UNIVERSITI PUTRA MALAYSIA

ASSESSMENT OF EXPOSURE TO METALWORKING FLUIDS AND RESPIRATORY HEALTH ALLERGIES AMONG MACHINING INDUSTRY WORKERS IN SELANGOR, MALAYSIA

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FPSK(m) 2015 37

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By

LIAW SOO HUI

Thesis Submitted to the School Of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

August 2015

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

ASSESSMENT OF EXPOSURE TO METALWORKING FLUIDS AND RESPIRATORY HEALTH ALLERGIES AMONG MACHINING INDUSTRY WORKERS IN SELANGOR, MALAYSIA

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Chair: Prof. Zailina binti Hashim, PhD
Faculty: Medicine and Health Sciences

Metal machining processes such as cutting, turning, machining, grinding, milling and drilling require lubrication and dispersal of heat generated. Major chemicals used in machining industry include metalworking fluids (MWFs). Exposure to MWFs are associated with various types of respiratory and health problems. This study was to assess, compare and determine the association between the use of MWFs with respiratory problems and allergies among machining industry workers in Selangor.

The study design was a cross-sectional comparative study. The workers were purposely sampled from the staff list and classified into the MWFs exposed group who consisted of machining and stamping workers while the unexposed group consisted of assembly and administrative workers. The types and uses of metalworking fluids, respiratory and allergy symptoms were obtained through questionnaire interviews. Personal air samples were collected to assess the chromium and aluminum of the MWFs. Blood samples were collected for total immunoglobulin E (TIgE) analysis as indicator of respiratory allergy. The lung function tests were carried out at the beginning (pre-shift) and at the end of work (post-shift) using Spirolab II model spirometer to assess the cross-shift lung function capacity.

This study showed that the MWFs unexposed group had significantly higher TWA_8 airborne aluminum concentration (*median*=0.24 µg/m^3) than the exposed group (*median*=0.13 µg/m^3) (p=0.027). Further analysis showed this was contributed from warehouse workers and quality control (QC) workers. Findings showed significantly higher cough symptom (19.6%) (p=0.036), morning cough with sputum (3.9%) (p=0.021), skin itchiness (10.5%) (p=0.014) and high serum total IgE (54.3%) (p=0.004) among the MWFs exposed group than the unexposed group. The uses of MWFs were significantly associated with higher risk of skin itchiness (OR 4.82, CI 1.54-15.16). Skin itchiness was significantly higher with the use of soluble oil (OR 7.48, CI 1.97-28.38) followed by stamping

oil (OR 5.10, CI 1.33-19.61). Further analysis based on operation showed the machining workers reported significantly higher risk of cough symptom (OR 2.54, CI 1.18-5.47) and Grade 1 Dyspnea (OR 2.28, CI 1.00-5.16) than the administrative workers. The cough symptom was significantly associated with the use of straight oil.

Our study results showed the presence of respiratory and allergy risks among workers in the machining industry. Findings showed significantly higher TWA_8 airborne aluminum among the MWFs unexposed group suggested the management might need to review the structure design and current location of the warehouse and quality control offices as it is currently located with close proximity to its production line. Our study findings revealed an elevated risk of skin itchiness among exposed group associated with the use of soluble and stamping oil. The cough symptom was significantly associated with the use of straight oil. This suggested the management and future study shall examine the effectiveness of ventilation system and the use of personal protective equipment or clothing when working with different types of MWFs.

Keywords: *Machining industry, types of metalworking fluids, allergy symptoms, serum total IgE.*

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

PENILAIAN PENDEDAHAN KEPADA CECAIR KERJA LOGAM DENGAN KESIHATAN PERNAFASAN DAN ALAHAN DI KALANGAN PEKERJA INDUSTRI PEMESINAN DI SELANGOR, MALAYSIA

Oleh

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Ogos 2015

Pengerusi: Prof. Zailina binti Hashim, PhD
Fakulti: Perubatan dan Sains Kesihatan

Proses pemesinan logam seperti memotong, membelok, pemesinan, pengisaran, pengilangan dan penggerudian memerlukan pelinciran dan penyebaran haba yang dijana. Bahan kimia utama yang digunakan dalam industri pemesinan termasuk cecair kerja logam (MWFs). Pendedahan kepada MWFs dikaitkan dengan pelbagai jenis gejala pernafasan dan penyakit. Kajian ini adalah untuk menentukan hubungan antara penggunaan cecair kerja logam (MWFs) dengan gejala-gejala pernafasan dan alahan di kalangan pekerja industri pemesinan di Selangor.

Reka bentuk kajian ini adalah kajian perbandingan jenis deskriptif. Para pekerja telah disampel secara sengaja daripada senarai pekerja dan dikelaskan kepada kumpulan terdedah MWFs (yang terdiri daripada pekerja pemesinan dan pengecapan "stamping") dan kumpulan yang tidak terdedah (yang terdiri daripada pekerja pemasangan dan pentadbiran) berdasarkan penggunaan MWFs secara langsung. Penggunaan dan jenis bendalir kerja logam, gejala-gejala pernafasan dan alahan diperoleh melalui temuramah menggunakan borang soal selidik. Sampel udara peribadi dikumpulkan untuk menilai komponen kimia cecair kerja logam logam iaitu logam berat (kromium dan aluminium). Sampel darah daripada semua responden telah dikumpulkan untuk analisis jumlah imunoglobulin E (TIgE) sebagai petunjuk alahan pernafasan. Ujian fungsi paru-paru telah dijalankan pada permulaan (pra-peralihan "pre-shift") dan pada akhir kerja (post-peralihan "post-shift") dengan menggunakan Spirolab II model spirometer untuk menilai nilai-nilai peralihan silang bagi fungsi paru-paru demi menerokai kesan pendedahan bahan kimia.

Kajian ini menunjukkan bahawa kumpulan yang tidak terdedah MWFs mempunyai TWA_8 kepekatan aluminium bawaan udara yang lebih tinggi (median=0.24 $\mu g/m^3$) daripada kumpulan terdedah MWFs (median=0.13 $\mu g/m^3$) (p=0.027). Analisis selanjutnya menunjukkan ini adalah berpunca

daripada pekerja gudang dan pekerja kawalan kualiti (QC). Kumpulan terdedah MWFs melaporkan kelaziman yang lebih tinggi dari segi gejala batuk (19.6%) (*p*=0.036), batuk pagi dengan kahak (3.9%) (*p*=0.021), kegatalan kulit (10.5%) (*p*=0.014) dan jumlah kepekatan serum IgE (TIgE) (54.3%) (*p*=0.004) berbanding dengan kumpulan yang tidak terdedah. Kaitan penggunaan MWFs adalah signifikan dengan risiko yang lebih tinggi dalam kegatalan kulit (OR 4.82, 95% CI 1.54-15.16). Kegatalan kulit adalah ketara berkaitan dengan penggunaan 'soluble oil' (OR 7.48, CI 1.97-28.38) diikuti oleh 'stamping oil' (OR 5.10, CI 1.33-19.61). Analisis terlanjut berdasarkan operasi menunjukkan para pekerja pemesinan melaporkan risiko yang lebih tinggi dan ketara dalam gejala batuk (OR 2.54, 95% CI 1.18-5.47) dan Gred 1 dyspnea atau sesak nafas (OR 2.28, 95% CI 1.00-5.16) berbanding dengan para pekerja pentadbiran. Gejala batuk adalah ketara berkaitan dengan penggunaan 'straight oil' (OR 4.82, CI 1.97-11.81).

Hasil kajian kami menunjukkan kewujudan risiko pernafasan dan alahan dalam industri pemesinan. Kajian ini menunjukkan TWA_8 kepekatan aluminium bawaan udara yang jauh lebih tinggi di antara kumpulan yang tidak terdedah MWFs mencadangkan pihak pengurusan hendaklah mengkaji semula reka bentuk struktur dan lokasi pejabat-pejabat gudang dan kawalan kualiti kerana ia kini terletak berdekatan dengan unit pengeluarannya. Hasil kajian kami mendapati peningkatan risiko gatal kulit di kalangan kumpulan terdedah adalah berkaitan dengan penggunaan minyak 'soluble' dan 'stamping' Gejala batuk dengan ketara berkaitan dengan penggunaan minyak 'straight'. Ini mencadangkan pihak pengurusan dan kajian masa depan hendaklah memeriksa keberkesanan peralatan perlindungan peribadi dan sistem pengudaraan kerana kemungkinan berkait rapat dengan pelbagai jenis pendedahan minyak MWFs yang berlainan.

Kata kunci: *Industri pemesinan, jenis cecair kerja logam, gejala alahan, jumlah serum IgE.*

ACKNOWLEDGEMENTS

I sincerely credit the completion of my master degree to Prof Dr. Zailina, my supervisory chair, who provides financial supports in the laboratory analysis works and she is so compassionate and be patient enough to me throughout the thesis submission process. I am impressed with her strong passionate in promoting awareness in environmental health and safety. Special thanks to Prof Dato' Dr. Lye, statistic guru of Faculty Medicine and Health Science and also is my research committee member, who guided me through my data analysis and interpretation. Your comments had always enlightened my thoughts! Not forgetting, I also wish to thank Dr Huda, my research committee member too, whose always provide constructive and prompt feedback helped strengthen my paper. I would like to thanks to Mr Yap, the managing director of my study site, who provides opportunity to me carried out the sampling work at his company.

I dedicate this paper to my children, Jeremy, Olivia, Yonas and Shawn who aged between 3 months to 9 years old but have been my inspiration for success in the past 5 years. I'm cheerful to raise my children along with my master research journey. I understood we have a lifetime to work but children are only young once. I'm grateful that they been so independent and hardly disturb my work. Much credit for completion of this thesis report goes to my husband, Timothy, who is the best companion in my life, kept me going through long nights of research. I also dedicate this paper to my father, Yoke Min, who diagnosed as lung cancer 4^{th} stage during my research journey but it would be a motivation to me to move forward and do the best although I have to delay in completion of my report.

Last but not least, this study could not have been completed without the supports from laboratory staffs and experts: Dr Chin-Chin Tee, director of ALS Technichem, who had generously allowed me enter to their strict security and stringent quality controlled lab; ALS's professional laboratory team who had also shared their know-how and expertise in air sample analysis works; Ms Siti, laboratory technician of Immunology Laboratory, who assisted me to analyse total serum IgE using ImmunoCAP assay; Mr Ahmad Sayuti, Executive Laboratory Division of NIOSH, who provides generous advise during my preliminary study and laboratory works; Mrs Norlijah and Mr Mohd Noor, who had assisted me in preparation of sampling equipment; Dr Juliana, who borrowed me the video clip on "How to perform lung function"; Dr Ali Karami, who guided me the EndNote software which had eased me wondrous of convenience in managing my bibliographies; Yee-Guan Ng and Vivien How, who had guided me the air sampling methods and shared of research journey. To my faculty-mate, Mun-Chieng Tan, thank you for your kindness downloaded the end note software for me and shared of your research journey. Last but not least, I offer my sincere gratitude and blessings to all of those who not listed but had supported me in my master research journey. Thank you!

I certify that a Thesis Examination Committee has met on 7th August 2015 to conduct the final examination of Liaw Soo Hui on her thesis entitled "Assessment of, and comparison and association between exposure to metalworking fluids, and respiratory health allergies among machining industry workers in Selangor" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

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LIST OF ABBREVIATIONS

ACGIH : American Conference of Governmental Industrial Hygienists

ATS : American Thoracic Society

CHRA : Chemical Health Risk Assessment

CSDS : Chemical Safety Data Sheet

FEV_1 : Forced expiratory volume in one second

FEV_1/FVC: Ratio of FEV_1 to FVC (FEV_1/FVC ratio)

FVC : Forced vital capacity

IARC : International Agency for Research on Cancer

ICP-MS : Inductively-coupled plasma mass spectrometer

MWFs : Metalworking Fluids

NIOSH : National Institute of Occupational Safety and Health

PEL : Permissible exposure limit

QC : Quality Control

TIgE : Total immunoglobulin E

TLV : Threshold limit value

TWA : Time weighted average

CHAPTER 1

INTRODUCTION

1.1 Chemical usage in machining industry

Metal machining processes such as cutting, turning, machining, grinding, milling and drilling require lubrication and dispersion of generated heat. Major chemical used in machining industry include metalworking fluids (MWFs) which are categorized into straight or neat oils, soluble oils, semi synthetic and synthetic fluids. MWFs is a generic term which describes the function of a range of chemicals used in metal machining processes rather than a specific chemical composition (Godderis et al., 2008; O'Brien et al., 2001). It describes the function of the chemical that provides lubricity in order to remove friction and control thermal distortion by carrying away the heat and thereby improving the machinability. At the same time, it increases tool life, minimizes corrosion and removes metal chips.

According to IARC (1984, 2000), straight or neat oils are mineral oils (60-100%), do not contain water and ethanolamines as additives. It may contain elemental sulfur, sulfur compounds and chlorinated compound such as chlorinated paraffin. Soluble oils are aqueous emulsions of highly refined petrochemicals (30-85%), with added emulsifiers (eg. petroleum sulfonates, amine soaps, and sodium naphthenates), biocides (eg. formaldehyde-releasing triazines, chlorophenols, hexachlorophene, and quaternary ammonium compounds), corrosion inhibitors (eg. amines, fatty oils, sodium nitrite, sulfurized fatty oils), antifoaming agents, dyes and high pressure stabilizers. It may frequently contain ethanolamines. Synthetic fluids do not contain oil but are primarily water with alkanolamines. Mono- and diethanolamine may be present in concentration of 2 – 3% and triethanolamine may up to 25%. It contains additives (eg. nitrites, nitrates, phosphates and borates), surfactants (eg. complex alcohols and esters), biocides, silicone as lubricant and antifoaming agent. Semi-synthetic fluids are a hybrid of soluble and synthetic fluids. It contain smaller amount of oil than soluble oils (3-30%) and mixture of additives same as synthetic fluids.

In general, metalworking fluids are alkaline solutions (pH 8.5 to 9), which contain water, metals, microbes, mineral oils, fatty acid sulfonates, biocides, ethanolamine, di- and tri- ethanolamine, organic acids, nonylphenoxy-polyethoxyethanol, caprylic acid and antifoaming agents (Gordon, 2004). During machining processes, aerosols from the MWFs are generated together with thermal degradation products from the machining process. It contains fluid mists, vapors, smoke, gases, fines metallic particles, microbial fungi and bacteria. Machine operators are exposed to MWFs aerosols by inhalation (Lillienberg et al., 2008). These aerosols are dispersed into the air by mechanical forces produced by the moving tools and/or work pieces,

condensation of fluids vapors formed by heat in the cutting zone and misdirected or extraneous spraying of fluids directly into the air. Inhalation can occur during the direct application of the fluid and during set up or removal of the work pieces from the machine spray (Park et al., 2009a).

1.2 Problem statement

According to Gordon (2004), most of the epidemiology studies only measured the metalworking fluids aerosol concentration. The agent responsible for adverse health effects is difficult to determine due to its complexity and the variety of chemicals found in MWFs. Little research has been conducted on the soluble chemical components, or particulate forms of metal that are present in MWFs which contribute to the adverse effects of in-use MWFs. Microbial and chemical components changes occurred after dumping, cleaning and refilling of MWFs solution tank. The study results can be hard to interpret and influence by various factors such as types of metalworking fluids, the care and maintenance program of MWFs at the workplace.

According to criteria in recommended standard for occupational exposure to metalworking fluids (NIOSH, 1998), a variety of components, additives and contaminants of metalworking fluids (MWFs) are sensitizers or irritants known to induce new-onset asthma, aggravate pre-existing asthma and irritate the airways of non-asthmatic workers. These sensitizers, irritants or toxicants include ethanolamine and other amines, metals and metallic salts (eg. chromium, nickel, cobalt and tungsten carbine), formaldehyde, fungal and microbial contaminants. However, only a few of these agents have been documented as causes of MWFs associated asthma (NIOSH, 1998). Only few case studies had determined the specific risk factor of occupational asthma, one of the causatives reported was alkanolamines (Piipari et al., 1998; Savonius et al., 1994).

Robins et al. (1997) commented several studies have reported that metalworking fluids or their components can cause impairment of airway functions. But the mechanisms, magnitude and the specific agent(s) responsible for airway dysfunction among workers exposed to different metalworking fluids have not been studied.

Suuronen et al. (2008) suggested alkanolamines is one of the chemical composition in air that should be measured. Study of Henriks-Eckerman et al. (2007) also showed that alkanolamines was a better marker compared to oil mist, which could provide much reliable information about airborne exposure to MWFs. The exposure to alkanolamines should be kept as low as possible in order to minimize the health effects such as irritant, allergic contact dermatoses and asthma. Hence, the variable alkanolamines were initially proposed to be studied in this research in order to assess the chemical exposure to metalworking fluids.

Suuronen et al. (2007) also suggested epidemiological studies in combination with clinical investigations were required to assess causative agents, immunologic mechanisms and cumulative effect of sensitizers or irritants in metalworking fluids that cause respiratory allergies. There is still a lack of knowledge regarding the exposure-response relationship and the adverse effects especially in other countries besides USA (Linnéa Lillienberg et al., 2010).

1.3 Study Justification

The research proposed was a health risk assessment of occupational exposure to chemicals among production and office workers in a machining industry. The study was specifically designed to determine the effects of metalworking fluids exposure on lung functions, respiratory allergy and respiratory symptoms. The aim was to assess the chemical components of metalworking fluids specifically metal (chromium and aluminum) in air, respiratory allergy (total immunoglobulin E) in blood samples and respiratory health effect (lung function capacity).

Metalworking fluids are chemicals widely used in various fabricated metal products industries in Malaysia. Globalization in Malaysia results in high employment growth in manufacturing industry compared to agriculture industry. According to the report on the annual survey of manufacturing industries (DOSM, 2009), the number of workers engaged in manufacturing industries in Malaysia in the year 2008 were 1,771,331. Manufacturing industry of fabricated metal products and metal working service activities was ranked 8th among other industries and contributed to 69,069 jobs or 3.9% of the total employment.

Malaysia is at an epidemiological transition from communicable to non-communicable diseases. Health Facts 2013 (MOH, 2013) showed that diseases of the respiratory system was ranked 2nd (11.02%) among top ten principal causes of hospitalization and it was also ranked 2nd (18.8%) among top ten principal causes of death in Ministry of Health Hospitals in year 2012. Annual report of the National Council for Occupational Safety and Health showed that 54 cases among total 949 occupational diseases reported in year 2009 are occupational respiratory diseases (eg. occupational asthma and pneumoconiosis) that were caused by aluminum, sensitizing agents and mineral. The occupational respiratory diseases were in increasing trend to 113 cases in Year 2010 (myMetro, 2011).

Hence, it is important to determine the respiratory health effect of metalworking fluids exposure. People who are not aware of the signs and symptoms of airways disorders (chronic cough, phlegm and wheeze) that may associate with their exposure to the chemical at the workplace. A research is therefore essential to determine the personal exposure level to metalworking fluids in term of the content of metals, as well as to assess the total immunoglobulin E (TIgE) in blood samples as an indicator of respiratory allergy and lung functions ability. The result of the research can also be utilized to evaluate the

effectiveness of the existing engineering control measures and personal protective program in order to preserve the workers' respiratory health.

1.4 Research Objective

1.4.1 General Objective

To assess and compare respiratory health complaints and reported allergy symptoms and metalworking fluids (MWFs) exposure between workers of a machining industry workers in Selangor.

1.4.2 Specific Objectives

1. To determine the profile of workplace such as chemical usage, job task and type of operation.

2. To determine and compare the prevalence of the respiratory health complaints and reported allergy symptoms between the MWFs exposed and unexposed workers.

3. To determine and compare the metals (aluminum and chromium) concentrations in personal air samples between the MWFs exposed and unexposed workers.

4. To determine and compare the lung functions capacity (Forced Expiratory Volume in One Second, FEV_1 and Forced Vital Capacity, FVC) between the MWFs exposed and unexposed workers.

5. To determine and compare serum total Immunoglobulin E (TIgE) levels between the MWFs exposed and unexposed workers.

6. To determine association between selected factors (chemical exposure, job tasks and types of operations) with respiratory health complaints among the MWFs exposed and unexposed workers.

7. To determine association between selected factors (chemical exposure, job tasks and types of operations) with reported allergy symptoms and respiratory allergy (high TIgE) among the MWFs exposed and unexposed workers.

8. To determine association between selected factors (chemical exposure, job tasks and types of operations) with lung functions capacity among the MWFs exposed and unexposed workers.

1.5 Study Hypotheses

1. The respiratory health complaints and reported allergy symptoms among MWFs exposed workers were significantly higher than the unexposed workers.

2. The metals (aluminum and chromium) concentrations in personal air samples among MWFs exposed workers were significantly higher than unexposed workers.

3. The lung functions capacity (Forced Expiratory Volume in One Second, FEV_1 and Forced Vital Capacity, FVC) among MWFs exposed workers were significantly lower than unexposed workers.

4. The serum total Immunoglobulin E (TIgE) levels among MWFs exposed workers were significantly higher than unexposed workers.

5. There was significant association between selected factors (chemical exposure, job tasks and types of operations) with respiratory health complaints among the MWFs exposed and unexposed workers.

6. There was significant association between selected factors (chemical exposure, job tasks and types of operations) with reported allergy symptoms and respiratory allergy (high TIgE) among the MWFs exposed and unexposed workers.

7. There was significant association between selected factors (chemical exposure, job tasks and types of operations) with lung functions capacity among the MWFs exposed and unexposed workers.

1.6 Conceptual Framework

The conceptual framework of this study is illustrated in Figure 1.1 which shows the variables being studied. Layout plan (see Appendix H), process flow charts and material safety datasheets (see Appendix I) were obtained from the management of company for determination of chemical usage at the study site. The production operations that were studied were turning, machining, grinding and stamping which used various type of metalworking fluids. Machining industry workers (production, administrative and assembly workers) were potentially exposed to metal dust (aluminum and chromium) through contaminated air in the workplace from the metalworking fluids.

Questionnaire survey was used to collect respiratory health complaints and allergy symptoms among the machining industry workers. Personal air sampling was carried out to determine metal dust (aluminum and chromium) in the workplace. Lung function test was carried out to determine lung functions capacity (Forced Expiratory Volume in One Second, FEV_1 and Forced Vital Capacity, FVC) among machining industry workers. Blood samples were

collected to assess the total immunoglobulin E (TIgE) as indicator of respiratory allergy.

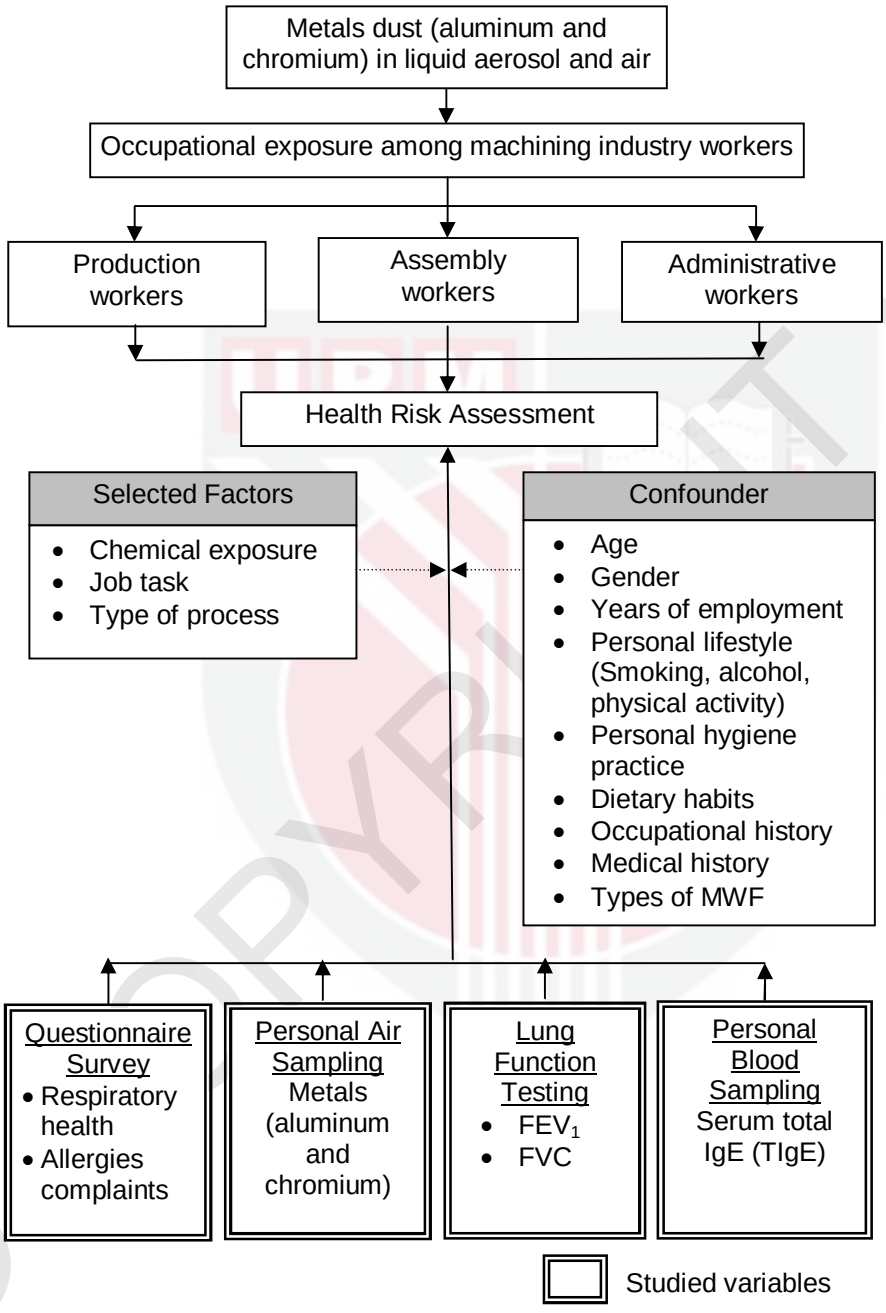

Figure 1.1. Illustration of the conceptual framework on health risk assessment of occupational exposure to metalworking fluid.

1.7 Operational Definition

1.7.1 Respiratory health

Respiratory health includes the respiratory symptoms reported during interview of questionnaire as well as the lung functions capacity measured in the pre-and post-shift of the work.

1.7.2 Respiratory symptoms

The American Thoracic Society Adult Respiratory Questionnaire (ATS-DLD-78) was used in determining respiratory symptoms among machining industry workers. It measures the report of cough, chronic cough, phlegm, chronic phlegm, wheeze, wheezing with dyspnea, grade 1 and grade 2 dyspnea and dyspnea.

1.7.3 Allergies

Allergies include the allergy symptoms reported in the questionnaire such as drug allergy, foods allergy, cosmetics allergy as well as the total immunoglobulin E (TIgE) levels in the blood.

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