RISK MANAGEMENT OF NEUROBEHAVIORAL HEALTH OF TYRE MANUFACTURING INDUSTRY WORKERS EXPOSED TO NAPHTHA

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Introduction: Neurobehavioral effects on cognitive functioning and motor disturbances were linked to organic solvents even in setting exposure standards in the workplace which may interfere with job tasks resulting in costly injuries and lost of productivity. This study is aimed to assess and manage the risks of naphtha exposure and the neurobehavioral health effects among workers in a tyre manufacturing industry. **Methodology:** A cross-sectional study was carried out in Phase I, followed by an intervention study in Phase II. A total of 119 male workers exposed to naphtha were universally recruited as the exposed group, while 72 male administrative workers who did not exposed to naphtha were selected as the unexposed group. In Phase I, questionnaires were used to collect the information on general background, occupational profile and the risk factors. Environmental and personal air monitoring were carried out using a portable volatile organic compound (VOC) monitor and personal air sampling pump. Neurobehavioral performance was measured using the Neurobehavioral Core Test Battery (NCTB). The respondents from the Phase 1 were

then followed up in the second phase for the intervention study. They were later undergone a workplace health promotion (WHP) programme for three consecutive days in order to improve their knowledge, attitude and practice (KAP) of safe handling of naphtha. Seminar and small group discussion were carried out in this WHP programme. The pre- and post- questionnaires were administered before and after the WHP programme among the respondents. **Results:** The range of VOC concentration was from 1.10 to 546.10 ppm, with the highest mean of 92.93 (SD153.63) ppm found in the "repair" area. Laboratory analysis found various organic compounds such as 2-methyl pentane, hexane, methyl cyclopentane, heptane, cyclohexane and toluene made up the liquid naphtha. The mean neurobehavioral score of the exposed group was significantly lower than the unexposed group ($p=0.001$). There were significant differences in the tests of Digit Symbol ($p=0.001$), Pursuit Aiming ($p<0.001$), and Santa Ana Manual Dexterity for dominant hand ($p=0.021$) and non-dominant hand ($p=0.048$) scores between the 2 groups. However, there was no correlation between personal air naphtha concentration and the total NCTB scores among the exposed group. The personal air naphtha concentrations among the exposed group were significantly higher than the unexposed group ($p<0.001$). Factors such as duration of work, total years of education, age, household income, knowledge and practice influenced the neurobehavioral performance. The level of knowledge among workers was significantly higher after the intervention programme ($p<0.05$). **Conclusion:** An early sign of neurobehavioral impairment was identified among the exposed group to low level of VOC and naphtha exposure. Therefore, attention to the chronic adverse health effects of organic solvent exposure should be given for safe and healthy working environment. The WHP package is a good mechanism of communicating risk at the workplace for an early detection and

prevention of adverse health effect. A continual education should be implemented through various methods to enhance and retain workers' good performance at the workplace.

Key words: *Risk management, naphtha, neurobehavioral health, knowledge, attitude, practice, occupational health promotion.*

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

PENGURUSAN RISIKO KESIHATAN TINGKAH LAKU SARAF PEKERJA INDUSTRI PEMBUATAN TAYAR YANG TERDEDAH KEPADA NAFTA

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Pengenalan: Kesan tingkah laku saraf terhadap fungsi kognitif and gangguan motor adalah berkait dengan pelarut-pelarut organik walaupun pada ketetapan pendedahan piawai di tempat kerja yang boleh mengganggu tugasan kerja sekaligus menyebabkan banyak kecederaaan dan kehilangan produktiviti. Kajian ini bertujuan untuk menilai dan mengurus risiko pendedahan nafta dan kesan kesihatan tingkah laku saraf di kalangan pekerja di industri pembuatan tayar. **Kaedah:** Kajian keratan rentas dilakukan dalam Fasa 1, disusuli oleh kajian intervensi dalam Fasa 2. Seramai 119 orang pekerja lelaki yang terdedah kepada nafta telah dipilih secara universal sebagai kumpulan terdedah manakala 72 orang pekerja pentadbiran lelaki yang tidak terdedah kepada nafta dipilih sebagai kumpulan tidak terdedah. Dalam Fasa 1, soal-selidik digunakan untuk mengumpul data latar belakang, profil pekerjaan dan faktor-faktor risiko. Pemantauan udara persekitaran dan individu masing-masing dilakukan menggunakan alat pemantau bahan organik meruap (*VOC*) mudah alih dan pam persampelan udara individu. Pengukuran performan tingkah laku saraf dilakukan menggunakan peralatan *Neurobehavioral Core Test Battery (NCTB).* Responden dari

fasa 1 kemudiannya diikuti di dalam fasa 2 untuk menjalani kajian intervensi. Mereka kemudiannya menjalani program promosi kesihatan tempat kerja (*WHP*) selama 3 hari berturut-turut untuk meningkatkan tahap pengetahuan, sikap dan amalan terhadap penggunaan nafta secara selamat. Seminar dan perbincangan dalam kumpulan kecil telah dijalankan di dalam program *WHP* ini. Soal-selidik dijalankan ke atas responden sebelum dan selepas program WHP tersebut. **Hasil:** Julat kepekatan *VOC* adalah daripada 1.10 hingga 546.10 ppm, dengan min tertinggi sebanyak 92.93 (*SD*153.63) ppm ditemui di kawasan "baik pulih". Analisis makmal mendapati pelbagai pelarut seperti 2-metil pentana, heksana, metal siklopentana, heptana, sikloheksana dan *toluene* hadir dalam cecair nafta. Min skor total tingkah laku saraf kumpulan terdedah adalah lebih rendah secara signifikan daripada kumpulan tidak terdedah ($p=0.001$). Terdapat perbezaan signifikan dalam ujian-ujian Simbol Digit ($p=0.001$), Sasaran Mengejar ($p<0.001$), Kepantasan Tangan Santa Ana bagi tangan dominan ($p=0.021$) dan bukan dominan ($p=0.048$). Walau bagaimanapun, tiada korelasi di antara kepekatan nafta dalam udara individu dan skor total tingkah laku saraf kumpulan terdedah. Kepekatan nafta dalam udara individu bagi kumpulan terdedah adalah lebih tinggi daripada kumpulan tidak terdedah ($p<0.001$). Faktor-faktor seperti tempoh bekerja, jumlah tahun pendidikan, umur, pendapatan isi rumah, pengetahuan dan sikap mempengaruhi prestasi tingkah laku saraf. Tahap pengetahuan pekerja adalah lebih tinggi setelah menjalani program intervensi ($p<0.05$). **Kesimpulan:** Tanda awal kerosakan tingkah laku saraf telah dikenal pasti di kalangan kumpulan terdedah pada tahap pendedahan *VOC* dan nafta yang rendah. Oleh itu, kesan kesihatan teruk yang kronik terhadap pendedahan pelarut organik perlu diberi perhatian untuk persekitaran kerja yang selamat dan sihat. Pakej *WHP* merupakan mekanisma yang baik untuk komunikasi risiko di

tempat kerja sebagai pengesanan dan pencegahan awal terhadap kesan kesihatan yang teruk. Pendidikan berterusan harus dilaksanakan melalui pelbagai kaedah untuk meningkatkan dan mengekalkan prestasi pekerja yang baik di tempat kerja.

Kata kunci: *Pengurusan risiko, nafta, kesihatan tingkah laku saraf, pengetahuan, sikap, amalan, promosi kesihatan pekerjaan.*

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LIST OF ABBREVIATIONS

ACGIH	American Conference of Governmental Industrial Hygienist
ADDIE	Analysis, Design, Develop, Implement, Evaluate
ANCOVA	Analysis of Covariance
C	ceiling value should not be exceeded at any time
CAS	Chemical Abstract Service
CHRA	Chemical Health Risk Assessment
CI	Confidence interval
CNS	Central nervous system
DOSH	Department of Occupational Safety and Health
EPA	Environmental Protection Agency
ER	exposure rating
GC/FID	gas chromatography with flame ionization detector
GC/MS	Gas Chromatography Mass Spectrometry
GLR	General Linear regression
HR	hazard rating
IDLH	Immediately dangerous to life and health concentrations
IQR	Interquartile Range
KAP	Knowledge, attitude and practice
MLR	Multiple linear regression
MR	magnitude rating
MSDS	Material Safety Data Sheet
NCTB	Neurobehavioral Core Test Battery
NGOs	Non-governmental organizations
NIOSH	National Institute of Occupational Safety and Health

OEL	Occupational exposure limits
OSHA	Occupational Safety and Health Act
PID	Photo-Ionization Detector
PPE	personal protective equipment
PRECEDE	Predisposing, Reinforcing, Enabling Constructs in Educational/Environmental Diagnosis and Evaluation
PROCEED	Policy, Regulatory, and Organizational Constructs in Educational and Environmental Development
Q&A	question and answer
REL	Recommended Exposure Limit
RR	risk rating
SD	Standard deviation
SLR	Simple linear regression
SPSS	Statistical Package for Social Sciences
STEL	short term exposure limit
TLV	Threshold Limit Values
TNA	Training needs analysis
TWA	time-weighted average
UHA	Urinary hyppuric acid
UMHA	Urinary methyl hyppuric acid
VOC	Volatile organic compound
WHO	World Health Organization
WHP	Workplace Health Promotion

CHAPTER 1

INTRODUCTION

Organic solvents are liquid substances at normal temperature and pressure. They are extensively used in many industries to dissolve organic chemicals such as oil, fat, resin, rubber, plastic and wax. Organic solvents such as methanol, acetone, isopropyl alcohol, toluene, petroleum benzin, n-hexane and xylene are widely used in several industries for painting, chemical analysis, wiping, degreasing, printing, gluing, solvent manufacturing, paint manufacturing and dry cleaning (NIOSH/JICA, 2003). These organic solvents are commonly used as mixtures rather than as an individual chemical. For example, in tyre manufacturing industry, naphtha which is a petroleum distillate containing principally aliphatic hydrocarbons is widely used as an adhesive, segregative and cleansing agent. It is made up of organic solvents mixture such as hexane, benzene and ethylbenzene (MSDS, 2006). However, these organic solvents have been listed as chemicals that are hazardous to health under the Occupational Safety and Health (Use and Standards of Exposure Chemicals Hazardous to Health) Regulations 2000 (OSHA, 2008).

Although the lipid solubility property of organic solvents plays an important role in the industrial setting, it does not work in human body. Their high lipophylicity

property makes it accessible to different tissues and organs containing lipids such as the brain and nerve cells. Numerous epidemiological studies have documented occupational exposure to organic solvents caused neurobehavioral and neurological impairments (Ovid MEDLINE, 2008). Chronic toxicity of organic solvent exposure to the central nervous system includes syncope, mental disorder, ataxia and brain atrophy while the effect on peripheral nerve results in polyneuropathy. Symptoms of neurotoxicity include muscle weakness, loss of sensation and motor control, tremors, memory loss, extreme fatigue, dizziness, sleep disturbances, depression, pain and/or numbness of the extremities, lightheadedness, loss of interest in hobbies, and confusion.

Attention has been given on the need to identify neurotoxic effects of the brain as early as possible to avoid permanent damages of continuing exposures because repeated exposures to solvents may cause cumulative and irreversible damages to the nervous system. Cross-sectional studies supported the hypothesis that occupational, long-term solvent exposures may cause adverse effects on the central nervous system at exposure levels below the accepted threshold limit values (Mikkelsen, 1997). Therefore, an early detection of neurotoxicity is important in occupational health to prevent neurotoxic illnesses in the working populations. The Neurobehavioral Core Test Battery (NCTB) is one of the most common methods used to investigate the specific functions of the nervous system. It is shown to be sensitive to neurotoxic damage such as reduction in memory and learning ability, decrease in attention, and alteration of behaviour due to the exposures to toxic solvents in the workplace (WHO, 1986). Moreover, the previous local studies also noted significant results of those functional domains tested using this method to detect early abnormalities of

neurobehavioral impairment among workers exposed to organic solvents such as toluene, xylene, naphtha and benzene in various industries (Zailina et al., 2005a; 2005b; 2005c; and Mazalisah *et al.*, 2006). Apart from that, symptoms such as poor attention, drowsiness, memory problems, mood changes, and impaired fine motor performance may interfere with job tasks resulting in costly injuries and loss of productivity.

Studies on petroleum distillates like naphtha and its health effects are not commonly carried out like the other solvents such as benzene, toluene, xylene and hexane either in developed or developing countries. Most of the studies emphasized on the individual organic solvents namely benzene, toluene, xylene, ethanol and others. Studies on the solvent mixtures are rare because of the difficulties in terms of understanding its mechanism of action. There are limited number of studies on naphtha; studies are mainly conducted in shoe making industry and glove manufacturing industry.

In line with those issues, this study is aimed to assess the risk of organic solvent (naphtha) exposure towards the neurobehavioral impairment among workers in tyre manufacturing industry. As demand for tyre products are increasing, there will be more plants set up and more workers employed, hence there will be more potentially exposed to this organic solvent hazard. Therefore, the study on the prevalence of neurobehavioral effects and understanding on their risk factors will be definitely beneficial towards contributing effective intervention strategies for workers in this industry to sustain the productivity as well as better quality of work life.

Since organic solvent poisoning is one of the compensated illnesses listed under the Employees' Social Security Act 1969, it is important for workers who potentially come into contact with organic solvents to know and understand the associated risks and the safe work procedures to reduce the risk. To fulfil this need, the Malaysian Standard of Occupational Safety and Health Management Systems – Part 1: Requirements (MS 1722: Part 1: 2005) has been developed to provide requirements on occupational safety and health (OSH) management system and a basis for the development of a sustainable safety and health culture in the organization. Risk management has become a concern of management systems. It provides the framework for the process of identifying hazards, assessing associated risks, taking actions to mitigate risks, and reviewing the outcome by monitoring the effectiveness.

Therefore, this study is aimed to develop a Workplace Health Promotion Programme to communicate the risks associated with naphtha exposure among workers in order to increase their awareness on safety and health in the work culture. This contribution to Occupational Safety and Health Management System approach can assist organizations of this industry to successfully manage the related risks as well as their safety and health prevention programme as prevention is the best antidote. Furthermore, this is a good effort to practice the worker "right-to-know" principle. It is supplemented by providing a manual on safe handling of organic solvents at the workplace which has been developed to provide guidelines especially for employers to assist them on the management of safe and healthy working environment.

1.1 Problem Statement

Volatile organic solvents have become the early focus of human neurobehavioral toxicology during 1980s. Their neurotoxic properties have always been recognized even in setting exposure standards in the workplace (Weiss & Elsner, 1996). Many studies demonstrated the association between neurobehavioral effects and the low-level exposure to organic solvents among workers (Tsai et al., 1997; Kishi et al., 2000). They also revealed that the neurobehavioral effects were linked to the long-term exposure of organic solvents like xylene and mixed organic solvents (Hooisma et al., 1994; Colvin et al., 1993). To date, the neurotoxic effects of exposure to organic solvent mixtures have become an increasing concern. Related studies were done among the shipyard painters (Lee et al., 2005; Ruüten et al., 1994). In other studies, it was found that workers who use organic solvent mixtures in paint and varnish production industry have experienced the neurological manifestation (Indulski et al., 1996).

In organic solvents group, components of petroleum distillate are not constant. Some kinds of organic solvents derived from this distillation might contain small amount of benzene, toluene and n-hexane which cannot be neglected. It was reported that workers who used the organic solvents from this group such as petroleum benzene containing n-hexane suffered from difficulty in walking due to polyneuropathy (Takeuchi et al., 1975).

The central nervous system is vulnerable to neurotoxic effects at lower levels of exposure than the peripheral nervous system (Ladefoged et al., 1995). In fact,