BTEX CONCENTRATION PREDICTED MODEL IN SMALL PRINTING ENTERPRISE

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Thesis
entitled

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BTEX CONCENTRATION PREDICTED MODEL IN SMALL PRINTING ENTERPRISE

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ABSTRACT

Benzene, toluene, ethylbenzene and xylene (BTEX) compounds, 480 air samples, were collected from the working environment of 112 small printing factories. Information collected included data on job tasks during air sampling, type of paper, printing speed, the thickness of the paper, the number of chemicals used during air sampling, packaging of printing colour, packaging of other chemicals, printing room characteristics, number of printing room entrance doors, number of printing room windows, type of building, ventilation type, printing room surface (m^2), and the number of printers in printing factory.

Research has shown that the concentration of benzene in the air located within workplaces has increased as a result of increased printing speed, the number of mechanical ventilation outlets, and open packages of printing colour. Concentration of toluene in the air of the workplace has increased as a result of increased numbers of printers and printing of one side coated board, by contrast, toluene levels were lower in printing rooms as a result of the increase in the number of exits and ventilation machines. This model also found that the different types of ventilation machine affect the toluene levels. Concentration of ethylbenzene in the air of workplaces has increased as a result of increased printing speeds, and open packages of printing colour and other chemicals. Ethyl benzene levels were lower when closed rooms were located in commercial buildings. Concentrations of xylene in the air of workplaces has increased when there are more open packages of printing colour; by contrast, xylene levels were lower in printing rooms that had existing air conditioners, open packages of other chemicals or the rooms were closed.

KEY WORDS: PRINTING FACTORY/VOLATILE ORGANIC COMPOUNDS/BTEX

85 pages

แบบจำลองทำนายความเข้มข้นของสารเบนซีน โทลูอีน เอททิลเบนซีน ไซลีน ในโรงพิมพ์ขนาดเล็ก

MODEL OF MEASURE CONCENTRATION OF VOLATILE ORGANIC COMPOUNDS IN SMALL PRINTING WORKING AREA.

กรรณิการ์ ไทยเจริญ 5136419 PHIH/M

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บทคัดย่อ

สารอินทรีย์ระเหยง่ายได้แก่ เบนซีน โทลูอีน เอททิลเบนซีนและ ไซลีน จำนวน 480 ตัวอย่าง ถูกเก็บจากอากาศในพื้นที่ทำงานของโรงพิมพ์จำนวน 112 โรงพิมพ์ขนาดเล็กทั่วกรุงเทพมหานคร พร้อมกับการเก็บข้อมูลเกี่ยวกับลักษณะการทำงานและพื้นที่การทำงานของแต่ละโรงพิมพ์ในระหว่างการเก็บตัวอย่างอากาศ ได้แก่ชนิดของกระดาษที่ใช้พิมพ์ ความเร็ว, ความหนาของกระดาษ จำนวนของการใช้สารเคมีในระหว่างการเก็บตัวอย่างอากาศ ลักษณะของบรรจุภัณฑ์ของสีที่ใช้พิมพ์และบรรจุภัณฑ์ของสารเคมีอื่น ๆ ลักษณะทั่วไปของห้อง จำนวนของประตูทางเข้าออก จำนวนของหน้าต่างภายในห้อง ประเภทของอาคาร ประเภทของการระบายอากาศ พื้นที่ของห้องพิมพ์ (ตารางเมตร) และจำนวนของเครื่องพิมพ์ในโรงพิมพ์

ผลการวิจัยได้แสดงให้เห็นว่า ความเข้มข้นของ สารเบนซีนในอากาศจะเพิ่มมากขึ้น เมื่อความเร็วในการพิมพ์เพิ่มขึ้น มีการติดตั้งพัดลมระบายอากาศ มีการเปิดบรรจุภัณฑ์สีทิ้งไว้ในพื้นที่ทำงาน ความเข้มข้นของโทลูอีนในอากาศจะเพิ่มขึ้นเมื่อมีจำนวนเครื่องพิมพ์เพิ่มขึ้น และการพิมพ์เป็นเคลือบด้านหนึ่ง ในขณะเดียวกันพบว่าความเข้มข้นจะลดลงเมื่อเพิ่มการระบายอากาศ นอกจากนี้ยังพบว่า ประเภทที่แตกต่างกันของระบบระบายอากาศมีผลกระทบต่อระดับความเข้มข้นของโทลูอีนอีกด้วย ความเข้มข้นของเอทิลเบนซีนในอากาศในบริเวณโรงพิมพ์จะเพิ่มขึ้นเมื่อมีเพิ่มความเร็วในการพิมพ์ และเปิดบรรจุภัณฑ์สีและสารเคมีอื่นๆ ทิ้งไว้ในพื้นที่ทำงาน ในขณะเดียวกันพบว่าค่าความเข้มข้นของเอทิลเบนซีนจะต่ำลงเมื่อปิดห้อง และตั้งอยู่ในอาคารพานิชย์ ความเข้มข้นของไซลีนในอากาศของสถานที่ทำงานได้เพิ่มขึ้นเมื่อเปิดบรรจุภัณฑ์สีทิ้งไว้ในพื้นที่ทำงาน ขณะเดียวกันความเข้มข้นของไซลีนจะมีต่ำลงหากมีการใช้เครื่องปรับอากาศเป็นห้องปิด

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CHAPTER I
INTRODUCTION

1.1 Background and Rationale:

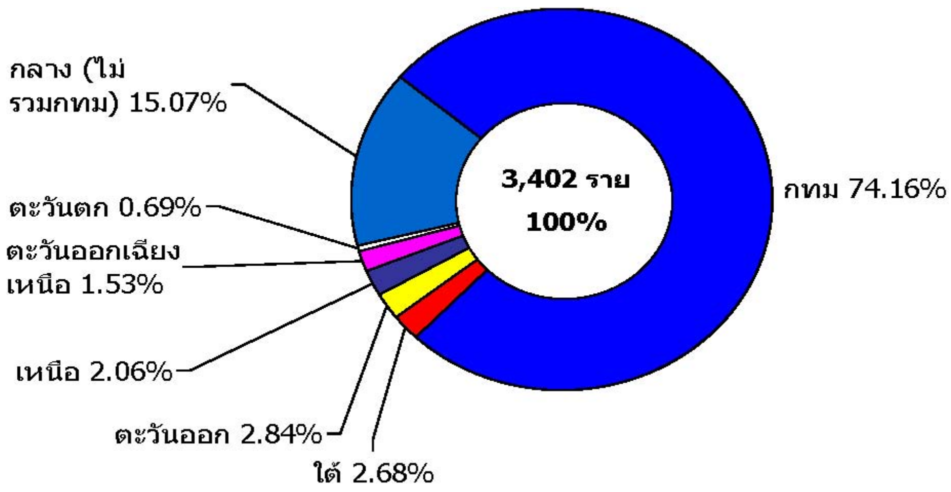
Volatile Organic Compounds (VOCs) that vapors through the environment such as air, surface water, underground water, sediment and food is the significant problem in Thailand that is needed to be addressed. Each type of VOCs has its distinct effect on human health, for example some can disrupt central nervous system causing stupor or comatose, some can cause cancers and diseases of internal organs in the long term. Currently, various industries need to use VOCs in their production processes, such as color manufacturing, petroleum industry, automobile parts manufacturing, etc. Moreover, the medium and small industries also use VOCs, such as textile/bleach industry, printing center, automotive paint, solvent packaging, chemical plant, fertilizer/pesticide/herbicide plant, waste treatment plant, electronics/disk manufacturing, and industries that require metal/machine/equipment cleaning process, etc.

Manufacturing industry statistic in 2545, which data are categorized by the size of industries, reveals 351,091 of small industries according to the definition by ministerial regulation of employment and medium-small enterprise's total assets standard 2545. The number of employees in this type of industries is 1,400,736 (The National Statistical Office; Ministry of Information and Communication Technology's survey of manufacturing industries in Thailand in 2546 [monograph on the Internet]. Available from : http://service.nso.go.th/ nso/nsopublish/service/ survey/prod_ind46_ whole.pdf) Furthermore, the collected data in 2545 shows 9,596 industries that are advertising publication, flyer and music book printing, copying of recording media, and etc, and the number increased in 2546 that is 10,598. 736 (The National Statistical Office; Ministry of Information and Communication Technology's survey of manufacturing industries in Thailand in 2547[monograph on the Internet]. Available from: http://service.nso.go.th/nso/ nsopublish/service/survey/020348sme.pdf)

Small and medium industries that use VOCs in their manufacturing processes have the same health risk of being affected by VOCs as those big industries. The causes of high contamination of VOCs in the air are inappropriate management, lack of knowledge, and careless usage. These behaviors increase the risk of health problem from contact with organic solvents. According to the data of individuals that registered in publishing business, there are 3,402 individuals from all regions, and 2,587 of those are in Bangkok that is 74.16% of all (Grouped data statistics; Department of Business and Information Services; Department of Publishing Business Development (Individuals) in 2552 [monograph on the Internet]. Available from:http://www.dbd.go.th/mainsite/fileadmin/statistic/statisticbycategory/0006/120090619.pdf).

Table 1.1 The number of publishing business in each region of Thailand

Region / Business	**BKK**	**Central not include BKK**	**South**	**East**	**North**	**Northeast**	**West**	**Total**
Company	1,309	313	41	53	27	14	9	**1,766**
Partnership	1,233	201	37	25	39	41	9	**1,585**
Corporate Partnership	42	-	-	-	4	1	-	**47**
Public Company	3	1	-	-	-	-	-	**4**
Total	**2,587**	**515**	**78**	**78**	**70**	**56**	**18**	**3,402**



Central region (except Bangkok) 15.07%

Western region 0.69%

Northeast region 1.53%

Northern region 2.06%

Eastern region 2.84%

Southern region 2.68%

Bangkok 74.16%

Figure 1.1 The number of publishing business in each region of Thailand

The report from the study of Benzene, Toluene, Ethylbenzene and Xylene concentration in printing centers in Bangkok indicates the concentration as follows: 63.9-126.1 ppm, 1.3-2.1 ppm, 0.8-6.5 ppm, and 1.1-2.7 ppm, respectively. Especially, Benzene concentration is 10 ppm higher than the criteria of American Conference of Governmental Industrial Hygienists (ACGIH). (Available from: Thanacharoenchanap has K,Changsuphan A, R. Nimnual, Thongsri T, Phetkasem S, Lertkanawanitchakul C. Investigation of BTEX and ozone concentrations in a printing facility in Bangkok, Thailand. International Journal of Applied Environmental Sciences [serial on the Internet]. 2007 June [cited 2010 Aug 27] Available from:http://www.dbd.go.th/ mainsite/fileadmin/statistic/statisticbycategory/0006/1_20090619.pdf)

Currently, Benzene is indicated as carcinogen, so the danger assessment is needed for security and health of employees who have to work with Benzene in the business like publishing and printing because this type of businesses uses organic solvent to clean insulator, printing plate, and so on. In the danger assessment processes, the concentration of air pollution must be investigated, and biological indices may also need to be investigated, but it will take long time in the investigation. Hence, the objective of this study is to apply the investigation results and environmental attributes of manufacturing processes in determining danger of employees in this type of business that is similar to the sample group.

1.2 Objective

1.2.1 The general objective:

To create model of benzene concentrations, toluene concentrations,ethylbenzene concentrations and xylene concentrations in smaller printing factory.

1.2.2 The specific objective:

1.2.2.1 To study general characteristic of small printing enterprise.

1.2.2.2 To study the atmospheric concentration of benzene, toluene, ethylbenzene and xylene in small printing enterprise.

1.2.2.3 To study the relationship between general characteristics of small printing factory and atmospheric concentration of benzene , toluene, ethylbenzene and xylene and develop the BTEX concentration predicted model in small printing enterprise.

1.3 Hypothesis

1.3.1 The atmospheric concentrations of benzene, toluene, ethylbenzene and xylene have positive relationship with the kind of job, printing speed (sheet/hr), paper size, number of used chemical and no. of floor.

1.3.2 The atmospheric concentrations of benzene, toluene, ethylbenzene and xylene have negative relationship with the number of door, printing room serface (m^3), number of mechanical (ventilation system).

1.4 Scope of study

The scope of this study is to assess atmospheric concentration of benzene, toluene, ethylbenzene and xylene with general characteristics of printing house among the small offset printing house located in Bangkok.

The scope of this study can be summarized as follows:

1.4.1 The study is an investigation in the field.

1.4.2 The atmospheric concentrations of benzene, toluene, ethylbenzene and xylene were collected in normal working time.

1.4.3 Investigation in the field and collected data of

1.4.3.1 Number of chemical ingredient that contain benzene, toluene, ethylbenzene and xylene during printing process

1.4.3.2 Kind of paper in used

1.4.3.3 Thickness of paper in used

1.4.3.4 Size of paper in used

1.4.3.5 Printing speed

1.4.3.6 Characteristics of chemical bottle in printing room

1.4.3.7 Characteristics of printing room

1.4.3.8 Number of door and window

1.4.3.9 Situation of building

1.4.3.10 Characteristics of ventilation

1.4.3.11 Printing room surface

1.4.3.12 Number of printer in printing room

1.5 Definition

1.5.3 Printing factory means to print letter pattern, or something else. On various materials such as thin plastic sheet printing system which has several systems. And used differently. Depending on the design components that include offset gravure systems Letter Press and screening systems etc. This study focuses on the industrial printing systems offline, I

1.5.4 Industry, small business, small refers to the definition of Determine the number of ministerial employment and fixed assets of Reynolds and Medium Enterprise 2545 is the number of workers with less than 50 employees or fixed assets not exceeding fifty million baht

CHAPTER II
LITERATURE REVIEW

This study is to investigate employees' activities and risk of health problems in printing center. The researcher has studied and reviewed documents, articles, and literature as follows:

2.1 Volatile Organic Compounds (VOCs)

2.1.1 General information about Volatile Organics Compounds (VOCs)

Volatile organics compounds are organic compounds that can vapor easily in the normal temperature and air pressure. Most of their molecules comprise of carbon and hydrogen atoms. VOCs may also comprise of oxygen and chlorine, and they have bad water-solubility. Due to their good solvent ability, VOCs are used in various industries such as wooden furniture manufacturing, printing, car care, gas station, electronics manufacturing, ceramic production for porcelain and bowls, and etc. to clean oil, grease, cleaning solution, color, and vanish. So the products from this type of industries are needed in our daily life that people have or may have to touch and smell. Figure 2-1 shows chemicals that create VOCs in our daily life (Assoc. Prof. Vongphun Limpsenee, The Analysis of Volatile Organics Compounds in the Air: July 2550)

The definitions of Volatile Organics Compounds (VOCs) that are defined by each institution are different depending on their objective and mission. Typically, VOCs comprise of various kind of chemicals that have different environmental characteristics. VOCs can be destroyed or altered by sunlight, and the result will be the chemical compounds that have simpler structure. The definitions of VOCs are as follows:

2.1.1.1 Definition by The World Health Organization (WHO) :

VOCS are organic compounds that comprise of Carbon and Hydrogen, which has boiling point at 50-260^oC, except for pesticide., VOCs are the compounds that can vapor through the air. They can be categorized into different types as follows: Aliphatic Hydrocarbons, such as Hexane; Aromatic Hydrocarbons, such as Benzene Toluene and Xylenes; and Oxygeneted, such as Acetone and Ketones.

2.1.1.2 Definition by Australian National Pollutant Inventory :

VOCs are chemical compounds that have structure of carbon chain or ring in the vapor pressure over 2 mmHg (0.27 kPa) at 25^oC.VOCs are Hydrocarbons, Oxygenates and Halocarbons compounds that can vapor at the room temperature. VOCs are Hydrogen, Oxygen, Nitrogen and other chemical elements compounds, except for Methane, Carbon Monoxide, Carbon Dioxide, Carbonic Acid, Metallic Carbides and Carbonate Salts.

2.1.1.3 Definition by U.S. EPA CFR from 40 CFR Part 51.100

VOCs are chemical compounds that comprise of Carbon, except for Carbon Monoxide, Carbon Dioxide, Carbonic Acid, Metallic Carbides (Carbonates) and Ammonium Carbonate that can create photochemical reaction in the air. VOCs are other volatile compounds that can create low photochemical reaction, such as Methane, Ethane, Methylene Chloride, Methyl Chloroform, Trichlorofluoromethane (CFC–11) and 1,1,2-Trichloro-1,2,2-Trifluoroethane (CFC–113).

Summary of All Definitions

✓ Volatile organics compounds (VOCs) comprise of Carbon and

Hydrogen that has boiling point at 50-260, except for pesticide. VOCs can vapor at the air and room temperate. VOCs consist of Aliphatic Hydrocarbons, such as Hexane.

✓ Aromatic Hydrocarbons, such as Benzene Toluene and Xylenes

✓ Oxygeneted, such as Acetone and Ketones. Including organic compound that can create low photochemical reaction such as, Methane, Ethane, Methylene Chloride, Methyl Chloroform, Trichlorofluoromethane (CFC–11) and 1,1,2-Trichloro-1,2,2-Trifluoroethane (CFC–113) and chemical compounds that comprise of Carbon, except for Carbon Monoxide, Carbon Dioxide, Carbonic Acid, Metallic Carbides (Carbonates) and Ammonium Carbonate that can create photochemical reaction in the air.

Volatile organics compounds can be categorized into two major groups:

✓ Non-Chlorinated VOCs or Non-Halogenated Hydrocarbons that comprise of fuels, such as Hexane, Alcohol, Aldehyde, Toluene, Benzene, Ethybenzene, Xylene, styrene and Phenol

✓ Chlorinated VOCs or Halogenated Hydrocarbons are synthetics that are used in industries, and they has higher toxicity and more stability in the environment than Non-Chlorinated VOCs because of their strong and condense carbon and halogen structure that are difficult to be disintegrated by nature, biological, physical, or typical chemical reaction. The examples of Non-Chlorinated VOCs are Trichloroethylene (TCE), 1,1,1-Tricholoroethane, Tetrachloroethylene, Perchloroethylene (PCE). Trichloroethylene (TCE) is used to clean oil, grease, and resins. TCE is also used with cleaning solution for laundry that creates Halogenated Hydrocarbons, which can vapor through the environment.

2.1.2 The Sources of VOCS:

VOCs are usually in the form of gas or vapor at the room temperature, then VOCs can cause fugitive emission from production processes, fuel usage in transportation, and using them as solvents in other activities. VOCs can be found in both urban and industrial area, such as Bangkok and Mab-ta-pud district in Rayong province. There are different sources of VOCs as follows:

Stationary sources, for example petroleum industry,and industry that uses solvent in its production and cleaning processes.

✓ Sources in the area, such as pesticide

✓ Movable sources, such as vehicle

VOCs are precursors for Photochemical Smog and they can be interacted with NO_x to create Ozone and other chemicals that are the secondary air pollutants. VOCs can pollute air, surface water, and underground water. When the pollutants fall to the ground, plants, and water resources, these pollutants will be toxic for human who consume foods or water that are polluted. Suspended particles (SPM) and poison gas are from different sources as shown in Table 2-2. In the recent 2 – 3 years, these suspended particles are concerned globally because they can infiltrate and embed inside the lungs. Furthermore, there are other air pollutants that can cause health problems, such as Sulphur Dioxide (SO_2), Carbon Monoxide (CO), Nitrogen Dioxide (NO_2) and Hydrocarbons (HC) etc.

2.1.3. Effects of VOCs on Health:

VOCs can enter human body by breathing, contact, and eating or drinking. The effects on health are different depending on the type and amount of VOCs. The effects on nervous system are narcosis, dizziness, headache, depression, and comatose. If people smell VOCs, then VOCs will affect on respiratory system, such as mucous membranes inflammation, skin and eye irritation. People who receive VOCs for a long time, their liver and kidney will be damaged. Some type of VOCs can damage genetic, hormone, reproductive, and nervous system, and VOCs can also cause cancers. The details about the health problem from receiving VOCs are:

2.1.3.1 Effects on Immune System:

Many of VOCs can infest or destroy immune system. The blood and skin test on 302 people (aged 40-59) in Aberdeen, North Carolina and vicinity indicates the average amount of Dichloroethylene (DCE) 4.05 ppb in blood of people who live near pesticide dump cites comparing to the average amount of DCE 2.95 ppb ($p = 0.01$) in blood of the other people. The control group of people who live closer to the site will have more DCE in blood same as people who live near the site for a longer time will have more DCE. Leukocytes of these people will also have worse immunological properties than the other people.

2.1.3.2 Effects on Nervous System:

Effects of VOCs on nervous system can be narcosis, dizziness, headache, depression, and comatose. The experiment with mice (and rats) indicates mice that receive 1,1,1-Trichloroethane (TRI) 5,500 ppm by breathing for 40 minutes will have problem in their nervous system**,** such as lower interaction with the environment. The mechanism of this problem is the effects of TRI that reduce Cyclic

GMP, which is the intermediary that stimulates nervous system to work, and Medulla Oblongata. The reduced amount is 55-58% comparing to the control group, and the level of Cyclic GMP will be dramatically reduced when the mice receive TRI in 100 minutes. Shoemakers who receive VOCs by continual breathing VOCs, which are organic solvents, or shoe polish (dichloromethane and hexane), and synthetic rubber (isocyanates and polyvinylchloride) will have nervous symptoms. These symptoms are headache for 65%, anxiety for 53%, leg and foot itching for 46%, eye sore for 43%, and respiratory distress for 1.1-3.5 %. Furthermore, the study on the effects on 14,000 pregnant women in Bristol, U.K. who normally use air spray (aerosols) found that these women have high amount VOCs (xylene, ketones and aldehydes) in their blood. These pregnant women have symptoms, such as headache for 25%, postpartum depression for 19%. Children of these women have more symptoms of diarrhea than other children for 22%

2.1.3.3 Effects on other health problems:

VOCs can damage genetic, hormone, reproductive, and nervous system, and VOCs can also cause cancers. The effects on reproductive system are sterile men**,** deformation of child's sex, mutation, and so on. The toxicity of each type of VOCs are different, then the toxicity assessment can be done by following the criteria of International Agency for Research on Cancer: LARC as follows:

Table 2.1 The criteria of International Agency for Research on Cancer: LARC

Group 1	Carcinogenic to Humans that has causal relationship between the amount of receiving carcinogens and cancers in human.
Group 2A	Probably Carcinogenic to Humans that has positive association between the amount of receiving carcinogens and cancers in human. The effects may come from bias or confounding factors that can not be separated clearly and the evidences are adequate for carcinogenicity in experimental animals.
Group 2B	Possibly Carcinogens to Humans that has adequate evidence of cancers in experimental animals, but not in humans.
Group 3	Not Classifiable as to its Carcinogenicity to Humans
Group 4	Probably not Carcinogenic to Humans
Source: http://www.techno.msu.ac.th/fn/ecenter/cancer/cause.htm	

2.2. Related Volatile Organic Compounds

2.2.1 Benzene

Benzene Clear liquid at the room temperature that has unique smell. Benzene is soluble, volatile, and combustible. In late 19^{th} century, benzene was used as a solvent in robber industries. After that, benzene had been widely used in color, pesticide, and chemicals manufacturing before the use of benzene was limited and replaced by the safer chemical according to the report of aplastic anemia and suspected carcinogen class I: IARC from the use of benzene.

2.2.1.1 Entering Human Body and Mechanisms of Disease:

Benzene can enter human body by breathing, contact, and eating, in the order of significance. When benzene enters human body, it will spread quickly through cardiovascular system, such as brain, liver, kidney, marrow, hearts and muscles. 25% of benzene in lungs will be disposed by breathing or exhaled air. Other absorbed benzene will be altered its chemical structure by live with cytocrome P-450 dependent monooxygenase enzyme, and being disposed by kidney. Benzene and metabolite has effects on marrow similar to colchicine-like effect that reduces cell division in mitosis. This effect reduces erythropoiesis and blood platelet that cause aplastic anemia.

2,2,1,2 Acute Effects:

Vapor of benzene (over 3000 ppm) cause eyes and respiratory tract irritation. Liquid benzene can cause more skin respiratory, and it causes acute effect by contact. In the case of eating, the effects will be on the lining of gastrointestinal tract that cause hoarse sound, cough, stomachache, and vomit. In the case that received little amount of benzene (lower than 250 ppm), the effects will be on the central system that cause people to be exited and euphorbia. If the received amount is increased (500-3000 ppm for 10-60 minutes), it will cause headache, numb, sick, vomit, hallucination and depression. If the received amount is increased dramatically (20,000 ppm for 5-10 minutes), it will cause respiratory failure and cardiac arrhythmia. The others symptoms can be headache, nausea, anxiety, being bored with food, and so on.

2.2.1.3 Chronic Effects:

Benzene can destroy morrow and replacing with fat that cause anemia, then low amount of leukocytes and platelets can cause aplastic anemia. Furthermore, benzene has been categorized as carcinogen type I (suspected carcinogen class I : IARC) because it can cause leukocytes cancer and benzene also cause myelogenuous leukemia and acute myeloblastic leukemia (AML) that are the most occurring leukocytes cancer causing by benzene, followed by chronic lymphocytic leukemia. The toxic effects on nervous system can be symptoms (e.g. neurophysiologic and neuropsychiatric disturbance), nerve abnormalities (e.g. corticospinal tract and nerve root dysfunction), and transverse myelitis. The toxic effects on the other systems, such as liver hepatitis symptoms, skin irritation, erythema, blister, and scaly dermatitis are caused by contact with little amount of benzene in a long time.

2.1.1.4 Measuring Amount of Benzene from Direct Contact:

The level of benzene in breath is related to the amount of benzene that enters human body and the concentration of benzene in blood. Measuring the amount of benzene in breathing has lower accuracy and reliability than measuring in blood or metabolite in urine. So this method is used in the case of accident or acute effect. Currently, measuring the amount of benzene in blood is the best method because this method can derive the specific results sensitively, and blood can also be kept at the room temperature for 2 days. The lowest value that this method can measure is 0.64 nmol/L. For workers who do not smoke or contact with benzene, the result will be lower than 8 nmol/L and lower than 15 nmol/L for workers who do not contact with benzene. The disadvantage of this method is the requirement of puncture and Halflife in blood for 1 – 3 hours. Measuring the amount of phenol in urine is a simple and convenient method that is widely used in Thailand. The regular amount of workers who have never contacted benzene is less than 10 mg./gram creatinin and less than 50 mg/ gram creatinin for workers who usually contact with benzene. The amount of phenol in urine is directly related to the concentration of benzene in the air. So this method is best for measuring the amount of benzene in worker's body who usually breathe the air that polluted with benzene. However, this method derives low specific result and taking long time that can not be used with the modern working, due to the standard of very low amount of benzene in workplace that is 1 ppm (TWA-OSHA). Otherwise, some medicine and food additives, such as salicylate, pepto bismol, and chloraseptic can cause higher level of benzene. Measuring metabile, such as phenylmercapturic acid, in urine, can derive the specific result sensitively, but the processes is complex and difficult. For the measuring transmuconic acid in urine can derive the sensitive result but low specific.

2.1.1.5 Test of the Effect on Human Body:

For workers who received the amount of benzene over the standard, their complete blood count (CBC) should be tested to measure the amount of erythrocyte, leukocytes, and platelets. If the test result indicates that the blood cell production is pressed, then workers' marrow should be tested. Moreover, workers' liver should be tested before staring their works and continuing checks their liver periodically after that.

Neurophysiological test and neurobehavioral test are not the specific tests; these tests can be used to ensure the diagnosis, to estimate the decease and treatment of workers who have been contacted with benzene for a long time. The popular tests are Digit symbols, DOTs, PINS, and etc.

Special test, such as brainwave test may result the *slower characteristic frequency than the regular test. Tomography image may help to find* cerebral atrophy, but the result is usually not specific. Mostly, the finding indicates the last stage of cerebral atrophy, then this test is only used for monitoring of treatment.

2.2.2 Toluene

Liquid toluene or methylbenzene that are aromatic hydrocarbon ($C_6H_5CH_3$)**,** which are organic solvent that are clear, colorless, smelled like benzene, insoluble in water, and soluble in alcohol, chloroform, ether, acetone, carbon disulfide and acetic acid. Toluene, which is flammable liquid in hazard class 3.2, has flash point at -18^oC and 23^oC. Toluene is also hazardous material type 3 according to Hazardous Materials Act 2535, which hazardous materials that are produced, imported, exported or possessed must be done under the permission by Department of Industrial Works. Toluene is a by-product from coal and petroleum industry by naphtha's catalytic reforming or paraffin hydrocarbon's cyclization or aromatization.

2.2.2.1 Entering Human Body and Mechanisms of Disease:

Toluene can enter human body by breathing, absorbing through skin, and eating. Mostly, entering by breathing and 50% of Toluene that are breathed in will remain in lungs. The remaining toluene will be spread to the other organs, such as fat tissues (e.g. brain, liver, and kidney). For fat people, the collection of toluene in tissues will be increased. This implies that fat people has higher chance of getting chronic health problems than slim people. The absorbed toluene will be disposed out of the body by breathing out without any reformation 15–20% approximately. The absorbing of toluene through skin caused by the contact with liquid toluene 14-23 mg/cm^3 approximately. The remaining toluene in the body that are eaten or drunk will be reformed by metabolism in liver. Less than 1% of toluene will be reformed to be cresol and more than 75% will be reformed to be hippuric acid. This reformed toluene will be disposed with urine. Hippuric acid has very short half life of 1 – 2 hours approximately, and all of hippuric acid will be disposed out of the body within 24 hours.

2.2.2.2 Acute Effects:

It is similar to the effects of alcohol poisoning. Starting from the stimulation, and following by the pressing on the central nervous system. Toluene has acuter effects than benzene, and its' relationship between the absorbed amount and time of entering the body is shown in Table 1. Receiving extreme high amount of toluene can cause comatose and death. An instant contact with this extreme high amount of toluene can cause ventricular fibrillation and cardiac arrest. The acute effects for people who receive toluene by eating will be sick, vomit, and flux together with the pressing on nervous system and comatose. If the received amount reaches 625 mg/kg, then it may cause death.

2.2.2.3 Chronic Effects:

Can be muscle weakness symptoms, abnormalities of brain function, and optic nerve atrophy. People who breathe toluene for a long time will get symptoms that are similar to *volatile* dependent users', such as headache, dizziness, sick, and being bored of food. These symptoms often occur at the end of the day and occurring more often in the weekend. After that the symptoms will be mitigated or turning back to normal during the holidays. Toluene is effective fat solvent, then making contact with toluene for a long time will eliminate natural fats of skin and causing dry skin, broken skin, and fissured dermatitis. Toluene can also cause kidney and liver failure. There is a report about the higher rate of abortion on pregnant women who contact with toluene. Workers who contact with toluene, which containing benzene, for a long time will get abnormalities in the blood system. Currently, there is no study that can assert the effects of toluene on heredity or causing cancers.

2.2.2.4 Laboratory Tests:

The tests on the contact with toluene can be measuring the amount of toluene in breathing and blood, measuring the amount of hippuric acid and o-cresol in urine, and so on. Measuring the amount of toluene in blood is a specific method that can be used to measure the amount of toluene less than 50 ppm effectively. People who have never contacted with toluene will have the amount of toluene less than 0.015 mg/l. Measuring the amount of hippuric acid in urine is a simple and convenient method that is widely used because this method can derives the accurate result of high amount of toluene. To use this method, other factors must be considered, for example food that contains sodium benzoate for preservation, vegetables and fruits that have benzoic acid, and contact with ethyl benzene, styrene. If these substances are inside human body, they will be metabolized to be hippuric acid. If ethanol is inside human body, then metabolism of toluene will be inhibited. So the amount of toluene from the test will be lower than the actual amount. The amount of hippuric acid in human urine is 0.5-1.5 mg/g.

2.2.3 Xylene:

Xylene ($C_6H_4(CH_3)_2$)'s molecule weight is 106.17, and the other names of Xylene are dimethylbenzene, xylain, xylol. Xylene is aromatics hydrocarbon that produced from distillation of coal tar and petroleum. In business, Xylene is a mixture of three isomers that are 30% of ortho-xylene (o-xylene), 60-70% of meta-xylene (m-xylene), and about 5% of para-xylene (p-xylene). Xylene is in the form of liquid (Pure para-xylene is in the form of solid at the temperature lower than $12.7\,^oC$). Xylene is colorless, volatile, and soluble in fats. Xylene is flaming liquid class 3 according to the classification by United Nation.

2.2.3.1 Entering Human Body and Mechanisms of Disease:

Mostly, Xylene enters human body by absorbing through skin and breathing. If xylene is absorbed through skin, it will cause more skin irritation than benzene and toluene. If xylene is breathed in to the lungs, then xylene will be spread through circulatory system. These xylenes will be altered to be o-, m- or p-toluic acid ($CH_3C_6H_4COOH$), which will be mixed with glycine. These acids will be disposed in the form of methyhippuric acid; $CH_3C_6H_4COONHCH_2COOH$, which is specific with xylene.

2.2.3.2 Acute Effects:

If contact with xylene that has concentration higher than 200 ppm, the symptoms can be

- Stupor, headache, dizziness, malaise, vomit, and sensitive neck or chest.
- Effects on respiratory tract, such as cough and runny nose.
- Skin and eyes irritation, and mucous membrane depending n the level of concentration.

2.2.3.3 Chronic Effects:

Are similar to acute effects, but the effects will be more drastic.

Contact with the volatile xylene in a long time can cause eyes tissue inflammation, dry skin, nose, and throat. Contact with xylene directly can cause flaky skin and dermatitis. Breathing xylene in can cause effects on central nervous system, such as paraesthesis, tremors, apprehension, amnesia, tiredness, anxiety, difficulties in body balancing, headache, being bored of food, flatulence, hyperplasia, necrosis, and kidney disease.

2.2.3.4 Laboratory Tests:

Help in diagnosis, such as measuring the amount of methylhappuric acid in urine, which is xylene's metabolite, by using the technique of High Performance Liquid Chromatography (HPLC). This method requires to separate sample people who addicted aspirin and alcohol because these behaviors affect the amount of methylhappuric acid in urine. This method is specific, then it is appropriate for monitoring biological samples. The examples of testing the effects on health are liver function, kidney function, and nervous system test.

2.3 Definition and Meaning of Medium Enterprise, Small Enterprise, and Household

Ministry of Industry has defined medium enterprise, small enterprise, and household or SMEs. Thailand abides “invest amount” as a criteria, so medium enterprise is the business that invested money less than 200 million baht, and small enterprise is the business that invested money less than 50 million baht. This classification is related to the definition by Department of Industrial Promotion, Ministry of Industry.

2.4 Printing Industry

Printing Industry includes letter and pattern printing on materials, such as paper, slim plastic plate, and etc. According to the ministerial regulations 2535 in the Factory Act 2535 Section 41, printing industries are:

- ✓ Document printing, producing, binding, covering, and embellishing**.**
- ✓ Metal mold production, such as the described printing industries that can be categorized into three type (type 1, 2, and 3) by the horse power of the machine as follows:

Type 1 Industry uses machine that has horse power less than 20 hp,

Type 2 Industry uses machine that has horse power less than 50 hp (machines that are used in Type 1 industry)

Type 3 Industry uses machine that has horse power higher than 50 hp.

There are various printing systems depending on the design, such as offset system, letterpress system, gravure system, screening system and so on. The study emphasizes the offset printing because this printing system is widely used in medium enterprise, small enterprise, and household. Offset printing is four colors printing that can produce various and more media than other printing system. Offset printing is industrial printing that can print in number quickly, and low costing. Color printing and including images will result in high quality same as the original one. Two types of papers can be used: Web Fed Offset Press and Sheet Fed Offset Press. Offset printing is normally used in magazine, annual report, news letter, flyer, brochure, and newspaper printing.

Offset printing is four color printing and printing two pages at once. Therefore, this printing system is convenient for user and this system is called four color printing or Full-Color printing.

Offset printing machines can be categorized by the size of printing plates as follows (Paper Choice, 2005):

✓ Small offset plate is the printing plate for paper that has size not over 13” x 17”. This type of offset printing machine is used for letterhead, flyer, book, and small poster printing.

✓ Medium offset plate is the printing plate for paper that has size not over 18” x 25”. This type pf offset printing machine can be used for general printing purposes.

✓ Large offset plate is the printing plate for paper that has size not over 28” x 40”. This type of offset printing machine can print quickly and accurately.

✓ Huge offset plate is the printing plate for paper that has size not over 30” x 40”. This type of offset printing machine can use both Web Fed Offset Press paper and Sheet Fed Offset Press paper depending on the printing amount.

Processes in printing industry begin with the creation of “Plate” by pattern copying with UV radiation on the printing machine. To start the printing process, ink must be filled into the plate that use insulator as a pattern copier from the gravure to print on the paper. Ink on the plate, insulator, and other equipment must be clean every time that the plate is changed by using the organic solvent. Therefore, volatile organic compounds can leaks easily in this cleaning process.

2.4.1 Plate Preparation

Description:

Digital printing design and pattern copying on aluminum plate with UV radiation for 5 minutes. The copied aluminum plate will have the same pattern as the design, and this aluminum plate is called “Plate”. Clean the plate with plate cleaning solution, and gluing the plate to protect its surface.

Chemicals:

Plate cleaning solution, such as Plate Thinner, Developer, Fixer, Plate Pressitve, and etc. These cleaning solutions comprise of Liquid Polyethylene. The ratio of mixture for using is cleaning solution 5 : water 1

Plate surface maintenance glue is called Gum Arabic is think, yellow, scentless. This glue is used to coat the plate surface.

Pollutants: The smell of vapor of volatile organic compound in plate cleaning process and gluing is dangerous for workers

Waste water from plate cleaning process

Wastes: Chemical containers

Management: Keeping in the black bags

2.4.2 Printing process

Description: The copied plate will be radiated with UV. The printing processes begin from putting the plate into the printer, and the desired printing area and the floor will be on the same plane. The rolling balls are used for water casting on the undesired printing area. The desired printing area is coated with oil. In this process, Fountain is used to lubricate the plate and insulator is used as an ink stamp to roll on the desired printing area, the result will be the invert print. The paper will be inserted between the insulator and compressor, then the insulator will print on that inserted paper.

Chemicals:

Ink Most of the printing center used instant use ink that comprises of solvent. Fountain is a chemical that is used to coat plate surface and moistening the surface. Fountain also helps to lubricate the ink to spreads thoroughly on the plate before printing.

Pollutants: VOCs in Ink

Wastes: Ink cans

Management: Keeping in the black bags

Cleaning Processes

Description: This process that can release the highest amount of VOCs because ink comprises of high amount of VOCs. The cleaning process can be categorized as follows:

Plate Cleaning Used plated will be clean with plate cleaning solution that is a mixture of thinner. The clean plate will be coated with glue by using the sponge that is soaked with the solution. In this process, the worker will touch and breathe VOCs directly.

Insulator Cleaning Insulator that is used as a copy of plate is confused with ink, then insulator is needed to be clean. Benzene is normally used to clean the ink on the insulator. From the survey on small enterprise and household, they usually clean the insulator by putting it into the benzene tank, then the workers touch benzene directly.

Printer Equipment Cleaning Using paraffin to clean the equipment every time after use.

Chemicals: Chemicals that are used for plate cleaning are plate cleaning solution (Plate Thinner) that is a mixture of thinner. This solution comprises of Suphuric acid 5%, Sodium Carbonate, Gecerine Pure, White Oil, Emontional Dioxide, Calcium Bicarbonate, Stearic acid and distillate water. This solution is used to clean offset printing plate by eliminating dust and oil color on the plate.

Chemicals that are used for insulator cleaning are benzene and white benzene that is scentless, having higher purity than normal benzene. White benzene is a drastic solvent and causing healthy problem on workers who touch and breathe for a long time. In one day, benzene is used to clean insulator for 2 liters per one insulator.

Chemical that is used in printer equipment cleaning is paraffin or kerosene is the liquid that is clear, and colorless. Paraffin is a type of fuels, which is hydrocarbon compound that has boiling point at 150-300^oC. Paraffin comprises of paraffin naphtha and aromatics. Typically, water color will be added to paraffin before distribution.

Pollutants: Vapors of VOCs are released in cleaning processes, then workers who associate in this process will have breathe and touch these vapors.

Wastes: 20 clothes moistened with petrol are daily used for insulator cleaning, Management: Keeping in the black bags

Publishers have ratable and appropriate chemical storage system. Flammable chemicals will be kept in the room outside the building. From the survey on the production of publishing industry, the processes that release the highest amount of VOCs are plate, insulator, and equipment cleaning process. The organic solvents are used in these processes, such as benzene, thinner, paraffin. These organic solvents are VOCs that can produce intense odor. In small enterprise and household, there is no ventilation system and odor treatment system installed, and there is no appropriate room for color mixing process. From these reasons, the workers have a chance of being affected by breathing and contact with the dangerous chemicals in cleaning and mixing process for a long time. Hence, it is really important to suggest the guideline for eliminating VOCs in each process of printing industry.

2.5 Related Studies

There were various studies that were about VOCs, such as Bing-Ling Wang, Tomoko Takigawa, Akito Takeuchi, Yukie Yamasaki, Hiroyuki Kataoka, Da-Hong Wang and Keiki Okino (2007) that studied on the possibility of using VOCs in urine as an index of VOCs concentration. The findings indicated the significant relationship between VOCs concentration in the air in bedroom and concentration of o-xylene, total xylene and p-dichlorobenzene in morning urine (correlation coefficients 0.54, 0.61, 0.56, and 0.84).There was a possibility that measuring method of VOCs in urine could be used as an index of the amount of VOCs in people who did not touch or work with VOCs directly.

Brinke, J. Ten , Selvin, S, Hodgson, A. T. , Fisk, W. J. , Mendell, M. J., Koshland, C. P. , Daisey, J. M. (1998) studied on 22 people who worked in the office building, California. The findings indicated the significant statistical relationship between VOCs concentration in the room and Sick Building Syndrome.

Marja-Liisa Lindbohm' Markku Sallmén' Pentti Kyyrönen' Timo Kauppinen' Eero Pukkala (2009) studied on the relationship between VOCs receiving and liver cancer in printers and polishers. The findings shown that group of men has the highest risk with aromatic hydrocarbons (RR 1.77, 95% confidence interval (CI), aliphatic/alicyclic hydrocarbons (RR 1.47, 95% CI 0.99-2.18), chlorinated hydrocarbons (RR 2.65, 95% CI 1.38-5.11), and other solvents (RR 2.14, 95% CI 1.23-3.71) . For the group of women, risk will increase with other solvents (RR 2.73, 95% CI 1.21-6.16) only.

M. Dosemeci, PhD, G.-L. Li, PhD, R. B. Hayes, PhD, S.-N. Yin, MD, M. Linet, MD, W.-H. Chow, PhD, Y.-Z. Wang, MD, Z.-L. Jiang, T.-R. Dai, MD, W.-U. Zhang, MD, X.-J. Chao, MD, P.-Z. Ye, MD, Q.-R. Kou, MD, Y.-H. Fan, X.-C. Zhang, MD, X.-F. Lin, MD, J.-F. Meng, MD, J.-S. Zho, MD, S. Wacholder, PhD, R. Kneller, MD, W. J. Blot, PhD (2007) used a retrospective assessment in the study on abnormalities of workers who contact with benzene from various industries that use benzene in 12 cities in China with 1,429 divisions, and 3,179 types of jobs. The study used the information about the results of measuring benzene in workplace, details of materials, industry products, proportion of benzene in each substance in the frequency of days, the amount of benzene that being used, substances that comprise of benzene, using of private safety equipment, engineer controls, and other data about contact with chemicals.

Patricia A. Stewart, MS, CIH, Walter F. Stewart, PhD (2007) used contact assessment in contact estimating. This study assigned variable that can be biased in the assessment, for example the quality of the information (about types of jobs, industry, activities and materials), *industrial* hygienists bias, possibility of contact depending on the structure of factory, production technology, customers' demand, and diversities of jobs.

Ana F. L. Godoi ,Eliza Y. Sawada,Mary Rosa R. de Marchi,René Van Grieken and Ricardo H. M. Godoi· In this study, the BTEX concentrations were determined in two different printing plants that use distinct types of inks: the conventional and the so-called ecological, which is manufactured based on vegetal oil. Concentration ranges were 43–84, 15–3,480, 2–133, 5–459, and 2–236 μg m^{-3} for benzene, toluene, ethylbenzene, *m*□+□*p*-xylene, and *o*-xylene, respectively, for the conventional printing plant. At the ecological printing plant, concentration ranges were below limit of detection (<LD)-31, <LD-618, <LD-1,690, <LD-10,500, <LD-3,360 μg m^{-3} for benzene, toluene, ethylbenzene, *m*□+□*p*-xylene, and *o*-xylene, respectively. BTEX concentrations are lower at the ecological printing environment than in the

conventional, where mineral oil-based inks are used. However, the worker who cleans the printing matrices is exposed to high concentrations of ethylbenzene and xylenes, due probably to the cleaning product's composition (containing high amounts of BTEX). Although the BTEX concentrations found in both printing work environments were below the limits considered by the Brazilian Law for Activities and Unhealthy Operations (NR-15), the exposure to such vapors characterizes risk to the workers' health for some of the evaluated samples, mainly the personal ones.

Wadden, RA | Scheff, PA | Franke, JE | Conroy, LM. They test conducted at three offset printing shops that varied in size and by process. In each case, the building shell served as the test "enclosure," and air flow and concentration measurements were made at each air entry and exit point. Emission rates and VOC composition were determined during production for (1) a small shop containing three sheetfed presses and two spirit duplicators (36,700 sheets, 47,240 envelopes and letterheads), (2) a medium-size industrial in-house shop with two webfed and three sheetfed presses, and one spirit duplicator (315,130 total sheets), and (3) one print room of a large commercial concern containing three webfed, heatset operations (1.16 x 10 super(6) ft) served by catalytic air pollution control devices. Each test consisted of 12 one-hour periods over two days. Air samples were collected simultaneously during each period at 7-14 specified locations within each space. The samples were analyzed by gas chromatography (GC) for total VOC and for 13-19 individual organics. Samples of solvents used at each shop were also analyzed by GC.

Svendsen K, Rognes KS. The purpose of this study was to document the conditions regarding solvent exposure at offset printing offices in Norway at present and to study the variation of exposure between printing office technologies. Measurements were made at seven offset printing offices. The measurements consisted of five to 10 whole day personal exposure measurements at each office performed over a period of 2 months. Variables that may influence the level of exposure were registered by the occupational hygienist at the end of each measuring day using a check list. The influence of the variables on the "additive factor" was examined by linear regression analysis.The main contributor to the "additive factor" was isopropanol. The exposure to isopropanol sometimes exceeded the Norwegian TLV. The exposure decreased when a separate exhaust ventilation was used. The exposure increased when the machine had automatic cleaning. The variables automatic cleaning and separate exhaust ventilation explained 59% of the variation in the "additive factor". The results of this study indicate that the most important source of solvent exposure in printing offices at present is the moisturizer used in the printing machines. We think it is worth giving attention to this exposure and making efforts to reduce it.

R. A. Wadden; P. A. Scheff; J. E. Franke; L. M. Conroy; M. Javor; C. B. Keil; S. A. Milz. Emission rates were determined during production for a sheetfed offset printing shop by combining the measured concentrations and ventilation rates with mass balance models that characterized the printing space. Air samples were collected simultaneously on charcoal tubes for 12 separate 1-hour periods at 6 locations. Air samples and cleaning solvents were analyzed by gas chromatography for total volatile organic compounds (VOC) and 13 hydrocarbons. The average VOC emission rate was 470 g/hr with a range of 160ndash;1100 g/hr. These values were in good agreement with the amounts of VOC, hexane, toluene, and aromatic C_9s determined from estimated solvent usage and measured solvent compositions. Comparison of the emission rates with source activities indicated an emission factor of 30-51 g VOC/press cleaning. Based on the test observations it was estimated that this typical small printing facility was likely to release 1-2 T VOC/year. The methodology also may be useful for the surface coating industry, as emission rates in this study were determined without recourse to a temporary total enclosure and without interfering with worker activities, increasing worker exposure, or increasing safety and explosion hazards.

K. Thanacharoenchanaphas, A. Changsuphan, R.Nimnual, T. Thongsri, S. Phetkasem, C. Lertkanawanitchakul 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 [or -] 28 ppm, 1.7 [or -] 0.3 ppm 3.0 [or -] 2.5 ppm and 1.9 [or -] 0.7 ppm, espectively. The concentration of benzene, which is found as the most prevailingVOC, 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.

CHAPTER III
MATERIALS AND METHODS

3.1 Research Design

This study is a research analyst and details as below.

3.2 Population and sample characteristic

Air samples were collected from small offset printing plant in Bangkok. There are 480 air samples from 112 small printing factories.

3.3 Population and sample selection methods.

✓ The printing factory is in the definition of small business.

Determine the number of ministerial employment and fixed assets of small and Medium Enterprise 2545; the number of workers not more than 50 employees or fixed assets not exceeding fifty million Thai baht.

✓ Was printed by voluntary participants were told the details of the research project. And the management of printers allows sampling.

✓ Require the use of volatile organic compounds in a production process.

✓ Can collect air samples during the normal operation.

3.4 Materials

✓ Data collection form (Table 3-1, 3-2, 3-3).

✓ Air sampling unit

Thermal desorption tube

Vacuum pumps

Stopwatch

3.5 Data Collection.

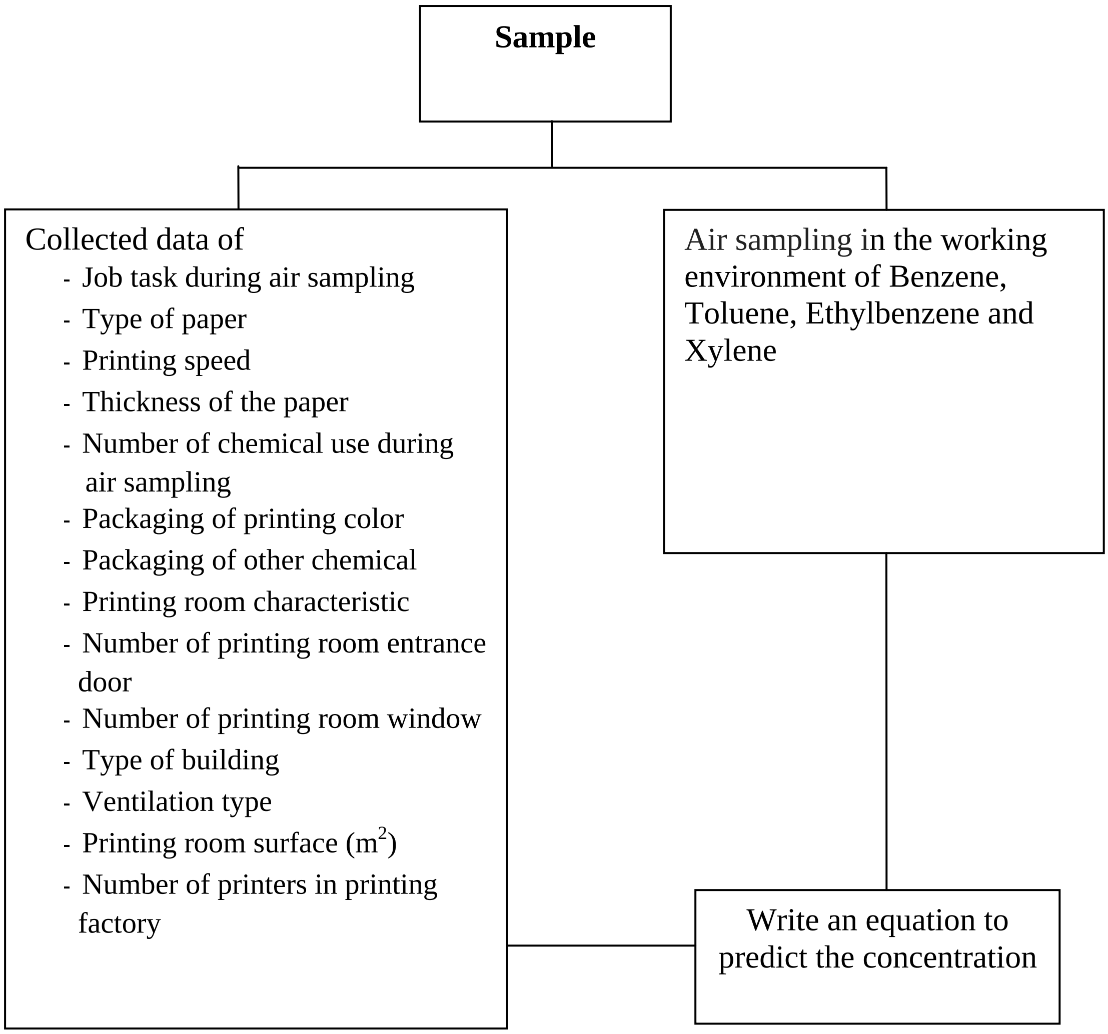


Figure 3-1 Schematic representation of the collected data.

Table 3.1 The data collection form I

วัน/เวลา	การพิมพ์(สี)	ชนิดของสารเคมีที่ใช้	ชนิดของกระดาษ	ความหนาของกระดาษ	ขนาดกระดาษ	ความเร็วในการพิมพ์	ลักษณะบรรจุภัณฑ์สี	ลักษณะบรรจุภัณฑ์สารเคมีอื่น

Table 3.2 The data collection form II

ลักษณะห้องพิมพ์	จำนวนหน้าต่าง	ทางเข้า-ออก	อาคารที่ตั้งโรงพิมพ์	ลักษณะระบบระบายอากาศ	ขนาดห้องพิมพ์	จำนวนเครื่องพิมพ์ในห้อง

3.6 Air sampling

a) Collect air samples in the working area.

b) Collect air samples for analysis of BTEX by means of the NIOH Method 2549 VOLATILE ORGANIC COMPOUNDS (SCREENING) follows.

- ✓ Sampling with Thermal Desorption Tube.
- ✓ Flow Rate 2 L / min at 40 minutes of each sampling point during the operation.

c) Collect data of printing factory characteristics

3.7 Method of analysis

The samples were analyzed for benzene, toluene, ethylbenzene and xylene by Gas Chromatograph Mass Spectrometry.

3.8 Reporting.

Report concentration of benzene, toluene, ethylbenzene and xylene in term of mg/m^3.

CHAPTER IV
RESULTS

The results of this study were divided into 3 parts as follows:

Part I: General characteristics of printing houses

Part II : Field Application

a) Atmospheric Benzene concentrations

b) Atmospheric Toluene concentrations

c) Atmospheric Ethylbenzene concentrations

d) Atmospheric Xylene concentrations

Part III: Statistical analysis of data

a) Relationship between benzene concentrations and general characteristics of printing houses

b) Relationship between toluene concentrations and general characteristics of printing houses

c) Relationship between ethylbenzene concentrations and general characteristics of printing houses

d) Relationship between xylene concentrations and general characteristics of printing houses

4.1 General characteristics of printing houses

The general characteristics of printing houses in this study are summarized in Table 4-1. The considered factors were job descriptions and room characteristics obtained from printing house observation.

This study was conducted at printing houses located in Bangkok. The average printing speed was 7,854.97 $\pm$ 1,857.54 sheets/hour. The average paper thickness was 132.48 $\pm$ 60.00gram/m^2. The average number of used chemical was4.47 $\pm$ 1.52 . The average number of floors was 2.52 $\pm$ 0.85. The average printing room surface was 786.29 ± 837.10 m^3. The average number of mechanical (ventilation) such as fan, was 3.61 ± 2.11. The average number of printer in printing room was 3.79 ± 2.14. Approximately, 41.7% of the printing houses in this study were one color printed, 32.9% printed on plain papers. 45.0% used size of paper 31 x 43 cm., Data from the observation founded that 50.6% of all printing houses closed printing ink bottles while monitored but 54.0% opened other chemical bottles such as benzene., The majority of printing rooms were closed room (58.1%) without window (81.3%) and they had two doors (56.7%). Approximately, 55.4% of them situated in commercial buildings, 57.9% of them had three levels and occupying a floor surface of 300-800 m^3. The majority of printing houses installed air conditioners in printing rooms (48.5%) with two machines (20.4%). The majority of them had 1-3 printers in room(55.6%).

Table 4.1 The general characteristics of printing houses

Characteristics	Frequency	Percent
Job description		
One color print	200	41.7
Two colors print	59	12.3
Four colors print	192	40.0
Five colors print	16	3.3
Six colors print	2	0.4
Drum clean	3	0.6
Printer clean	3	0.6
No activity	5	1.0
Printing Speed (sheet/hr)		
Lower than 5,000	44	9.2
5,000-10,000	409	85.2
10,001-15,000	16	3.3
Unknown	11	2.3
Mean ± SD (7,854.97±1,857.54)		
Min–Max (400 – 15,000)		
Paper		
Colored paper	8	1.7
Plain paper	158	32.9
Gloss coated paper	85	17.7
Matt coated paper	102	21.3
One side coated board	52	10.6
Two side coated board	63	13.1
DVD	2	0.4
Unknown	11	2.3

Table 4.1 The general characteristics of printing houses (cont.)

Characteristics	Frequency	Percent
Paper Thickness(gram per m^2)		
Lower than 80	47	9.8
80-130	275	57.3
131-180	38	7.9
181-230	82	17.1
231-280	12	2.5
Higher than 280	9	1.9
Unknown	17	3.5
Mean $\pm$ SD (132.48$\pm$60.00)		
Min – Max (55 – 450)		
Paper size (cm.)		
24 x 16.8	1	0.2
24 x 35	87	18.1
25 x 36	163	34.0
31 x 43	216	45.0
Unknown	13	2.7
Number of used chemical		
1	6	1.3
3	200	41.7
4	59	12.3
6	192	40.0
7	16	3.3
8	2	0.4
No activity	5	1.0
Mean $\pm$ SD (4.47$\pm$ 1.52)		

Table 4.1 The general characteristics of printing houses (cont.)

Characteristics	Frequency	Percent
Printing ink package		
Closed	243	50.6
Opened	237	49.4
Other chemical package		
Closed	221	46.0
Opened	259	54.0
Room characteristics		
Closed room	279	58.1
Opened room	201	41.9
Number of doors		
One door	166	34.6
Two doors	272	56.7
Three doors	42	8.8
Windows		
No have	390	81.3
Have	90	18.8
Situation		
Commercial building	266	55.4
Single building	214	44.6

Table 4.1 The general characteristics of printing houses (cont.)

Characteristics	Frequency	Percent
Number of floors		
1	84	17.5
2	91	19.0
3	278	57.9
4	27	5.6
Mean $\pm$ SD (2.52 $\pm$ 0.85)		
Printing room surface (m^3)		
Smaller than 300	109	22.7
300 – 800	239	49.8
801 – 1,300	33	6.9
1,301 – 1,800	60	12.5
1,801 – 2,300	9	1.9
More than 2,300	30	6.3
Mean $\pm$ SD (786.29 $\pm$ 837.10)		
Min – Max (144 – 5,760)		
Ventilation type		
Exhaust hood and air conditioner	13	2.7
Air conditioner	233	48.5
Fan	184	38.3
Natural (window only)	50	10.4

Table 4.1 The general characteristics of printing houses (cont.)

Characteristics	Frequency	Percent
Number of mechanical (ventilation)		
1	64	13.3
2	98	20.4
3	78	16.3
4	42	8.8
5	56	11.7
6	28	5.8
7	18	3.8
8	34	7.1
None	62	12.9
Mean ± SD (3.61±2.11)		
Number of printers in printing room		
1-3	267	55.6
4-6	176	36.7
7-9	25	5.2
10-12	12	2.5
Mean ± SD (3.79 ± 2.14)		
Min – Max (1 – 12)		

4.2 Field Application

4.2.1 Atmospheric benzene concentrations

For the analysis of benzene, air samples were collected from the breathing zone of workers in the printing houses (n=480). The air samples were analyzed using Gas Chromatography followed by NIOSH 1501 (GC-FID).

Table 4.2 Atmospheric benzene concentrations in the printing houses

Benzene concentration (mg/m^3)	Frequency	Percent
Lower than 0.01	256	53.3
0.01-1.00	188	39.2
1.01-2.00	18	3.8
2.01-3.00	9	1.9
3.01-4.00	8	1.7
4.01-5.00	1	0.2
Mean $\pm$ SD (0.1905 $\pm$ 0.4837)		
Max (4.2200)		

The average atmospheric benzene concentrations of 112 printing houseswere0.1905 $\pm$ 0.4837mg/m^3. All of atmospheric benzene concentrations 100% (n=480) were below 5 mg/m^3 which was compliance to the 10 mg/m^3 , which was the time weight average (TWA) airborne exposure limit recommended by ACGIH. Table 4-2 shows the levels of atmospheric benzene concentrations classified by the level of concentrations.

4.2.2 Atmospheric toluene concentrations

For the analysis of toluene, air samples were collected from the breathing zone of workers in the printing houses (n=480). The air samples were analyzed using Gas Chromatography followed by NIOSH 1501 (GC-FID).

Table 4.3 Atmospheric toluene concentrations in the printing houses

Toluene concentration (mg/m^3)	Frequency	Percent
Lower than 0.01	105	21.9
0.01-10.00	366	76.3
10.01-20.00	2	0.4
20.01-30.00	2	0.4
30.01-40.00	3	0.6
40.01-50.00	1	0.2
50.01-60.00	1	0.2
Mean $\pm$ SD (1.2686 $\pm$ 4.6436)		
Max (51.0000)		

The average atmospheric toluene concentrations of 112 printing houses were1.2686 $\pm$ 4.6436mg/m^3. All of atmospheric toluene concentrations 100% (n=480) were below 60 mg/m^3which was compliance to the 200mg/m^3 , which was the time weight average (TWA) airborne exposure limit recommended by OSHA. Table 4-3 shows the levels of atmospheric toluene concentrations classified by the level of concentrations.

4..2.3 Atmospheric ethylbenzene concentrations

For the analysis of ethylbenzene, air samples were collected from the breathing zone of workers in the printing houses (n=480). The air samples were analyzed using Gas Chromatography followed by NIOSH 1501 (GC-FID).

Table 4.4 Atmospheric ethylbenzene concentrations in the printing houses

Ethylenzene concentration (mg/m^3)	Frequency	Percent
Lower than 0.01	351	73.1
0.01-0.30	120	25.0
0.31-0.60	6	1.3
0.61-0.91	3	0.6
Mean $\pm$ SD (0.0379 $\pm$ 0.0977)		
Max (0.9020)		

The average atmospheric ethylbenzene concentrations of 112 printing houses were0.0379 $\pm$ 0.0977mg/m^3. All of atmospheric etylbenzene concentrations 100% (n=480) were below0.91mg/m^3 which was compliance to the 100 mg/m^3 , which was the time weight average (TWA) airborne exposure limit recommended by ACGIH. Table 4-4 shows the levels of atmospheric ethylbenzene concentrations classified by the level of concentrations.

4.2.4 Atmospheric xylene concentrations

For the analysis of xylene, air samples were collected from the breathing zone of workers in the printing houses (n=480). The air samples were analyzed using Gas Chromatography followed by NIOSH 1501 (GC-FID).

Table 4.5 Atmospheric xylene concentrations in the printing houses

Xylene concentration (mg/m^3)	Frequency	Percent
Lower than 0.01	191	39.8
0.01-1.00	270	56.3
1.01-2.00	12	2.5
2.01-3.00	3	0.6
3.01-4.00	4	0.8
Mean ± SD (0.1940 ± 0.4574)		
Max (3.7600)		

The average atmospheric xylene concentrations of 112 printing houses were0.1940 ± 0.4574mg/m^3. All of atmospheric xylene concentrations 100% (n=480) were below 4.00 mg/m^3 which was compliance to the 100 mg/m^3 , which was the time weight average (TWA) airborne exposure limit recommended by ACGIH. Table 4-5 shows the levels of atmospheric xylene concentrations classified by the level of concentrations.

4.3 Statistical analysis of data

4.3.1 Relationship between atmospheric benzene concentrations and general characteristics of printing houses.

Due to the wide variation of atmospheric benzene concentrations in the printing house, the relationship between the atmospheric benzene and the general characteristics of printing houses were determined and shown below.

4.3.1.1 Relationship between atmospheric benzene concentration and room characteristics.

Table 4.6 The relationship between atmospheric benzene concentration and room characteristics.

Benzene Concentration (mg/m^3)	Frequency	
	Closed room	Opened room
Lower than 0.01	110	148
0.01-1.00	144	50
1.01-2.00	15	3
2.01-3.00	9	0
4.01-5.00	1	0

Table 4-6 shows that the most of atmospheric benzene concentration from 480 samplesare less than 0.01 mg/m^3(258 from 480 samples) and found in opened room more than closed room.Moreover, in the closed room characteristicsfound atmospheric concentration of benzeneat a higher level in the range 4.01-5.00 mg/m^3, while the highest concentration found in opened room are in the range 1.01-2.00 mg/m^3only.

4.3.1.2 Relationship between atmospheric benzene concentration and number of printing room entrance door

Table 4.7 The relationship between atmospheric benzene concentration and number of printing room entrance door

Benzene Concentration (mg/m^3)	printing room entrance door		
	one door	two doors	three doors
Lower than 0.01	60	170	28
0.01-1.00	95	90	9
1.01-2.00	11	4	3
2.01-3.00	0	8	1
4.01-5.00	0	0	1

Table 4-7shows that the most of atmospheric benzene concentration from 480 samples are less than 0.01 mg/m^3 (258 from 480 samples) and found in the printing room with two doors (170 from 480 samples). While the highest concentration found in printing room with three doors.

4.3.1.3 Relationship between atmospheric benzene concentration and window in printing room

Table 4.8 The relationship between atmospheric benzene concentration and window in printing room

Benzene Concentration (mg/m^3)	**Frequency**	
	have window	**no have window**
Lower than 0.01	178	80
0.01-1.00	186	8
1.01-2.00	16	2
2.01-3.00	9	0
4.01-5.00	1	0

Table 4-8 shows that the most of atmospheric benzene concentration from 480 samples are less than 0.01 mg/m^3 (258 from 480 samples) and found in printing room with window more than without window (178 from 258 samples).But in higher concentration level we still found in printing room with window (highest concentration 1 sample in range 4.01-5.00 mg/m^3) more than without window (highest concentration 2 samples in range 1.01-2.00 mg/m^3)

4.3.1.4 Relationship between atmospheric benzene concentration and type of building.

Table 4.9 The relationship between atmospheric benzene concentration and type of building.

Benzene Concentration (mg/m^3)	Frequency	
	Commercial building	Small factory building
Lower than 0.01	128	130
0.01-1.00	122	72
1.01-2.00	10	8
2.01-3.00	6	3
4.01-5.00	0	1

Table 4-9 shows that the most of atmospheric benzene concentration from 480 samples are less than 0.01 mg/m^3 (258 from 480 samples) and found in both type of building (commercial 128 from 258 samples; small factory 130 from 258 samples).

4.3.1.5 Relationship between atmospheric benzene oncentration and ventilation type

Table 4.10 The relationship between atmospheric benzene concentration and ventilation type

Benzene Concentration (mg/m^3)	Frequency			
	Exhaust hood and air conditioner	Air conditioner	Fan	Natural (windows only)
Lower than 0.01	5	95	118	40
0.01-1.00	5	124	55	10
1.01-2.00	2	10	6	0
2.01-3.00	1	4	4	0
4.01-5.00	0	0	1	0

Table 4-10 shows that the most of atmospheric benzene concentration from 480 samples are less than 0.01 mg/m^3(258 from 480 samples). The highest concentration (range 4.01-5.00) we found in printing room with fan only.

4.3.1.6 Relationship between atmospheric benzene concentration and number of printer in printing room

Table 4.11 The relationship between atmospheric benzene concentration and number of printer in printing room

Benzene Concentration (mg/m^3)	**number of printer in printing room**			
	1-3	**4-6**	**7-9**	**10-12**
Lower than 0.01	148	82	19	9
0.01-1.00	108	77	6	3
1.01-2.00	10	8	0	0
2.01-3.00	1	8	0	0
4.01-5.00	0	1	0	0

Table 4-11 shows that the most of atmospheric benzene concentration from 480 samples are less than 0.01 mg/m^3 (258 from 480 samples). The highest concentration (range 4.01-5.00) we found in printing room with 4-6 printers only.

4.3.1.7 Relationship between atmospheric benzene concentration and printing room surface

Table 4.12 The relationship between atmospheric benzene concentration and printing room surface

Benzene Concentration (mg/m^3)	printing room surface (m^2)		
	<300	300-800	801-1,300
Lower than 0.01	79	165	14
0.01-1.00	59	132	3
1.01-2.00	5	13	0
2.01-3.00	0	9	0
4.01-5.00	0	1	0

Table 4-12 shows that the most of atmospheric benzene concentration from 480 samples are less than 0.01 mg/m^3 (258 from 480 samples). The highest concentration (range 4.01-5.00) we found in printing room with working area 300-800 m^2 only.

4.3.2 Relationship between atmospheric toluene concentrations and general characteristics of printing houses.

Due to the wide variation of atmospheric toluene concentrations in the printing house, the relationship between the atmospheric toluene and the general characteristics of printing houses were determined and shown below.

4.3.2.1 Relationship between atmospheric toluene concentration and room characteristics.

Table 4.13 The relationship between atmospheric toluene concentration and room characteristics.

Toluene Concentration (mg/m^3)	Frequency	
	Closed room	Opened room
Lower than 0.01	273	200
10.01-20.00	1	0
20.01-30.00	1	0
30.01-40.00	2	1
40.01-50.00	1	0
50.01-60.00	1	0

Table 4-13 shows that the most of atmospheric toluene concentration from 480 samples are less than 0.01 mg/m^3 (473 from 480 samples) and found in closed room more than opened room. Moreover, in the closed room characteristics found atmospheric concentration of toluene at a higher level in the range 50.01-60.00mg/m^3, while the highest concentration found in opened room are in the range 30.01-40.00mg/m^3 only.

4.3.2.2 Relationship between atmospheric toluene concentration and number of printing room entrance door

Table 4.14 The relationship between atmospheric toluene concentration and number of printing room entrance door

Toluene Concentration (mg/m^3)	printing room entrance door		
	one door	two doors	three doors
Lower than 0.01	166	265	42
10.01-20.00	0	1	0
20.01-30.00	0	1	0
30.01-40.00	0	3	0
40.01-50.00	0	1	0
50.01-60.00	0	1	0

Table 4-14 shows that the most of atmospheric toluene concentration from 480 samples are less than 0.01 mg/m^3(473 from 480 samples) and found in the printing room with two doors (272 from 480 samples). While the highest concentration found in printing room with two doors.

4.3.2.3 Relationship between atmospheric toluene concentration and number of printing room window

Table 4.15 The relationship between atmospheric toluene concentration and number of printing room window

Toluene Concentration (mg/m^3)	**number of printing room window**	
	Have	**No have**
Lower than 0.01	383	90
10.01-20.00	1	0
20.01-30.00	1	0
30.01-40.00	3	0
40.01-50.00	1	0
50.01-60.00	1	0

Table 4-15 shows that the most of atmospheric toluene concentration from 480 samples are less than 0.01 mg/m^3 (473 from 480 samples) and found in printing room with window more than without window (390 from 473 samples). But in higher concentration level we still found in printing room with window (highest concentration 1 sample in range 50.01-60.00 mg/m^3) more than without window (highest concentration in range lower than 0.01ppm)

4.3.2.4 Relationship between atmospheric toluene concentration and type of building.

Table 4.16 The relationship between atmospheric toluene concentration and type of building.

Toluene Concentration (mg/m^3)	Frequency	
	Commercial building	Small factory building
Lower than 0.01	266	207
10.01-20.00	0	1
20.01-30.00	0	1
30.01-40.00	0	3
40.01-50.00	0	1
50.01-60.00	0	1

Table 4-16 shows that the most of atmospheric toluene concentration from 480 samples are less than 0.01 mg/m^3 (473 from 480 samples) and found in both type of building (commercial 266 from 473 samples; small factory 207 from 473 samples).

4.3.2.5 Relationship between atmospheric toluene concentration and ventilation type

Table 4.17 The relationship between atmospheric toluene concentration and ventilation type

Toluene Concentration (mg/m^3)	Ventilation type			
	Exhaust hood and air conditioner	Air conditioner	Fan	Natural (windows only)
Lower than 0.01	13	227	183	50
10.01-20.00	0	1	0	0
20.01-30.00	0	1	0	0
30.01-40.00	0	2	1	0
40.01-50.00	0	1	0	0
50.01-60.00	0	1	0	0

Table 4-17 shows that the most of atmospheric toluene concentration from 480 samples are less than 0.01 mg/m^3(473 from 480 samples). The highest concentration (range 4.01-5.00) we found in printing room with air conditioner only.

4.3.2.6 Relationship between atmospheric toluene concentration and number of printer in printing room

Table 4.18 The relationship between atmospheric toluene concentration and number of printer in printing room

Toluene Concentration (mg/m^3)	**number of printer in printing room**			
	1-3	**4-6**	**7-9**	**10-12**
Lower than 0.01	267	175	19	12
10.01-20.00	0	0	1	0
20.01-30.00	0	0	1	0
30.01-40.00	0	1	2	0
40.01-50.00	0	0	1	0
50.01-60.00	0	0	1	0

Table 4-18 shows that the most of atmospheric toluene concentration from 480 samples are less than 0.01 mg/m^3 (473 from 480 samples). The highest concentration (range 4.01-5.00) we found in printing room with 7-9 printers only.

4.3.2.7 Relationship between atmospheric toluene concentration and printing room surface

Table 4.19 The relationship between atmospheric toluene concentration and printing room surface

Toluene Concentration (mg/m^3)	printing room surface (m^2)		
	<300	300-800	801-1,300
Lower than 0.01	143	313	17
10.01-20.00	0	1	0
20.01-30.00	0	1	0
30.01-40.00	0	3	0
40.01-50.00	0	1	0
50.01-60.00	0	1	0

Table 4-19 shows that the most of atmospheric toluene concentration from 480 samples are less than 0.01 mg/m^3 (473 from 480 samples). The highest concentration (range 4.01-5.00) we found in printing room with working area 300-800 m^2 only.

4.3.3 Relationship between atmospheric ethylbenzene concentrations and general characteristics of printing houses.

Due to the wide variation of atmospheric ethylbenzene concentrations in the printing house, the relationship between the atmospheric ethylbenzene and the general characteristics of printing houses were determined and shown below.

4.3.3.1 Relationship between atmospheric ethylbenzene concentration and room characteristics.

Table 4.20 The relationship between atmospheric ethylbenzene concentration and room characteristics.

Ethylbenzene Concentration (mg/m^3)	Frequency	
	Closed room	Opened room
Lower than 0.01	188	161
0.01-0.30	90	40
0.30-0.60	1	0

Table 4-20 shows that the most of atmospheric ethylbenzene concentration from 480 samples are less than 0.01 mg/m^3 (349 from 480 samples) and found in closed room more than opened room. Moreover, in the closed room characteristics found atmospheric concentration of ethylbenzeneat a higher level in the range 0.30-0.60mg/m^3, while the highest concentration found in opened room are in the range 0.01-0.30mg/m^3 only.

4.3.3.2 Relationship between atmospheric ethylbenzene concentration and number of printing room entrance door

Table 4.21 The relationship between atmospheric ethylbenzene concentration and number of printing room entrance door

Ethylbenzene Concentration (mg/m^3)	number of printing room entrance door		
	One door	**Two doors**	**Three doors**
Lower than 0.01	108	210	31
0.01-0.30	58	61	11
0.30-0.60	0	1	0

Table 4-21 shows that the most of atmospheric ethylbenzene concentration from 480 samples are less than 0.01 mg/m^3 (349 from 480 samples) and found in the printing room with two doors (210 from 480 samples). While the highest concentration found in printing room with two doors.

4.3.3.3 Relationship between atmospheric ethylbenzene concentration and number of printing room window

Table 4.22 The relationship between atmospheric ethylbenzene concentration and number of printing room window

Ethylbenzene Concentration (mg/m^3)	number of printing room window	
	Have	**No have**
Lower than 0.01	264	85
0.01-0.30	125	5
0.30-0.60	1	0

Table 4-22 shows that the most of atmospheric ethylbenzene concentration from 480 samples are less than 0.01 mg/m^3 (349 from 480 samples) and found in printing room with window more than without window (264 from 349 samples). But in higher concentration level we still found in printing room with window (highest concentration 1 sample in range 0.30-0.60mg/m^3) more than without window (highest concentration in range 0.01-0.30 mg/m^3)

4.3.3.4 Relationship between atmospheric ethylbenzene concentration and type of building.

Table 4.23 The relationship between atmospheric ethylbenzene concentration and type of building

Ethylbenzene Concentration (mg/m^3)	**Type of building**	
	Commercial building	**Small factory building**
Lower than 0.01	193	156
0.01-0.30	73	57
0.30-0.60	0	1

Table 4-23 shows that the most of atmospheric ethylbenzene concentration from 480 samples are less than 0.01 mg/m^3 (349 from 480 samples) and found in both type of building (commercial 193 from 349 samples; small factory 156 from 349 samples).

4.3.3.5 Relationship between atmospheric ethylbenzene concentration and ventilation type

Table 4.24 The relationship between atmospheric ethylbenzene concentration and ventilation type

Ethylbenzene Concentration (mg/m^3)	**number of printing room entrance door**			
	Exhaust hood and air conditioner	**Air conditioner**	**Fan**	**Natural (windows only)**
Lower than 0.01	7	162	133	47
0.01-0.30	6	71	50	3
0.30-0.60	0	0	1	0

Table 4-24 shows that the most of atmospheric ethylbenzene concentration from 480 samples are less than 0.01 mg/m^3 (349 from 480 samples). The highest concentration (range 0.30-0.60) we found in printing room with fan only.

4.3.3.6 Relationship between atmospheric ehylbenzene concentration and number of printer in printing room

Table 4.25 The relationship between atmospheric ethylbenzene concentration and number of printer in printing room

Ethylbenzene Concentration (mg/m^3)	**number of printer in printing room**			
	1-3	**4-6**	**7-9**	**10-12**
Lower than 0.01	203	111	23	12
0.01-0.30	63	65	2	0
0.30-0.60	1	0	0	0

Table 4-25 shows that the most of atmospheric ethylbenzene concentration from 480 samples are less than 0.01 mg/m^3 (349 from 480 samples). The highest concentration (0.30-0.60) we found in printing room with 1-3 printers only.

4.3.3.7 Relationship between atmospheric Ethylbenzene concentration and printing room surface

Table 4.26 The relationship between atmospheric ethylbenzene concentration and printing room surface

Ethylbenzene Concentration (mg/m^3)	printing room surface (m^2) <300	300-800	801-1,300
Lower than 0.01	114	229	6
0.01-0.30	29	91	10
0.30-0.60	0	0	1

Table 4-26 shows that the most of atmospheric ethylbenzene concentration from 480 samples are less than 0.01 mg/m^3 (349 from 480 samples). The highest concentration (range 0.30-0.60) we found in printing room with working area 801-1,300 m^2 only.

4.3.4 Relationship between atmospheric xylene concentrations and general characteristics of printing houses.

Due to the wide variation of atmospheric xylene concentrations in the printing house, the relationship between the atmospheric xylene and the general characteristics of printing houses were determined and shown below.

4.3.4.1 Relationship between atmospheric xylene concentration and room characteristics.

Table 4.27 The relationship between atmospheric xyleneconcentration and room characteristics.

Xylene Concentration (mg/m^3)	Frequency Closed room	Opened room
Lower than 0.01	74	112
0.01-1.00	190	86
1.01-2.00	9	2
2.01-3.00	3	0
3.01-4.00	3	1

Table 4-27 shows that the most of atmospheric benzene concentration from 480 samples are 0.01-1.0 mg/m^3 (276 from 480 samples) and found in opened room more than closed room. Moreover, in the closed room and opened room characteristicsfound atmospheric concentration of xylene at a higher level in the range 3.01-4.00 mg/m^3,

4.3.4.2 Relationship between atmospheric xylene concentration and number of printing room entrance door

Table 4.28 The relationship between atmospheric xylene concentration and number of printing room entrance door

Xylene Concentration (mg/m^3)	printing room entrance door		
	one door	two doors	three doors
Lower than 0.01	36	130	20
0.01-1.00	126	130	20
1.01-2.00	3	7	1
2.01-3.00	0	3	0
3.01-4.00	1	2	1

Table 4-28 shows that the most of atmospheric xylene concentration from 480 samples are 0.01-1.00mg/m^3 (276 from 480 samples) and found in the printing room with two doors (130 from 276 samples). While the highest concentration found in printing room with one, two and three doors.

4.3.4.3 Relationship between atmospheric xylene concentration and window in printing room

Table 4.29 The relationship between atmospheric xylene concentration and window in printig room

xylene Concentration (mg/m^3)	Frequency	
	have window	no have window
Lower than 0.01	117	69
0.01-1.00	255	21
1.01-2.00	11	0
2.01-3.00	3	0
3.01-4.00	4	0

Table 4-29 shows that the most of atmospheric xyleneconcentration from 480 samples are 0.01-1.00 mg/m^3 (276 from 480 samples) and found in printing room with window more than without window (255 from 276 samples). But in higher concentration level we still found in printing room with window (highest concentration 1 sample in range 3.01-4.00 mg/m^3) more than without window.

4.3.4.4 Relationship between atmospheric xylene concentration and type of building.

Table 4.30 The relationship between atmospheric xylene concentration and type of building.

Xylene Concentration (mg/m^3)	Frequency	
	Commercial building	Small factory building
Lower than 0.01	106	80
0.01-1.00	146	130
1.01-2.00	8	3
2.01-3.00	3	0
3.01-4.00	3	1

Table 4-30 shows that the most of atmospheric xylene concentration from 480 samples are 0.01-1.00 mg/m^3(276 from 480 samples) and found in both type of building (commercial 146 from 276 samples; small factory 130 from 276 samples).

4.3.4.5 Relationship between atmospheric xylene concentration and ventilation type

Table 4.31 The relationship between atmospheric xylene concentration and ventilation type

Xylene Concentration (mg/m^3)	Frequency			
	Exhaust hood and air conditioner	Air conditioner	Fan	Natural (windows only)
Lower than 0.01	5	63	85	33
0.01-1.00	7	162	90	17
1.01-2.00	1	7	3	0
2.01-3.00	0	1	2	0
3.01-4.00	0	0	4	0

Table 4-31 shows that the most of atmospheric xylene concentration from 480 samples are 0.01-1.00 mg/m^3 (276 from 480 samples). The highest concentration (range 3.01-4.00) we found in printing room with fan only.

4.3.4.6 Relationship between atmospheric xylene concentration and number of printer in printing room

Table 4.32 The relationship between atmospheric xylene concentration and number of printer in printing room

Xylene Concentration (mg/m^3)	number of printer in printing room			
	1-3	4-6	7-9	10-12
Lower than 0.01	115	50	15	6
0.01-1.00	146	114	10	6
1.01-2.00	4	7	0	0
2.01-3.00	0	3	0	0
3.01-4.00	2	2	0	0

Table 4-32 shows that the most of atmospheric xylene concentration from 480 samples are0.01-1.00 mg/m^3 (276 from 480 samples). The highest concentration (range 3.01-4.00) we found in both printing room with 1-3 and 4-6 printers.

4.3.4.7 Relationship between atmospheric xylene concentration and printing room surface

Table 4.33 The relationship between atmospheric xylene concentration and printing room surface

Xylene Concentration (mg/m^3)	printing room surface (m^2)		
	<300	300-800	801-1,300
Lower than 0.01	69	113	4
0.01-1.00	69	194	13
1.01-2.00	5	6	0
2.01-3.00	0	3	0
3.01-4.00	0	4	0

Table 4-33 shows that the most of atmospheric xylene concentration from 480 samples are 0.01-1.00 mg/m^3 (276 from 480 samples). The highest concentration (range 3.01-4.00) we found in printing room with working area 300-800 m^2 only.

4.3.5 Factors Contributing to atmospheric concentration of benzene

We then modeled various factors that could explain measured concentrations of benzene, obtaining the following model (see Table 4-34):

ln(ethyl benzene) = 1.740(*X1.1*) + 1.618(*X1.2*) + 1.841(*X1.3*) + 1.988(*X1.4*) + 0.000(*X2*) + 0.544(*X3.1*) + 0.442(*X3.2*) - 0.006(*X3.3*) - 0.067(*X3.4*) + 0.148(*X3.5*) + 0.003(*X4*) + 0.025(*X5.1*) + 0.331(*X5.2*) + 0.182(*X5.3*) - 0.086(*X6.1*) - 1.150(*X6.2*) + 1.105(*X6.3*) + 0.061(*X6.4*) + 2.780(*X6.5*) - 1.490(*X6.6*) + 0.491(*X6.7*) + 0.965(*X6.8*) - 0.386(*X6.9*) + 1.383(*X7*.1) - 0.128(*X8.1*) - 0.017(*X9.1*) - 1.134(*X10.1*) + 0.029(*X11*.1) + 0.361(*X12*) - 0.155(*X13*) + 1.967(*X14.1*) - 0.894(*X14.2*) - 0.210(*X14.3*) - 0.253(*X15*) + 0.024(*X16*) - 4.704

where

X1 = Job task during air sampling (Dummy Variable: Other is Reference Group)

X1.1 = Job task: One color print

X1.2 = Job task: Two color print

X1.3 = Job task: Four color print

X1.4 = Job task: Five color print

X2 = Printing Speed

X3 = Paper Type (Dummy Variable: Other is Reference Group)

X3.1 = Paper Type: Colored Paper

X3.2 = Paper Type: Plain Paper

X3.3 = Paper Type: Gloss Coated paper

X3.4 = Paper Type: Matt Coated paper

X3.5 = Paper Type: One Side Coated board

X4 = Paper Thickness (X4)

X5 = Paper Size (Dummy Variable: Other is Reference Group)

X5.1 = Paper Size: 24 x 16.8

X5.2 = Paper Size: 24 x 35

X5.3 = Paper Size: 25 x 43

X6 = Type of Chemical Used (Dummy Variable: Other is Reference Group)

X6.1 = Type of Chemical Used: Colorful Jupiter ink

X6.2 = Type of Chemical Used: Colorpia

X6.3 = Type of Chemical Used: Horsehead ultimate

X6.4 = Type of Chemical Used: IIK

X6.5 = Type of Chemical Used: Interink

X6.6 = Type of Chemical Used: Rocket printing ink

X6.7 = Type of Chemical Used: S.R. Color ink pro art

X6.8 = Type of Chemical Used: T&K Toka

X6.9 = Type of Chemical Used: Toyo king

X7 = Printing Ink Package (Dummy Variable: Open is Reference Group)

X7.1 = Printing Ink Package: Close

X8 = Other Chemical Package (Dummy Variable: Open is Reference Group)

X8.1 = Other Chemical Package: Close

X9 = Room Characteristics (Dummy Variable: Opened Room is Reference Group)

X9.1 = Room Characteristics: Closed Room

X10 = Windows (Dummy Variable: Have Windows is Reference Group)

X10.1 = Windows: No Windows

X11 = Situation (Dummy Variable: Single building is Reference Group)

X11.1 = Situation: Commercial building

X12 = Number of Doors

X13 = Number of floors

X14 = Ventilation type (Dummy Variable: Natural is Reference Group)

X14.1 = Ventilation type: Exhaust hood and Air Conditioner

X14.2 = Ventilation type: Air Conditioner

X14.3 = Ventilation type: Fan

X15 = Number of mechanical (ventilation)

X16 = Number of printers in printing room

This model explained 43.4 percent of variability of log transformed benzene concentrations. Based on this model, when we have more printing speed, more Number of mechanical (ventilation), open packaging of printing color and Interink used resulted in elevated benzene concentrations.

Table 4.34 Factors contributing to benzene concentration in working area of printing factor

Parameter	B	S.E.	Beta	t	Sig.
Job Description (Dummy Variable)					
- One color print (*X1.1*)	1.740	1.342	.606	1.297	.196
- Two color print(*X1.2*)	1.618	1.356	.394	1.193	.234
- Four color print(*X1.3*)	1.841	1.319	.664	1.396	.165
- Five color print(*X1.4*)	1.988	1.371	.288	1.450	.149
Other (Reference Group)					
Printing Speed(*X2*)	.000	.000	.177	2.442	.016
Paper Type (Dummy Variable)					
- Colored Paper (*X3.1*)	.544	.680	.059	.800	.425
- Plain Paper (*X3.2*)	.442	.371	.157	1.191	.235
- Gloss Coated paper (*X3.3*)	-.006	.404	-.002	-.015	.988
- Matt Coated paper (*X3.4*)	-.067	.418	-.021	-.161	.872
- One Side Coated board (*X3.5*)	.148	.463	.032	.320	.749
- Other (Reference Group)					
Paper Thickness (*X4*)	.003	.002	.129	1.769	.079
Paper Size (Dummy Variable)					
- 24 x 16.8 (*X5.1*)	.025	1.282	.001	.020	.984
- 24 x 35 (*X5.2*)	-.331	.243	-.103	-1.359	.176
- 25 x 43 (*X5.3*)	-.182	.228	-.063	-.798	.426
- Other (Reference Group)					
Type of Chemical Used (Dummy Variable)					
- Colorful Jupiter ink(*X6.1*)	-.086	.633	-.012	-.135	.893
- Colorpia(*X6.2*)	-1.150	1.255	-.057	-.917	.360
- Horsehead ultimate(*X6.3*)	1.105	1.253	.054	.882	.379

Table 4.34 Factors contributing to benzene concentration in working area of printing factor (cont.)

Parameter	B	S.E.	Beta	t	Sig.
- IIK(*X6.4*)	.061	.345	.017	.176	.861
- Interink(*X6.5*)	2.780	1.352	.137	2.056	.041
- Rocket printing ink(*X6.6*)	-1.490	1.252	-.073	-1.191	.235
- S.R. Color ink pro art(*X6.7*)	.491	.352	.122	1.396	.164
- T&K Toka(*X6.8*)	.965	1.337	.048	.722	.472
- Toyo king(*X6.9*)	-.386	.306	-.139	-1.260	.209
- Other (Reference Group)					
Printing Ink Package(Dummy Variable)					
- Close (*X7.1*)	1.383	.395	.417	3.503	.001
- Open (Reference Group)					
Other Chemical Package(Dummy Variable)					
- Close (*X8.1*)	-.128	.442	-.034	-.288	.773
- Open (Reference Group)					
Room Characteristics (Dummy Variable)					
- Closed Room(*X9.1*)	-.017	.435	-.005	-.038	.969
- Opened Room (Reference Group)					
Windows (Dummy Variable)					
- No Windows (*X10.1*)	-1.134	.506	-.164	-2.244	.026
- Have Windows (Reference Group)					
Situation(Dummy Variable)					
- Commercial building (*X11.1*)	.029	.310	.010	.095	.925
- Single building (Reference Group)					
Number of Doors (*X12*)	.361	.202	.160	1.788	.076
Number of floors (*X13*)	-.155	.186	-.090	-.835	.405
Ventilation type (Dummy Variable)					
- Exhaust hood and Air Conditioner (*X14.1*)	1.967	1.312	.235	1.500	.135
- Air Conditioner (*X14.2*)	-.894	.716	-.309	-1.248	.214
- Fan (*X14.3*)	-.210	.644	-.068	-.326	.745

Table 4.34 Factors contributing to benzene concentration in working area of printing factor (cont.)

Parameter	B	S.E.	Beta	t	Sig.
- Natural (Reference Group)					
Number of mechanical (ventilation) (*X15*)	-.253	.091	-.431	-2.780	.006
Number of printers in printing room (*X16*)	.024	.080	.030	.302	.763
(Constant)	-4.704	2.041		-2.304	.022

R^2 = 0.434, standard error of estimate = 1.141

4.3.6 Factors Contributing to atmospheric concentration of toluene

We modeled various factors that could explain measured concentrations of toluene, obtaining the following model (see Table 4-35):

ln(toluene) = - 1.192(*X1.1*) - 1.140(*X1.2*) - 0.820(*X1.3*) - 1.043(*X1.4*) - 0.000(*X2*) - 0.017(*X3.1*) - 0.259(*X3.2*) - 0.267(*X3.3*) - 0.101(*X3.4*) - 0.701(*X3.5*) - 0.001(*X4*) + 1.748(*X5.1*) + 0.160(*X5.2*) + 0.256(*X5.3*) - 0.341(*X6.1*) + 0.839(*X6.2*) + 0.504(*X6.3*) + 0.453(*X6.4*) + 2.486(*X6.5*) + 0.808(*X6.6*) + 0.419(*X6.7*) - 0.288(*X6.8*) - 0.464(*X6.9*) + 0.570(*X7.1*) + 0.345(*X8.1*) + 0.005(*X9.1*) - 0.172(*X10.1*) - 0.332(*X11.1*) - 0.451(*X12*) + 0.185(*X13*) - 1.796(*X14.1*) - 1.865(*X14.2*) - 1.392(*X14.3*) - 0.299(*X15*) + 0.398(*X16*) + 0.000(*X17*) + 1.168

where

X1 = Job task during air sampling (Dummy Variable: Other is Reference Group)

X1.1 = Job task: One color print

X1.2 = Job task: Two color print

X1.3 = Job task: Four color print

X1.4 = Job task: Five color print

X2 = Printing Speed

X3 = Paper Type (Dummy Variable: Other is Reference Group)

X3.1 = Paper Type: Colored Paper

X3.2 = Paper Type: Plain Paper

X3.3 = Paper Type: Gloss Coated paper

X3.4 = Paper Type: Matt Coated paper

X3.5 = Paper Type: One Side Coated board

X4 = Paper Thickness (X4)

X5 = Paper Size (Dummy Variable: Other is Reference Group)

X5.1 = Paper Size: 24 x 16.8

X5.2 = Paper Size: 24 x 35

X5.3 = Paper Size: 25 x 43

X6 = Type of Chemical Used (Dummy Variable: Other is Reference Group)

X6.1 = Type of Chemical Used: Colorful Jupiter ink

X6.2 = Type of Chemical Used: Colorpia

X6.3 = Type of Chemical Used: Horsehead ultimate

X6.4 = Type of Chemical Used: IIK

X6.5 = Type of Chemical Used: Interink

X6.6 = Type of Chemical Used: Rocket printing ink

X6.7 = Type of Chemical Used: S.R. Color ink pro art

X6.8 = Type of Chemical Used: T&K Toka

X6.9 = Type of Chemical Used: Toyo king

X7 = Printing Ink Package (Dummy Variable: Open is Reference Group)

X7.1 = Printing Ink Package: Close

X8 = Other Chemical Package (Dummy Variable: Open is Reference Group)

X8.1 = Other Chemical Package: Close

X9 = Room Characteristics (Dummy Variable: Opened Room is Reference Group)

X9.1 = Room Characteristics: Closed Room

X10 = Windows (Dummy Variable: Have Windows is Reference Group)

X10.1 = Windows: No Windows

X11 = Situation (Dummy Variable: Single building is Reference Group)

X11.1 = Situation: Commercial building

X12 = Number of Doors

X13 = Number of floors

X14 = Ventilation type (Dummy Variable: Natural is Reference Group)

X14.1 = Ventilation type: Exhaust hood and Air Conditioner

X14.2 = Ventilation type: Air Conditioner

X14.3 = Ventilation type: Fan

X15 = Number of mechanical (ventilation)

X16 = Number of printers in printing room

X17 = Room Sized

This model explained 38.0 percent of variability of log transformed toluene concentrations. Based on this model, increased number of printer and printing One Side Coated boardresulted in elevated toluene concentrations. By contrast, toluene levels were lower in printing room when increase number of exit and ventilation machine. This model also found that difference type of ventilation machine effect the number of toluene levels.

Table 4.35 Factors contributing to toluene concentration in working area of printing factor

Parameter	B	S.E.	Beta	t	Sig.
Job Description (Dummy Variable)					
- One color print (*X1.1*)	-1.192	.984	-.384	-1.211	.227
- Two color print(*X1.2*)	-1.140	.993	-.260	-1.149	.252
- Four color print(*X1.3*)	-.820	.970	-.269	-.845	.399
- Five color print(*X1.4*)	-1.043	1.036	-.143	-1.007	.315
Other (Reference Group)					
Printing Speed (*X2*)	.000	.000	-.047	-.899	.369
Paper Type (Dummy Variable)					
- Colored Paper (*X3.1*)	-.017	.549	-.002	-.031	.975
- Plain Paper (*X3.2*)	-.259	.253	-.081	-1.024	.307
- Gloss Coated paper (*X3.3*)	-.267	.273	-.067	-.976	.330
- Matt Coated paper (*X3.4*)	-.101	.274	-.028	-.367	.714
- One Side Coated board (*X3.5*)	-.701	.292	-.151	-2.400	.017
- Other (Reference Group)					
Paper Thickness (*X4*)	-.001	.001	-.045	-.865	.388

Table 4.35 Factors contributing to toluene concentration in working area of printing factor (cont.)

Parameter	B	S.E.	Beta	t	Sig.
Paper Size (Dummy Variable)					
- 24 x 16.8 (*X5.1*)	1.748	1.332	.061	1.312	.190
- 24 x 35 (*X5.2*)	.160	.199	.042	.805	.422
- 25 x 43 (*X5.3*)	.256	.175	.081	1.462	.145
- Other (Reference Group)					
Type of Chemical Used (Dummy Variable)					
- Colorful Jupiter ink(*X6.1*)	-.341	.351	-.058	-.969	.333
- Colorpia(*X6.2*)	.839	1.317	.029	.637	.524
- Horsehead ultimate(*X6.3*)	.504	1.328	.018	.379	.705
- IIK(*X6.4*)	.453	.282	.112	1.605	.109
- Interink(*X6.5*)	2.486	1.339	.087	1.857	.064
- Rocket printing ink(*X6.6*)	.808	1.315	.028	.615	.539
- S.R. Color ink pro art(*X6.7*)	.419	.286	.090	1.466	.144
- T&K Toka(*X6.8*)	-.288	1.411	-.010	-.204	.838
- Toyo king(*X6.9*)	-.464	.237	-.153	-1.959	.051
- Other (Reference Group)					
Printing Ink Package (Dummy Variable)					
- Close (*X7.1*)	.570	.337	.185	1.691	.092
- Open (Reference Group)					
Other Chemical Package(Dummy Variable)					
- Close (*X8.1*)	.345	.346	.108	.998	.319
- Open (Reference Group)					
Room Characteristics (Dummy Variable)					
- Closed Room(*X9.1*)	.005	.337	.001	.013	.989
- Opened Room (Reference Group)					
Windows (Dummy Variable)					
- No Windows (*X10.1*)	-.172	.287	-.036	-.600	.549
- Have Windows (Reference Group)					

Table 4.35 Factors contributing to toluene concentration in working area of printing factor (cont.)

Parameter	B	S.E.	Beta	t	Sig.
Situation(Dummy Variable)					
- Commercial building (*X11.1*)	-.332	.225	-.110	-1.480	.140
- Single building (Reference Group)					
Number of Doors (*X12*)	-.451	.154	-.179	-2.923	.004
Number of floors (*X13*)	.185	.128	.103	1.442	.150
Ventilation type (Dummy Variable)					
- Exhaust hood and Air Conditioner (*X14.1*)	-1.796	.855	-.206	-2.101	.036
- Air Conditioner (*X14.2*)	-1.865	.546	-.611	-3.417	.001
- Fan (*X14.3*)	-1.392	.464	-.439	-3.000	.003
- Natural (Reference Group)					
Number of mechanical (ventilation) (*X15*)	-.299	.068	-.481	-4.383	.000
Number of printers in printing room (*X16*)	.398	.056	.537	7.123	.000
Room Size (*X17*)	.000	.000	.201	1.620	.106
(Constant)	1.168	1.472		.793	.428
R^2 = 0.380, standard error of estimate = 1.253					

4.3.7 Factors Contributing to atmospheric concentration of ethylbenzene

We modeled various factors that could explain measured concentrations of ethyl benzene, obtaining the following model (see Table 4-36):

ln(ethyl benzene) = 0.585(*X1.1*) - 0.430(*X1.2*) - 0.173(*X1.3*) - 0.000(*X2*) + 0.255(*X3.1*) - 0.187(*X3.2*) + 0.031(*X3.3*) - 0.204(*X3.4*) - 0.579(*X3.5*) + 0.003(*X4*) - 0.414(*X5.1*) - 0.019(*X5.2*) - 0.140(*X6.1*) - 0.571(*X6.2*) + 0.202(*X6.3*) + 0.545(*X6.4*) - 0.182(*X6.7*) + 0.437(*X6.8*) - 0.308(*X6.9*) + 1.938(*X7.1*) - 2.053(*X8.1*) - 1.074(*X9.1*) + 0.681(*X10.1*) - 0.809(*X11.1*) + 0.093(*X12*) - 0.221(*X13*) + 0.964(*X14.1*) - 0.340(*X14.2*) + 0.247(*X14.3*) + 0.047(*X15*) - 0.130(*X16*) - 0.000(*X17*) + 1.719

where

X1 = Job task during air sampling (Dummy Variable: Other is Reference Group)

X1.1 = Job task: One color print

X1.2 = Job task: Two color print

X1.3 = Job task: Four color print

X2 = Printing Speed

X3 = Paper Type (Dummy Variable: Other is Reference Group)

X3.1 = Paper Type: Colored Paper

X3.2 = Paper Type: Plain Paper

X3.3 = Paper Type: Gloss Coated paper

X3.4 = Paper Type: Matt Coated paper

X3.5 = Paper Type: One Side Coated board

X4 = Paper Thickness (X4)

X5 = Paper Size (Dummy Variable: Other is Reference Group)

X5.1 = Paper Size: 24 x 35

X5.2 = Paper Size: 25 x 43

X6 = Type of Chemical Used (Dummy Variable: Other is Reference Group)

X6.1 = Type of Chemical Used: Colorful Jupiter ink

X6.2 = Type of Chemical Used: Colorpia

X6.3 = Type of Chemical Used: Horsehead ultimate

X6.4 = Type of Chemical Used: IIK

X6.5 = Type of Chemical Used: S.R. Color ink pro art

X6.6 = Type of Chemical Used: T&K Toka

X6.7 = Type of Chemical Used: Toyo king

X7 = Printing Ink Package (Dummy Variable: Open is Reference Group)

X7.1 = Printing Ink Package: Close

X8 = Other Chemical Package (Dummy Variable: Open is Reference Group)

X8.1 = Other Chemical Package: Close

X9 = Room Characteristics (Dummy Variable: Opened Room is Reference Group)

X9.1 = Room Characteristics: Closed Room

X10 = Windows (Dummy Variable: Have Windows is Reference Group)

X10.1 = Windows: No Windows

X11 = Situation (Dummy Variable: Single building is Reference Group)

X11.1 = Situation: Commercial building

X12 = Number of Doors

X13 = Number of floors

X14 = Ventilation type (Dummy Variable: Natural is Reference Group)

X14.1 = Ventilation type: Exhaust hood and Air Conditioner

X14.2 = Ventilation type: Air Conditioner

X14.3 = Ventilation type: Fan

X15 = Number of mechanical (ventilation)

X16 = Number of printers in printing room

X17 = Room Sized

This model explained 39.7 percent of variability of log transformed ethyl benzene concentrations. Based on this model, ethyl benzene concentrations increased with printing speed, open packaging of printing color and other chemical. Ethyl benzene levels were lower, when closed room and commercial building.

Table 4.36 Factors contributing to ethylbenzene concentration in working area of printing factor

Parameter	B	S.E.	Beta	t	Sig.
Job Description (Dummy Variable)					
- One color print (*X1.1*)	-.585	.421	-.266	-1.390	.168
- Two color print(*X1.2*)	-.430	.452	-.145	-.952	.344
- Four color print(*X1.3*)	-.173	.408	-.083	-.423	.673
- Other (Reference Group)					
Printing Speed (*X2*)	.000	.000	-.239	-2.011	.047
Paper Type (Dummy Variable)					
- Colored Paper (*X3.1*)	.255	1.054	.022	.242	.809
- Plain Paper (*X3.2*)	-.187	.391	-.086	-.479	.633
- Gloss Coated paper (*X3.3*)	.031	.393	.011	.080	.936
- Matt Coated paper (*X3.4*)	-.204	.439	-.079	-.465	.643
- One Side Coated board (*X3.5*)	-.579	.383	-.195	-1.511	.134

Table 4.36 Factors contributing to ethylbenzene concentration in working area of printing factor (cont.)

Parameter	B	S.E.	Beta	t	Sig.
- Other (Reference Group)					
Paper Thickness (*X4*)	.003	.002	.185	1.670	.098
Paper Size (Dummy Variable)					
- 24 x 35 (*X5.1*)	-.414	.282	-.177	-1.469	.145
- 25 x 43 (*X5.2*)	-.019	.249	-.009	-.078	.938
- Other (Reference Group)					
Type of Chemical Used (Dummy Variable)					
- Colorful Jupiter ink (*X6.1*)	-.140	.827	-.026	-.169	.866
- Colorpia (*X6.2*)	-.571	1.126	-.049	-.507	.613
- Horsehead ultimate (*X6.3*)	.202	1.076	.017	.188	.851
- IIK (*X6.4*)	.545	.392	.226	1.390	.168
- S.R. Color ink pro art (*X6.5*)	-.182	.459	-.069	-.397	.692
- T&K Toka (*X6.6*)	.437	1.135	.037	.385	.701
- Toyo king (*X6.7*)	-.308	.430	-.144	-.715	.477
- Other (Reference Group)					
Printing Ink Package (Dummy Variable)					
- Close (*X7.1*)	1.938	.775	.638	2.502	.014
- Open (Reference Group)					
Other Chemical Package (Dummy Variable)					
- Close (*X8.1*)	-2.053	.871	-.622	-2.358	.020
- Open (Reference Group)					
Room Characteristics (Dummy Variable)					
- Closed Room (*X9.1*)	-1.074	.535	-.475	-2.009	.047
- Opened Room (Reference Group)					

Table 4.36 Factors contributing to ethylbenzene concentration in working area of printing factor (cont.)

Parameter	B	S.E.	Beta	t	Sig.
Windows (Dummy Variable)					
- No Windows (*X10.1*)	.681	.705	.115	.965	.337
- Have Windows (Reference Group)					
Situation (Dummy Variable)					
Commercial building (*X11.1*)	-.809	.346	-.387	-2.339	.021
Single building (Reference Group)					
Number of Doors (*X12*)	.093	.258	.057	.362	.718
Number of floors (*X13*)	-.221	.265	-.147	-.834	.407
Ventilation type (Dummy Variable)					
- Exhaust hood and Air Conditioner (*X14.1*)	.964	2.118	.163	.455	.650
- Air Conditioner (*X14.2*)	-.340	.809	-.163	-.421	.675
- Fan (*X14.3*)	.247	.763	.116	.324	.747
- Natural (Reference Group)					
Number of mechanical (ventilation) (*X15*)	.047	.099	.104	.473	.637
Number of printers in printing room (*X16*)	-.130	.106	-.176	-1.227	.223
Room size (*X17*)	.000	.000	-.064	-.139	.890
Intercept	1.719	1.872		.918	.361
R^2 = 0.397, standard error of estimate = 0.938					

4.3.8 Factors Contributing to atmospheric concentration of xylene

We modeled various factors that could explain measured concentrations of xylene, obtaining the following model (see Table 4-37):

Concentrations of xylene =0.848(*X1.1*) + 0.798(*X1.2*) + 0.807(*X1.3*) + 1.019(*X1.4*) + 0.000(*X2*) - 0.294(*X3.1*) - 0.141(*X3.2*) - 0.079(*X3.3*) - 0.463(*X3.4*) - 0.465(*X3.5*) + 0.002(*X4*) - 0.819(*X5.1*) - 0.334(*X5.2*) - 0.256(*X5.3*) + 0.510(*X6.1*) - 0.047(*X6.2*) + 1.035(*X6.3*) + 0.541(*X6.4*) + 1.781(*X6.5*) - 0.355(*X6.6*) + 0.271(*X6.7*) + 0.593(*X6.8*) - 0.534(*X6.9*) + 1.479(*X7.1*) - 0.839(*X8.1*) - 1.241(*X9.1*) + 0.533(*X10.1*) - 0.359(*X11.1*) + 0.147(*X12*) + 0.178(*X13*) - 0.064(*X14.1*) - 1.087(*X14.2*) - 0.172(*X14.3*) - 0.095(*X15*) - 0.017(*X16*) + 0.000(*X17*) + 2.488

where

X1 = Job task during air sampling (Dummy Variable: Other is Reference Group)

X1.1 = Job task: One color print

X1.2 = Job task: Two color print

X1.3 = Job task: Four color print

X1.4 = Job task: Five color print

X2 = Printing Speed

X3 = Paper Type (Dummy Variable: Other is Reference Group)

X3.1 = Paper Type: Colored Paper

X3.2 = Paper Type: Plain Paper

X3.3 = Paper Type: Gloss Coated paper

X3.4 = Paper Type: Matt Coated paper

X3.5 = Paper Type: One Side Coated board

X4 = Paper Thickness (X4)

X5 = Paper Size (Dummy Variable: Other is Reference Group)

X5.1 = Paper Size: 24 x 16.8

X5.2 = Paper Size: 24 x 35

X5.3 = Paper Size: 25 x 43

X6 = Type of Chemical Used (Dummy Variable: Other is Reference Group)

X6.1 = Type of Chemical Used: Colorful Jupiter ink

X6.2 = Type of Chemical Used: Colorpia

X6.3 = Type of Chemical Used: Horsehead ultimate

X6.4 = Type of Chemical Used: IIK

X6.5 = Type of Chemical Used: Interink

X6.6 = Type of Chemical Used: Rocket printing ink

X6.7 = Type of Chemical Used: S.R. Color ink pro art

X6.8 = Type of Chemical Used: T&K Toka

X6.9 = Type of Chemical Used: Toyo king

X7 = Printing Ink Package (Dummy Variable: Open is Reference Group)

X7.1 = Printing Ink Package: Close

X8 = Other Chemical Package (Dummy Variable: Open is Reference Group)

X8.1 = Other Chemical Package: Close

X9 = Room Characteristics (Dummy Variable: Opened Room is Reference Group)

X9.1 = Room Characteristics: Closed Room

X10 = Windows (Dummy Variable: Have Windows is Reference Group)

X10.1 = Windows: No Windows

X11 = Situation (Dummy Variable: Single building is Reference Group)

X11.1 = Situation: Commercial building

X12 = Number of Doors

X13 = Number of floors

X14 = Ventilation type (Dummy Variable: Natural is Reference Group)

X14.1 = Ventilation type: Exhaust hood and Air Conditioner

X14.2 = Ventilation type: Air Conditioner

X14.3 = Ventilation type: Fan

X15 = Number of mechanical (ventilation)

X16 = Number of printers in printing room

X17 = Room Sized

This model explained 39.9 percent of variability of log transformed xylene concentrations. Based on this model, whenusing IIK and open packaging of printing color, resulted in elevated xylene concentrations. By contrast, xylene levels were lower in printing room when used Toyo King, used air conditioner, open packaging of other chemical and the room are closed.

Table 4.37 Factors contributing to xylene concentration in working area of printing factor

Parameter	B	S.E.	Beta	t	Sig.
Job Description (Dummy Variable)					
- One color print (*X1.1*)	.848	1.234	.311	.687	.493
- Two color print(*X1.2*)	.798	1.236	.206	.645	.519
- Four color print(*X1.3*)	.807	1.223	.308	.660	.510
- Five color print(*X1.4*)	1.019	1.255	.180	.812	.417
Other (Reference Group)					
Printing Speed (*X2*)	.000	.000	.112	1.867	.063
Paper Type (Dummy Variable)					
- Colored Paper (*X3.1*)	-.294	.493	-.037	-.598	.551
- Plain Paper (*X3.2*)	-.141	.244	-.051	-.578	.564
- Gloss Coated paper (*X3.3*)	-.079	.272	-.022	-.291	.772
- Matt Coated paper (*X3.4*)	-.463	.262	-.148	-1.769	.078
- One Side Coated board (*X3.5*)	-.465	.283	-.116	-1.645	.101
- Other (Reference Group)					
Paper Thickness (*X4*)	.002	.001	.094	1.582	.115
Paper Size (Dummy Variable)					
- 24 x 16.8 (*X5.1*)	-.819	1.177	-.037	-.696	.487
- 24 x 35 (*X5.2*)	-.334	.206	-.103	-1.623	.106
- 25 x 43 (*X5.3*)	-.256	.171	-.096	-1.494	.136
- Other (Reference Group)					
Type of Chemical Used (Dummy Variable)					
- Colorful Jupiter ink(*X6.1*)	.510	.426	.085	1.197	.233
- Colorpia(*X6.2*)	-.047	1.156	-.002	-.041	.968
- Horsehead ultimate(*X6.3*)	1.035	1.167	.047	.887	.376
- IIK(*X6.4*)	.541	.273	.167	1.984	.048
- Interink(*X6.5*)	1.781	1.208	.081	1.475	.142
- Rocket printing ink(*X6.6*)	-.355	1.154	-.016	-.308	.759
- S.R. Color ink pro art(*X6.7*)	.271	.276	.072	.982	.327
- T&K Toka(*X6.8*)	.593	1.249	.027	.475	.635

Table 4.37 Factors contributing to xylene concentration in working area of printing factor (cont.)

Parameter	B	S.E.	Beta	t	Sig.
- Toyo king(*X6.9*)	-.534	.235	-.201	-2.272	.024
- Other (Reference Group)					
Printing Ink Package (Dummy Variable)					
- Close (*X7.1*)	1.479	.377	.514	3.919	.000
- Open (Reference Group)					
Other Chemical Package(Dummy Variable)					
- Close (*X8.1*)	-.839	.404	-.277	-2.076	.039
- Open (Reference Group)					
Room Characteristics (Dummy Variable)					
- Closed Room(*X9.1*)	-1.241	.334	-.434	-3.714	.000
- Opened Room (Reference Group)					
Windows (Dummy Variable)					
- No Windows (*X10.1*)	.533	.338	.102	1.579	.116
- Have Windows (Reference Group)					
Situation(Dummy Variable)					
- Commercial building (*X11.1*)	-.359	.221	-.137	-1.624	.106
- Single building (Reference Group)					
Number of Doors (*X12*)	.147	.152	.070	.967	.335
Number of floors (*X13*)	.178	.137	.113	1.298	.195
Ventilation type (Dummy Variable)					
- Exhaust hood and Air Conditioner (*X14.1*)	-.064	.982	-.007	-.065	.948
- Air Conditioner (*X14.2*)	-1.087	.522	-.408	-2.083	.038
- Fan (*X14.3*)	-.172	.456	-.061	-.377	.707
- Natural (Reference Group)					
Number of mechanical (ventilation) (*X15*)	-.095	.071	-.180	-1.331	.185
Number of printers in printing room (*X16*)	-.017	.060	-.024	-.284	.777
Room Size (*X17*)	.000	.000	.084	.568	.571
(Constant)	-2.488	1.645		-1.513	.132

R^2 = 0.399, standard error of estimate = 1.084

CHAPTER V
DISCUSSION

5.1 Discussion

This study took place in the Bangkok, Thailand, and 480 air samples in the working environment from 112 printing factories were carried out between December 2009 and April 2010. A random sample of 112 small printing factories in Bangkok, according to the data of individuals that registered in publishing business; Department of Business and Information Services constituted our sampling base. In each of the printing factory, the atmospheric concentrations of BTEX were collected between working hour (9.00-17.00). During visit to the printing factory, we investigated in the field and collected data of job task during air sampling, printing speed, type of paper, the thickness of the paper, chemicals types as a source of BTEX, the number of chemical use during air sampling, packaging of printing color, packaging of other chemical, room characteristics, entrance door of printing room, window of printing room, type of building, ventilation type, printing room surface (m^2) and number of printers in printing factory.

The average atmospheric benzene concentrations of 112 printing houses were 0.1905 $\pm$ 0.4837 ppm. All of atmospheric benzene concentrations 100% (n=480) were below 5 ppm which was compliance to the 10 ppm , which was the time weight average (TWA) airborne exposure limit recommended by ACGIH.

The average atmospheric toluene concentrations of 112 printing houses were 1.2686 $\pm$ 4.6436 ppm. All of atmospheric toluene concentrations 100% (n=480) were below 60 ppm which was compliance to the 200 ppm , which was the time weight average (TWA) airborne exposure limit recommended by OSHA.

The average atmospheric ethylbenzene concentrations of 112 printing houses were 0.0379 $\pm$ 0.0977 ppm. All of atmospheric etylbenzene concentrations 100% (n=480) were below 0.91 ppm which was compliance to the 100 ppm , which was the time weight average (TWA) airborne exposure limit recommended by ACGIH.

The average atmospheric xylene concentrations of 112 printing houses were 0.1940 $\pm$ 0.4574 ppm. All of atmospheric xylene concentrations 100% (n=480) were below 4.00 ppm which was compliance to the 100 ppm , which was the time weight average (TWA) airborne exposure limit recommended by ACGIH.

The results above was differ from the research of K. Thanacharoenchanaphas, A. Changsuphan, R.Nimnual, T. Thongsri, S. Phetkasem, C. Lertkanawanitchakul that study the concentration of four VOCs namely benzene, toluene, ethylbenzene, xylene (BTEX) and ozone in a large printing facility located in Bangkok, Thailand 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. In current study the results was lower than this research.

5.2 The research controlling

Errors could easily happen in the research if it was conducted by individuals who were not skillful. Hence actions were planned to control errors as follows;

5.3 Systematic errors

Personal errors: This study may have an error during collecting the printing factory characteristics. In this study, Sample sizes have to survey by only researcher.

Method errors: The atmospheric concentrations of BTEX were collected between working hour (9.00 am -5.00 pm) in each printing factory follow the NIOSH method 1501 HYDROCARBONS, AROMATIC

5.4 Random errors

Random errors could be reduced by selecting a large sample size. In this study, there were 112 printing factories and 480 air samples in the working environment.

CHAPTER VI
CONCLUSION

6.1 Conclusion

As expected in this type of industry and reported in the literature, concentration of air contaminants was well below air quality standards for occupational exposures. The BTEX levels we found were lower than those reported in recent peer-reviewed papers. Numerous factors could explain these differences, including important variations in chemical formulation, patterns of printing color use during printing, characteristics of buildings where the printing factories are located (ventilation, etc.); different sampling strategies could also have contributed. These data suggest that comfort of employees of printing factory could be improved by increasing the proportion of outside air by increase window and entrance door. This study also confirmed a few a priori expectations: exposures appear to be higher when packaging of printing color and other chemicals opened, increasing with number of chemical used during printing, more thickness of paper and more printer in printing room.

6.2 Limitation of this research

Our sample was a simple random sampling of printing factory in Bangkok. We sampling at working hour but not the same time in every printing factory. In conclusion, despite its limitations, this study presents very informative results from an occupational health point of view. Although measured levels of most chemicals were well below legal standards, it appears plausible that concentrations may get quite high (possibly close to threshold limit values) at certain times, such as very active periods, especially if the amount of fresh air is not optimal and if other process entailing the use of more chemicals are being provided. These results will be used in the preparation of guidelines for the reassignment of workers working in printing factories.

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