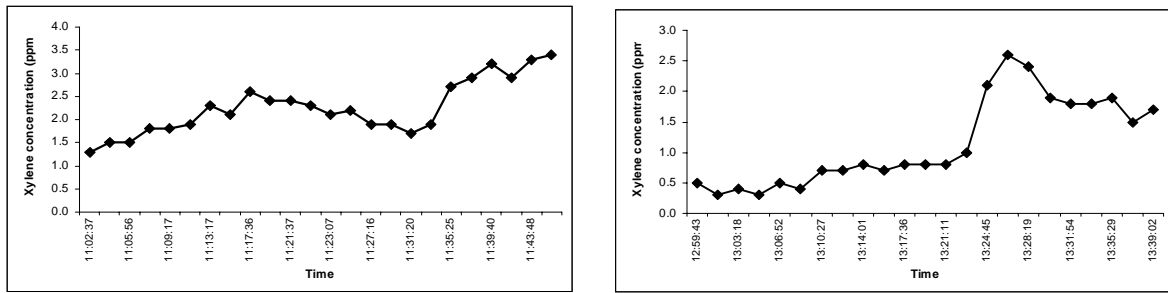


Figure 4: Xylene concentration profile during working period.

Discussion

Results obtained in this study confirm the presence of BTEX in the atmosphere of printing facilities. This is expected since they are emitted from the printing process. Wadden *et al.* [12] investigated emissions in an offset printing shop and measured 13 different VOCs, including toluene. The average toluene concentration of 1.7 ppm found in this study was in the same range of concentrations observed by Wadden *et al.*[12], i.e. 0.9 ppm to 7.6 ppm. Guo *et al.* [2] also studied risk assessment of exposure to VOCs in different indoor environments. They reported that 7 different VOCs, 1,1-Dichloroethene, methylene chloride, chloroform, benzene, trichloroethene, tetrachloroethene and styrene could be found in printing facilities. This confirms the important economic role of lithographic printing industry in the United States, which is constituted of approximately 53,000 firms. These industries are responsible for emitting up to 6.17×10^8 metric tons per year of VOCs into the atmosphere [13]. Similarly to the situation observed in Thailand, about 85% of the firms are small enterprises employing less than 20 workers.

The American Council of Governmental Industrial Hygienists (ACGIH) recommends a maximum level Time-Weight Average (TWA) in the working environment [14]. In this study, the average concentrations of toluene, ethylbenzene and xylene are well below the standard TWAs for employee in the working environment (Table 2). However, the benzene concentration is found to largely exceed the recommended TWA for this compound. This result indicates that benzene may exert a substantial risk for the worker health in the printing facility in Thailand, in addition to other VOCs identified as contributors to a wide range of human health symptoms, which may lead to adversely affect the health of the workers in indoor environment [15]. Also, Stefaniak *et al.* [16] explained in their report that the symptoms may be due to the additive or synergistic interactions of VOCs and not the presence of individual compounds. For example, in an indoor environment with 35 different VOCs, there are 595 different combinations in which any 2 VOCs can interact.

Concerning ozone concentration, the TWA value in the working environment is set at 0.1 ppm for light work (Table 3). In this study, ozone concentration was found to be always lower than 0.01 ppm for the whole duration of the experimental campaign, and hence are far below the standard for all types of work, i.e. 0.05 ppm for heavy work and 0.08 ppm for moderate work (Table 3).

Table 3: Four months average concentration of ozone during June-September 2005.

Ozone Concentration (ppm) in study	TWA(ppm)*	
≤ 0.01 ppm	Heavy work	0.05 ppm
	Moderate work	0.08 ppm
	Light	0.10 ppm
	Heavy, moderate, or light worklode (≤ 2 hours)	0.20 ppm

*TWA=Time-Weight Average, maximum level of TWA in the work environment that are suggested by American Conference of Governmental Industrial Hygienists (ACGIH).

Conclusion

The results of this study indicate that sheet-offset printing operations conducted in printing facility in Thailand emit benzene, toluene, ethylbenzene and ethylbenzene. The average concentrations of toluene, ethylbenzene, ethylbenzene and ozone were found to be below the standard set by the American Council of Governmental Industrial Hygienists for employee in the working environment. However, the four months average concentration of benzene was found to largely exceed this standard. Benzene may therefore present a risk to health of the workers of the printing industry in Thailand. Considering the high concentration observed for this compound, it is strongly recommended to carry out further investigation and long-term monitoring in order to better quantify the level of exposure. As expected, no relationship between BTEX indoor concentration and ozone production could be identified, confirming that in indoor atmosphere ozone is whether a primary pollutant resulted from printing processes, or transferred from outdoor through ventilation.

Acknowledgements

This study was supported by the research grant of the Faculty of Agriculture, Natural Resources and Environment of Naresuan University. The authors would like to express their sincere gratitude to the Physics and Engineering Division, Department of Science Service, Ministry of Science and Technology, Thailand, for the assistance in the measurement of ozone and BTEX concentrations and for the laboratory facilities.

References

- [1] Nilsson, A., Nosratabadi, A.R., Lagesson, H.V., Murgia, N., Leanderson, P., Tagesson, C., 2002, " Novel technique for measuring low molecular weight chemicals in indoor dust, *Indoor. Built. Environ.*, 11, 153-161.
- [2] Guo, H., Lee, S.C., Chan, L.Y., and Li, W.M., 2004." Risk Assessment of exposure to volatile organic compounds in different indoor environments", *Environ. Research*, 94, 57-66.
- [3] Zuraimi, M.S., Tham, K.W., Sekhar, S.C., 2003, " The effects of ventilation operations in determining contributions of VOCs sources in air conditioned tropical buildings". *Build. and Environ.*, 38(1), 23-32.
- [4] Hsieh, L.T., Yang, H.H. and Chen, H.W., 2005, "Ambient BTEX and MTBE in the neighborhoods of different industrial parks in Southern Taiwan, " *Journal of Hazardous Materials.*, Article in press, Available online at www.sciencedirect.com.
- [5] Wolkoff, P., Wilkins, C.K., Clausen, P.A., and Larsen, K., 1993, " comparison of volatile organic compounds from processed paper and toners from office copies and printer: methods, emission rates, and modeled concentrations", *Indoor Air.*, 3, 113-1
- [6] Na, K., Kim, Y.P., Moon, I. and Moon, K.C., 2004, " Chemical composition of major VOC emission sources in the Seoul atmosphere", *Chemosphere*, 55, 585-594.
- [7] Sherwood, L.B., 2003, *Tropospheric Ozone and Photochemical Smog*, Elsevier.
- [8] Sillman, S., 1999, "The relation between ozone, NO_x, and hydrocarbons in urban and polluted rural environments", *Atmos. Environ.*, 33(12), 1821-1845.
- [9] Allen, R.J., Wadden, R.A., and Ross, E.D., 1978, " Characterization of potential indoor sources of ozone", *Am. Ind. Hyg. Assoc. J.*, 39, 466-471.
- [10] Selway, M.D., Allen, R.J., and Wadden, R.A., 1980, "Ozone production from photocopying machines", *Am. Ind. Hyg. Assoc. J.*, 41, 455-459.

- [11] Hansen, T.B., and Andersen, B., 1986, “ Ozone and other air pollutants from photocopying machines”, *Am. Ind. Hyg. Assoc. J.*, 47, 659-665.
- [12] Wadden, R.A., Scheff, P.A., Franke, J.E., Conroy, L.M., Javor, M., Keil, C.B., and Milz, S.A., 1995, “ VOC emission rates and emission factors for a sheeted offset printing shop”, *Am. Ind. Hyg. Assoc. J.*, 56, 368-376.
- [13] Bartlett, I.W., Dalton, A.J.P., McGuinness, A. and Palmer, H., 1999, “ Substitution of Organic Solvent Cleaning Industry ,” *The Annals of Occupational Hygiene*, 43(2), 83-90.
- [14] American Conference of Governmental Industrial Hygienistes (ACGIH), 2001, Threshold limit values for chemical substances and physical agents, Cincinnati.
- [15] Zuraimi, M.S., Roulet, C.A., Tham, K.W., Sekhar, S.C., Cheong, K.W.D., 2005, “A comparative of VOCs in Singapore and European office buildings”. *Build. and Environ.*, Article in Press, Available online at www.sciencedirect.com.
- [16] Stefaniak, A.B., Breyse, P.N., Murray, M.P.M., Rooney, B.C., and Schaefer, J., 2000, “ An evaluation of employee exposure to volatile organic compounds in three photocopy centers”, *Environ. Res. Sect.*, 83, 162-173.