SOLVENT EXPOSURE AND RESPIRATORY HEALTH STATUS AMONG WORKERS IN A TIRE RETREADING FACTORY

By

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LIST OF ABREVIATIONS

ATS	American Thoracic Society
ATSDR	Agency for Toxic Substance and Disease Registry
BTPS	Body Temperature, ambient Pressure, Saturated water vapour
CI	Confidence Interval
COAD	Chronic Obstructive Airway Disease
COPD	Chronic Obstructive Pulmonary Disease
CSDS	Chemical Safety and Data Sheet
D_{LO}	Diffusing Capacity of Oxygen
D_{LCO}	Diffusing Capacity of Carbon Monoxide
DD	Detectable Difference
ERV	Expiratory Reserved Volume
ETS	Environmental Tobacco Smoke
$FEF_{25-75\%}$	Force Expiratory Flow at 25-75% or MMF
FEV_1	Force Expiratory Volume in one second
FEV_1/FVC ratio	The ratio of FEV_1 over FVC
FRC	Functional Residual Capacity
FVC	Force Vital Capacity
GLR	General Linear Regression
HPLC	High Performance Liquid Chromatography
IQR	Interquartile Range
IRPA	Intensification of Research in Priority Areas
IRV	Inspiratory Reserved Volume
ITRA	International Tires and Rubber Association Foundation, Inc
JICA	Japanese International Cooperation Agency
KAP	Knowledge, Attitude and Practice
L	Litre
LLN	Lower Limit of Normal
LTI	Loss of Time Injury
MC	Multicollinearity

MLR	Multiple Linear Regression
MMF	Maximal Mid-expiratory Flow
MOSTE	Ministry of Science, Technology and Environment
NIOSH	National Institute of Safety and Health
NORMS	National Occupational Risk Management Study
OSHA Act	Occupational Safety and Health Act 1994
PEF	Peak Expiratory Flow
PEL	Permissible Exposure Level
PPE	Personal Protective Equipment
RV	Residual Volume
SD	Standard Deviation
SLR	Simple Linear Regression
SPSS	Statistical Package for Social Sciences
TLC	Total Lung Capacity
TV	Tidal Volume
UOSHERC	Universities Occupational Safety and Health Education Research Centre
USA	United State of America
USECHH 2000	Standards of Exposure of Chemical Hazardous to Health 2000
USM	Universiti Sains Malaysia
VIF	Variance Inflation Factor

ABSTRAK

Pengenalan: Industri getah terkenal dengan penggunaan pelbagai jenis kimia, terutamanya bahan pelarut di dalam persekitaran tempat kerja. Walaupun kesan bahan-bahan ini terhadap sistem pernafasan adalah diketahui umum, maklumat tempatan berkenaan dengan perkara ini adalah terhad. Kajian ini bertujuan untuk meninjau tahap kesihatan sistem pernafasan pekerja, pendedahan terhadap bahan pelarut. Tahap KAP dan faktor-faktor yang mempengaruhi sistem pernafasan di kalangan pekerja tayar'celup' (*retread*).

Metodologi: Seramai 95 orang pekerja lelaki terlibat di dalam kajian keratan-lintang ini. Borang kajiselidik telah di gunakan untuk mendapat maklumat tentang sosiodemografi, pekerjaan, peribadi, simptom-simptom pernafasan dan tahap KAP. Pemeriksaan fizikal, ujian fungsi paru-paru dan penyukatan udara kawasan (untuk toluene, xylene dan benzene) telah dijalankan, diikuti dengan penyukatan udara individu (personal) untuk toluene (kandungan di udara yang tertinggi) dan pengambilan metabolit toluene di dalam urin.

Keputusan: Semua peserta adalah Melayu dengan purata umur mereka adalah 36.6 tahun dengan 'standard deviation'(SD) adalah 6.29 tahun. Manakala penengah (median) dan interquartile range (IQR) untuk jangka masa bekerja pula adalah 133.8 dan 63.53 bulan. Ketat dada (32.6%) adalah simptom tertinggi yang dilaporkan oleh pekerja diikuti dengan berkahak (27.4%), batuk di pagi hari (10.5%) dan sesak nafas (10.5%). Pemeriksaan fizikal menunjukkan kesemua pekerja adalah normal dan purata (SD) untuk fungsi paru paru seperti FVC, FEV_1, FEV_1/FVC ratio dan $FEF_{25-75\%}$, adalah 3.6 (0.56) liter, 2.9 (0.45) liter, 80.4 (7.82) peratus dan 3.5 (1.52) liter/saat, setiap satu. Faktor-faktor yang mempengaruhi seperti umur, tinggi dan berat sebagaimana yang telah diketahui, menunjukkan kaitan yang signifikan terhadap sekurang-kurangnya satu dari parameter-parameter fungsi paru-paru. Faktor-faktor pekerjaan seperti pendedahan terhadap habuk dan 'kerja shif' juga didapati mempunyai kaitan yang signifikan terhadap sekurang-kurangnya satu dari parameter-parameter fungsi paru-paru. Untuk KAP, prevalen bagi kedua-dua skor pengetahuan di bawah 80 peratus skor adalah sebanyak 45.3% dan 21.1%, manakala prevalen bagi skor sikap di bawah 70 peratus skor adalah sebanyak 25.3% dan skor amalan di bawah 80% skor adalah sebanyak 89.5%. Bagi penyukatan udara persekitaran, bahan pelarut yang paling tinggi kandungannya di udara adalah toluene dimana tahapnya adalah dari kosong hingga 300 ppm. Tahap toluene di dalam penyukatan udara individu pula adalah dari kosong hingga 5.5 mg/m^3 dan tahap asid hippurik di dalam air kencing adalah dari 0.02 hingga 3.63 dengan penengah (IQR) adalah sebanyak 0.26 (0.40) g/gram creatinine.

Kesimpulan: Kajian ini membuktikan bahawa berlakunya pendedahan toluene di dalam persekitaran kilang manakala kesan terhadap kesihatan pernafasan adalah rendah di kalangan pekerja. Ia juga menunjukkan perlu wujudnya satu program intervensi untuk meningkatkan tahap KAP.

Keywords: Toluene, fungsi paru-paru, pendedahan di tempat kerja, pengetahuan, sikap, amalan

ABSTRACT

Introduction: Rubber industry is known to have abundant chemicals, mainly solvents, in their working environment. Although the effects of these substances on respiratory health are well known, there is limited local information. This study was aimed to explore the respiratory health status among workers, solvent exposure in the workplace, level of KAP, and associated factors, which potentially impair the lung function among workers in a tire retreading factory.

Methods: In this cross sectional study, questionnaires were distributed to available 95 male production workers to obtain sociodemography, personal and work related information, respiratory symptoms and KAP. Physical examination and lung function test were conducted. Area samplings were done for toluene, benzene and xylene, followed by personal air sampling and urine sampling for toluene. Toluene was selected to be checked because toluene level was highest in area sampling.

Result: All participants were Malay with mean (SD) age of 36.6 (6.29) years and median (IQR) working duration was 133.8 (63.53) months. Chest tightness (32.6%) was the commonest symptom followed by phlegm production (27.4%), morning cough (10.5%) and shortness of breath (10.5%). Physical examination revealed normal findings whereas mean (SD) of FVC, FEV_1, FEV_1/FVC ratio and $FEF_{25-75\%}$, were 3.6 (0.56) litre, 2.9 (0.45) litre, 80.4 (7.82) percents and 3.5 (1.52) litre/second, respectively. Known associated factors for lung function such as age, height and weight, and occupational factors such as exposure to dust and work shift were noted to be significantly associated with at least one parameter of lung functions. In KAP assessment, prevalence for both knowledge level below 80 percent score were 45.3% and 21.1%, whereas prevalence for attitude level below 70 percent score was 25.3% and prevalence for practice level below 80% score was 89.5%. In environmental sampling, toluene level was ranged from undetectable to 300 ppm, level of personal sampling ranged from undetectable to 5.5 mg/m^3 and range of urine hippuric level was from 0.02 to 3.63 with median (IQR) of 0.26 (0.40) g/g creatinine.

Conclusion: The study demonstrated an evidence of toluene exposure and mild effect on respiratory health among workers. It also revealed the needs for intervention in order to improve KAP in this workplace.

Keywords: Toluene, lung function, workplace exposure, knowledge, attitude, practice

CHAPTER 1

INTRODUCTION

CHAPTER ONE

1 INTRODUCTION

1.1 Background of the study

Malaysia is a leading producer of rubber products in the world (MREPC, 2005). In the first 8 months of 2000, rubber products export increased by 15.6% to RM1,750 million and contributed 2.6% of total Malaysian export structure which was the 3rd highest agriculture based products export after palm oil and timber (MOF, 2000). Rubber hand gloves, condom and tire manufacturing industries are among the important activities in Malaysian rubber based industry. Rubber based manufacturing industry is known to use abundant and variety of chemicals including solvents. Approximately, about 500 well-defined chemicals have been identified in the rubber industry and more than 25 chemicals have been detected as by-products generated during several steps in the manufacturing process (Greenberg, 1997). Previous reports noted the presence of numerous fumes, vapor and dust in the environment of rubber based factories (Dost *et al.*, 2000, Greenberg, 1997). Human exposure to these substances leads to various health effects such as respiratory illnesses (Zuskin *et al.*, 1996, Greenberg, 1997), cancer occurrence (Straif *et al.*, 1999, Mundt *et al.*, 1999) and dermatological problems (Vermeulen *et al.*, 2001). Those health effects are potentially preventable only if appropriate measures are taken. Engineering control such as better ventilation, regular training of workers and provision and the use of personal protective equipment (PPE) are among those important preventive measures. Malaysian laws such as Occupational Safety and Health Act 1994, and Use and Standards of Exposure of Chemicals Hazardous to Health (USECHH) 2000 regulation emphasize the use of these measures in Part V- Action to Control Measure (OSHA, 1994). Hence, the importance of good knowledge, attitude and practice (KAP) among employers as well as employees towards prevention from occupational hazard are mandatory to avoid the occurrence of medical illnesses as mentioned. For example, improve knowledge on the importance of PPE use, will improve attitude and create better compliance towards safe work practice. Unfortunately, there is limited local report and data on the compliance of the employer and employees toward the OSHA act, their KAP level and respiratory health status in workers in rubber industry especially rubber retreading factory. Thus, this study was intended to explore the respiratory health status among workers in tire retreading factory, presence of solvent and other associated factors (including KAP level) which potentially can impair the lung function parameters and a situational analysis of the factory's environment.

1.2 Justification of study

Based on several studies around the world (Dost *et al.*, 2000, Zuskin *et al.*, 1996, LaDou, 1997, Straif *et al.*, 1999, Mundt *et al.*, 1999, Vermeulen *et al.*, 2001), environment in rubber processing area is a potential place to cause health hazard because of the use of mixtures of chemicals. Health hazard includes respiratory impairment, development of cancers and dermatological illnesses.

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The effect of this chemical mixture towards increase prevalence of respiratory diseases has been reported in Croatia (Zuskin *et al.*, 1996), USA (Hnizdo *et al.*, 2002) and Netherlands (Vermeulen *et al.*, 2002).

Once a disease stage has occurred, long life treatment is usually required. Therefore, it is important to detect the early period of disease progression. Lung function test is one of the assessment tools that able to show the respiratory impairment, that is the early stage and the probability of developing respiratory illnesses. Respiratory impairment is a reversible condition whereas respiratory illnesses usually irreversible (Cotes and Steel, 1987). Thus, it is important to detect respiratory impairment early in order to prevent the development of respiratory illnesses.

In Malaysia, although rubber industry is one of the important income sources and the presence of several worldwide epidemiological studies that showed relationship between work exposure and adverse health affects, there is limited local studies available for rubber manufacturing workers. Therefore, this study was intended to explore more on the exposure status of working environment in our work places and gathered information about the respiratory health status among workers. Consequently, we would be able to answer some questions such as how much our rubber workers were exposed to solvents and dust, how much their health had been affected, and what would be the best ways to improve the situation. If we understand the above local situation very well, we would be able to provide information to employer and employees, policy makers and related government authorities regarding the local work situation. Specifically, corrective actions could be taken by employer to solve the shortcomings if they were present e.g. excessive fumes and dust in the working environment. In addition, government regulatory bodies would get more data on situational analysis of the local factories and these data could help the policy makers to improve the working environment. The information from this study would also be a good input for proper intervention program later such as improving the KAP of the workers.

1.3 Rationale of the study

This study is important since the best to our knowledge, there is limited local data on the personal information and level of KAP among our local employee and situational analysis of the workplace.

This study offers collection of information of the workers in term of sociodemograhic and personal data (which include KAP level). This helps us to know which target group of the workers, who are potentially at risk of contracting adverse health effects due to work.

This study also provides a situational analysis where the measurement of exposure to chemical or solvent in the factory at the environment, personal and biological level is done. This analysis quantifies the amount of exposure in the workplace at a point of time.

The identification of associated factors is helpful to recognize the high-risk groups in this population and also to develop an intervention package to reduce the exposure at the environment and hence to prevent the occurrence of adverse health effects. This intervention can be done by taking appropriate control measures either at organizational level such as providing sufficient ventilation at workplace or at individual level such as appropriate practice of wearing PPE.

By knowing all this facts and implementing all the possible control measures, hopefully this study will contribute at some portion for the vision of making our workplaces a safer place to work and improving our workers with better KAP level and higher health standard.

1.4 Conceptual Framework

Figure 1 indicates the outline of conceptual framework. There are various determinants of respiratory impairment and disablement which is interrelated to each other. The determinants that within the area of this study are;

1. Personal factors such as age, sex, body mass index (BMI), smoking status, educational level, history of respiratory illnesses and knowledge, attitude and practice (KAP) level. Smoking habit is an established causative factor that gives negative influence on lung function. The lung function parameter on spirometry that usually affected is reduction of FEV_1 (Hole *et al.*, 1996, Kerstjens *et al.*, 1997). Chest illnesses such as recurrent pulmonary tuberculosis can cause chronic impairment of lung function which increases incrementally with the number of

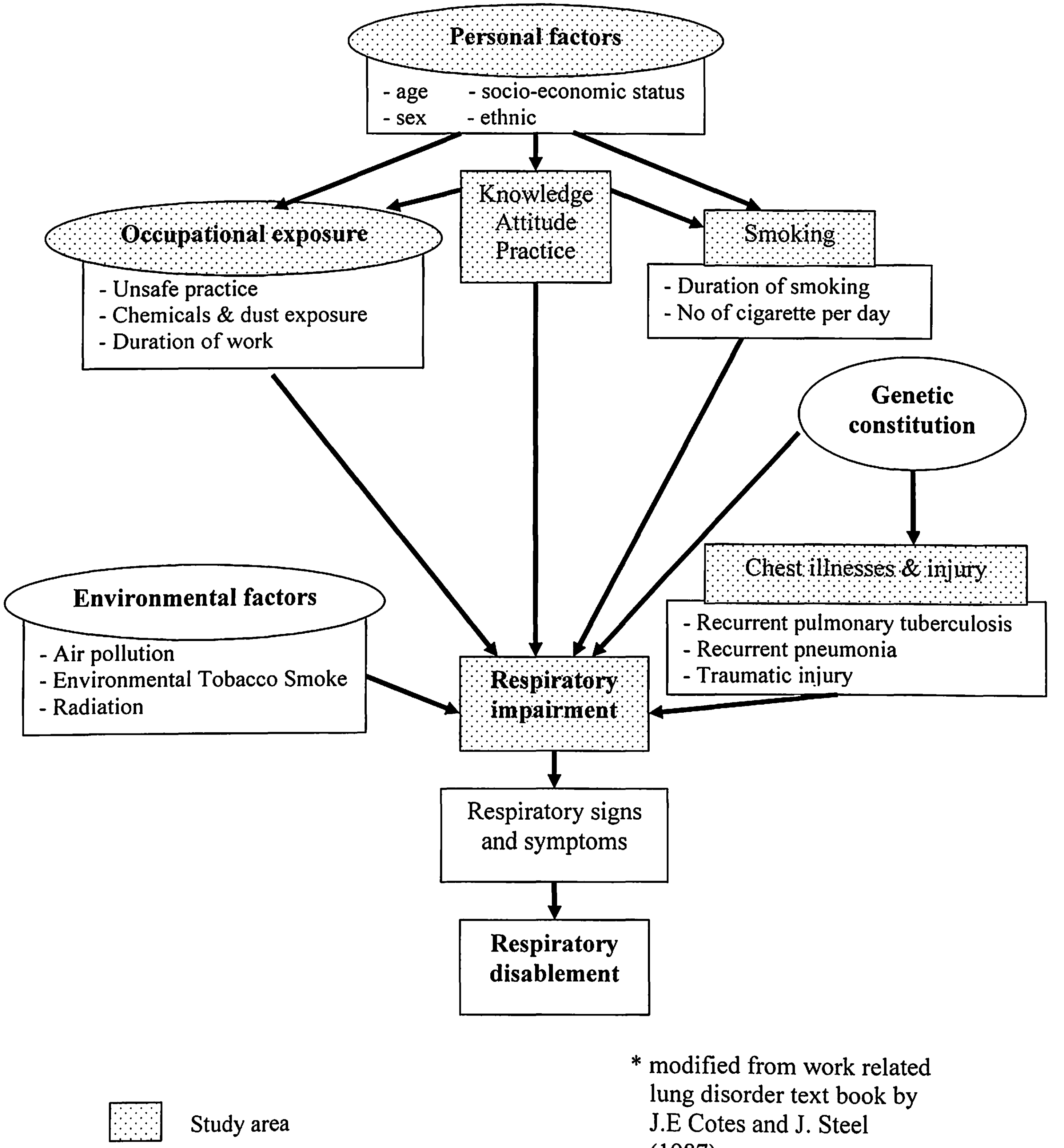
episodes of tuberculosis (Hnizdo *et al.*, 2000). A study on the effects of obesity among children in Hong Kong showed reduction in functional residual capacity (FRC) and diffusion impairment as the most common abnormalities found (Li *et al.*, 2003). Socioeconomic circumstances like social class, household income and educational level play an indirect role for determinants of respiratory health. Eva Prescott reported several studies had showed a significant vast different of FEV_1 where highest social class in men had 400ml higher than those lowest social class (Prescott and Vestbo, 1999).

2. Job type, duration of work and current or history of previous exposure to dust and fumes are among occupational related variables which potentially affect the respiratory health. A study on a general population of five areas in Spain suggested that exposure to high level of biological dust plays a role in the development of pulmonary ventilatory defects, independent of smoking and asthma (Sunyer *et al.*, 1998).

The presence of these determinants especially occupational related factors leads to respiratory impairment which is preventable. If not detected early and no control measures taken it eventually causes respiratory disablement and diseases.

Inhaled dusts and vapors and pathological conditions of the lung impair its function. The physiological functions of the lung that normally affected are production and clearance of secretions, airways size, gas exchange, respiratory control and musculoskeletal function. Any such abnormalities constitute respiratory impairment. They can be assessed in terms of specific respiratory symptoms such as cough, production of sputum and wheeze or as changes in lung function (Cotes and Steel, 1987).

During activity a person with respiratory impairment experiences breathlessness on exertion or has a reduced exercise performance as a result of persistent cough or related symptoms. The loss of performance constitutes respiratory disablement (Cotes and Steel, 1987).



* modified from work related lung disorder text book by J.E Cotes and J. Steel (1987).

Figure 1 Conceptual framework

CHAPTER 2

OBJECTIVES

CHAPTER TWO

2 OBJECTIVES

2.1 General Objective

This study was aimed to investigate the respiratory health status among workers and workplace exposure status in a tire retreading factory in Melacca.

2.2 Specific Objectives

The specific objectives of the study were as follows:

1. To determine the respiratory health status among workers in the tire retreading factory (study population)
2. To determine the knowledge, attitude and practice (KAP) of workers in the study population regarding the effects of working environment towards lung function
3. To determine factors that were associated with each lung function parameter in the study population
4. To determine the exposure level of the most commonly used solvent in the environment of the factory
5. To determine the personal exposure level of the most commonly used solvent in the sub sample of the study population
6. To determine the urinary level of the metabolite of most commonly used solvent in the sub sample of the study population

2.3 Research hypothesis

1. Age, sex, level of education, KAP score, job type and duration of work are associated factors with the level of lung function.
2. There is the presence of solvent fume and dust in the environment of retreading tire factory.

2.4 Operational Definitions

Respiratory health status is a status of respiratory health in term of four cardinal respiratory symptoms (such as cough, phlegm production, chest tightness and shortness of breath), clinical finding on respiratory examination and finding of lung function test.

Lung function parameters in this study refer to the level of force vital capacity (FVC), force expiratory volume in one second (FEV_1), ratio of FEV_1/FVC and maximal mid-expiratory flow ($FEF_{25-75\%}$).

"Most commonly used solvent" means a solvent that abundantly used by factory based on verbally reported information from the management of the factory. Naphtha was noted to be the most commonly used solvent which composed of mixture of toluene, xylene and benzene. Since toluene was noted to be at the highest level during environmental sampling, it was decided to be the solvent of interest in personal and biological sampling.

CHAPTER 3

LITERATURE REVIEW

CHAPTER THREE

3 Literature Review

3.1 Rubber industry

Rubber industries such as tire and glove manufacturing are known sectors which involved various types of processes, requires abundant and variety of chemicals (NIOSH, 1993). These chemicals and its mixtures potentially can induce health and medical problems.

Several studies have shown the relationship between rubber industry and the development of adverse health effects namely respiratory illnesses (Zuskin *et al.*, 1996), cancer occurrence (Straif *et al.*, 1999, Mundt *et al.*, 1999) and dermatological problems (Vermeulen *et al.*, 2001).

A six year follow up study in Croatia indicated that the development of acute and chronic respiratory impairment was may be due to exposure to noxious agents in working environment of a tire factory (Zuskin *et al.*, 1996).

In USA, prevalence of COAD in rubber, plastic, leather manufacturing workers was 14.8% with these workers had a higher odd by 2.5 times for developing COAD than office workers (Hnizdo *et al.*, 2002).

A cross sectional population study in Netherlands revealed that rubber, plastics and synthetics industry positively associated with the symptoms of chronic bronchitis at a higher odd by 6.52 for developing those symptoms compared to occupations with few chemical exposures (Vermeulen *et al.*, 2002).

Generally, a tire manufacturing factory practices a complex-40 processing steps and can be simplified into several main steps (which also applied to other rubber products) namely compounding and mixing, cutting and milling, extrusion, calendering and ply stock preparation, product fabrication, vulcanization or curing, finishing and inspection and repair (LaDou, 1997). In each step, workers are potentially exposed to various hazards such as chemical fumes, dust exposure and excessive heat and noise. Apart from that, ergonomic hazard such as repetitive motion and heavy lifting may also be present (NIOSH, 1993).

3.2 Processing steps in tire retreading factory

Even though tire retreading factory has less processing steps compared to a tire manufacturing factory, the types of chemicals used are similar and possesses similar potential health hazard. Retreading is a process whereby selected and inspected casings (worn tires) receive a new tread (ITRA, 2001). Major processing steps that involved are initial inspection, buffing, casing preparation/repairing, tread application, curing and final inspection (ITRA, 2001; Information from factory's management).

During initial inspection step, a worn tire is inspected thoroughly and decision is made whether it is acceptable for retreading or not. This preliminary inspection is the most important step in the retread process (ITRA, 2001). It determines whether the tire body is free of manufacturing defect, non-repairable damage and aging. Tire bodies that are not capable of service through another tread life are rejected. The decision to accept a tire for retreading is decided by the company. At this section, workers are exposed mainly to dust and particulate matters (Information from factory's management).

The accepted tire for retreading is sent to buffing section. Here, the worn tread is removed from a tire casing. The casing is mounted on the buffer, a lathe-type machine, and inflated. It is then rotated while a buffing rasp removes the worn tread material, buffing the casing surface to the correct shape, size and texture to receive a new tread (ITRA, 2001). Workers who do buffing are exposed to mainly tread dust and particulate matters (Information from factory's management).

At a casing preparation/repairing section, defects remaining in the tire casing after buffing can now be repaired if the damage is within acceptable limits. The repair operators recognize which defects can be repaired and which cannot. If the defects are too extensive, the tire casing is rejected. A rubber patch is used to cover the defect on the casing. This patch come with various sizes and applied according to size of the defect. In order to paste it firmly on the casing, a solvent named trichloroethylene used (Information from factory's management). Workers who are at this section can potentially be exposed to this solvent.

Once all repairs are made, the buffed casing is ready for a new tread at tread application area. There are two types of vulcanizing processes used to bond the tread to the casing, a hot-cure and a pre-cure (Information from factory's management). In a hot-cure process, the application of the tread is very similar to that of a new tire manufacturing. Uncured tread is applied to the buffed casing. During this process, naphtha is used abundantly as rubber glue and paint. The prepared casing, built up to the correct diameter with uncured rubber material, is now ready to go into the mold for curing. On the contrary, for the pre-cure process of tread application, the tread used here is molded and pre-cured by either tread rubber manufacturer or the company itself. A cushion gum bonding layer is placed between the tread and the casing. The proper tread width is applied to the prepared casing in a straight and even fashion. The tire then moves on towards the curing chamber.

Curing or vulcanization, is the process of bonding the new tread material to the prepared tire body (ITRA, 2001). During the curing process, uncured rubber is transformed from a soft, tacky, stretchy substance to a tough, hard tread that resist abrasion and provides excellent mileage and traction (ITRA, 2001). In the hot-cure process, the prepared casing, built up to the correct diameter with uncured rubber material, is placed into a mold. When the mold is closed and tire body is inflated to the proper pressure, the swelling of the casing conforms the uncured material to the mold, forming the tread design. Heat is then applied for a specific period of time to accomplish curing. In the pre-cure process, curing on the other hand, takes place within chambers pressurized by heated air produced by electricity, steam or hot fluid such as oil. The prepared casing then installed with sealing plastic envelope before it is put into the chamber where pressure and temperature, applied over the correct length of time, cure the cushion gum layer and bond the tread to the tire. The major hazard during curing is excessive heat and possible rubber fumes exposure.

The last step in the retread process is final inspection. At this section, all retreaded tire are closely inspected to ensure the safety and quality of the products. During this final step, workers are potentially exposed to dust and particulate matters (Information from factory's management).

In general, from all these processes in a retread tire factory, workers are potentially exposed to various solvents, dust, particulate matters and excessive heat which potentially affect their respiratory health status.

3.3 Health effects in workers in rubber manufacturing industry

As mention earlier, workers in rubber industry i.e. tire retreading factory exposed to various hazards such as chemical or solvents, dust factories (Dost *et al.*, 2000, Greenberg, 1997), excessive heat and noise and ergonomic problems. These conditions give rise to numerous ill health effects such as respiratory health ailments (Zuskin *et al.*, 1996, Greenberg, 1997, LaDou, 1997), dermatological illnesses (Vermeulen *et al.*, 2001, LaDou, 1997), various type of cancer occurrences (Straif *et al.*, 1999, Mundt *et al.*, 1999, Straughan and Sorahan, 2000), reproductive abnormalities (Khattka *et al.*, 1999), heat related stress, noise induce hearing loss and musculoskeletal disablements.

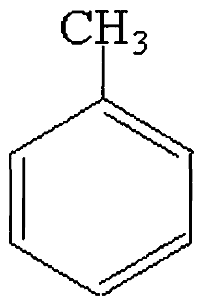
3.4 Solvents used in rubber industry

Various types of chemicals and solvents are used in a tire retreading factory. Toluene is one of the major constituents in naphtha mixture where naphtha is the most commonly used solvent in this factory. Other major aromatic hydrocarbons in this solvent mixture are benzene, xylene and styrene (DGC, 2003). The amount of each component varies depending on the brand of the products in which toluene and benzene remain the major constituents of this mixture. There was a report where toluene was detected during air sampling of tire vulcanization process together with other solvents such as styrene, ethyl benzene and oligomers of butadiene (Greenberg, 1997).

3.4.1 Chemical identity and properties of toluene

Information regarding chemical identity and properties of toluene are shown in Table 1 and Table 2, respectively.

Table 1 Chemical identity of toluene

Characteristic	Information
Chemical name	Toluene
Synonym(s)	Methylbenzene; phenylmethane; benzene, methyl-; toluol; methylbenzol
Registered trade name(s)	Methacide
Chemical formula	$C_6H_5CH_3$
Chemical structure	
Identification numbers:	
CAS registry	108-88-3
NIOSH RTECS	XS5250000
EPA hazardous waste	U220
OHM/TADS	7216928

CAS = Chemical Abstracts Services; NIOSH = National Institute for Occupational Safety and Health; RTECS = Registry of Toxic Effects of Chemical Substances; EPA= Environmental Protection Agency; OHM/TADS = Oil and Hazardous Materials/Technical Assistance Data System

(ATSDR, 2000)

Table 2 Physical and chemical properties of toluene

Property	Information
Molecular weight	92.14
Color	Colorless
Physical state	Liquid
Melting point	-95°C
Boiling point	110.6°C
Density:	
at 20°C	0.8669 g/mL
Odor	Benzene-like
Odor threshold:	
Water	0.04-1ppm
Air	8 ppm
Solubility	
Water at 25°C	534.8 mg/L
Organic solvent(s)	Miscible
Partition coefficients:	
Log K_{ow}	2.72
Log K_{oc}	1.57-2.25
Vapor pressure at 25°C	28.4 mm/Hg
Henry's law constant;	$5.94X10^{-3}$atm-m^3/mol
Autoignition temperature	480°C (896°F)
Conversion factors ppm (v/v) to mg/m^3 in air (20°C)	1 ppm = 3.75 mg/m^3

v/v = volume for volume

(ATSDR, 2000)

3.4.2 Routes of intake and metabolism of Toluene

Toluene is absorbed into the human body via three main routes i.e. respiratory tract, dermal route and oral exposure. This solvent rapidly absorbed via respiratory tract which is the main route of uptake. It takes about 10 to 15 minutes for toluene to be appeared in the blood with the exposure of 80 ppm toluene (ATSDR, 2000). About 50-70% of inhaled toluene will be taken into bloodstream (NIOSH and JICA, 2003). Exercise seems to affect the uptake rate of toluene where the amount of uptake during heavy exercise becomes five times of each amount of uptake at the rest time (NIOSH and JICA, 2003).

Toluene is absorbed through human skin slowly either in liquid or vapor form. The absorption rate is up to 23 $mg/cm^2/hour$ for liquid and 0.19-1.24 cm/hr for vapor form (NIOSH and JICA, 2003).

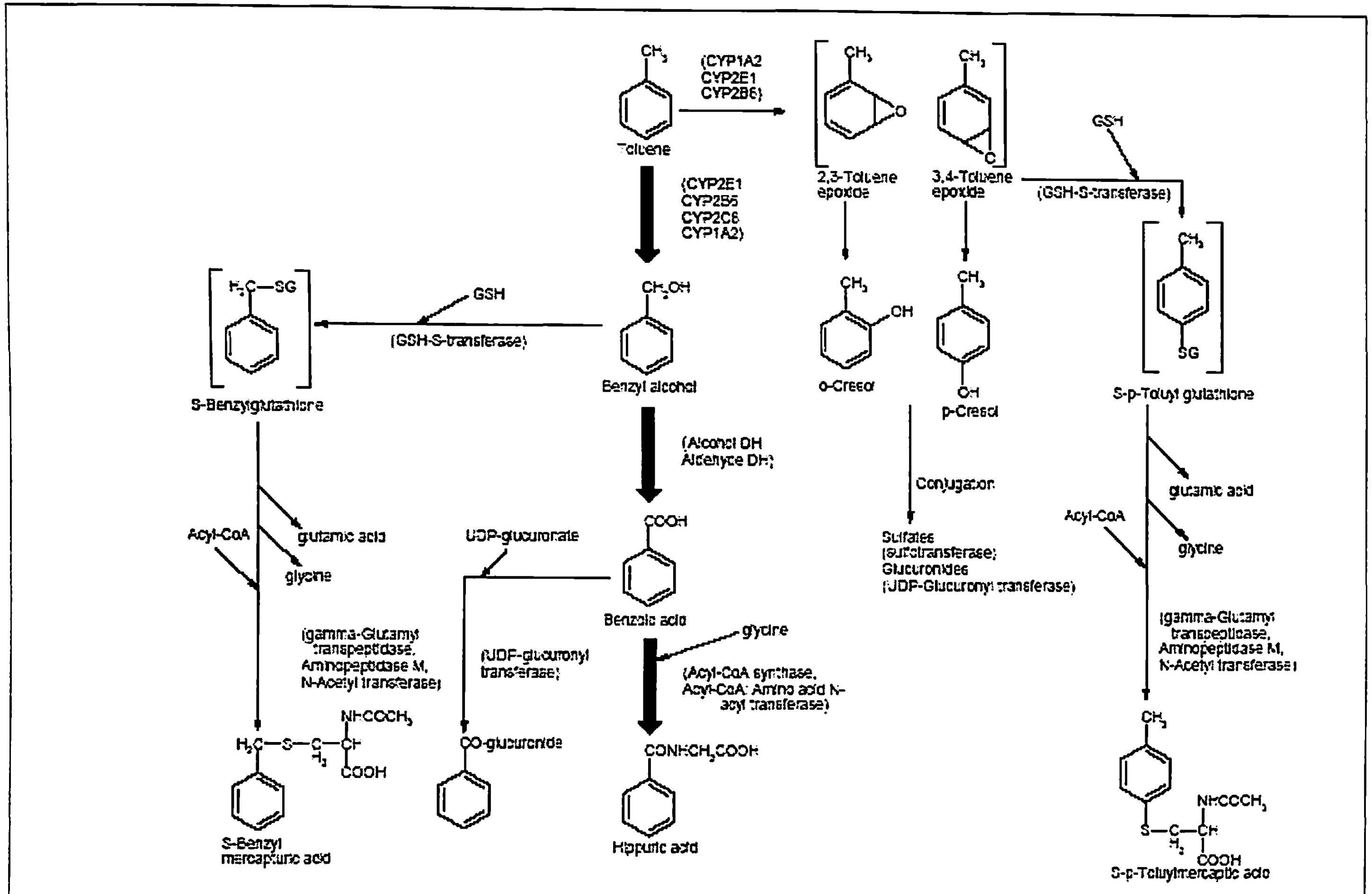
Oral route of toluene appears to be at a slower rate than pulmonary absorption. In previous animal study, maximum blood concentration was observed within 1.5 to 3 hours after administration (ATSDR, 2000). It is absorbed into the blood stream along the gastrointestinal tract through lipophilic matrix of the membrane (ATSDR, 2000).

Toluene in the blood stream is distributed into all tissues, particularly those with a high lipid content such as brain, adipose tissue and bone marrow (Greenberg, 1997).

Liver is the prime organ for metabolism of toluene (ATSDR, 2000, NIOSH and JICA, 2003). It is metabolized by cytochrome P-450 system enzymes where the predominant initial step is methyl hydroxylation of toluene to form benzyl alcohol and at a very small portion, ring hydroxylation occurred to form *ortho* or *para-cresols* (ATSDR, 2000). Therefore, toluene is metabolized mainly to hippuric acid, 19% expired unchanged and less than 1% transformed into *ortho*, *meta* and *para-cresols* (Greenberg, 1997). Metabolism of toluene in human is presented in Figure 2.

In case of high exposure, benzoyl glucoronide is also excreted as metabolite (NIOSH and JICA, 2003). These metabolites (hippuric acid, *ortho*, *meta* and *para-cresols*, benzoyl glucoronide) are excreted predominantly in the urine with a significant portion (about 20%) is exhaled nonmetabolized in air. This is true for absorbed toluene from inhalational and oral exposures without co-exposure with ethanol (ATSDR, 2000). In the condition where there is presence of ethanol and for toluene absorbed from dermal exposure, it is exhaled as parent compound (ATSDR, 2000). There is no information available concerning the possible urinary excretion of metabolites for toluene absorbed dermally (ATSDR, 2000).

Generally, biological half life of hippuric acid in urine is about 1.5 hours and biological half life of toluene in expired air is about 0.7 hours (NIOSH and JICA, 2003).



Proposed enzymes are noted in parentheses.

CoA = coenzyme A; CYP = cytochrome P-450; DH = dehydrogenase; GSH = glutathione; UPD = uridine 5'-diphosphate

(adopted from ATSDR, 2000)

Figure 2 Scheme for metabolism of toluene and animal

3.4.3 Adverse health effects of toluene

There are reported acute and chronic effects of toluene (ATSDR, 2000, NIOSH and JICA, 2003, Greenberg, 1997). Acute toxicity from inhalation is determined by the ambient concentration of toluene, the minute ventilation and the activity of the affected individual (Greenberg, 1997). Effects on chronic exposure of toluene are of similar in term of target organs to acute exposure but in a less dramatic manner. Acute refers to an exposure period of 14 days and less whereas chronic refers to 365 days or more (ATSDR, 2000).

3.4.3.1 Acute toxicity of toluene

The effects of acute toxicity from toluene inhalation involve mainly on the neurological system. The observed effects include reversible neurological symptoms progressing from fatigue, headache, and decreased manual dexterity to narcosis with increasing exposure level. Table 3 summarizes the acute effects of toluene exposure with regards to amount of concentration in the environment (ppm) and duration of exposure (hour).

Table 3 Acute adverse health effects

Ppm	hour	Health effect
0.03~3		Odor threshold
75	7h/d, 3d	Headache, thirst, sleep, eye and mucus membrane irritation
100	6	Headache, dizziness
100	6.5	Fatigue, sleepiness
200	7	Elongation of hand-eye reaction time
400		Lacrimation, hilarity
600		Lassitude, hilarity, slight nausea
800		Drowsiness, ataxia, metallic taste
≥1842	2~3	Collapse

(NIOSH and JICA, 2003)

3.4.3.2 Chronic toxicity of toluene

In the chronic exposure of toluene, the health effects are described under organs systems of the human body such as central and peripheral nervous system, renal system, reproductive system and respiratory system.

Degenerative changes in a white matter of the brain was observed in chronic solvent abusers and subtle changes in neurological functions including congnitive and neuromuscular performance, hearing, and color discrimination (ATSDR, 2000). Symptoms like headache, dizziness, forgetfulness, difficulty in concentration, loss of smell, low grade fever and numbness of the extremities are commonly reported (NIOSH and JICA, 2003).

Renal toxicity was observed in a subgroup of printers who had several years of hippuric acid concentration recorded, had a positive correlation with an acceleration of the age-related decline in creatinine clearance (Greenberg, 1997).

A study in printing industry revealed the toluene exposure in women was associated with subfecundity (Plenge-Bonig and Karmaus, 1999). There were several case reports of birth defects and developmental delays in children of mothers who abused solvents, which include toluene (ATSDR, 2000).

In respiratory system, human exposure to toluene irritates respiratory tract whereas irritation of the upper airways and degeneration of the nasal epithelium have been observed in animal studies (ATSDR, 2000). However, at various level of toluene concentration (ppm) and duration of exposure (hours), no changes was noted in lung function result (ATSDR, 2000). Perhaps this study would be able to provide more information with regards to the effect of toluene exposure towards the lung function parameters.

3.4.4 Environmental level and monitoring of toluene

Released toluene enters various environmental media such as air, water and soil. Nearly all of toluene that released enters air environment. Small portion may be directly entered the surface and underground water. Hazardous waste disposal sites are principal source for toluene contaminated water and soil in USA (ATSDR, 2000). Table 4 shows variety