EXPOSURE OF VOLATILE ORGANIC COMPOUNDS (VOCs) AND NEUROBEHAVIOURAL EFFECTS AMONG CHEMICAL PLANT WORKERS

by

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Dissertation submitted in partial fulfillment of the requirements for the degree of Bachelor of Health Sciences (Honours) (Environmental and Occupational Health)

June 2015

ACKNOWLEDGEMENT

In the name of Allah, the Most Gracious, the Most Merciful. All the praises and thanks to be to Allah.

First and foremost, I'd like to thank my supervisor, Dr.Siti Marwanis Anua, who has been supportive, gave guidance and encouragement, gave full attention and effort, and fully concerned about me and my research, also her understanding on the challenge from the beginning until the research completion.

Many thanks and deepest appreciation to Mr Fitroy Gerald Pickthall, site manager of Synthomer Sdn Bhd because giving me opportunity to conduct my field work at this company. I am thankful and appreciate all Nitrile Butadiene Rubber plant (NBR) and administration staff involved. Not to forget Mrs. Ashikin binti Othman clerk in NBR plant who helps me carried the instrument and arrange the staff despite their busy time. My deepest gratitude for all respondents for the cooperation they gave along the study, although they have their own commitment. Special thanks and appreciation to En Azmi Mohd Yusof, En Salehuddin Mustapha and En Firdaus Kamarudin for their kindness help, contribution, support, and advised me until this research completed. Last but important, I'd like to thank my parents and families for their supplication, concerned, and motivation. *May Allah bless them all.*

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LIST OF ABBREVATIONS AND SYMBOLS

%	Per cent
CHT	Charge Holding Tank
et al.	*Ex alia* (and others)
F	Frequency
ILO	International Labour Organisation
IQR	Interquatile Range
MOART	Multi-Operational Apparatus for Reaction Time
N	Number
NCTB	Neurobehavioural Core Test Battery
NBR	Nitrile Butadiene Rubber
OSHA	Occupational Safety and Health administration
US OSHA	United State Occupational Safety and Health administration
p	*p value*
PPE	Personal Protective Equipment
SD	Standard deviation
SPM	Sijil Pelajaran Tinggi
STPM	Sijil Tinggi pelajaran Malaysia
USEPA	United States Environmental Protection Agency
VOCs	Volatile Organic Compounds
WHO	World Health Organisation
X^2	Chi Square
Z	Z-score

PENDEDAHAN SEBATIAN ORGANIK MERUAP DAN KESAN TINGKAHLAKU NEURO DALAM KALANGAN PEKERJA DI LOJI KIMIA

ABSTRAK

Sebatian organik meruap adalah bahan kimia organik berasaskan karbon. Sebatian organic meruap mendatangkan kesan kesihatan kepada manusia seperti kerengsaan tekak, sakit kepala, kehilangan kesimbangan, loya, kerosakan kepada hati, buah pinggang dan sistem saraf. Satu kajian mengenai pendedahan sebatian organik meruap dan kesan tingkahlaku neuro dalam kalangan pekerja di loji kimia telah dilaksanakan melalui kajian rentas perbandingan. Pemantauan persekitaran sebatian organik meruap diukur selama 15 minit selama tiga kali sehari selama 5 hari mengunakan alat Phocheck+ untuk tiga lokasi berbeza iaitu proses bangunan, penyimpanan butadiene dan Bioplant (kawasan sisa). Tingkahlaku neuro telah diperiksa dalam kalangan kumpulan terdedah seramai 40 subjek dari loji getah butadiena nitril. Perbandingan dilakukan dengan kumpulan tidak terdedah terdiri daripada 40 orang kakitangan pengurusan. Pemantauan alam sekitar terhadap kepekatan pendedahan sebatian organik meruap menunjukan Bangunan Proses merupakan yang paling tinggi berbanding Simpanan Butadiena dan Bioplant (kawasan sisa). Satu set soalan soal selidik ditanya kepada subjek berkenaan latar belakang diri, sejarah pekerjaan, tahap terkini kesihatan dan simptom tingkah laku mengunakan soalan soal selidik yang diubah suai. Ujian tingkah laku neuro dilakukan dengan mengambil masa 40 minit untuk seorang subjek. Bangunan proses menunujukan kepekatan sebatian organik meruap paling tinggi berbanding penyimpanan butadiene dan Bioplant (kawasan sisa). Tiga bahan kimia tertinggi yangt terdedah kepada pekerja adalah butadiene, ammonia dan akrilonitril. Hanya kegatalan kulit menunjukan perbezaan yang signifikan antara kumpulan terdeah dan tidak terdedah ($p=0.001$). Skor ujian tingkahlaku neuro menunjukan signifikan di antara kumpulan terdedah dan tidak terdedah dalam memori auditori (Digit Span Forward, Digit Span Backward), kestabilan dan getaran (Steadiness Test). Hanya jantina dalam faktor latar belakang diri yang mempengaruhi memori auditori (Digit Span Forward, Digit Span Backward). Merokok memberi kesan visual persepsi / memori (Benton Visual Retention) dan kestabilan tangan/gegaran (Steadiness Test). Status kesihatan faktor yang memberi kesan kepada ketangkasan manual (Minnesota Manual Dexterity for non-dominanat). Nilai tingkahlaku neuro tidak mempengaruhi pendedahan sebatian organik meruap dan ciri pekerjaan. Majikan perlu sedar pendedahan bahan kimia boleh memberi kesan tingkahlaku neuro di tempat kerja.

EXPOSURE OF VOLATILE ORGANIC COMPOUND (VOCS) AND NEUROBEHAVIOURAL EFFECT AMONG CHEMICAL PLANT WORKERS

ABSTRACT

VOCs are carbon-based organic chemicals. VOCs effects human health such as throat irritation, headaches, loss of coordination, nausea, damage to liver, kidney, and central nervous system. A study on exposure of volatile organic compounds (VOCs) and neurobehavioural effects among chemical plant workers has been implemented through comparative cross sectional study. Environmental monitoring of volatile organic compounds (VOCs) was measured using Phocheck+ instruments for three locations which are Process Building, Butadiene Storage and Bioplant (waste area) for 15 minutes three times daily for five days. Neurobehavioural effects were examined among the exposed group of 40 subjects consists of Nitrile Butadiene Rubber (NBR) plant. It was compared with non-exposed of 40 administrative staff. Subjects were asked about socio demographic, work characteristics, health status and neurobehavioural symptoms using a modified questionnaire. Neurobehavioural core test battery tests (NCTB) were conducted for 50 minutes among them. Process building had the highest VOCs concentration in NBR plant compared to Butadiene Storage and Bioplant (waste area). The top three chemicals exposed to workers were butadiene, ammonia and acrynotrile. Only itchiness showed significant association between exposed and non-exposed group (p=0.001). NCTB score showed significant difference between exposed and non-exposed group in Digit Span Forward, Digit Span Backward (auditory memory) and Steadiness Test (hand steadiness and tremor). Only gender in socio demographic factors affecting auditory memory (Digit Span Forward and Digit Span Backward). Smoking affecting visual perception/memory (Benton Visual Retention) and hand steadiness/tremor (Steadiness Test). Health status factors affecting manual dexterity (Minnesota Manual Dexterity (non-dominant). None of the NCTB scores were affected by VOCs exposure or work characteristics. As conclusion, employers must be aware of the chemical exposure which can affect the neurobehavioural of workers in the workplace.

CHAPTER 1

INTRODUCTION

1.1 Background of study

Volatile organic compounds (VOCs) are emitted as gases from certain solids or liquids (USEPA, 2012). VOCs are carbon-based organic chemicals that are present as vapours at room temperature and have low solubility (USEPA, 2010). WHO (1989) classify VOCs into three categories of very volatile organic compounds (VVOCs), volatile organic compounds (VOCs) and semi-VOCs. VVOCs (gaseous) have a lower boiling point of less than 50 – 100°C such as propane, butane and methyl chloride. VOCs have a lower boiling point limit between 50°C and 100°C and upper boiling limit between 240°C and 260°C. Compounds with the boiling point in the intermediate range 240 to 260 °C and up to 380 to 400°C are semi- VOCs. Organic compounds with boiling points above 400°C are solids (Halim, Said & Leman, 2013).

Hundreds of VOCs present indoors comprise a wide variety of hydrocarbons and hydrocarbon derivatives, including aliphatics, aromatics, alkylbenzenes, ketones, and chlorinated and polycyclic hydrocarbons. The semi-VOCs are presented indoor both in particles and in the gaseous phase (Halim, Said & Leman, 2013). VOCs are emitted by a wide array of products, such as paints and lacquers, paint strippers, cleaning supplies, pesticides, building materials and furnishings, printers and copiers and others (USEPA, 2012).

Volatile organic compounds (VOCs) can be detected in the urban and industrial atmosphere mainly originate from motor vehicles exhausts and other combustion process utilising fossil fuels, petroleum storage and distribution, solvent other industrial processes (Eylem, Odabahasi & Seyfioglu, 2003). Leaks, as well as regulated emissions, contribute to ambient concentrations of VOCs (Liu, Shao, Fu, Lu, Zeng, & Tang, 2008).

Figure 1.1 shows the sources of VOCs emissions in outdoor such as fuel combustion, on road vehicles, non-road vehicles and engines and industrial processes. Example of fuel combustions includes emissions from coal, gas, and oil-fired power plants and industrial. Other industrial processes include chemical production, petroleum refining, and metals production. On-road vehicles involve cars, trucks, buses, and motorcycles and example for non-road vehicles and engines such as farm and construction equipment, chainsaws, boats, ships, aircraft, and others (USEPA, n.d)

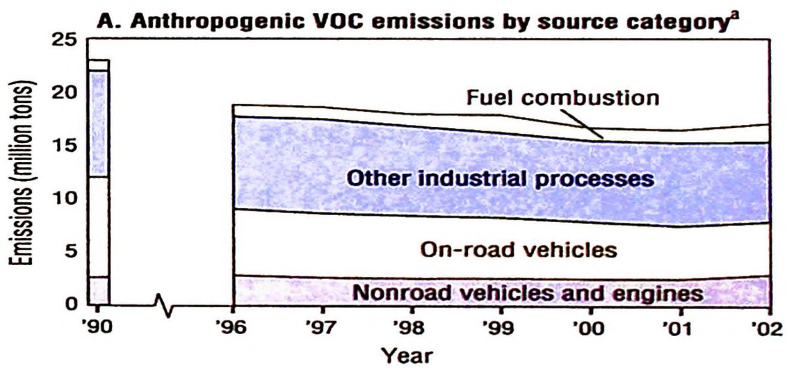

Figure 1.1: Anthropegenic source category of VOCs emissions in the United States 1990 and 1996 to 2002.

Table 1.1 shows that VOC emission from other industrial processes was the highest in 1990 with 9.99 million tons compared to sources category of fuel combustion, on road vehicles and non-road vehicles and engine. Industrial processes had maintained as highly emitted VOCs sources from 1996 until 2002.

Table 1.1: Anthropegenic source category of VOCs emissions in the United States 1990 and 1996 to 2002

Source category	**1990**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**
Fuel combustion	1.00	1.12	1.12	1.12	1.65	1.18	1.19	1.72
Other industrial processes	9.99	8.65	8.86	8.41	7.97	7.63	7.82	7.50
On-road vehicles	9.39	6.22	5.99	5.86	5.68	5.33	4.95	4.92
Non road vehicles and engines	2.66	2.93	2.75	2.67	2.68	2.64	2.62	3.06

Source: US Environmental Protection Agency (2010).

Petroleum refineries and petrochemical plants are generally large industrial installations. Their operation is associated with the emission of various organic compounds into the atmosphere, mainly originating from the production processes, the storage tanks and the waste areas (Kalabokas, Hatzaianestis, Bartzis, Papagiannakopoulos, 2001).

All VOCs share one important characteristic such as they are all fat or lipid soluble and for that they have an affinity for the fatty or lipid tissues of the body. Renal, liver, and haematological effects have been noted in people exposed to hydrocarbons, and they cause central nervous system damage in those suffering high exposure (Hayden, Comstock, & Comstock, 1976).

The brain is a prime target of the VOCs due to its high lipid content and rich blood supply, hence symptoms are primarily cerebral in nature. Acute symptoms include dizziness, forgetfulness, headaches, mental fogginess, difficulty in concentrating, and poor coordination (Abhijeet, 2005).

Therefore, neurobehavioural effects can be detected through the presence of the neurological symptoms and using Neurobehavioural Core Test Battery (NCTB) which was outlined by World Health Organisation in 1986 (WHO, 1986).

1.1.1 Work process of place of study

Figure 1.2 shows the flowchart of work process in Synthomer Sdn Bhd. The process begins with the preparation of two solution make up tanks. The first solution make up tanks contains chelating agents, electrolytes, initiators and caustic solution. These solutions are directed to aqueous weigh tank. After the weigh tank, the solution flows via gravity into charge holding tank (CHT). Chemical preparation consists of chemicals such as 1,3- butadiene, acrynotrile and metacyclic acid in CHT.

Before the start of polymerisation reaction, the reactor needs to be kept at vacuum state. Inert gas and high pressure steam are injected into the reactor to purge out any trapped oxygen. The solution in CHT is heated up to appropriate temperature, depending on the desired recipe, before being directed to the reactor. This process of preheating reduces the amount of heat required to rise reactor temperature. Chelating agents and electrolytes from the catalyst manifold is injected into the top of reactor. After that, process water is pumped into the reactor to create a dispersion medium prior to reaction.

The reaction rate is highest at the beginning of reaction in the reactor. Almost 60% of monomers would have reacted at operating temperature. Over time, the reaction rate slows down and the reaction temperature needs to be increased to polymerise the remaining unreacted monomers. Once the desired conversion is achieved, short stop is injected to stop the reaction preventing excessive gel formation. High gel content would alter the properties of latex. The latex from reactor is transferred to the stripper via steam purging.

Once the reaction has reached targeted conversion, the latex will still contain a minimal amount of unreacted monomers. These monomers are very toxic and needs to be processed to safe levels. The stripping stage is a distillation process where the latex is boiled to certain temperature to vaporise unwanted materials such as water, impurities and unreacted monomers. Some impurities will dissolve in water while others might be trapped within the chains in the polymer particles. Next in condenser, water is discharged to effluent system & incondensable (unreacted monomer) is diluted and released to air via a vent stack. This is the major sources of VOCs emission.

Then, the coagulum free latex is then pumped into the compounder. The compounder prepares latex for handling and storage. The properties of latex which are examined in the compounder include total solid content, coagulum level, pH, gel content and residual monomer. Lastly, the finishing latex is ready to dispatch.

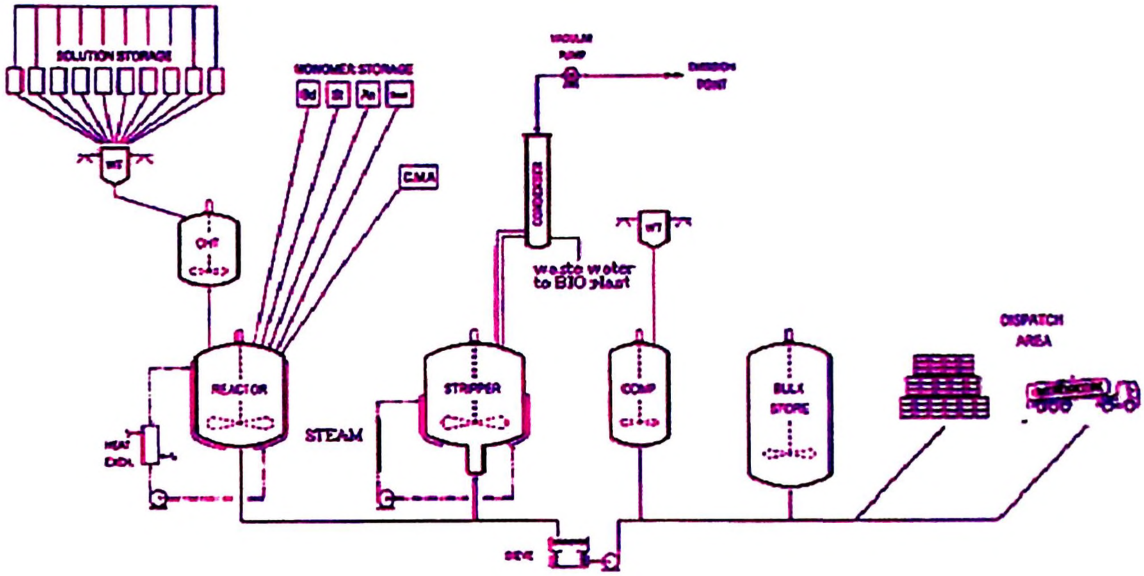

Figure 1.2: Flowchart of work process in Synthomer Sdn Bhd.

1.2 Problem statement

Synthomer Sdn Bhd was known for manufacturing natural rubber and synthetic latex. The workers in the plant are well known to be exposed to the various kinds of hazards such as biological hazard, physical hazard, and mostly chemical hazard. Therefore, the plant workers are highly exposed to chemical at workplace. According to the safety manager at Synthomer Sdn Bhd, there were many issues had been raised by the workers regarding the unpleasant chemical smell in the plant. There was one foreign worker had collapsed due to chemical inhalation (Azmi Yusof, personal communication, September 13, 2014).

Some VOCs are classified as known or suspected carcinogens, including benzene, 1,3-butadiene, formaldehyde, naphthalene, p-dicholobenzene, perchoroethylene, styrene, and trichchloroethylene (Stephen & Lawrence, 2003). The workers at Synthomer Sdn Bhd were mostly exposed to 1,3- butadiene, acrytnitrile and metacrylic acid. 1,3-butadiene can effect the neurological, such as blurred vision, fatigue, headache, and vertigo, at a very high exposure levels (USEPA, 2013).

There were previous studies looking at chemical exposure effect of the neurobehavioural. The most common symptoms among workers exposed to fuel oil spill in Spain were back problems, headache, irritated eyes, throat, and respiratory problem (Gema, Paul & Isabel, 2007). Fuel oil is an organic compound which composed of a complex mix of hydrocarbons and toxic substances. Shakeel at al. (2006) conducted a study among spray painter. The results showed that spray painters were at risk of developing neurological, thyroid and reproductive problems. Zailina et al. (2010) concluded in their study that naphtha exposure gave neurotoxin effect among tyre factory workers.

There is limited published research available on the VOCs exposure leading to the exacerbation of neurobehavioural effects in the Malaysian occupational setting. Therefore this study is aimed to determine such association in identifying suitable prevention and control of VOCs exposure and neurobehavioural effect.

1.3 Research objective

1.3.1 General Objective

To study the exposure of volatile organic compound (VOCs) and the neurobehavioural effects among chemical plant workers.

1.3.2 Specific Objective

1) To determine and compare the level of VOCs exposure between different sampling sites in the chemical plant.
2) To determine and compare the neurobehavioural symptoms and neurobehavioural score among chemical plant workers and non exposed workers.
3) To determine the relationship between factors affecting the neurobehavioural score and neurobehavioural symptoms among subject workers.

1.4 Research hypothesis

1) There is significant difference of level of volatile organic compounds exposure between different sampling sites.
2) There is significant difference of neurobehavioural symptoms and neurobehavioural score between chemical plant workers and non-exposed workers.
3) There is significant relationship between the factors affecting the neurobehavioural symptoms and neurobehavioural score among subject workers.

1.5 Significance of study

The importance of this study was to detect any symptoms arise regarding the exposure of volatile organic compounds (VOCs) and to conduct a Neurobehavioural Core Test Battery (NCTB) assessment among chemical plant workers. Furthermore, this study would fill the research gap because so far there was no study that has been conducted regarding the neurobehavioural effect due to the VOCs exposure in Malaysia.

Moreover, this study would give benefits to the employers and the employees, to be able to know their neurobehavioural status from the NCTB test. This study can determine their neurobehavioural effect regarding the exposure of volatile organic compound as well improve employers' and employees' awareness about their safety and health in the workplace. Employer can take further action for prevention and control to improve the worker's health at the factory.

CHAPTER 2

LITERATURE REVIEW

2.1 VOCs exposure in chemical industry

Volatile organic compounds (VOCs) in the chemical industry are the main concern to the surrounding and can effects health of the workers or the resident nearby. There are many studies regarding the volatile organic compounds (VOCs) in the petrochemical plant. Eylem, Odabahasi & Seyfioglu, (2003) reported VOC concentrations measured in their study around the petrochemical complex and oil refinery were 4–20-fold higher than those measured at the Buca suburban site in Izmir, Turkey. Total VOCs concentrations were the highest in summer, followed by autumn. The higher concentrations measured in summer and autumn may be due in part to increased evaporation from fugitive sources as a result of higher temperatures. VOC concentrations generally increased with temperature and wind speed. Temperature and wind speed together explained 1–60% of the variability in VOCs concentrations.

Tiwari, Hanai & Masunaga (2009) measured the ambient levels of volatile organic compounds in the vicinity of petrochemical industrial area of Yokohama, Japan. The results show strong variation between day and night time concentrations and among the seasons. The observed ambient concentrations increased during midnight (11:00 pm–1:00 am) and then decreased during 1:00 to 2:00 am; with a steady increasing pattern which then increased at 10:00 am. High concentration of benzene (8 $\mu g/m^3$), m,p-xylene (10.8 $\mu g/m^3$) were observed at midnight (11:00 pm–1:00 am), and toluene (19.3 $\mu g/m^3$) was observed during early morning (4:00–5:00

am). Overall, the observed high concentrations of BTEX during night time can be attributed to the calm atmospheric conditions and lack of photochemical activity.

Balaji & Murugesan (2010) stated that total VOCs concentration in process area were higher than storage tank farm and Maleic-Fumaric acid plant from petrochemical industry in Inranipet South India.

2.2 Routes of entry

Most sites contain a variety of chemical substances in gaseous, liquid, or solid form. These substances can enter the unprotected body by inhalation, skin absorption, and ingestion. A contaminant can cause damage at the point of contact or can act systemically, causing a toxic effect at a part of the body distant from the point of initial contact (United States OSHA, 1985).

2.1.1 Inhalation

In chemical industry, inhalation is a primary and efficient route for exposure and the most common route for gases, vapours, aerosols, mists, fumes, and small particulates to enter the body (Hassim & Hurme, 2009). Once inhaled, chemicals are either exhaled or deposited in the respiratory tract. If deposited, damage can occur through direct contact with tissue or the chemical may diffuse into the blood through the lung-blood interface. Upon contact with tissue in the upper respiratory tract or lungs, chemicals may cause health effects ranging from simple irritation to severe tissue destruction. Substances absorbed into the blood are circulated and distributed throughout the body (University of Nebraska Lincoln Environmenatal Health and Safety, 2014).

2.1.2 Skin Absorption

Chemicals can soften the keratin cells in the skin and pass through this layer to the dermis, where they are able to enter the veins and hence the blood stream (Canadian Centre for Occupational Health and Safety, 2009). Other routes in industrial chemical can be corrosive or scalding, liquids spillage, leakage or splash (Hassim & Hurme, 2009).

2.1.3 Ingestion

Chemical exposure via ingestion route may occur via the gut through eating or drinking by contaminated hands (Hassim & Hurme, 2009). Smoking cigarettes can be ingestion which comes into hand to mouth contact with chemical or unclean hands (Health Canada, 2008).

2.3 Personal Protective Equipment

Personal protective equipment, commonly referred to as "PPE", is equipment worn to minimise exposure to a variety of hazards. Examples of PPE in the chemical plant are respirators, gloves, face mask, safety shoes, safety helmet, impact glasses or goggles, and others. There are six hierarchy of control measures which are elimination, substitute, engineering control, administration control and PPE. PPE is the last resort in the hierarchy of control.

Aigbokhaode, Isah, & Isara (2011) did a study on awareness using PPE among 410 quarry workers in Ikpeshi, a rural community in Edo State, Nigeria. The study showed 235 workers (57.3%) were aware about PPE. The PPE mentioned by the respondents were hand gloves (15%), safety boots (19.5%), and hard hats (17.8%), hand gloves (15.0%), and nose / face mask (1.2 %). Furthermore, Aigbokhaode, Isah, & Isara (2011) also conducted study with regards to the frequency of PPE used. The outcomes were listed as never (41%), sometimes (33.4%) and all the time (28.6%).

2.3.1 Types of personal protective equipment used in chemical industry

Types of PPE using for chemical industry includes protective suit, chemical-resistant gloves, boots, face and eye protection, and respiratory protection (Robert, 1994). Hearing protection also include in PPE requirement (United States OSHA, 2003).

List of types of PPE used in chemical industry are:

1. Head protection such as safety helmet can protect head from impact from falling or flying objects, risk of head bumping, hair getting tangled in machinery, chemical drips or splash, climate or temperature.

2. Protective suits or jacket can provide protection against skin contamination, heat, chemical or metal splash.

3. Leg protection such as safety shoes or boots to prevent from slipping, cuts and punctures, falling objects, heavy loads, metal and chemical splash.

4. Face and eye protection such as goggle or safety spectacles to provide protection from flying particles, molten metal, liquid chemicals, acids or caustic liquids and chemical gases or vapors.

5. Respirator protection can prevent from inhaling the chemical gases and vapours.

6. Hand protection such as gloves can prevent injuries from potential hazards include skin absorption of harmful substances, chemical or thermal burns, electrical dangers, bruises, abrasions, cuts and others

7. Ear protection such as earplug reduces the noise exposure in the workplace.

2.4 Neurotoxicity

Neurotoxicity refers to the capability of inducing adverse effects in the central nervous system, peripheral nerves or sensory organs. A chemical is considered to be neurotoxic if it is capable of inducing a consistent pattern of neural dysfunction or change in the chemistry or structure of the nervous system (ILO, 2011).

Neurotoxicity occurs when the exposure to natural or man made toxic substances (neurotoxicants) alter the normal activity of the nervous system. This can eventually disrupt or even kill neurons, the key cells that transmit and process signals in the brain and other parts of the nervous system (National Institute of Neurological Disorders and Stroke, 2007).

Neurotoxicity is generally manifested as a continuum of symptoms and effects, which depends on the nature of the chemical, the dose, and the duration of exposure and the traits of the exposed individual (ILO, 2011). A small number of industrial chemicals such as lead, methylmercury, polychlorinated biphenyls, arsenic, and toluene are recognised causes of neurodevelopmental disorders and of subclinical brain dysfunction. Exposures to these chemicals during early development can cause brain injury at dose levels much lower than those affecting adult brain functions (Grandjean, 2006).

Takeuchi (2013) reported 34 numbers of main neurotoxic chemicals which workers may exposed in the workplace. In 2006, Grandjean reported there are 200 neurotoxic chemical known to cause clinical neurotoxicity in adults (Grandjean, 2006).

2.5 Neurobehavioural effects

The central nervous system is vulnerable to neurotoxic effects at lower levels of exposure in comparison to the peripheral nervous system. Attention has been given on the need to identify neurotoxic effects of the brain as early as possible to avoid permanent damages. The continuing exposures due to the repeated exposures to solvents may cause cumulative and irreversible damages to the nervous system (Norazura, 2011).

The symptoms of exposure to the neutoxic agent can be distinguished. These include the sensory, motor, cognitive, mood and personality and general effects. General effect exposures to neutoxic agent are appetite loss, headache, depression, drowsiness and thirst. Examples of sensory effects are dizziness, tingling, numbness, impaired color vision, night blindness and others. Motor effects symptoms are tremor, twitching, lack of coordination, reflex abnormalities and others. Cognitive effects include loss of concentration, fatigue, memory problems, learning and speech impairment, hallucinations and others. Otherwise, mood and personality effect presentable as sleep disturbance, depression, nervousness, restlessness, irritability and others (ILO, 2011).

Fidler, Baker & Letz (1987) studied the neurobehavioural effects of occupational exposure to organic solvents among construction painters and reported the neurotoxic symptoms such as dizziness, nausea, fatigue and problems with their arm strength.

2.6 Neurobehavioural Core Test Battery (NCTB)

The NCTB is used to for evaluating the nervous system effects among working populations exposed to toxic agents. This test measures the basic neurobehavioural functions or can detect the presence of sign and symptom of neurological disorders. It also assess exposure-effect and exposure-response relationship and in some instances as guides in establishing standards for workplace exposure control.

The NCTB test is simple, not expensive, and appropriate battery comprising mainly paper and pencil, which is short and easy. Most importantly, the test is not tiring. There are two purpose of this test:

a) To be used in health hazard evaluations which testing time per person is limited and cannot use advanced method

b) To be used as standard marker tests within larger test batteries, to allow comparison between studies and countries.

There are seven tests of WHO Neurobehavioural Core Test Battery (WHO, 1986) which are:

1. Profile of Mood States to test affect
2. Simple Reaction Time to test attention or response speed
3. Digit Span to test auditory memory
4. Santa Ana dexterity test to test manual dextextity
5. Digit Symbol to test perceptual-motor speed
6. Benton Visual Retention to test visual perception
7. Pursuit Aiming to test motor steadiness

Several studies regarding NCTB tests have been conducted. Farahat, Abdelrasoul, Shebl & Anger (2003) studied about the neurobehavioural effects among exposed workers to pesticides. Zailina et al. (2010) studied on neurotoxin effect of naphtha exposure in tyre factory workers. Jonathan et al. (2003) studied nervous system effects of occupational manganese exposure among South African manganese mineworkers. Jonathan et al. (2003) also studied nervous system effects of occupational exposure on workers in South African manganese smelters. While in Rongzhua, China, Ziqiangb, Fusheng & Collins (2005) studied neurobehavioural effects of occupational exposure to acrylonitrile in chinese workers. Maryse, Donna & Mary (2005) studied manganese exposure and age effects on neurobehavioural performance among alloy production workers in Canada.

2.7 Law related chemical exposure in malaysia

There is in no permissible exposure limits provided for VOCs in outdoor compare to indoor exposure with 3.0 ppm in Malaysia. Occupational Safety and Health Act (1994) had stated the permissible exposure limits only for specified chemical, listed in schedule 1 of the Occupational Safety and Health (Use and Standards of Exposure of Chemicals hazardous to Health Regulations 2000) (not specified to VOCs).

CHAPTER 3

METHODOLOGY

3.1 Study design

This research design was a cross sectional comparative study where the purpose of this study was to determine the relationship between volatile organic compounds (VOCs) exposure and neurobehavioural effect among chemical plant workers.

3.2 Study location

This research sampling was conducted at Synthomer Sdn Bhd, located at Kluang Johor. Synthomer Sdn Bhd produces natural rubber and synthetic latex. This company was selected for sampling because it is one of the chemical plant in Malaysia which involves three monomer used of 1, 3-Butadiene (BD), Acrylonitrile (ACN) and Metacrylic Acid (MAA).

The plant was built to supply the demand for specialty latex in the Southeast Asia, particularly in the glove dipping industry. Gloves are manufactured for a wide range of industrial and medical fields. Other important end use markets in Asia for Synthomer's lattices are construction, adhesives, nonwoven fabrics and textile printing.

3.3 Study participants

Target population of this study was the plant workers who were exposed directly to chemical at the workplace. The sample population was Nitrile Butadiene Rubber (NBR) plant workers for exposed subjects.

Non exposed subjects were included in order to obtain standard mean score of non-exposed subjects to chemical exposure (control). The score was used as a differentiation between exposed subjects and non - exposed subjects. The matched non-exposed subjects were selected based on their education level, age and gender. This non exposed group was the administrative workers. Employees from various departments in Synthomer Sdn Bhd which included: finance, human resources, purchasing and handling, and customer services department. Inclusion and exclusion criteria for subjects can be referred on Table 3.1.

Table 3.1 Inclusion and exclusion criteria.

Inclusion	Exclusion
Age between 20 to 60 years	Had any injury at their hand
Can read and communicate in Malay and English.	
Workers who have worked for more than 6 months.	
Willing to take part in this test which is Neurobehavioral Core Test Battery.	

3.4 Sample size

In order to determine the minimal sample size for a given population, Krejcie and Morgan table was used. The total number of workers in NBR plant was 60 and the non exposed workers was 45. Based on Table 3.2, when the total population is 105, the sample size needed would be 86. For an equal number between exposed and non-exposed, 43 NBR plant workers and 43 non-exposed workers were invited into this study.

Table 3.2: Krejcie and Morgan table for determining sample size for a given population

Table for Determining Sample Size for a Given Population

N	S	N	S	N	S	N	S	N	S
10	10	100	80	280	162	800	260	2800	338
15	14	110	86	290	165	850	265	3000	341
20	19	120	92	300	169	900	269	3500	246
25	24	130	97	320	175	950	274	4000	351
30	28	140	103	340	181	1000	278	4500	351
35	32	150	108	360	186	1100	285	5000	357
40	36	160	113	380	181	1200	291	6000	361
45	40	180	118	400	196	1300	297	7000	364
50	44	190	123	420	201	1400	302	8000	367
55	48	200	127	440	205	1500	306	9000	368
60	52	210	132	460	210	1600	310	10000	373
65	56	220	136	480	214	1700	313	15000	375
70	59	230	140	500	217	1800	317	20000	377
75	63	240	144	550	225	1900	320	30000	379
80	66	250	148	600	234	2000	322	40000	380
85	70	260	152	650	242	2200	327	50000	381
90	73	270	155	700	248	2400	331	75000	382
95	76	270	159	750	256	2600	335	100000	384

Note: "N" is population size
"S" is sample size.

Source: Krejcie & Morgan, 1970

3.5 Sampling method

Grab sampling was used for VOCs measurements. For subjects recruitments, purposive sampling method was applied whereby all workers involved with chemical exposure (exposed) and non-exposed workers at the chosen workplaces were asked to join this study (refer section 3.3).

3.6 Data collection

The sample of the VOCs concentration was measured using Phocheck+ instrument. The questionnaire and Neurobehavioural Core Test Battery (NCTB) were also used as instrument for neurobehavioural effects testing. Operational Guide for Neurobehavioural Core Test Battery (WHO, 1986) was used as guidance. Every session of data collection was held and instructed in both language Bahasa Melayu and English.

3.6.1 VOCs measurement using Phocheck+

PhoCheck+ is the most advanced handheld humidity resistant photo ionisation detector (PID) for volatile organic compounds (VOCs), providing rapid response and accurate detection. Its unique patented Fence Electrode Technology incorporates a three-electrode format enabling proven resistance to humidity and contamination, giving optimal performance in the field. It can use in many field such as confined space, soil headspace analysis, indoor air quality, first response of HazMat, as well as petrochemical (Ion Science Phocheck, n.d).

There are many feature of PhoCheck, it can detects VOCs from 1 ppb–10,000 ppm which included all major industrial VOCs, data available for over 450 gases. It is intrinsically safe for use inflammable areas. It has two principle modes of operation which are health and safety mode for Short Term Exposure Level (STEL) and Time Weight Average (TWA). It also had choice of readouts–numbers or real-time graph. The enhanced 8Mb memory capacity of PhoCheck+ allows for continuous data logging of readings every second with the ability to store over 130,000 individual readings. The unique memory saving feature only logs a value if the detector senses a changes in the detected level of gas. It also has continuous data logging which can stores over 130,000 individual readings. This instrument has rechargeable batteries and also the readings can be in fully interactive Ion PC software (Ion Science Phocheck, n.d).

The sampling of VOCs was conducted at three different locations which were Butadiene Storage, Process Building and Bioplant (waste area). Measurements were made three times per day, in the morning, afternoon and evening for five consecutive days at each sampling sites. For each session, sampling duration was 15 minutes.

Figure 3.1: Phocheck+ instrument
Source: U.S. Environmental Rental Corporation, 2014

3.6.2 Questionnaire

The subjects were given questionnaire which covers personal data, health status, occupational data, and subjective symptoms. Questionnaire was given either before or after the subjects had completed the NCTB test. There were 37 questions listed to monitor early effects neurotoxic exposures in working populations (refer appendix A). These questions detect impaired memory, irritability, emotional effect, sleeping problems and others.

The questionnaire was modified from the standard questionnaire of World Health Organisation (WHO). Several validation processs such as content validity, face validity and predictive validity (Allison & Linda, 2004) was conducted. Content validity was reviewed by three panels, Dr. Siti Marwanis Anua, a lecturer of Environmental and Occupational Health programme, Mr. Azmi bin Yusof, a Safety and Health Officer (SHO) of the company, and Mr. Salehuddin Mustapha, a Safety Executives (SE). Face validity refers to the degree to which a test appears to measure what it purports to measure. It is covering the concept to measure and be understandable for the target population. The questionnaire had been piloted among 10 workers about the suitability of the questionnaire. Lastly, from the piloted questionnaire, predictive validity was performed. Predictive validity refers ability of the questionnaire to predict results in the future. The result of cronbatch alpha test was 0.766. The questionnaire was translated back to back by the supervisor who had used similar questionnaire among formaldehyde exposed workers (Siti Marwanis, 2008).

3.6.3 NCTB

NCTB is a validated and standardised psychological test battery by World Health Organisation (WHO). Special instrument with pencil and paper were used to run the NCTB test. A specific room was prepared for every test. There were seven tests involved per session which are Simple Reaction time, Digit Span, Minnesota manual Dexterity, Benton Visual Retention, Pursuit Aiming and Steadiness Test.

Material required for the tests:

i. Background form and questionnaire
ii. Test performance record form
iii. Equipment for every series of test
iv. Stopwatch
v. Pencils and sharpeners

3.6.3.1 Testing session

The testing was divided into two slots. It started with questionnaire session which followed by NCTB. However, occasionally NCTB were performed first and then finished with answering the questionnaire.

3.6.3.2 Administration of test

Approximately 40 to 50 minutes was required for one subject to complete all the test including answering the questionnaire. The test was administered by the researcher. The researcher was trained to conduct the test in a standardised manner.

One small or medium size room at the workplace was made ready before the test started. Every testing room was ensured free from distraction of noise with adequate lightning. Table and seats was prepared for the subject and researcher. Temperature was maintained at room temperature. Every material to be used for the test was put on the table. The participant must ensure to feel comfortable before starting the test and during the test.

The subject was being informed about the details of study and informed consent form was collected from the subject. This is important to make sure every subject were well informed about the reason why they were participating in this study, and know the aim for every test performed. This pre-test activity important to make a bond between researcher and subject, subject can felt comfortable with the researcher.

3.6.3.3 Series of NCTB tests

1. Simple reaction time

Simple reaction time measures how fast a person reacts. It is also to measure the response time of specific sensory modalities. A device of Reaction Time panel with psycmcon control Model 35600, Multi-Operational Apparatus for Reaction Time (MOART) (figure 3.2) was used for this test. The subject needs to put their thumb in