ENHANCING CHEMICAL HEALTH RISK ASSESSMENT PRACTICES IN MALAYSIAN HIGHER ACADEMIC INSTITUTION THROUGH INDOOR AIR QUALITY (IAQ): MIXED METHODS ANALYSIS

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by

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LIST OF ABBREVIATIONS

AP	Action Priority
CHRA	Chemical health risk assessment
CLASS 2013	The Occupational Safety and Health (Classification, Labelling and Safety Data Sheet of Hazardous Chemicals) Regulations 2013
CHTH	Chemicals hazardous to health
CO	Carbon monoxide
CO_2	Carbon dioxide
DOSH	Department of Occupational Safety and Health
ER	Exposure rating
GHS	Globally Harmonized System of Classification and Labelling of Chemicals
HR	Hazard rating
HVAC	Heating, ventilation, and air conditioning
IAQ	Indoor air quality
NCOSH	National Council of Occupational Safety and Health
NIOSH	National Institute of Occupational Safety and Health
O_2	Oxygen
OSH	Occupational Safety and Health
PM_{10}	Particulate matter 10 micrometers or less in diameter
RR	Risk rating
TVOC	Total Volatile Organic Compound

USECHH 2000	Use and Standard of Exposure of Chemicals Hazardous to Health Regulation 2000

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MENINGKATKAN AMALAN PENILAIAN RISIKO KESIHATAN KIMIA DI INSTITUSI PENGAJIAN TINGGI MALAYSIA MELALUI KUALITI UDARA DALAMAN: ANALISIS KAEDAH CAMPURAN

ABSTRAK

Kajian ini menilai risiko kesihatan kimia di makmal sebuah institusi pengajian tinggi di Malaysia menggunakan pendekatan kualitatif dan kuantitatif. Objektif am kajian adalah untuk menilai risiko pendedahan dengan mengintegrasikan Penaksiran Risiko Kesihatan Kimia (CHRA) bersama penilaian Kualiti Udara Dalaman (IAQ). Sebanyak 79 makmal telah disaring menggunakan CHRA bagi menentukan Tahap Keutamaan Tindakan (Action Priority, AP). Sebanyak 34 makmal kemudiannya dipilih untuk pemantauan IAQ. Parameter IAQ yang diukur termasuk suhu udara, kelembapan relatif, pergerakan udara, karbon monoksida (CO), karbon dioksida (CO_2), sebatian organik meruap (VOCs), dan zarah terampai (PM_{10}), yang dibandingkan dengan had yang ditetapkan dalam Kod Amalan Industri bagi Kualiti Udara Dalaman 2010. Analisis statistik yang digunakan merangkumi analisis deskriptif, tabulasi silang, ANOVA sehala, korelasi Spearman, Ujian Khi-Kuasa Dua Pearson, dan regresi logistik. Analisis deskriptif menunjukkan ketidakpatuhan yang kerap terhadap parameter suhu, tahap CO_2, dan aliran udara. Analisis inferensi menggunakan korelasi Spearman menunjukkan hubungan songsang yang signifikan antara pergerakan udara dan kepekatan CO_2 ($p<0.05$), yang menunjukkan pengudaraan yang tidak mencukupi. Dapatan kajian ini menekankan kepentingan integrasi penilaian IAQ bersama CHRA dalam mengenal pasti persekitaran berisiko tinggi serta memperkukuh amalan keselamatan kimia di makmal akademik.

ENHANCING CHEMICAL HEALTH RISK ASSESSMENT PRACTICES IN MALAYSIAN HIGHER ACADEMIC INSTITUTION THROUGH INDOOR AIR QUALITY (IAQ): MIXED METHODS ANALYSIS

ABSTRACT

This study evaluates chemical health risks in laboratories at a Malaysian higher academic institution using a combination of qualitative and quantitative approaches. The general objective was to assess exposure risks by integrating Chemical Health Risk Assessment (CHRA) with Indoor Air Quality (IAQ) evaluation. Initially, 79 laboratories were screened using CHRA to determine Action Priority (AP) levels. 34 of the laboratories were selected for detailed IAQ monitoring. Measured IAQ parameters included air temperature, relative humidity, air movement, carbon monoxide (CO), carbon dioxide (CO_2), volatile organic compounds (VOCs), and particulate matter (PM_{10}), compared against Industry Code of Practice on Indoor Air Quality (ICOP IAQ) 2010 limits. Statistical analysis used included descriptive, cross-tabulation, one-way ANOVA, Spearman correlation, Pearson Chi-Square and logistic regression. Descriptive analysis revealed frequent non-compliance in temperature, CO_2 levels, and airflow. Inferential analysis using Spearman's correlation identified a significant inverse relationship between air movement and CO_2 concentration ($p < 0.05$), indicating poor ventilation. The findings highlight the importance of integrating IAQ assessment with CHRA to identify high-risk environments and enhance chemical safety practices in academic laboratories.

CHAPTER 1

INTRODUCTION

1.1 Introduction

To maintain a sustainable workplace, it is essential to prioritise and ensure workers' safety, health, and well-being. To achieve this, improvements need to be embedded into organisational culture and management practices for long-term sustainability. It's crucial to foster a culture of safety and health prevention through ongoing preparation and effective communication of job-related information (Corvino et al., 2021). This thesis focuses on assessing chemical health risks in the workplace by utilising the quantitative method of indoor air quality (IAQ) assessment in supporting the qualitative method of chemical health risk assessment (CHRA) in evaluating hazards posed to laboratory workers and students in higher academic institutions.

Today, practical laboratory sessions are an integral part of teaching science subjects globally. A key reason for this is that hands-on lab experience allows students to grasp scientific theories and concepts that would otherwise be difficult to understand in their abstract form. Besides helping students to develop a range of skills in science knowledge and conceptual understanding, laboratory classes motivate (inspire) students (or potential future scientists) to develop a scientific attitude (spirit) toward science research. These sessions also provide students with the chance to develop safe and confident handling of chemicals, as well as hands-on experience with chemical equipment (Goh, 2018).

Laboratories in the natural sciences frequently utilize a wide range of chemicals with varying levels of hazard. Chemistry and biology are two fields that heavily rely on the use of chemicals for practical lab sessions and experimental work. These chemicals, whether inorganic or organic, can exist as gases, liquids, or solids. Additionally, they may pose risks such as being corrosive, explosive, highly oxidizing, flammable, harmful, irritating, radioactive, or toxic to humans, while also having the potential to pollute the environment (DOSH, 2017). As a result, students and staff in these laboratories are exposed to numerous chemicals, placing them at a greater risk of potential hazards compared to individuals in other work environments(Abbas et al., 2016; Abdul Samad et al., 2021). For instance, toxic gases, fumes, or liquids can leak from their containers or spill during handling, leading to health issues such as poisoning, cancer, allergies, or respiratory complications if ingested or after prolonged exposure. Acids and bases can irritate or burn the eyes, skin, and respiratory system. Additionally, some chemicals, like anaesthetic gases or lead compounds, are known or suspected to harm foetal development or affect the reproductive health of adults. Some chemicals are highly flammable and can easily catch fire causing fire hazards. Others could be explosive which can explode upon exposure to air or due to mishandling causing explosive hazards. Chemicals also cause catastrophic damage to humans and the environment because of their release to the environment. This occurs because of human error or negligence (e.g. the 1986 Chornobyl nuclear disaster in Ukraine and the Bhopal factory explosion, in India) (Ager et al., 2019; De et al., 2020) or even due to unseen consequences while utilising chemicals in health and agricultural sectors for other purposes (e.g. DDT and CFCs).

Chemical-related accidents in laboratories are more likely to occur among inexperienced employees and students who may not fully understand the risks associated with many of the substances they work with. Even highly experienced individuals can be at risk if safety precautions are not properly followed when handling hazardous chemicals (Ta et al., 2020). Several reports from Malaysia highlight chemical accidents in science laboratories due to improper handling or misuse of chemicals. For example, incidents have been reported across various campuses of the Malaysian research university, such as laboratory fire cases in 2001, 2002, and 2005 (Syed Draman et al., 2010). Another incident also occurred in 2013 at a research university, where a chemistry lab caught fire while students and lab assistants were conducting experiments (Ramli et al., 2020). In 2019, 13 students in Bayan Lepas, Penang accidentally inhaled iodine gas due to inadequate air ventilation in the lab, highlighting the need for proper indoor air quality assessments. Additionally, three other fire-related emergencies were reported in various Malaysian research universities, in 2001, 2002 and 2005 (Al-Zyoud et al., 2019). In another research university in Malaysia, there was one case of occupational poisoning reported back in 2016, 2 cases of occupational poisoning, 1 case of chemical spillage and 1 complaint of chemical odour in 2017 as reported (UKKP, 2017, 2018).

Other than that, reports indicated that 49% of campus accidents in Taiwan are linked to the improper handling of chemicals by users and the misclassification of chemicals in laboratories (Su & Hsu, 2008). A research assistant was killed in a fatal chemical accident in the University of California, Los Angeles' Organic Chemistry lab (Kemsley, 2018). Previous safety inspections of the laboratory also revealed several safety lapses in the laboratory. For example, workers were not using lab coats, flammable liquids were not being stored correctly, and volatile chemicals were not being handled carefully (Adane & Abeje, 2012). In a similar incident, a chemistry professor at Dartmouth College (USA) tragically passed away from mercury poisoning after a small drop of diethyl mercury permeated her latex gloves. It was later determined that the gloves used were unsuitable for handling dimethylmercury

(Lemonick, 2022). In another case from the UK, a researcher was testing the pH of a four-litre container of hazardous waste when the bottle fell and shattered. The researcher slipped in the spilt liquid, hitting his head hard on the floor and soaking one side of his body in the hazardous substance. As a result, he sustained cuts and eye burns.

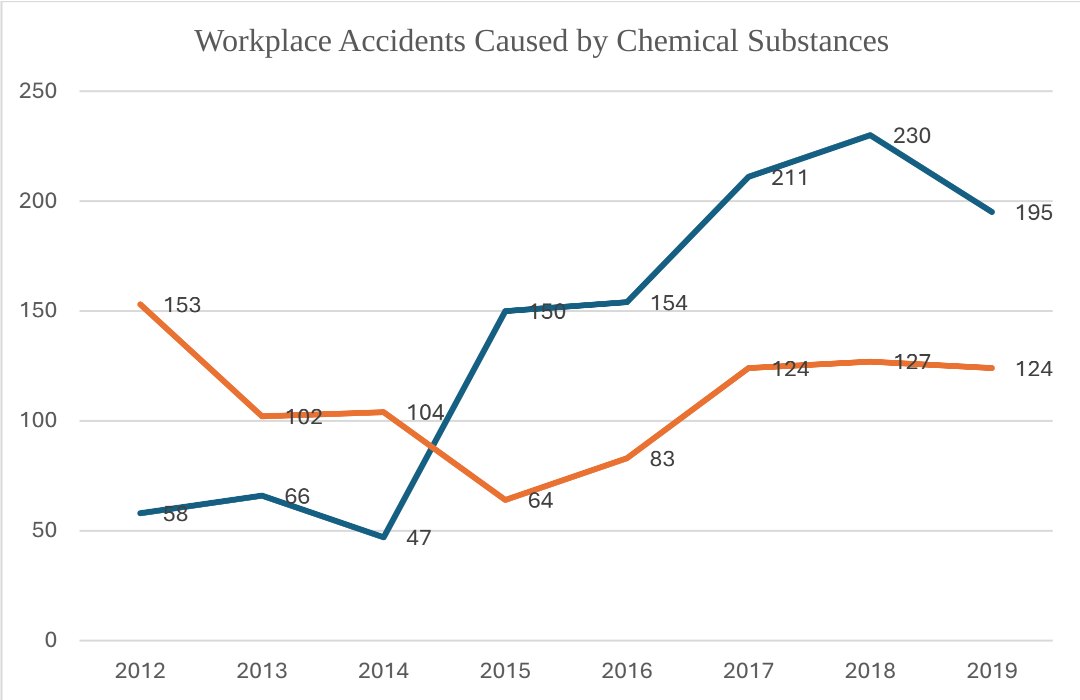

Figure 1.1 Workplace Accidents and Occupational Diseases Caused by Chemical Substances

Figure 1.1 highlights a clear trend of increasing workplace accidents in Malaysia caused by chemical substances between 2012 and 2018, followed by a slight reduction from 2018 to 2019. Over this period, the total workforce in Malaysia experienced significant growth, starting with 5,876,934 workers in 2012 and steadily rising each year—6,089,054 in 2013, 6,198,657 in 2014, 6,376,984 in 2015, 6,597,948 in 2016, 6,803,948 in 2017, 7,077,431 in 2018, and reaching 7,199,814 by 2019 (Kementerian Sumber Manusia, 2012; Pertubuhan Keselamatan Sosial, 2013, 2014, 2015, 2016, 2017, 2018, 2019) . This expansion in the workforce appears to have contributed to the upward trend in chemical-related workplace accidents and occupational diseases, as more workers were exposed to hazardous substances.

Figure 1.1 also reveals the increasing incidence of occupational illnesses linked to chemical substances during the same period, suggesting that hundreds of workers have been impacted by chemical exposure each year. Both trends underscore the significant health and safety risks posed by chemical hazards in Malaysian workplaces, making chemical management and occupational safety critical concerns for industries in the country.

Nevertheless, it would be incorrect to assume that all chemicals are inherently dangerous or hazardous. When handled and used properly, chemicals can be highly beneficial (Abdullateef & Oloduowo Ameen, 2024; Warhurst, 2006). A clear example of this is their valuable role in various research activities and laboratory classes in science disciplines at higher academic institutions. In addition to abiding by the "DOs and DON'TS" rules, it is very crucial to understand the potential hazard of each chemical and its associated labels for safe use and handling. Moreover, these hazardous properties (information) of chemicals must be adequately communicated to various groups of people such as chemical transporters, storekeepers, distributors, users and/or regulating authorities to minimize chemical-related accidents in laboratories, stores and the wider environment (Hara et al., 2007; Kan, 2007; Ryan, 2022).

From the year 2014 – 2023, the Department of Occupational Safety and Health (DOSH) reported a total of 60,914 cases of occupational diseases, with 2,227 of these related to chemicals, including occupational lung disease, skin disease, chemical poisoning, and cancer. Table 1.1 shows reported cases of occupational diseases in Malaysia from 2014 - 2023.

Table 1.1 Reported Cases of Occupational Poisoning and Occupational Diseases of 2014 - 2023

Num.	Reported Occupational Diseases and Occupational Poisoning	Number of Cases Reported										
		2014	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**TOTAL**
i	Occupational Lung Disease	1	8	98	56	70	101	134	32	50	41	591
ii	Occupational Skin Disease	10	29	25	69	33	137	80	67	38	47	535
iii	Occupational hearing loss due to Noise at Workplace	6	36	2876	2478	2465	8997	7941	7253	9180	9455	50687
iv	Occupational Bone-Muscle Problem	38	109	173	126	147	408	237	301	363	361	2263
v	Disease caused by occupational poisoning	0	0	67	44	136	97	110	80	244	303	1081
vi	Disease caused by a physical agent	1	0	2	3	1	9	4	8	3	2	33
vii	Disease caused by a biological agent	0	0	39	23	17	47	583	1987	742	63	3501
viii	Occupational Cancer	0	0	0	0	0	5	1	4	1	9	20
ix	Occupational Psychosocial Disease	7	11	0	5	0	11	3	4	3	0	44
x	Other Occupational Disease	0	0	0	8	2	9	9	5	4	2	39
xi	Non Occupational Disease	9	24	574	0	1276	39	6	81	79	26	2114
	Total	72	217	3860	2812	4147	9860	9108	9822	10707	10309	60914

Under the Occupational Safety and Health Act 1994 (Act 514) as amended by the Occupational Safety and Health (Amendment) Act 2022 (Act A1648), employers are primarily responsible for protecting employees and consumers from the harmful effects of chemicals in the workplace. To fulfil this duty, a chemical health risk assessment (CHRA) must be carried out to identify and assess the risks associated with chemical exposure in laboratories. This process also helps to evaluate whether current safety measures practised by workers and students are adequate (Mohamad Jamil & Mohamad Hanapi, 2024; Mohammad Rohmatullah, 2018).

Compared to spaces like offices, classrooms, and libraries, laboratories are considered high-risk environments due to the presence of numerous hazards, including chemicals and biological substances used in teaching and research. However, there is a lack of research specifically investigating indoor air quality (IAQ) and sick building syndrome (SBS) among laboratory users. Most studies on SBS related to poor IAQ have focused on office buildings (Abu Mansor et al., 2024; Kwong et al., 2019). These studies revealed that poor ventilation and elevated levels of indoor pollutants were significant factors in triggering SBS among office workers (Abu Mansor et al., 2024; Kwong et al., 2019). A study in Malaysia found that despite carbon dioxide (CO_2), carbon monoxide (CO), and total volatile organic compounds (TVOCs) being within acceptable limits, a considerable number of laboratory workers were still vulnerable to SBS (Rasdi et al., 2016; Salvaraji et al., 2022) .

Maintaining a clean and optimal environment in a laboratory is crucial for protecting the health of workers and preserving the integrity of equipment, materials, and samples (Odunayo, 2024; Yau et al., 2012a). Indoor air quality (IAQ) refers to the quality of air inside and around buildings and structures, with an emphasis on the comfort and health of the occupants (*Introduction to Indoor Air Quality | US EPA*, 2023). Maintaining optimal health for laboratory users and ensuring the precision of conducted experiments heavily relies on the quality of air conditioning and ventilation systems. Recent research indicates that the average standard of these laboratory systems might present potential health hazards to those inside (Yogeswaran et al., 2023).

To ensure a clean, secure, and suitable working environment, every laboratory must adhere to the prescribed standard guidelines outlined by the Department of Occupational Safety and Health (DOSH) through the Industry Code of Practice on Indoor Air Quality 2010 (DOSH Malaysia, 2010). Comprehending and managing prevalent indoor contaminants may assist in mitigating hazards and problems related to indoor health.

Scientific methodology is a crucial tool for understanding the techniques used in creating scientific documents like manuscripts, dissertations, or academic projects. This methodology encompasses the study of the necessary methods and instruments for crafting scientific work. The scientific method is a powerful approach to uncovering truths about the world, developing new theories, and validating them empirically. Scientific research involves systematic and thorough investigations aimed at discovering and interpreting facts within a specific context. It can be either qualitative or quantitative.

Qualitative research focuses on understanding a problem in depth rather than quantifying it. The goal of qualitative methodology is to provide detailed and illustrative insights into various aspects of the issue being examined. This type of research explores dimensions of reality that are not easily quantified, emphasizing the understanding and explanation of social dynamics. Qualitative research delves into meanings, motives, beliefs, values, and attitudes, reflecting a deeper layer of relationships and phenomena that cannot be reduced to simple variable measurements (W. M. Lim, 2024a; Maxwell, 2013).

In contrast, quantitative research involves the collection and analysis of numerical data. Typically, large samples are used, which are representative of the population, allowing results to be generalized to a broader context (W. M. Lim, 2024b). Mathematics and statistics play a critical role in analysing and interpreting these results. Quantitative research aims for objectivity and is suitable when variables can be measured and inferred from samples. It employs structured methods and formal tools for data collection, with data gathered systematically and objectively. Numerical data analysis is conducted using statistical methods and software such as SPSS, R, or Stata (Masuadi et al., 2021; Matthew & Sunday, 2014).

1.2 Problem Statement

In Malaysian academic laboratories, hazardous chemicals are commonly used across various disciplines such as science, engineering, and medicine. Past incidents in Malaysian universities, such as laboratory fires, chemical spills, and poisonings, underscore these risks (Al-Zyoud et al., 2019; Ramli et al., 2020; Syed Draman et al., 2010; UKKP, 2017, 2018; Ukkp, 2018). Furthermore, national data reflects ongoing occupational diseases linked to chemical exposure, indicating a persistent challenge in ensuring workplace safety within these environments (Pertubuhan Keselamatan Sosial, 2013, 2014, 2015, 2016, 2017, 2018, 2019, 2020).

However, current practices for evaluating chemical health risks are often limited to qualitative method like the Chemical Health Risk Assessment (CHRA). While CHRA helps identify and categorize risks, it does not account for real-time environmental conditions, such as airborne chemical concentrations, that could influence actual exposure levels. Similarly, Indoor Air Quality (IAQ) assessments are typically conducted in isolation, focusing on general air quality without directly linking findings to specific chemical hazards or occupational exposure risks.

Currently, there is limited study in Malaysia that integrates both CHRA and IAQ methodologies to provide a comprehensive evaluation of chemical health risks in laboratory environments. This happens because CHRA and IAQ are governed by different regulations and code of practices being carried out independently. Furthermore, there is currently no standardized framework in Malaysia to guide the integration of CHRA and IAQ, which adds to the challenge.

This gap in practice and research may lead to incomplete or inaccurate assessments, potentially affecting the safety of laboratory users. Therefore, this study aims to bridge that gap by examining the relationship between CHRA and IAQ methods and determining whether IAQ data can enhance or validate CHRA outcomes. The goal is to develop a more holistic and evidence-based approach to chemical risk assessment that can inform better safety practices and support regulatory improvements in Malaysia's higher education sector.

Current practice in Malaysia is further limited as the Industry Code of Practice on Indoor Air Quality (2010) explicitly excludes laboratories where hazardous chemicals are used for research or analytical purposes, creating a regulatory gap (DOSH Malaysia, 2010). Academic institutions often exhibit poor safety culture and face resource limitations for thorough inspections compared to industrial laboratories, potentially underestimating the risks involved (Wu et al., 2007).

This highlights a significant knowledge gap and a lack of integration between qualitative risk assessment (CHRA) and quantitative environmental monitoring (IAQ) within Malaysian higher academic institutions. Relying solely on qualitative CHRA may not capture the full scope of airborne risks, while standard IAQ assessments do not apply to these specific high-risk laboratory environments. Therefore, this research aims to bridge this gap by exploring the integration of qualitative CHRA methodology with quantitative IAQ assessment. The goal is to develop a more holistic and effective approach to evaluating and managing chemical health risks, ultimately enhancing safety protocols and creating a healthier environment for workers and students in Malaysian academic laboratories.

1.3 Research Objectives

The main objective of this research is to assess the impact of chemical risk exposure towards workers and students of a higher academic institution using Chemical Health Risk Assessment (CHRA) as a qualitative methodology supported by Indoor Air Quality (IAQ) as a quantitative methodology. To achieve the main objective, the objectives below must be achieved which are:

i. To evaluate the level of Action Priority according to CHRA amongst the various academic programs
ii. To assess the level of indoor air quality in the laboratory which was identified as high risk using IAQ as a supporting methodology for CHRA.
iii. To determine if there is a relationship between the IAQ assessment method and the CHRA method when evaluating chemical risk to health.

1.4 Research Questions

To achieve the objectives of the study, below are the research questions to be answered for this study, which are:

i. What are the levels of Action Priority according to CHRA amongst the various academic programs?

ii. What are the levels of indoor air quality in the laboratory which was identified as high risk using IAQ as a supporting methodology for CHRA?

iii. Is there any relationship between the IAQ assessment method and the CHRA method when evaluating chemical risk to health?

1.5 Scope of Study

This study research focuses on assessing chemical health risks and indoor air quality (IAQ) in selected laboratories of a Malaysian higher academic institution. There are no specific types of laboratories determined to be chosen for the purpose of this study. The only criteria determined is that the laboratories chosen must be chemical laboratories that uses chemicals classified as hazardous to health under the Occupational Safety and Health (Use and Standard of Exposure of Chemicals Hazardous to Health) Regulations 2000. The research targets laboratories from a range of academic programs—science, engineering, and medical—to capture variation in chemical use and risk levels across different disciplines.

The first part of the study evaluates the level of chemical health risks using the Chemical Health Risk Assessment (CHRA) method. This involves identifying hazardous chemicals, analyzing work activities, and assessing exposure factors such as duration, frequency, and existing control measures. The study will determine the Action Priority levels for each laboratory, which indicate the urgency and extent of required risk control actions. This helps to establish how well chemical risks are managed across different academic environments.

Next, the study assesses IAQ in laboratories identified as high risk based on the CHRA findings. IAQ monitoring will include the measurement of key parameters such as volatile organic compounds (VOCs), carbon dioxide (CO_2), temperature, humidity, and particulate matter. These parameters provide insight into airborne chemical exposure and ventilation effectiveness. The IAQ assessment supports the CHRA by offering a quantitative view of environmental conditions that may influence chemical health risks.

Finally, the research will examine whether there is a significant relationship between CHRA results and IAQ measurements. This will help determine if IAQ monitoring can be used to support or enhance the outcomes of CHRA, offering a more holistic approach to chemical risk assessment in laboratory environments. By integrating both methods, the study aims to provide a more comprehensive understanding of chemical health risks and propose improved strategies for chemical safety management in academic institutions.

1.6 Research Significance

The findings of this study will be valuable for future researchers in establishing risks involved in different programs of the academic sector especially in science, engineering and medical. It is also hoped that the outcome of this study will be able to help in identifying and analysing the risks that are faced by the workers and students and able to represent different academic programmes of higher learning institutions in Malaysia. This study is expected to determine the level of air quality of various types of chemical laboratories and its relation to chemical risk assessment.

The result of the study is expected to determine if there is any relationship between air quality in the laboratories with hazardous chemicals used in the laboratories. The result of this study will be able to contribute to academic knowledge for future researchers, especially in the field of chemical safety in the Malaysian Higher Academic sector.

1.7 Thesis Organisation

The thesis regarding this study has been divided into three main parts which are Part 1 (preliminary study); Part 2 (Research Analysis and Findings on CHRA and IAQ in laboratories of a local higher academic institution) and Part 3 (Discussions on the analysis and findings of the CHRA and IAQ).

Part 1 of this thesis represents the first three chapters in the thesis, namely Chapter I (introduction); Chapter II (literature review) and Chapter III (methodology). Chapter I is an introduction to the study by touching on the importance of chemistry subjects in higher learning institutions, the occurrence of incidents caused by chemicals around the world, especially in the academic field and the importance of qualitative and quantitative assessment methods. It also explains the hazardous nature of chemicals and the risks associated with them when exposed towards workers and students. The problem statement mentions the occurrence of accidents involving chemicals in academic institutions and the lack of chemical health risk assessment and indoor air quality in chemical laboratories. In this chapter, the research objective, research question and research significance are also discussed.

Chapter II of this thesis is literature review. Previous literature reviews have been made covering the aspects of the study to be presented. Reviews from journals, scholarly books, annual reports, internet sources, articles from local and abroad and papers are also reviewed in this chapter. This literature review provides a perspective on the direction of the study, the elements to be tested and the final picture related to the results of the study. Through the literature review, a conceptual framework that represents chemical safety management in Malaysia in the aspect of occupational safety and health has been prepared. This is used as a guide to the research conducted.

Chapter III of this thesis serves to convey information related to the study methodology. There are four levels of research that have been presented in this chapter. Starting with theoretical research, data and information collection, data analysis and research findings. The research stages that have been identified are a guide in producing a study that is able to answer the objectives and goals of the study and bring positive implications to the academic field and society.

Part 2 of this thesis represents Chapter IV (Research Analysis, Findings and discussions on CHRA and IAQ in laboratories of a university). Chapter IV details the assessment result of CHRA and IAQ which was conducted throughout the chemical laboratories of a university, and it explains the current state of the hazard involved in those chemical laboratories which are currently exposed to the workers. This chapter explains all the results of the study and analysis carried out in this research. Here the results and analysis produced are presented and discussed. Basically, it gives an overview of the situation of the chemical laboratories in an academic institution in general.

The last part of this study is part 3 which is the Chapter V of this thesis which is the conclusion of the whole thesis. In Chapter V, the discussion about the importance of the study and the direction of the study is made as the final word for this study. It is hoped that this thesis can provide positive implications to those responsible towards the safety and health of workers and students working in chemical laboratories of academic institutions. Figure 1.2 below explains the thesis organisation.

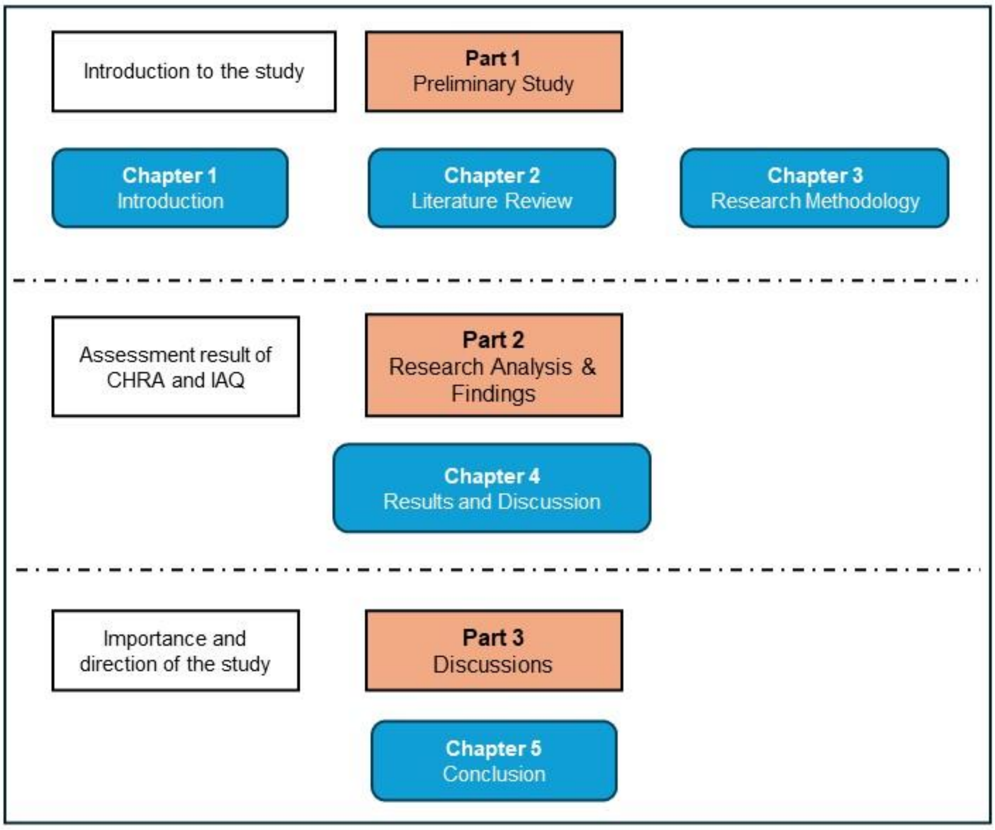

Figure 1.2 Thesis Organisation

1.8 Summary

Higher academic institutions in Malaysia are exposed to various types of hazards present in laboratories, including chemical spills, exposure to toxic substances, and inadequate ventilation, which can lead to serious health issues and accidents. Therefore, workers and students are at risk of getting health risks caused by chemicals. Currently, assessing hazardous chemicals in laboratories is only limited to chemical health risk assessment (CHRA) methodology as required by the Use and Standard of Exposure of Chemicals Hazardous to Health Regulation 2000 (USECHH 2000 Regulation).

This study proposes the importance of both Chemical Health Risk Assessment (CHRA) as a qualitative assessment method supported by Indoor Air Quality (IAQ) as a quantitative assessment method for ensuring the safety and well-being of students, workers, and the environment. The main focus is on the need for a combined approach that integrates the qualitative insights from CHRA with the quantitative data provided by IAQ assessments. This holistic approach aims to better understand and mitigate the risks associated with chemical usage in academic laboratories. The ultimate goal is to enhance safety protocols, improve hazard management, and create a healthier working and learning environment in academic institutions.

The objectives of the study have been determined to answer all the research questions identified to support the call for a more robust and integrated risk management strategy in chemical laboratories, advocating for better implementation of safety measures and more comprehensive risk assessments to protect everyone involved.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter provides an overview of the legislative framework governing chemical safety in Malaysia. It underscores the vital role of implementing robust chemical safety management systems and conducting comprehensive chemical health risk assessments. The chapter further explores the serious consequences and potential hazards that can arise from lacking safety protocols, highlighting the critical importance of adhering to established regulations and practices. Discussion on these legislations will give insight into how chemicals are managed and controlled in Malaysia.

This chapter also discusses and gives insight into what hazards and risks are. Both terms are inter-related and inter-connected. Hence the explanation of both terms will give a better understanding of what they are. It also discusses chemical accidents/ incidents among academic institutions in Malaysia to see the severity of chemical hazards towards this institution.

This chapter also discusses in detail chemical health risk assessment and its importance towards the safety and health of workers. Indoor air quality and its importance towards the safety and health towards the workers are also discussed. Furthermore, the hierarchy of control and conceptual framework were also discussed.

2.2 Malaysian Higher Academic Institution

The Malaysian higher academic system traces its origins back to the founding of the Medical College in Singapore in 1905, which eventually evolved into the

University of Malaya in 1962. Since then, there are over 500 higher academic institutions including 20 public universities have been established, with campuses set up in nearly every state across the country (Hussein, 2014; Kementerian Pengajian Tinggi, 2024; Wan, 2017). There are 20 public universities, 36 polytechnic, 105 university colleges and 390 private higher academic institutions (Kementerian Pengajian Tinggi, 2024).

The public universities are categorized into 3 groups which are Research Universities, Comprehensive Universities and Focused Universities. To date, there are 5 research universities, 4 comprehensive universities and 11 focused universities (Kementerian Pendidikan Tinggi, 2021).

Malaysian higher academic institutions are governed by regulations and guidelines set forth by the Ministry of Higher Education and other relevant governments such as the Department of Occupational Safety and Health (DOSH). The key legislative framework governing occupational safety and health in Malaysia is the Occupational Safety and Health Act 1994 (Act 514) as amended by the Occupational Safety and Health (Amendment) Act 2022 (Act A1648). This legislation requires employers to ensure a safe and healthy working environment for the employees, which encompasses the appropriate handling, storage, and disposal of hazardous chemicals, along with the execution of chemical health risk assessments and management strategies.

Higher academic institutions are well-known to be centres for learning, research, innovation, and services that take place daily. These institutions offer a variety of academic programs, including undergraduate and postgraduate degrees across multiple disciplines. Students are involved in lots of activities such as lectures, seminars, laboratory experiments, and fieldwork as part of their curriculum.

Ensuring sound chemical management in academic laboratories involves several key components such as effective risk assessment methods, such as Chemical Health Risk Assessment (CHRA) and Indoor Air Quality (IAQ) assessment; the establishment of a strong safety culture; regular safety training; and continuous monitoring and inspection at workplaces. Integrating all these components will be able to ensure the safety of academic laboratories.

2.3 Malaysia Legislation on Chemical Safety

In Malaysia, chemical safety regulations were first established with the Factory and Machinery Act (FMA) of 1967. This act included various regulations such as the Mineral Dust Regulations (1989), the Asbestos Regulations (1986), the Safety, Health, and Welfare Regulations (1970), and the Lead Exposure Regulation (1984) (Shazwani Omar et al., 2019; H. Yon, 2022). However, these regulations primarily focus on specific chemicals used in factories and quarries and fall short of ensuring comprehensive safety for workers exposed to chemicals (Shazwani Omar et al., 2019). They also do not extend to non-factory workplaces.

Significant updates occurred with the introduction of the Occupational Safety and Health Act in 1994 (H. Yon, 2022). In the year 1997, the Occupational Safety and Health (Classification, Packaging, and Labelling) Regulation was introduced to establish a comprehensive legal framework for the labelling, classification, and packaging of hazardous chemicals. This regulation is designed to address the physical-chemical properties and health impacts of these substances, ensuring that they are correctly categorised and communicated to minimize risks and enhance safety in the workplace.

The Occupational Safety and Health (Use and Standard Exposure of Chemicals Hazardous to Health) (USECHH) Regulation was implemented in the year 2000. This regulation aimed to establish guidelines for employers on managing hazardous chemicals, setting exposure limits, and ensuring the safety and health of employees against chemical hazards to the extent possible (DOSH Malaysia, 2000). Under this regulation, hazardous chemicals are listed as “chemicals hazardous to health”, as illustrated in Table 2.1.

Table 2.1 Chemicals listed as chemicals hazardous to health under the USECHH 2000 regulation

	Chemicals Hazardous to Health
I	listed in Schedule I or II of the regulation
II	Classified in any hazard class classified under the Health Hazards of the First Schedule of the CLASS Regulations 2013
III	comes within the definition of "pesticide" under the Pesticides Act 1974 [Act 149]
IV	listed in the First Schedule of the Environmental Quality (Schedule Wastes) Regulations 1989.

2.3.1 Occupational Safety and Health Act 1994 (Act 514)

Malaysia's Occupational Safety and Health Act (OSHA) was introduced in 1994, marking a significant step forward in enhancing the country's effort to secure occupational safety and health at the workplace. This act represented an upgrade from previous legislation, with a broader scope of protection for all workers, in contrast to the more limited coverage under the Factory and Machinery Act (1967). The

Occupational Safety and Health Act (1994) placed a strong emphasis on establishing a national tripartite advisory body to enhance collaborative efforts in workplace safety. It outlines the obligations of employers to safeguard their workers, delineates the responsibilities of manufacturers, importers, and suppliers concerning equipment safety, and requires the establishment of safety and health committees, alongside the appointment of designated safety and health officers.

Under the OSHA (Act 514), Malaysia embraced Roben's principle as the guiding philosophy, which says that "*The primary responsibility for safety and health at work lies with those who create the risks and those who work with them*". Responsibility for safety and health at the place of work has now shifted to the management level. This approach underscores the importance of an efficient "internal responsibility" approach, where the organisation takes a proactive leadership role while actively involving employees in safety and health initiatives. Simultaneously, the government will establish the legal framework by setting the goals to be met, while leaving the methods of achieving them to the discretion of the organisation.

At present, the Department of Occupational Safety and Health (DOSH) of Malaysia, which operates under the Ministry of Human Resources, is given the responsibility of upholding occupational safety and health regulations. Its objective is to ensure the safety, health, and well-being of workers and to shield others in the workplace from dangers related to occupational activities across diverse sectors. DOSH’s enforcement efforts are guided by three primary legislations: Occupational Safety and Health Act 1994 (Act 514) as amended by the Occupational Safety and Health (Amendment) Act 2022 (Act A1648), the Petroleum Act (Safety Measures) (1984) and the Factories and Machinery Act (1967).

At the national level, the Ministry of Human Resources holds the responsibility for overseeing the formulation, implementation, and enforcement of occupational safety and health policies. This ministry also oversees the function of the National Institute of Occupational Safety and Health (NIOSH), which serves as the principal institution for training on occupational safety and health (Kementerian Sumber Manusia, 2012). Under the purview of the Ministry of Human Resources, two other key organisations are involved in occupational safety and health: the Department of Occupational Safety and Health (DOSH), which is responsible for regulatory enforcement; and the National Council of Occupational Safety and Health (NCOSH), which functions as an advisory body, offering expert guidance on occupational safety and health issues to the ministry.

2.3.2 Occupational Safety and Health (Use and Standard Exposure of Chemicals Hazardous to Health) Regulations 2000

Awareness of the significance of chemical safety has grown steadily following the enactment of the Occupational Safety and Health (Use and Standard Exposure of Chemicals Hazardous to Health) Regulations 2000. Nevertheless, the persistence of occupational poisoning, hazardous incidents, accidents, and related diseases suggests that the degree of understanding and implementation of chemical safety measures remains inadequate. Despite regulatory advancements, the ongoing occurrence of such incidents indicates that the full significance of chemical safety may not yet be fully comprehended or effectively addressed within various sectors (Kavalela et al., 2019).

On 4th April 2000, a regulation under the Occupational Safety and Health Act (1994), which is known as the Occupational Safety and Health (Use and Standard Exposure of Chemicals Hazardous to Health) Regulations 2000, was enacted. This regulation establishes a legal framework that enables employers to effectively manage and control hazardous chemicals within the workplace (Aznan et al., 2019). Following its implementation, several guidelines were published to assist with the implementation of the USECHH 2000 regulations. The provisions of the regulation are:

a. Identification of chemicals hazardous to health
b. Permissible exposure limit
c. Assessment of risk to health
d. Action to control exposure
e. Labelling and relabelling
f. Information, instruction, and training
g. Monitoring of exposure at the place of work.
h. Health surveillance
i. Medical removal protection
j. Warning sign
k. Record keeping

The USECHH 2000 Regulation specifies the necessary actions to decrease chemical risks in the workplace (Aznan et al., 2019; H. Yon, 2022). Over 600 hazardous chemicals are listed under Schedule I of the regulation along with their permissible exposure limits (PELs) (Appendix I). Additionally, 34 other hazardous chemicals, primarily heavy metals and solvents are also listed under Schedule 2 (Appendix II) of the regulation which requires workers to undergo medical surveillance when deemed appropriate by a Chemical Health Risk Assessment (CHRA). The regulation requires employers to conduct the assessment.