# CHEMICAL HEALTH RISK ASSESSMENT AT THE THERMODYNAMIC LABORATORY, UNIVERSITY OF MALAYA

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**RESEARCH REPORT SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SAFETY, HEALTH AND ENVIRONMENT ENGINEERING**

**FACULTY OF ENGINEERING**
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**CHEMICAL HEALTH RISK ASSESSMENT AT THE THERMODYNAMIC LABORATORY, UNIVERSITY OF MALAYA**

## ABSTRACT

Use of chemicals in university laboratory is unavoidable as it is part of the teaching and learning process. Chemical exposure could lead to acute or chronic occupational diseases and even leads to fatality if the chemical is not handled properly. Therefore, chemical health risk assessment (CHRA) plays an important role to evaluate the risk of chemical hazardous to health used at the Thermodynamic Laboratory, University of Malaya, by referring to the Manual of Recommended Practice on the Assessment of the Health Risks Arising from the Use of Chemicals Hazardous to Health at the Workplace 3rd Edition. The assessment was divided into 3 main phases, which are data collection, on-site assessment, and risk evaluation. Action priority was assigned for each chemical assessed to establish the action plan if further control measures needed. Methanol is required for the highest priority as it has the highest risk rating for both inhalation and dermal, followed by benzoic acid, boric acid, diethanolamine, ethanolamine, silver oxide and sulfuric acid as these chemicals resulted high risk for dermal exposure. The management shall consider to give the access permission to handle these chemicals only to the authorized personnel. This study is beneficial to the university management in order to comply to the Occupational Safety and Health (Use and Standards of Exposure of Chemicals Hazardous to Health) Regulations 2000 as chemical health risk assessment is mandatory to be conducted at workplace in every 5 years.

**Keywords:** chemical health risk assessment, hazardous, action priority, safety, chemical exposure

**PENILAIAN RISIKO KESIHATAN KIMIA DI MAKMAL TERMODINAMIK, UNIVERSITI MALAYA**

## ABSTRAK

Penggunaan bahan kimia di makmal universiti tidak dapat dielakkan kerana ia adalah sebahagian daripada proses pengajaran dan pembelajaran. Pendedahan kepada bahan kimia boleh menyebabkan penyakit pekerjaan akut atau kronik dan akan membawa maut sekiranya bahan kimia tidak ditangani dengan betul. Oleh itu, penilaian risiko kesihatan kimia (CHRA) memainkan peranan penting untuk menilai risiko bahan kimia berbahaya kepada kesihatan yang digunakan di Makmal Termodinamik, Universiti Malaya, dengan merujuk kepada *Manual of Recommended Practice on the Assessment of the Health Risks Arising from the Use of Chemicals Hazardous to Health at the Workplace 3rd Edition*. Penilaian ini dibahagikan kepada 3 fasa utama termasuk pengumpulan data, penilaian *on-site*, dan penilaian risiko. Keutamaan tindakan diberikan untuk setiap bahan kimia yang dinilai untuk menetapkan rancangan tindakan sekiranya langkah-langkah kawalan secara lanjut diperlukan. *Methanol* dikelaskan sebagai keutamaan tertinggi kerana ia mempunyai peringkat risiko tertinggi untuk penyedutan dan juga kulit, diikuti oleh *benzoic acid, boric acid, diethanolamine, ethanolamine, silver oxide* dan *sulfuric acid* kerana bahan kimia ini menghasilkan risiko tinggi untuk pendedahan pada kulit. Pihak pengurusan harus mempertimbangkan untuk memberi kebenaran akses kepada pihak yang berkuasa untuk menangani bahan kimia ini sahaja. Kajian ini bermanfaat bagi pihak pengurusan universiti untuk mematuhi *Occupational Safety and Health (Use and Standards of Exposure of Chemicals Hazardous to Health) Regulations 2000* kerana penilaian risiko kesihatan kimia adalah wajib dilakukan di tempat kerja pada setiap 5 tahun.

**Kata kunci:** penilaian risiko kesihatan kimia, berbahaya, keutamaan tindakan, keselamatan, pendedahan kepada bahan kimia

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| | | |
|---|---|---|
| ACGIH | : | American Conference of Governmental Industrial Hygienists |
| AP | : | Action priority |
| C | : | Ceiling Limit |
| CEI | : | Combined exposure index |
| CFD | : | Computational fluid dynamics |
| CHRA | : | Chemical health risk assessment |
| CHTH | : | Chemical hazardous to health |
| CLASS | : | Classification, Labelling and Safety Data Sheet of Hazardous Chemicals |
| CNS | : | Central nervous system |
| DOSH | : | Department of Occupational Safety and Health |
| DR | : | Duration rating |
| ER | : | Exposure rating |
| FDR | : | Frequency-duration rating |
| fpm | : | feet per minute |
| FMECA | : | Failure mode, effects and Criticality Analysis |
| FR | : | Frequency rating |
| HAZOP | : | Hazard and Operability study |
| HR | : | Hazard rating |
| IARC | : | International Agency for Research on Cancer |
| INRS | : | French National Institute of Research and Safety |
| JKKP | : | Jabatan Kesihatan dan Keselamatan |
| LARA | : | Laboratory Assessment and Risk Analysis |
| LEV | : | Local exhaust ventilation |

| | | |
|---|---|---|
| MR | : | Magnitude rating |
| OC | : | Organizational Control |
| OSHA | : | Occupational Safety and Health Act |
| PEL | : | Permissible exposure limit |
| PPE | : | Personal protective equipment |
| PreHA | : | Preliminary Hazard Analysis |
| ROE | : | Route of exposure |
| RR | : | Risk rating |
| SDS | : | Safety Data Sheet |
| STOT SE | : | Specific target organ toxicity, single exposure |
| STOT RE | : | Specific target organ toxicity, repeated exposure |
| TC | : | Technical Control |
| TWA | : | Time-weighted average |
| USECHH | : | Use and Standards of Exposure of Chemicals Hazardous to Health |
| VOC | : | Volatile organic compound |

## LIST OF APPENDICES

# CHAPTER 1

# INTRODUCTION

## 1.1. Background

Occupational diseases and illnesses are mainly caused by the chemical exposure as it is unavoidable to deal with materials that are hazardous. Long-term and short-term exposure could lead to either acute or chronic diseases or even fatal, depends on the characteristic and concentration of the chemical exposed (Debra K. Nims, 1999). The risk of chemical exposure are dependent on the characteristic of the chemical in terms of physical, biological and chemical, route of exposure and degree of exposure (Laal et al., 2017).

In analytical laboratory of university, it is very common for the lab personnel and students to handle and expose to the chemical. Laboratory safety becomes a critical and essential issues to be established. Under Occupational Safety and Health Act (OSHA) 1994, employers have the responsibility to provide a safe working environment and protect the workers from the adverse effects of chemicals. Therefore, assessment on the health risk caused by the chemicals used is required to ensure the workers are protected against the adverse health effects (Department of Occupational Safety and Health, 1994).

In this study, the risk of chemical hazardous to health used at the Thermodynamic Laboratory, University of Malaya is studied and this study focus on the chemical hazardous to health (CHTH) used in the Thermodynamic Laboratory that are defined under the Occupational Safety and Health (Use and Standards of Exposure of Chemicals Hazardous to Health) (USECHH) Regulations 2000 (Department of Occupational Safety and Health, 2000). The most common methods of assessment is the Chemical Health Risk

Assessment (CHRA) introduced by the Department of Occupational Safety and Health Malaysia (Department of Occupational Safety and Health, 2017).

## 1.2. Objectives

The aim of this study is to evaluate the risk of chemical hazardous to health used at the Thermodynamic Laboratory, University of Malaya. To achieve this aim, the following objectives have been derived:

i. To identify the hazards posed by each chemical hazardous to health used at the Thermodynamic Laboratory

ii. To evaluate the degree of exposure of postgraduate students to the chemical hazardous to health

iii. To evaluate the adequacy of existing control measures for the identified hazards

iv. To recommend further suitable control measures based on the assigned action priority (AP)

## 1.3. Scope of Study

This study generally focused on the chemical that are hazardous to health that are listed under the Occupational Safety and Health (Use and Standards of Exposure of Chemicals Hazardous to Health) (USECHH) Regulations 2000 (Department of Occupational Safety and Health, 2000).

The chemical health risk was assessed using the method according to the Manual of Recommended Practice on the Assessment of the Health Risks Arising from the Use of Chemicals Hazardous to Health at the Workplace 3rd Edition (Department of Occupational Safety and Health, 2017). The assessment was divided into 3 main phases, which are data collection, on-site assessment, and risk evaluation. Routes of entry identified were based on inhalation and dermal, including eyes and skin contact. However, exposure through ingestion was excluded as the university management prohibits eating or drinking in the laboratory.

## 1.4. Structure of The Research Project

This research project is organized into six chapters which are shown below:

**Chapter 1** is the introductory statement about the study which presents the background of study, aim and objectives and scope of study.

**Chapter 2** presents the literature review, which the previous studies by other researchers related to the title were being summarized into few sub-topics which are occupational health hazard at laboratory, chemical toxicology, chemical exposure, chemical health risk assessment and safety data sheet.

**Chapter 3** describes the research methodology including the study framework as well as the assessment method used during this study.

**Chapter 4** presents the data of results obtained from the assessment.

**Chapter 5** discusses on the results obtained.

**Chapter 6** concludes the findings from the study and recommendations were proposed to improve the future study.

# CHAPTER 2

# LITERATURE REVIEW

University laboratories always being overlooked on the safety and health perspective as every university normally has quite a number of laboratories and shortage of man power (Marendaz et al., 2013). As chemical exposures are one of the main hazards from the university laboratory, this study is conducted to evaluate the risk of chemical hazardous to health using the Chemical Health Risk Assessment (CHRA) method. Common health hazard and its exposure will be studied in this part. This part will also review on the previous researches using different methods to evaluate the risk at different workplace.

## 2.1. Occupational Health Hazard at Laboratory

According to Suhardi et al. (2017), occupational safety and health is essential to any of the organization and community as it protects the employers and employees from any direct and indirect adverse effect especially from injuries and illnesses, compensation, business downtime and company image. Employer has the responsibility and accountability to ensure the workplace is safe to work.

Ritch & Rank (2001) implemented a Chemical Hygiene plan and conducted pre and post survey study on the safety knowledge gained on the laboratory safety topics. The study found out that laboratory personnel had relatively low knowledge on the topics like emergency response during the fire or splash and the permissible exposure limits (PEL) for the chemical used. This gives an evidence that laboratory personnel do not have the

awareness on the potential occupational health hazard resulting from the chemical exposure.

Kang et al. (2006) conducted questionnaire to 1,000 university students at Korea regarding on the university laboratory safety. The questionnaire concluded that adequate safety training and safe practice must be implemented by each university to decrease the laboratory accidents and diseases. Therefore, development of systematic safety training program, assessment and monitoring related to the specific conditions of the individual laboratory are required to maintain a safe working environment.

## 2.2. Chemical Toxicology

Referring to Debra K. Nims, (1999), toxicology is a study on how the harmful substances found in chemical react with the exposed organism by considering the linked relationship between dose and response. Toxicology explains the capacity of the substance could leads to the adverse effect to the specific living organism. Toxins will enter to the organism through skin absorption, inhalation, ingestion or injection, and will be distributed to the target organs and at last will undergo the biotransformation and be excreted out from the body mainly through kidneys. Nervous system is one of the most sensitive target organs and has a higher focus priority as the health effects could bring the negative impact on the motor and sensory neuropathy, behavioural changes, regulation of breathing and pulse. Therefore, the exposure of harmful substances must be ensured that it is below the permissible exposure limit.

Christiansen et al. (2020) conducted a study on the human hormone effects resulting from endocrine disrupting chemicals by using rats as the experimental model. From the findings obtained, it was proven that endocrine disrupting chemicals brought

significant adverse effects on the reproductive development systems such as reduction of sperm counts and anogenital distances, referring to the dose-response relationship and toxicokinetic of the chemicals. In other words, this study had the same outcome with the study by Bergman et al. (2012) stating that exposed to chemical has the high potential to cause endocrine system disorders especially in the western country due to the complex properties of chemicals.

Taboureau et al. (2020) studied on the chemical effect towards human health especially systems in human body by developing an integrative computed model. The results showed that almost all chemicals have significant effects to more than 1 human systems, and have a linked connection between affected system. For instance, liver illnesses are reflected to kidney illnesses; mutagenic is reflected to tumorigenic; reproductive system is reflected to abnormal growth. Therefore, it can be concluded that accumulation of chemical toxicity in human body are bound to destroy the human systems and thus the human organs and even tissues.

Chassis dynamometer test was conducted by Wang et al. (2020) to evaluate the toxicity of particulate matter emitted by vehicles that uses diesel as fuel. The particulate matter collected contains high concentration of polycyclic aromatic hydrocarbons from different stages of driving while polycyclic aromatic hydrocarbons are organic compounds that can be exist as particulates or gases (Yamasaki et al., 1982). According to the International Agency for Research on Cancer (IARC), polycyclic aromatic hydrocarbons are highly suspected carcinogenic to human health (IARC, 2010).

Phillips et al. (2019) compared the toxicology effects to human health between cigarette smoke and modified risk tobacco aerosol by using mice as the experimental model. This study focuses on the effects on cardiovascular and respiratory systems of mice over six months of experiment. It was found out that the tobacco has lower effect

on both of the systems compared to the cigarette smoke. Cigarette smoke has contributed higher level of cholesterols and hence the risk of cardiovascular disease is much higher compared to the tobacco aerosol. Lung infection was found to be lower risk at tobacco aerosol is due to oxidative stress activated the cytokine that have proinflammatory properties.

Peng et al. (2019) established an approach that uses a computational system to estimate the potential targets of 1478 types of drug induced liver injury chemicals. It was found out that there are almost 10% of the chemicals are hepatotoxic, which could lead to liver damage, mainly due to the biotransformation enzymes that linked to the hepatitis and liver fibrosis. However, the severity of liver damage is the gap of this study and should be focus on for the further research.

Koual et al. (2019) studied the relationship between human exposure to the persistent organic pollutants and the probability of getting breast cancer after the exposure to the persistent organic pollutants. Adipose tissue samples were collected from the biopsy of female breast cancer patient and sent to the laboratory for persistent organic pollutants detection. From the results obtained, persistent organic compounds were found in the tissues block samples and found that 2.3.7.8- tetrachlorodibenzodioxin and 2 types of polychlorinated biphenyls showed significant aggressive risk for breast cancer, especially towards the female who have obesity problems. Besides that, the concentration of these chemicals was found dependent to the size of tumour and the node metastasis. Hence, it was concluded that exposure to persistent organic pollutants brings the higher chances to have breast cancer especially to female due to the hormones effect. This research was in line with the study done by Wu et al. (2020). Total 28 persistent organic compounds were targeted to analyse their toxicity. Most significant effects are reproductive system damage, followed by nervous system. There are some organic

compounds were found to have infertility in female while another group of chemicals give the effects of depression and neurological disorders.

## 2.3. Chemical Exposure

Tates et al. (1991) reported that 24 workers who exposed to ethylene oxide at their workplace had the symptoms of mutagenic effect after the analysis of their blood samples. Comparison was made according to the time of exposure, smoking habit and age. The results concluded that age increasing and with smoking habits leads to the increase of mutant frequency up to 36%. It also indicated that daily exposed workers had a higher frequency percentage compared to the occasionally exposed workers.

Brooks (1982) conducted a clinical study and pulmonary function test on 2 groups of workers, who are working with isocyanates and without isocyanates respectively. Results showed gradually increases of occupational asthma on workers who had exposed to isocyanates. Besides that, 59% of workers who exposed to isocyanate had requested for job transfers due to having respiratory diseases after $\geq$ 3 days away from the workstation. In order to recover from the occupational respiratory diseases, it might take up to months or years as the lung damage could be irreversible. The management of workplace should consider to take industrial hygiene measures and conduct medical surveillance for the exposed workers to ensure they are working in a safe and healthy working condition.

According to Mourry et al. (2020), laboratory workers are not only exposed to physical hazard but also chemical and biological hazards. These hazards are characterized into 6 category which are irritant, harmful, corrosive, toxic, very toxic and last but not least, non-hazardous. Severity of health effects lead from the chemicals are dependent

also on the dosage, frequency, duration and route of entry of each chemical being exposed to the workers.

Research team from Suhardi et al. (2017) conducted a survey at the Batik manufacturing industry, the feedbacks from employees were skin irritation and sensitization after exposed to the colouring agent that are used to dye the batiks, as well as breathing disorders when they are using the cleaning agent to wash the batiks. In a nutshell, employees chose not to wear the personal protective equipment due to the workplace is too hot and not comfortable. Employers should seek an alternative personal protective equipment and take the welfare facilities into consideration as the improvement plan. Hazards of dye and cleaning agents should be assessed by referring to the respective safety data sheet and appropriate assessment method. If possible, eliminate or substitute the use of hazardous chemical to a less hazardous chemical.

Marendaz et al. (2013) identified that chemicals with extremely low boiling point in the laboratory can cause burning of skin and reduction of oxygen percentage at the workplace. Less ventilation at the laboratory increases the risk of being exposed to these hazardous chemicals. Therefore, the most effective way to reduce the risk is by using less hazardous chemicals or reduce the storage volume of hazardous chemical in the laboratory.

Another study on the effect of atmospheric chemical pollutants to the lung disease in children was conducted by Agier et al. (2019). The main exposures of the children are nitrogen dioxides and particulate matters in the ambient air. Spirometry test results were taken when the children ate at the age of six to twelve years old. According to the results obtained, sign and symptoms of lung function disorder were found associated by the chemical exposures from the environment, by taking their lifestyle factors into account. Therefore, in order to minimize the risk of long-term exposure respiratory system

disorders or illnesses, reduction of the chemical exposure is the most effective way especially to the children and pregnant woman as their lung function are still under the development stages.

## 2.4. Chemical Health Risk Assessment

Davardoost & Kahforoushan (2018) used computational fluid dynamics (CFD) model to determine the emission volatile organic compounds (VOCs) in a laboratory and evaluate the health risk leads from the emission. The researcher concluded that the workers should not work or stay in the laboratory with contaminated VOCs for 8 hours continuously. The reason is because the time-weighted average for 8 hours (TWA-8hrs) for toluene, acetone and benzene were above the permissible exposure limit (PEL). Hierarchy of control should be implemented to reduce the health risk.

Husin et al. (2012) conducted the chemical health risk assessment at 13 laboratories with average 27 chemicals use at each laboratory. The research was conducted according to the Assessment of the Health Risk Arising from the Use of Hazardous Chemicals in the Workplace (A Manual of Recommended Practice, 2nd Edition), published by DOSH Malaysia. From the conclusion given, all chemicals used at these 13 laboratories had significant risk as the risk ratings are 3, however the existing control measures were insufficient to reduce the risk. Therefore, few recommendations were given to the management to improve the control measures: issuance of suitable personal protective equipment based on the safety data sheet, training on emergency response and proper chemical storage with appropriate hazard pictogram. Re-assessment is recommended every 5 years, referring to the USECHH Regulations 2000.

Rohmatullah (2018) assessed the chemical risk at a private medical laboratory which contains 108 chemicals in the laboratory. Higher prioritize was given to the work unit with significant risk but the control measures were not sufficient. The researcher recommended the management to implement mitigation measures based on the hierarchy of control. Chemical exposure monitoring and medical surveillance were suggested in order to monitor the workers' health condition.

A research from Beronius et al. (2020) in order to evaluate the risk of chemical mixtures was established by introducing a web-based toolbox named EuroMix. By using this approached method, they were able to assess the hazard and risk of different types of chemical mixtures, as this toolbox contains databases that includes the toxicokinetic of chemicals.

Mourry et al. (2020) studied the chemical health risk assessment in laboratories using the method recognized by the local research centre - French National Institute of Research and Safety (INRS). The study mainly focused on the chemical risk hierarchy by taking consideration on the toxicology, exposure frequency and duration, job nature and amount of exposure on the chemicals. Risk score was given to each chemical to indicate the priority that required control measures.

Pluess et al. (2016) conducted few comparisons among the Laboratory Assessment and Risk Analysis (LARA), Hazard and Operability study (HAZOP), Failure mode, effects and Criticality Analysis (FMECA) and Preliminary Hazard Analysis (PreHA) in order to evaluate the laboratory safety and risk assessment in a university laboratory. The comparisons were captured based on the selected tasks that involved chemical handling and testing. The research team concluded that LARA is more suitable to access the hazardous chemical health risk to the exposed group, as this method is able to link the identified hazards with the hazardous characteristics of each chemical used.

Besides that, LARA can be easily understood and performed by the non-experts and it requires minimum data and information during the assessment.

Marendaz et al. (2013) created the hazard mapping after conducting the risk assessment by including the scale level based on the risk rating. The hazard mapping is very useful for laboratory operators as it visualized the existing location of chemical hazards and highlighted in different colour according to its scale level that divided into 3 categories: flammable, toxic (acute) and toxic (chronic). The hazard mapping was then displayed at the entrance of the laboratory to ease the operators and students understand the hazard locations before they enter and start any activity or task in the laboratory.

## 2.5. Safety Data Sheet

Willey (2012) stated that Safety Data Sheet (SDS) is playing an important role to convey the information including the chemical hazards, control measures especially when using. handling, transporting and storing the chemicals. This information is essential for an organization to start up the occupational safety and health management system.

There are sixteen sections of information will be presented in each of the approved SDS (Nayar et al., 2016). Table 2.1 below shows the sections that are relevant to the chemical health risk assessment.

**Table 2.1: Section in Safety Data Sheet**

| Section | Section Name | Description |
|---|---|---|
| 2 | Label elements | • Hazard pictograms<br>• Hazard statements<br>• Precautionary statements |
| 3 | Composition / information on ingredients | • Hazardous components |
| 8 | Exposure controls / personal protection | • Control parameters<br>• Exposure controls |
| 9 | Physical and chemical properties | • Information on basic physical and chemical properties |
| 11 | Toxicological information | • Information on toxicological effects |

Section 2 and 3 provide the basic information on the hazardous components and hazardous statements named H statements. H statements will be used to identify the hazard rating and in order to determine the action priority to be taken according to the potential health effect of the chemicals. Besides that, Section 8 in the SDS states the permissible exposure limit (PEL) of the chemical which identify the acceptable safe level exposed by the laboratory operators. Section 9, 11 and 12 gives the physical and chemical properties as well as the toxicological effects. From the boiling point, degree of release can be identified.

Hodson et al. (2019) evaluated the engineering nanomaterial SDS for each section using scoring system and he concluded that information obtained from the SDS are not reliable upon to provide sufficient and adequate chemical health hazards as there are lacking of some information. Therefore, the research team suggested to consult the certified organization during the preparation of SDS to ensure the SDS published is meeting the requirement with adequate information.

# CHAPTER 3

# METHODOLOGY

This research was carried out according to the Manual of Recommended Practice on the Assessment of the Health Risks Arising from the Use of Chemicals Hazardous to Health at the Workplace 3rd edition, for the purpose of complying the requirements stated under the Occupational Safety and Health (Use and Standard of Exposure of Chemicals Hazardous to Health) Regulations 2000, by Department of Occupational Safety and Health (DOSH) Malaysia.

The assessment was divided into 3 main phases, which are data collection, on-site assessment, and risk evaluation.

## 3.1. Data Collection

Data collection plays an important role in this project as it kickstarts the assessment. The data collected helps for better understanding before proceeding to the next phase. Data required are listed as below:

- Master list of active chemicals used or stored in the workplace
- Safety Data Sheet (SDS) for each chemical
- Number of staff exposed to the chemical
- Information on existing control measures if available
- Personal protective equipment provided to the workers

### 3.2. On-site Assessment

On-site assessment included the walkthrough observations and interview. This phase was crucial to determine the degree of hazards and exposure to the workers. First and foremost was to observe the work nature, working method. working environment, possible route of exposure and suitability of existing control measures. Factors that have potential to affect the risk were observed and took into account at the third phase.

The purpose of conducting interview session is to get feedbacks from the workers if there is any health feedback or reporting cases on health effect due to chemical exposure. Besides that, frequency and duration of exposure was obtained during the interview sessions.

### 3.3. Risk Evaluation

#### 3.3.1. Hazard Rating (HR) Through Inhalation

Hazard rating (HR) was used to determine the severity of potential health effect of CHTH. The HR through inhalation was rated on a scale of 1 to 5, referring to the hazard classification and H-code obtained from the safety data sheet, as shown in Table 3.1. The higher the HR, the higher the severity of adverse health effect.

**Table 3.1: HR through Inhalation Referring to the Hazard Classification and H-code**

| HR | Hazard Classification | H-code |
|---|---|---|
| **5** | Acute toxicity category 1 (inhalation) | H330 |
| | Carcinogenicity category 1A | H350, H350i |
| | Mutagenicity category 1A | H340 |
| | Reproductive toxicity category 1A | H360, H360D, H360F, H360FD, H360Fd, H360Df |
| | Specific target organ toxicity – single exposure category 1 | H370 |
| **4** | Acute toxicity category 2 (inhalation) | H330 |
| | Carcinogenicity category 1B | H350, H350i |
| | Mutagenicity category 1B | H340 |
| | Reproductive toxicity category 1B | H360, H360D, H360F, H360FD, H360Fd, H360Df |
| | Effects on or via lactation | H362 |
| | Specific target organ toxicity – repeated exposure category 1 | H372 |
| | Respiratory sensitisation category 1 | H334 |
| **3** | Acute toxicity category 3 (inhalation) | H331 |
| | Carcinogenicity category 2 | H351 |
| | Mutagenicity category 2 | H341 |
| | Reproductive toxicity category 2 | H361, H361f, H361d, H361fd |
| | Specific target organ toxicity – repeated exposure category 2 | H373 |
| **2** | Acute toxicity category 3 (inhalation) | H332 |
| | Specific target organ toxicity – single exposure category 3 | H335, H336 |
| | Specific target organ toxicity – single exposure category 2 | H371 |
| **1** | Chemical not otherwise classified | H333 |

### 3.3.2. Degree of Hazard for Dermal Exposure

Dermal exposure means chemicals to be exposed through eyes and skin. The health effects were categorized according to the hazardous properties as listed in Table 3.2.

**Table 3.2: Dermal Exposure According to the Hazardous Properties**

| Hazardous Properties | Hazard classification | H-code |
|---|---|---|
| Irritation | Skin corrosion or irritation category 2 | H315 |
| | Serious eye damage or eye irritation | H319 |
| Corrosion | Skin corrosion or irritation category 1 | H314 |
| | Serious eye damage or eye irritation category 1 | H318 |
| Sensitisation | Skin sensitisation category 1 | H317 |
| Acute toxicity | Acute toxicity (dermal) category 1 | H310 |
| | Acute toxicity (dermal) category 2 | H310 |
| | Acute toxicity (dermal) category 3 | H311 |
| | Acute toxicity (dermal) category 4 | H312 |
| Skin absorption and other properties | Specific target organ toxicity – single exposure category 1 | H370 |
| | Specific target organ toxicity – single exposure category 2 | H371 |
| | Specific target organ toxicity – repeated exposure category 1 | H372 |
| | Specific target organ toxicity – repeated exposure category 2 | H373 |
| | Carcinogenicity category 1 | H350 |
| | Carcinogenicity category 2 | H351 |
| | Germ cell mutagenicity category 1 | H340 |
| | Germ cell mutagenicity category 2 | H341 |

**Table 3.2: Dermal Exposure According to the Hazardous Properties continued**

| Hazardous Properties | Hazard classification | H-code |
|---|---|---|
| Skin absorption and other properties | Reproductive toxicity category 1 | H360, H360D, H360F, H360FD, H360Fd, H360Df |
| | Reproductive toxicity category 2 | H361, H361f, H361d, H361fd |

### 3.3.3. Evaluation of Inhalation Exposure

In order to determine the degree of exposure to CHTH, exposure rating (ER) was calculated based on the frequency, duration and magnitude of exposure. The ER through inhalation was rated on a scale of 1 to 5. The higher the ER, the higher the degree of exposure. To determine the ER, quantitative and qualitative evaluation can be used depending on the availability of monitoring data. Quantitative evaluation is commonly used, unless no monitoring data is available (Department of Occupational Safety and Health, 2017). In this study, qualitative evaluation method was used as there is no chemical exposure monitoring data had been done in the past.

**(a) Quantitative Evaluation**

The ER was obtained based on the comparison between airborne exposure monitoring data and the permissible exposure limit (PEL) stipulated under the USECHH Regulations Schedule I. Table 3.3 shows the exposure rating based on the airborne exposure monitoring data.

- Time-weighted average (TWA) was calculated using the equation as below:

$$TWA = \frac{C_1T_1 + C_2T_2 + \cdots + C_nT_n}{T_1 + T_2 + \cdots + T_n}$$

Where C = Concentration of chemical sample

T = Sampling time

- Combined exposure index (CEI) was calculated using the equation as below:

$$CEI = \frac{TWA_1}{PEL_1} + \frac{TWA_2}{PEL_2} + \cdots + \frac{TWA_n}{PEL_n}$$

**Table 3.3: Exposure Rating (ER) Based on the Airborne Exposure Monitoring Data**

| TWA | CEI | ER |
|---|---|---|
| $x \geq$ PEL | $x \geq 1$ | 5 |
| $\geq 0.75$ PEL but < PEL | $0.75 \leq x < 1$ | 4 |
| $\geq 0.5$ PEL but < 0.75 PEL | $0.5 \leq x < 0.75$ | 3 |
| $\geq 0.1$ PEL but < 0.5 PEL | $0.1 \leq x < 0.5$ | 2 |
| < 0.1 PEL | $x < 0.1$ | 1 |

**(b) Quantitative Evaluation**

The exposure rating (ER) was estimated by taking into account the frequency-duration rating (FDR) and magnitude rating (MR).

- Frequency-duration rating (FDR)

i. Frequency rating (FR)

Frequency rating shows the frequency of workers potentially being exposed to CHTH. The FR was rated on a scale of 1 to 5 as shown in Table 3.4.

**Table 3.4: Frequency Rating**

| Frequency Rating (FR) | Exposure Frequency |
|---|---|
| 5 | Exposed more than once / shift or day |
| 4 | Exposed more than once / week |
| 3 | Exposed more than once / month |
| 2 | Exposed more than once / year |
| 1 | Exposed less than once / year |

ii. Duration rating (DR)

Duration rating shows the duration of workers potentially being exposed to CHTH. The FR was rated on a scale of 1 to 5 as shown in Table 3.5.

**Table 3.5: Duration Rating**

| Duration Rating (DR) | Duration of exposure per shift (x) |
|---|---|
| 5 | Exposed more than 7 hours |
| 4 | Exposed more than 4 hours, less than 7 hours |
| 3 | Exposed more than 2 hours, less than 4 hours |
| 2 | Exposed more than 1 hour, less than 2 hours |
| 1 | Exposed less than 7 hours |

Refer Table 3.6 to determine frequency-duration rating (FDR).

**Table 3.6: Frequency-Duration Rating**

| | | Frequency Rating (FR) | | | | |
|---|---|---|---|---|---|---|
| | | **1** | **2** | **3** | **4** | **5** |
| Duration Rating (DR) | **1** | 1 | 2 | 2 | 2 | 3 |
| | **2** | 2 | 2 | 3 | 3 | 4 |
| | **3** | 2 | 3 | 3 | 4 | 4 |
| | **4** | 2 | 3 | 4 | 4 | 5 |
| | **5** | 3 | 4 | 4 | 5 | 5 |

- Magnitude rating (MR)

Magnitude rating was identified by referring to the degree of chemical released and inhaled as shown in Table 3.7. Degree of chemical released was determined based on its boiling point at room temperature. Low degree when boiling point is more than 150 °C; moderate degree when boiling point is within 50 °C -150 °C; High degree when boiling point is less than 50 °C.

For degree of inhaled, it was observed during the on-site assessment. The degree was determined according to the breathing rate and physical activity being carried out. Usually, laboratory personnel are categorized under light work with low breathing rate, this the degree of inhaled is low.

**Table 3.7: Magnitude Rating**

| | | Degree of inhaled | | |
|---|---|---|---|---|
| | | **Low** | **Moderate** | **High** |
| Degree of chemical released | **Low** | 1 | 2 | 3 |
| | **Moderate** | 2 | 3 | 4 |
| | **High** | 3 | 4 | 5 |

Risk has been defined as a factor of probability of occurrence and the severity of consequences. The formulation can be expressed as following:

$$\text{Risk Rating} = \text{HR} \times \text{ER}$$

where RR - Risk rating (scale 1 to 25)

HR - Hazard rating (scale 1 to 5)

ER - Exposure rating (scale 1 to 5)

## 3.4. Assess Adequacy of Control Measures

The presence and adequacy of existing control measures are evaluated for each work unit. The adequacy of existing control measures is assessed by inspecting the control measures, biological monitoring and checking records on the inspection, testing and examination of control equipment.

### 3.5. Concluding the Assessment

After obtaining the risk rating (RR) and assessing the adequacy of existing control measures, action priority was assigned for each chemical assessed as shown in Table 3.8 in order to establish the action plan if further control measures needed.

**Table 3.8: Action Priority**

| Risk Rating | Risk Level | Adequacy of Control Measures | Action Priority (AP) |
|---|---|---|---|
| 15 to 25 | High (H1 & H2) | Inadequately controlled | AP-1 |
| HR could not be determined | - | - | |
| 5 to 12 | Moderate (M1 & M2) | Inadequately controlled | AP-2 |
| 1 to 4 | Low (L) | | |
| 1 to 25 | Low / Moderate / High | Adequately controlled | AP-3 |

# CHAPTER 4

# RESULTS

This chemical health risk assessment was carried out at the Thermodynamic Laboratory, located in Faculty of Engineering, University of Malaya, using the qualitative method. According to the information gathered from the laboratory personnel, there are 25 chemicals were being used and stored in the laboratory and total three postgraduate students are exposed to the hazardous chemical. Their working hour starts at 7.30 a.m. to 5.00 p.m. No feedback from the laboratory personnel on their health conditions and no cases reported in Jabatan Kesihatan dan Keselamatan JKKP 7 form and JKKP 8 form during the assessment.

## 4.1. On-site Assessment

Warning signs giving the hazard information was available at the entrance to the laboratory and was visible inside the laboratory. Food and drinks were prohibited in the laboratory. Hand soap was provided to maintain the personal hygiene in order to reduce the probability of chemical being ingested.

Emergency procedures was displayed at the notice board. Eye wash, first aid kit and fire extinguisher were observed located inside the laboratory. Besides that, emergency shower station was located just outside the laboratory, which is adequate for the emergency preparedness plan.

## 4.2. Existing Control Measures

This laboratory does not have any isolation or enclosure system to isolate the hazardous chemical. However, there are two fume hoods with local exhaust ventilation system were installed and inspected on yearly basis by the competent Hygiene Technician II, registered under DOSH.

It was observed that students working in the laboratory were provided personal protective equipment (PPE) such as lab coats, nitrile disposable gloves, face mask and safety goggles to prevent chemical splash.

No chemical exposure monitoring and medical surveillance had been conducted as the chemical health risk never been assessed before. Training on chemical handling and emergency preparedness had been conducted.

## 4.3. Action Priority (AP)

The results of this study were summarized in the Table 4.1. Risk rating (RR) was calculated using the hazard rating (HR) and exposure rating (ER). Among the 25 chemicals assessed, there are 5 chemicals are classified as not hazardous to human health. Action priority (AP) for all hazardous chemicals is AP-3 where the existing control measures are sufficient and adequate, corresponding with the risk identified. The details of each chemical assessed are presented in Appendix A.

## Table 4.1: Results Summary

| Chemical used | Inhalation | | | | | | Dermal | | |
|---|---|---|---|---|---|---|---|---|---|
| | Classification | HR | ER | RR | Risk Level | AP | Hazardous Properties | Risk Level | AP |
| 2-propanol | STOT SE (3) | 2 | 2 | 4 | L | 3 | Irritation | M2 | 3 |
| 4-Nitrophenyl Palmitate | Not applicable | | | | | | Sensitisation | M2 | 3 |
| Acetic Acid | Not applicable | | | | | | Corrosion | M1 | 3 |
| Acetonitrile | Acute toxicity (4) | 2 | 2 | 4 | L | 3 | Irritation | M1 | 3 |
| | | | | | | | Acute toxicity | M1 | |
| Ammonium Peroxidisulfate | STOT SE (3) | 4 | 1 | 4 | L | 3 | Irritation | M1 | 3 |
| | Respiratory Sensitisation (1) | | | | | | Sensitisation | L | |
| **Benzoic Acid** | STOT RE (1) | 4 | 1 | 4 | L | 3 | Irritation | L | 3 |
| | | | | | | | Corrosion | H1 | |
| **Boric Acid** | Reproductive toxicity (1B) | 4 | 1 | 4 | L | 3 | Other properties | H1 | 3 |
| Caprolactone | Not applicable | | | | | | Irritation | M2 | 3 |
| Chloroform | Acute toxicity (3) | 4 | 2 | 8 | M | 3 | Irritation | M2 | 3 |
| | Reproductive toxicity (2) | | | | | | | | |
| | Carcinogenicity (2) | | | | | | Other properties | M2 | |
| | STOT RE (1) | | | | | | | | |
| **Diethanolamine** | STOT RE (2) | 3 | 1 | 3 | L | 3 | Irritation | L | 3 |
| | | | | | | | Corrosion | H1 | |
| | | | | | | | Other properties | L | |
| **Ethanolamine** | Acute toxicity (4) | 3 | 1 | 3 | L | 3 | Acute toxicity | M1 | 3 |
| | STOT SE (3) | | | | | | Corrosion | H1 | |
| Mercury (II) Chloride | Mutagenicity (2) | 4 | 1 | 4 | L | 3 | Other properties | M1 | 3 |
| | Reproductive toxicity (2) | | | | | | Corrosion | M1 | |
| | STOT RE (1) | | | | | | | | |
| **Methanol** | Acute toxicity (3) | 5 | 2 | 10 | M | 3 | Acute toxicity | M1 | 3 |
| | STOT SE (1) | | | | | | Other properties | H1 | |
| n-Heptane | STOT SE (3) | 2 | 2 | 4 | L | 3 | Irritation | L | 3 |
| n-Hexane | Reproductive toxicity (2) | 3 | 2 | 6 | M | 3 | Irritation | M1 | 3 |
| | STOT SE (3) | | | | | | Other properties | M2 | |
| | STOT RE (2) | | | | | | | | |

## Table 4.1: Results Summary continued

| Chemical used | Inhalation | | | | | | Dermal | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Classification** | **HR** | **ER** | **RR** | **Risk Level** | **AP** | **Hazardous Properties** | **Risk Level** | **AP** |
| Potassium Hydroxide | Not Applicable (Acute Toxicity (Oral) (4)) | | | | | | Corrosion | M1 | 3 |
| **Silver Oxide** | Not applicable | | | | | | Irritation | L | 3 |
| | | | | | | | Corrosion | H1 | |
| Sodium Nitrite | Not Applicable (Acute Toxicity (Oral) (3)) | | | | | | Irritation | M1 | 3 |
| **Sulfuric Acid** | Not applicable | | | | | | Corrosion | H1 | 3 |
| Hydrochloric Acid | STOT SE (3) | 3 | 1 | 3 | L | 3 | Corrosion | M1 | 3 |
| Aluminium Oxide | Classified as Not Hazardous | | | | | | | | |
| Magnesium Sulphate Heptahydrate | | | | | | | | | |
| Potassium Hexacyanoferrate (II) Trihydrate | | | | | | | | | |
| Sodium Hydrogen Carbonate | | | | | | | | | |
| Sodium Oleate | | | | | | | | | |

# CHAPTER 5

# DISCUSSION

In general, the risk of chemical hazardous to health used at the Thermodynamic Laboratory at University of Malaya is studied and total 20 chemicals are classified as chemical hazardous to health (CHTH) that are defined under the Occupational Safety and Health (Use and Standards of Exposure of Chemicals Hazardous to Health) (USECHH) Regulations 2000 (Department of Occupational Safety and Health, 2000) and 5 chemicals are classified as not hazardous.

## 5.1. Hazard Rating (HR)

Referring to the Appendix 2, methanol has the highest hazard rating of 5. The main contribution that leads to the hazard rating of 5 is from the specific target organ toxicity with single exposure to eyes. Thus, it can be explained that methanol is highly toxic to humans that can cause damage to the optic nerve and leads to the permanent eye damage. However the minimum dosage that could leads to permanent eye damage is still obscured (Hovda et al., 2020).

Chemicals with hazard rating of 4 are ammonium peroxidisulfate, benzoic acid, boric acid, chloroform and mercury (II) chloride. These 5 chemicals are required more attention as they have the same hazard characteristics which are specific target organ toxicity and reproductive toxicity. For example, human reproductive organs will be targeted when exposed to the mercury as the testis and ovary are significantly sensitive to this chemical (Massányi et al., 2020).

For dermal exposure, benzoic acid, boric acid, diethanolamine, ethanolamine, methanol, silver oxide and sulfuric acid are classified as High Risk compared to the other chemicals, therefore higher priority shall be considered during the action plan for exposure control program. Main contribution of high risk is mainly due to the corrosive properties.

## 5.2. Action Priority (AP)

Control measures action plan should be established based on the action priority. Based on the findings obtained, action priority for all hazardous chemicals is AP-3 where the existing control measures are sufficient and adequate, corresponding with the risk identified.

Since action priority for all chemicals are same, when implementing the control measures action plan, priority shall be given to the chemicals according to the hazard rating and risk level. Highest priority will be methanol as methanol has the highest risk rating for both inhalation and dermal, followed by benzoic acid, boric acid, diethanolamine, ethanolamine, silver oxide and sulfuric acid as these chemicals resulted high risk for dermal exposure. The management shall consider to give the access permission to handle these chemicals only to the authorized personnel. Risk assessment shall be conducted prior to the access permission granted.

## 5.3. Control Measures

Control measures for the risk identified at the previous chapter shall be taken to minimize the risk by using the hierarchy of controls listed in the USECHH Regulations 2000 (Department of Occupational Safety and Health, 2000).

### 5.3.1. Technical Controls

From the on-site walkthrough observations, the chemicals are used to perform the laboratory analytical testing and act as the reagent during the laboratory test. Thus, it is not necessary to eliminate or substitute the chemicals with a lower hazard rating.

There are 2 fume hoods and local exhaust ventilation system installed in the laboratory. Fume hoods are used to capture the airborne contaminants such as chemical vapours, fumes or dust directly from the source of release. Both fume hoods were inspected on yearly basis by the competent Hygiene Technician II, registered under DOSH. According to the industrial ventilation design manual published by ACGIH (2007), recommended face velocity for the fume hood is within 80 fpm to 120 fpm, and the duct velocity of the local exhaust ventilation system is within 1000 fpm to 2000 fpm. For fume hoods, the sash door should be positioned at the suitable working height position to prevent chemical splash during performing the work activity. As mentioned in the USECHH Regulation 17 (2), the fume hoods have to be inspected by hygiene technician in yearly basis and being serviced and maintained internally on monthly basis (Department of Occupational Safety and Health, 2000). Therefore, the laboratory management shall continue with the existing control measures practice.

From the observation, the students were wearing the personal protective equipment (PPE) provided including lab coats, nitrile disposable gloves, face mask and safety glasses. The PPEs are adequate and suitable as they are fit to the hazardous properties of each chemical. Continuation of PPE issuance is recommended and the adequacy shall be reviewed for every new incoming chemical.

### 5.3.2. Organizational Controls

In general, adoption of safe work systems and practices were implemented at the laboratory. The risk of postgraduate students who are exposed to the chemicals are relatively low compared to the chemical manufacturing industry as their task activity and selection of chemicals to be used are project based and not consistent. Most of the chemicals, the exposure frequency is on yearly basis. The amount of chemicals used is small and they are sitting or standing in light movements. Rules prohibiting eating and drinking in the laboratory and hand soap was provided significantly reduce the risk of chemical being ingested.

The chemicals were stored in the chemical cabinets with proper labelling on the chemical containers. It was observed that the laboratory office was separated from the chemical storage, which is necessary to reduce the chemical risk of laboratory assistant working inside the office. However, it was found that almost all Safety Data Sheet (SDS) displayed at the workplace were expired. As stipulated in the CLASS Regulations 2013, Regulation 13 (4(b)), SDS has to be revised after the 5 years from the latest revision date (Department of Occupational Safety and Health, 2013). The laboratory management are required to request the latest version of SDS from the manufacturers or suppliers.

There is a safety and health information board located near the entrance of the laboratory, displaying warning sign, chemical handling method, emergency evacuation plan, emergency contact, emergency procedures and incident reporting procedures. Training for chemical handling and emergency preparedness were conducted on 2019. Therefore, the refresher training courses are recommended to be conducted once every two years, including the PPE and first aid training. Apart from this, other existing control measures can be continued to implement.

Eye wash, first aid kit and fire extinguisher were observed located inside the laboratory. Besides that, emergency shower station was located just outside the laboratory. Clear instructions were displayed together the emergency preparedness equipment. All equipment shall be inspected on regular basis to ensure they are ready to use during the emergency.

Chemical exposure monitoring and medical surveillance are not been conducted before this assessment. From the results obtained, personal exposure monitoring is not required as the likelihood of the chemicals to be airborne is slightly low with the presence of fume hoods. Medical surveillance is not recommended. However, medical surveillance for n-hexane, listed in Schedule II of the USECHH Regulations 2000, is recommended if there is any health feedback from the students or any changes in the frequency and duration of exposure (Department of Occupational Safety and Health, 2000).

### 5.3.3. Specific Control Measures

Specific control measures are required for ammonium peroxidisulfate as this chemical is categorized under respiratory sensitizers. Chemical under respiratory sensitizer targets the human respiratory tract through the route of inhalation and will trigger airway hypersensitivity (Chary et al., 2018). Elimination or substitution of this chemical is recommended. If not possible, approved respiratory personal protective equipment must be provided and used when handling this chemical.

# CHAPTER 6

# CONCLUSION

## 6.1. Research Conclusion

This study was conducted to evaluate the risk of chemical hazardous to health used at the Thermodynamic Laboratory, University of Malaya using the Chemical Health Risk Assessment (CHRA) method introduced by the Department of Occupational Safety and Health Malaysia. Among 25 chemicals used in the laboratory, 20 chemicals are classified as chemical hazardous to health (CHTH) and 5 chemicals are classified as not hazardous. The classification of hazards was identified from the Safety Data Sheet (SDS). Degree of exposure of workers to the CHTH was evaluated based on the frequency and duration of exposure to the entire chemicals. All 20 chemicals had the action priority of AP-3 due to the adequacy of existing control measures. Methanol is required for the highest priority as it has the highest risk rating for both inhalation and dermal, followed by benzoic acid, boric acid, diethanolamine, ethanolamine, silver oxide and sulfuric acid as these chemicals resulted high risk for dermal exposure. The management shall consider to give the access permission to handle these chemicals only to the authorized personnel.

Almost all Safety Data Sheet (SDS) displayed at the workplace were expired. The laboratory management are required to request the latest version of SDS from the manufacturers or suppliers. Refresher training courses are recommended to be conducted once every two years, since the last training was in year 2019. Personal chemical exposure monitoring and medical surveillance are not recommended but medical surveillance for n-hexane is recommended if there is any health feedback from the students or any changes in the frequency and duration of exposure. Apart from that, continuation of existing control measures is recommended.

This chemical health risk assessment needs to be re-assessed if there are any significant changes in this laboratory work unit in terms of chemicals used or changes in job nature, or after 5 years from the last assessment date.

## 6.2. Recommendation for Future Project

The users in university laboratory varies gradually as the students are using the laboratory on project or module basis. Therefore, the chemical exposed group is not consistent. The risk rating is expected to be lower compared to other exposed group at manufacturing industry as industry has standard working routine and same exposed group at all time. Under the circumstances, further research should be conducted to study the corelation analysis between consistent and non-consistent exposed group. Department of Occupational Safety and Health Malaysia shall consider to include the adjustment factor in the assessment method. Higher priority should go to chemical that are specific target organ toxicity – single exposure instead of repeated exposure to prevent overlooking of the chemical health hazards.

Physical hazards and chemical hazards in laboratory are most common and significant from the perspective of an occupational safety and health practitioner, but biological hazards are often overlooked and neglected. Microbes and viral vectors can lead to severe harm and infectious disease to human. Therefore, biological health risk assessment for the laboratory is recommended to be studied in the further research.

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