# BASELINE SURVEY ON THE USE AND MANAGEMENT OF HAZARDOUS CHEMICAL SUBSTANCES AT A CHEMISTRY DEPARTMENT IN A SELECTED HIGHER EDUCATION INSTITUTION IN GAUTENG PROVINCE

by

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**DECLARATION**

I declare that this dissertation entitled '**BASELINE SURVEY ON THE USE AND MANAGEMENT OF HAZARDOUS CHEMICAL SUBSTANCES AT A CHEMISTRY DEPARTMENT IN A SELECTED HIGHER EDUCATION INSTITUTION IN GAUTENG PROVINCE'** is my own work and that all the sources that I have used or quoted have been indicated and acknowledged by means of complete references, and that this work has not been submitted before for any other degree at any other institution.

20 February 2015

**SIGNATURE** **DATE**

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**BASELINE SURVEY ON THE USE AND MANAGEMENT OF HAZARDOUS CHEMICAL SUBSTANCES AT A CHEMISTRY DEPARTMENT IN A SELECTED HIGHER EDUCATION INSTITUTION IN GAUTENG PROVINCE**


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## ABSTRACT


**Background:** The aim of this study was to investigate the use and management of hazardous chemical substances (HCS) at a chemistry department in a selected Higher Education Institution in Gauteng province.

**Method:** A quantitative, baseline descriptive study was conducted using a structured survey checklist. The population consisted of the chemistry department. Other than purposive observation by the researcher, employees present during data collection were approached for further clarifying comment to survey questions.

**Results:** It emerged that physical-, health- and environmental hazard classes of HCS were present; and that hazard types included flammable liquids, HCS with acute toxicity and carcinogenicity. Selected exposure control measures were lacking which created risks of fire and explosion.

**Conclusion:** The study reflected the use and management of HCS, the actual and potential human exposure and the exposure control measures. Varying degrees of compliance were found, which, if attended to, should mitigate risks to health and safety.



**Key terms**

Hazardous chemical substances; chemistry department; laboratory; hazard; risk; survey; higher education institution.

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## *Dedication*

I dedicate this work to my mother, who selflessly sacrificed career for children.

*Ma, jy kon ‘n M met gemak gedoen het. Hierdie een is vir jou.*

# TABLE OF CONTENTS

## CHAPTER 1

## ORIENTATION TO THE STUDY

# CHAPTER 2

# LITERATURE REVIEW

## CHAPTER 3

## RESEARCH METHODOLOGY

## CHAPTER 4

## ANALYSIS, PRESENTATION AND DISCUSSION OF RESEARCH FINDINGS

# CHAPTER 5

# SUMMARY, CONCLUSIONS, RECOMMENDATIONS AND LIMITATIONS OF THE STUDY

# LIST OF TABLES

# LIST OF FIGURES

# LIST OF ANNEXURES

# CHAPTER 1

# ORIENTATION TO THE STUDY

## 1.1 INTRODUCTION

This chapter provides an orientation to the study by first outlining the context of the research problem and the background thereto, and then describing the actual research problem. A discussion of the aim of the study takes account of its research purpose and objectives. The significance of the study and its value to the study field are also highlighted. The research design and the methodology followed in the study include the population, the sample, data collection and, finally, an analysis.

The International Labour Organization (ILO) and the World Health Organization (WHO) have jointly defined the aims of occupational health as "the promotion and maintenance of the highest degree of physical, mental and social well-being of workers in all occupations; the prevention among workers of departures from health caused by their working conditions; the protection of workers in their employment from risks resulting from factors adverse to health; the placing and maintenance of workers in an occupational environment adapted to their physiological and psychological capabilities; and, to summarise, the adaptation of work to man and each man to his job" (ILO 2008:22). It is against this background that the proposed study will be conducted in a chemistry department of a selected higher education institution (HEI) in order to investigate the use and the management of hazardous chemical substances (HCS).

In South Africa, the amended Occupational Health and Safety Act 85 of 1993 (hereafter referred to as OHSA) regulates health and safety at work. The Hazardous Chemical Substances Regulations GNR 1179 of 1995 (OHSA Regulations) further prescribe the required measures to protect persons from the intake of an HCS at work (OHSA Regulation 1995:3). The OHSA requires employers to bring about and maintain, as far as reasonably practicable, a work environment "that is safe and without risk to the health of his [*sic*] employees" (OHSA 1993:8). The implication is that the employer must ensure the prevention of workplace risks of hazardous substances, equipment and processes that may cause occupational injury, damage, disease or ill health to workers. Where the latter is not possible, the employer must inform workers of the hazards and risks present in the workplace. The employer must also educate employees on how to prevent or control exposure to hazards, and how to work safely. The employer, therefore, has to provide protective measures for a safe workplace (OHSA 1993:8).

The WHO and the International Programme on Chemical Safety (IPCS) (2004), in their occupational risk management toolbox (enlisting control banding as a qualitative risk assessment instrument), provide the vehicle to prevent and control hazards. The toolbox explores scientific knowledge and various exposure types of occupational hazards to design measures that will control exposures adequately. The focus is more on controlling the hazard and less on quantifying it, which enables a wide scope of application (WHO/IPCS 2004d:1). Thus, the prevention and the control of most occupational chemical hazard risk elements are achievable by way of optimal risk assessment, risk prevention and risk reducing measures.

## 1.2 BACKGROUND INFORMATION ABOUT THE RESEARCH PROBLEM

### 1.2.1 The source of the research problem

In South Africa, the OHSA Regulations govern the assessment of potential HCS exposure of employees at workplaces. A *hazardous chemical substance*, according to the OHSA Regulations, means any toxic, harmful, corrosive and irritant, or a mixture of such substances for which an occupational exposure limit is prescribed; or for which an occupational exposure limit is not prescribed, but which creates a hazard to health (OHSA Regulation 1995:2).

The World Health Organization (WHO 2006a:4) reports that almost 25% of the global burden of disease and 23% of all deaths can be attributed to environmental factors *that can be averted*, including exposure to hazardous chemicals. *Unintentional injuries* are one of the four largest global disease burden factors and they include workplace hazards. A total of 44% of these injuries could be ascribed to environmental reasons. An excerpt from the WHO publication, *Comparative Quantification of Health Risks* (2010), verifies this fact by stating that the primary occupational cause for death among six occupational risk factors studied was unintentional injuries at 41%. This figure is followed by Chronic Obstructive Airway Disease (COPD) at 40% and cancer of the airway (13%) (WHO 2010a:1652).

In a systematic review of known estimates on the global burden of disease attributable to *chemicals,* in particular, the focus is on hazardous exposures to chemicals "which can be significantly reduced or eliminated through environmental and occupational management" (Prüss-Ustün, Vickers, Haefliger & Bertollini 2011:1). Unintentional, acute, occupational poisonings that involved chemicals accounted for 8.6% of the 2004 figure. Longer latency effects of occupational chemical exposures included COPD at 13% and cancer of the airway at 8.6%. The 4.9 million deaths per year signify 8.3% of total deaths globally. Prüss-Ustün et al (2011:11) further report that the 2020 goal of the World Summit on Sustainable Development to minimise the major adverse effects of chemicals on human health and the environment has not yet been achieved. The known burden is considerable, yet underestimated, and should be largely preventable through impact risk management (Prüss-Ustün et al 2011:13).

The Global Occupational Health Network (GOHNET) (WHO 2007/2008:2) stipulates that a healthy laboratory should not present any avoidable risk to the physical, psychological and social well-being of the employees/workers and should allow them to strengthen and promote their health. Improving the health of workers requires a comprehensive approach to the protection and promotion of health at work, including control of occupational hazards, development of an enabling physical, psychological and social working environment as well as promoting healthy behaviour.

Notwithstanding the requirements for a healthy laboratory, employees are exposed to chemicals. Franken, Du Plessis, Eloff, Laubsher and Van Aarde (2010:2) find that employees are exposed to a number of chemicals for extended periods, and these employees are not completely informed of the risks involved in working with the hazardous substances. There is a general lack of awareness and concern about employee health and safety in the workplace, especially in laboratories. This fact is corroborated by the United States Department of Labor's Occupational Safety and Health Administration (US-OSHA) in their *Occupational Exposure to Hazardous Chemical Substances in Laboratories* standard fact sheet: "Hazardous chemicals present physical and/or health threats to workers in … academic laboratories" (US-OSHA 2011c:1).

Underscoring the presence of hazardous chemicals in academic laboratories, Raja and Sultana (2012:36) note that during gross dissection in anatomy laboratories, anatomy lecturers, technicians and students are regularly exposed to the toxic effects of formaldehyde, a hazardous chemical. Exposure effects from inhalation may result in pulmonary oedema and nasal cancer, skin contact may cause severe allergic dermatitis and the teratogenic outcome is well documented (Raja & Sultana 2012:37).

Furthermore, it is noteworthy that the Chemical Safety and Hazard Investigation Board (CSB) finds in its case study on a fatal chemical detonation in a university laboratory (CSB 2011:2), that the *health* hazards of chemicals have been addressed in the national (US-OSHA) laboratory standard at the cost of the *physical* hazards of chemicals. Fortunately, global systems have been developed in the recent past to improve the integrated management of chemicals and ensure safety for humans and the environment.

In a much needed endeavour to harmonise global classification systems for hazardous chemicals, the United Nations (UN), at its 1992 United Nations Conference on Environment and Development, commenced work. *The Globally Harmonized System of Classification and Labelling of Chemicals* (GHS) was the resulting publication by the United Nations Economic Commission of Europe (UNECE) (UN 2013:iii). The fifth revised, comprehensive edition was published in 2013. GHS records that chemical products are used worldwide to enhance human life; however, chemicals may negatively affect people and the environment as unintended consequences. GHS aims to harmonise the global criteria for classifying chemical substances and mixtures in order to protect human health and the environment (UN 2013:3). The GHS classification provides for three chemical hazard *classes* that depict the nature of chemical hazards, whether health (such as carcinogens), physical (such as a flammable solid) or environmental (such as acute aquatic toxicity). A hazard *category* is assigned within a hazard class to denote severity (UN 2013:12). The physical state of a chemical refers to the naturally occurring form, being it a gas, liquid or solid. The GHS has the potential for global application and provides for the greater safeguarding of human health. It similarly provides for a recognised structure to communicate hazard in trade by providing uniform labelling and material safety data sheets, even in countries where no system exists (UN 2013:3).

The WHO, through its International Programme on Chemical Safety (IPCS), wishes to establish the sound management of chemicals and chemical safety. Human health should be safeguarded from exposure during all contact points, from extraction, transport and use to disposal. The aim of the IPCS Harmonization project is to collate global action on chemical risk management and, in this way, to contribute to the Strategic Approach to the International Chemicals Management (SAICM) movement. SAICM further addresses the objective of the WHO Global Plan of Action 2008 – 2017 to "develop and use new and harmonized methods for risk assessment" (WHO 2010d:3).

Furthermore, in the WHO publication, *Preventing Disease through healthy Environments* (WHO 2006c:3), the director of Public Health and Environment calls for the "more judicious use and management of toxic substances in the home and workplace" and notes that measures to mitigate risk can be implemented immediately to reduce the environmental burden of disease. A prime consequence of all measures that address environmental risks and exposures, including occupational chemical hazards, may be an enhanced quality of life, education and employment. These outcomes will correspondingly support the Millennium Development Goals (WHO 2006c:5).

Little is generally known about the occupational health needs of employees in academic chemistry departments in South Africa, despite the hazard risks and complexities involved in chemical handling and exposures. Therefore, the current study seeks to address this gap through investigating the use and management of HCS among workers of a chemistry department in an Higher Education Institution (HEI) in the Gauteng province.

### 1.2.2 Background to the research problem

Approximately 2.34 million workers are estimated to die annually from occupational or work-related injuries and disease, of which the majority (2.02 million every year) from occupational disease, such as pneumoconiosis (ILO 2013a:Director-General Guy Ryder's text message on World Day for Safety and Health at Work. 28 April 2013). This is relevant to the current study given that exposures to Hazardous Chemical Substances (HCS) among workers at academic chemistry laboratories could include adverse health and physical effects, particularly where adequate control measures are not in place. Consequently, it might lead to occupational injuries and diseases among workers who are exposed to such hazards.

## 1.3 RESEARCH PROBLEM

Literature has shown that there is an emerging higher prevalence of accidents as a result of exposures to HCS at academic research laboratories in American universities (Basken 2012:1). The United States Chemical Safety and Hazard Investigation Board (CSB) also conducted a study following an incident at a Texas Tech University laboratory in 2011 where a student was seriously injured when a chemical detonated during research in a laboratory. The outcome of the study uncovered a lack in risk assessment and in the mitigation of the physical hazards of chemicals. Furthermore, the HEI did not provide sufficient oversight and safety management accountability and no records were kept of previous near-miss incidents (CSB 2011b:2). *Significantly, findings from the CSB's case study serve as a call to HEIs to examine internal safety policies and procedures for research laboratories in order to ensure the health and safety of workers in these settings.*

The findings from the CSB study should alert HEIs in South Africa. Although it is accepted that business at an HEI is mainly administrative in nature, the scope of chemical occupational health hazards and risk present at research laboratories is wide, given that a substantial variety of hazardous chemical substances are procured, stored, decanted, transported and used for research purposes at a chemistry department.

Workers in the chemistry department at the targeted HEI are thus potentially exposed to HCS, which present physical and/or health hazards (US-OSHA 2011b:9). Physical hazards, according to the GHS (UN 2013:41), include explosives, pyrophoric substances, oxidizing liquids and flammable gases, while health hazards (UN 2013:109) comprise, *inter alia,* carcinogenicity, mutagenicity, reproductive toxicology, skin corrosion and acute toxicity.

Notably, a critical need exists to investigate the health and safety of HCS used in chemistry laboratories to prevent the occurrence of work-related injuries and diseases among workers exposed to chemical hazards and to promote their health and safety at work. Similarly, the OHSA sets out the general requirements for protecting the health and safety of workers in workplaces and it is crucial that every organisation complies with the OHSA and its regulations. It, therefore, places the responsibility for health and safety compliance on employers and employees. In the light of the provisions made in the OHSA to protect and promote the health and safety of workers, the researcher identified the need to conduct a baseline survey on the use and management of hazardous chemical substances in the chemistry department of a selected HEI in the Gauteng province of South Africa.

## 1.4 AIM OF THE STUDY

The aim of this study is to investigate the use and management of hazardous chemical substances at a chemistry department in a selected higher education institution in the Gauteng province.

### 1.4.1 Research objectives

The objectives of the current study are to:

- Identify and describe the types and forms of hazardous chemicals used at the chemistry department of the selected HEI in the Gauteng province.
- Examine exposure to hazardous chemical substances (actual and potential) among workers at the chemistry department of the selected HEI in the Gauteng province.
- Conduct an inspection of the physical working environment and the conditions at the chemistry department of the targeted HEI.
- Assess the exposure control measures (hazard management) implemented at the chemistry department of the targeted HEI.

## 1.5 SIGNIFICANCE OF THE STUDY

The value of the proposed study will include the design of a chemical inventory, which will align each identified HCS used and managed at the chemistry department with its corresponding Occupational Exposure Limit, its hazard classification and its toxicological effects. The actual and potential exposures to HCS at the chemistry department will be determined. This study will further provide a description of the prevailing working environment and the conditions therein, including an assessment of implemented exposure control measures at the chemistry department. The aforementioned is significant because it will contribute to legal compliance with the OHSA and the OHSA Regulations, yet exceed this minimum requirement by gleaning from lessons learned after incidents at other HEIs and from advanced standards and systems globally. The findings would also provide a valuable view on the use and management of HCS in one of the largest HEIs in South Africa.

## 1.6 DEFINITION OF TERMS

### 1.6.1 Employee

An employee is described in the OHSA (1993:3) as "any person who is employed by or works for an employer and who receives and is entitled to receive remuneration or who works under the direction or supervision of an employer or any other person". In this study, employee refers to an academic, technician or administrative employee at the chemistry department of the Higher Education Institution who conducts any act of work according to the contract of employment.

### 1.6.2 Exposure

Exposure in the OHSA Regulation (1995:1) means "exposure to an HCS whilst at the workplace". In this study, the primary focus is exposure; however, *exposure* may take account of exposure to all occupational health risks, such as noise, dust, ergonomic and psychosocial stressors.

### 1.6.3 Hazard

The term 'hazard' refers to a "source of or exposure to danger" (OHSA 1993:3). In this study, a hazard refers to the physical, chemical, ergonomic and biological environmental agents and conditions present at the chemistry department that may cause exposure health effects.

### 1.6.4 Hazardous chemical substances (HCS)

"Hazardous chemical substances refer to any toxic, harmful, corrosive, irritant or asphyxiant substance or a mixture of such substances for which

(a) an occupational exposure limit is prescribed; or
(b) an occupational exposure limit is not prescribed, but which creates a hazard to health" (OHSA Regulations 1995:2).

In this study, hazardous chemical substances refer to all chemical substances stored and used in the chemistry department of the targeted HEI.

### 1.6.5 Health and safety standard

The terms 'health and safety standard' refers to the "code of practice, irrespective of whether or not it has the force of the law, which, if applied for the purposes of this law, will in the opinion of the Minister promote the attainment of an object of this Act" (OHSA 1993:3). In this study, a standard refers to international and South African codes of practice, legislation and ethics that have relevance to occupational health and safety practices at an HEI.

### 1.6.6 Higher Education Institution (HEI)

Higher education institution means any institution that provides higher education on a full-time, part-time or distance basis and which is –

(a) established or deemed to be established as a public higher education institution under the Higher Education Act 101 of 1997 (HEA)
(b) declared as a public higher education institution under this Act
(c) registered or conditionally registered as a private higher education institution under this Act (HEA 1997:4)

In this study, the study site is the chemistry department at a large public Higher Education Institution in the Gauteng province, South Africa.

### 1.6.7 Intake

Intake means the inhalation, ingestion, skin absorption or absorption through the mucous membranes (OHSA Regulation 1995:2).

### 1.6.8 Medical surveillance

Medical surveillance refers to a planned programme or periodic examination (which may include clinical examinations, biological monitoring or medical tests) of employees by an occupational health practitioner, or, in prescribed cases, by an occupational medicine practitioner (OHSA 1993:4). In this study, medical surveillance refers to the programme, which may include biological monitoring, or the medical examination conducted by an occupational health nursing practitioner or an occupational medicine practitioner on an employee at risk of hazardous workplace exposures.

### 1.6.9 Occupational health

The OHSA determines that occupational health includes occupational hygiene, occupational medicine and biological monitoring (OHSA 1993:4). The joint WHO/ILO declaration on occupational health includes the prevention of occupational injuries and diseases as well as health promotion within the established definition of occupational health (ILO 2008:22).

In this study, occupational health refers to medical and nursing practice by occupational health practitioners in an occupational environment at an HEI, wherein the prevention of injuries and disease, as well as health promotion is pursued.

### 1.6.10 Risk

Risk refers to the probability that injury or damage will occur (OHSA 1993:5). In this study, a risk refers to the likelihood of occupational exposure to physical, chemical, ergonomic and biological environmental agents and conditions that academic, technical and administrative employees in the chemistry department may experience in the workplace, which may cause injury or disease.

### 1.6.11 Workplace

Workplace refers to any premises or place where a person performs work in the course of his or her employment (OHSA 1993:6). In this study, a workplace refers to the chemistry department at the HEI within which an academic or a support employee conducts any act of work according to the contract of employment.

## 1.7 RESEARCH DESIGN

### 1.7.1 Research paradigm

Creswell (2009:6) defines a paradigm as a "basic set of beliefs that guide action". In this research, the quantitative approach was used, because it is a research paradigm in which statistical measures of observations can be developed, as explained in Creswell (2009:7). The study is quantitative in nature and comprises an inspection to investigate the use and management of various types and forms of hazardous chemical substances in the study site.

### 1.7.2 Research design

A quantitative observational descriptive survey was used in this study. The researcher conducted walk-through inspections at the chemistry department of the selected HEI by using a checklist. In addition, workers in the chemistry department were consulted to verify some of the information required for this study.

## 1.8 RESEARCH METHODOLOGY

### 1.8.1 Population

All workers at the chemistry department at the HEI were included as target population for this study. Workers who formed part of the study population included lecturers (and researchers), laboratory technicians who were responsible for the maintenance of equipment, and administrative staff who executed office administration and procurement.

### 1.8.2 Sampling procedure

The study site was purposively sampled and the survey was conducted in one department (as there is only one chemistry department at the targeted HEI that deals with hazardous chemical substances).

### 1.8.3 The sample

The sample consisted of employees at the chemistry department at the targeted HEI who were present and responded to checklist enquiries during site sampling.

### 1.8.4 The research setting

This study was undertaken within the chemistry department of a selected HEI in the Gauteng province, South Africa. A chemistry department was selected because it embodies a wide range of hazards and risks associated with an academic laboratory at the HEI in South Africa. The HEI was selected as a research setting due to the advanced nature and scope of research involving HCS, which implied the presence, use and management of chemicals.

The Council of Higher Education (CHE) classifies the selected HEI in Gauteng as one of the six comprehensive universities in South Africa (CHE 2011:76) and the HEI strives for global excellence and stature.

### 1.8.5 Data collection method

The researcher conducted an inspection of the environmental risks and hazards as well as of the use and management of HCS in the chemistry department at the selected HEI by observing the practices by means of a checklist that had been pre-designed. The checklist was adapted from the regulation for HCS (incorporating both the international and local perspectives) as prescribed in the ILO guidelines and the OHSA. The focus of the inspection was to investigate the use and management of HCS in the study site.

The checklist enabled the researcher to identify the nature of chemical substances being used as well as the level of risks associated with hazardous chemicals and the level of exposures among workers. The checklist also allowed the researcher to record observations made during an inspection of the physical working environment and the prevailing conditions. Workers from the chemistry department who were available at the time of the inspection were requested to provide information for verification purposes.

The overall compliance with OHSA control measures was scored by using the ratings from observations and the inspection by means of ‘Yes’ or ‘No’ answers. The checklist was divided into eight sections, namely: written safety procedures; employee awareness and training; general emergency preparedness; laboratory conditions; hazardous material safety; hazardous chemical waste management; personal protective equipment; and occupational health.

No personal and social information was collected from human data sources and neither physical examination nor any form of treatment was conducted. Field workers were not used to collect data.

Ethical principles that were applied included maintaining confidentiality of all information obtained from conducting the inspection survey and ensuring anonymity by not disclosing the institution’s name even during the publication of findings. Workers who were present during the inspection survey were requested to provide information for clarification purposes and voluntary verbal informed consent was obtained from them.

Furthermore, the researcher maintained a high level of professional integrity during the execution of the study through high ethical standards of honesty and fairness when presenting findings, showing respect for workers who provided the necessary information and committing to the values of the targeted institution.

In order to get approval to conduct the research, it was necessary to get permission from three parties. Firstly, the Higher Degrees Committee of the Department of Health studies at the University of South Africa granted ethical clearance approval. Secondly, the Registrar of the HEI where the study was conducted also granted permission prior to the study being executed. Lastly, permission was also requested and obtained from the Head of the chemistry department where the study was conducted.

#### *1.8.5.1 Data collection process*

The researcher obtained approval from the chemistry department to conduct the site visit on 11, 12 and 13 November 2013. During the site visits, the researcher used the survey checklist to observe the current practices regarding the use and management of HCS at the chemistry department. Information was requested from workers in the chemistry department at the time of the site visits to clarify selected questions. In some instances, substantiating documents related to survey questions were requested. The departmental secretary supplied demographic information and the head of the chemistry department provided information on the types and forms of HCS.

### 1.8.6 Data analysis

Data were analysed by means of SPSS Version 18.0. A coding system was developed for data to be entered into a computer for subsequent processing and analysis. Data were checked, cleaned and entered into MS Excel and then imported into SPSS Version 18.0 for statistical analysis. Descriptive statistics, including mean, median and standard deviation, was used to calculate frequencies and percentages for various elements under study.

## 1.9 ABBREVIATIONS

| | |
|---|---|
| ACL | Academic Chemistry Laboratory |
| GHS | Globally Harmonized System of Classification and Labelling of Chemicals |
| HCS/HCS | Hazardous Chemical Substance/s |
| OHSA Regulations | Hazardous Chemical Substances Regulations GNR 1179 of 1995 |
| HEI/HEIs | Higher Education Institution/s |
| ILO | International Labour Organization |
| IPCS | International Programme on Chemical Safety |
| MSDS | Material Safety Data Sheets |
| OHSA | Occupational Health and Safety Act, No 85 of 1993, as amended |
| PPE | Personal Protective Equipment |
| SOP | Standard Operating Procedures |

| | |
|---|---|
| US-US-OSHA | United States Department of Labor Occupational Safety and Health Administration |
| UNECE | United Nations Economic Commission of Europe |
| WHO | World Health Organization |

## 1.10 SCOPE AND LIMITATIONS OF THE STUDY

The study was confined to one HEI located in the Gauteng province. The findings are limited to one setting and cannot be generalised to all HEIs in the country. However, findings of the current study could provide a snapshot of the occupational health and safety status regarding the use and management of hazardous chemical substances in HEIs locally.

## 1.11 STRUCTURE OF THE DISSERTATION

**Chapter 1:** This chapter introduces the study and provides background information about the research problem and explains the purpose, objectives and significance of the study. Operational definitions are included and the research design and methodology are discussed. Attention is given to abbreviations, the scope and limitations of the study and ethics in research. Finally, the structure of the dissertation is explained and the chapter is concluded.

**Chapter 2:** This chapter provides the findings of the reviewed literature to contextualise the study.

**Chapter 3:** This chapter explicates the research purpose, objectives, design and methodology. In clarifying the research method, the sampling procedure, sample, data collection and the instrument are also mentioned. The ethical considerations pertaining to data collection and data analysis are included. The scope and limitations of the study are highlighted and internal and external validity is discussed.

**Chapter 4:** This chapter deals with the presentation and discussion of research findings.

**Chapter 5:** This chapter concludes the study by proposing recommendations emanating from the research findings. The limitations of the study are finally discussed.

## 1.12 CONCLUSION

In this chapter, the orientation towards the research study was outlined. The themes included the research problem and the aim of the study, which were evident in the research purpose and the research objectives. The significance of the study was underscored and the research methodology followed was noted, including data collection and analysis. The scope and limitations of the study as well as the structure of the dissertation were mentioned.

This chapter is followed by a review of literature fundamental to the study. The foundations of occupational health, the medical surveillance of worker health and the recent raised prevalence of incidents involving hazardous chemical substances will be explored. Finally, hazard control measures will be discussed.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 INTRODUCTION

This chapter presents relevant literature that has been reviewed and synthesised to include an assessment of the regulatory framework and the classification of hazardous chemical substances (HCS) for Higher Education Institution (HEI) chemistry departments. An assessment of actual, emerging and potential risks of exposure to the physical and health hazards of HCS is made. The chapter is concluded with a discussion on hazard management measures.

## 2.2 THE REGULATORY UNIVERSE IN THE USE AND MANAGEMENT OF HCS

### 2.2.1 International perspective

#### *2.2.1.1 Aim of occupational health*

In their joint declaration on the objectives of *occupational health,* the International Labour Organization/World Health Organizations (ILO/WHO) is resolute on preventative, protective and promotive means to attain optimal health of workers (ILO 2008:22). The WHO *Workers' health: global plan of action 2008-2017* affords priority attention to the primary prevention of occupational health hazards (WHO 2007:5). The WHO Global Occupational Health Network (GOHNET) (WHO 2007/2008:33) further recommends that a healthy laboratory should be free of avoidable risk to the physical, psychological and social well-being of the workers and should allow them to support and promote their health. It is therefore understood that workers should be protected from risks to health and laboratories are no exception.

#### *2.2.1.2 Global chemical safety management*

With specific reference to chemicals, the United Nations Economic Commission of Europe (UNECE) published the comprehensive *Globally Harmonized System of*

*Classification and Labelling of Chemicals* (GHS). The objective was to harmonise the classification and labelling of chemicals and safety data sheets globally to accomplish chemical hazard communication (UNECE 2013:iii). The WHO also published a human health risk assessment toolkit for chemical hazards through its International Programme on Chemical Safety (IPCS) harmonisation project. It provides a roadmap to assess exposures to hazards in the workplace, as well as health risk assessment for chemicals (WHO 2010d:viii).

#### ***2.2.1.3 Occupational exposure to HCS in laboratories***

Farr (2000) in Leggett (2012c:26) comments on the accident rate in chemistry laboratories (being 10 to 50 times higher than in industrial laboratories): it is reported that hazard analyses and safety precautions are observed with care in industry, while very few chemistry scientists have received training in health, safety and toxicology.

Occupational exposure to hazardous chemicals in laboratories is addressed in the United States Occupational Safety and Health Administration (US-OSHA) laboratory standard entitled *Occupational Exposure to Hazardous Chemicals in Laboratories Standard* 29 CFR 1910.1450. The standard regulates the use of small quantities of chemicals in laboratories where research is conducted with a restricted variety of chemicals (US-OSHA 2011b:1).

#### ***2.2.1.4 A weak safety culture at HEIs***

In sharper focus on the academic landscape, HEI laboratories were found to be environments where exclusive potential exposures to a wide range of hazards could lead to acute and chronic risks. In a study conducted among five HEIs, it was found that the safety climate (“employee perceptions, attitudes and belief about risk and safety”) was in need of improvement. The primary emphasis on research at HEIs is associated with complexity and independence in operation, which often neglects administrative controls. The result is a weak safety culture (Gutierrez, Emery, Whitehead & Felknor 2013:2).

Avoidance of health and safety standards in academic research laboratories is an observation further supported by Huising and Silbey (2013:157), who state that academic research occurs against the background of the professional status of members, the shielded nature of scientific work within academic domains and the loose association between policy and practice. Leggett (2012a:393) finally endorses the above by ascribing the "the genesis of accidents" to lacking standards of hazard identification and risk analysis in academia.

It follows that strong fundamentals guide worker health and the management of hazards at laboratories. The HEI laboratory domain, however, presents a unique hazard profile owing to the independence of research work and lacking administrative and risk assessment controls, which impede the prevention of exposure to hazards, including those of HCS, in academic laboratories.

### 2.2.2 The national perspective

A view is provided next on the regulatory framework, which applies to the use and management of HCS at an HEI laboratory in South Africa.

#### *2.2.2.1 The South African Occupational Health and Safety Act No 85 of 1993, as amended (OHSA)*

According to the OHSA, the South African employer "shall provide and maintain, as far as is reasonably practicable, a working environment that is safe and without risk to the health of his employees" (OHSA 1993:8). The employer has the added duty to conduct health risk assessments and perform medical surveillance on those workers exposed to hazards (OHSA 1993:8). The HEI as the "employer" has the duty to provide a safe work environment that is without risks to the health of employees. General duties in section 8 further require the implementation of risk mitigating measures, and that no employee should be allowed to carry out work without taking precautionary measures, nor without receiving instruction, training and supervision. In section 9, a duty is imposed on the employer to conduct work in such a way to ensure that persons, *other than employees*, are also not exposed to hazards to their health or safety. The implication is that contractors, visitors and students at an HEI are added under this legal prescription. The employee, in section 14, is further required to take care of the health and safety of themselves and other persons, to obey lawful instruction and to report any unsafe or unhealthy situation.

OHSA therefore provides for health risk assessments and medical surveillance of persons at an HEI who may be exposed to health risk.

#### ***2.2.2.2 Hazardous Chemical Substances regulations***

##### *2.2.2.2.1 Prevention and control of exposure to HCS at a workplace*

The HCS regulations, published under section 43 of the OHSA, govern "work at a workplace which may expose any person to the *intake* of an HCS". HCS means "any toxic, harmful, corrosive, and irritant or asphyxiant substance, or a mixture of such substances for which an occupational exposure limit is prescribed; or an occupational exposure limit is not prescribed, but which creates a hazard to health" (OHSA Regulations 1995:2). The HCS regulations cover information and training, duties of persons who may be exposed to HCS, assessment of potential exposure and air monitoring. In addition, medical surveillance, the demarcation of a respirator zone, records management, handling of HCS, control of exposure to HCS, personal protective equipment and facilities are addressed. The prevention of exposure to HCS is imperative and, where this is not feasible, exposure should be adequately controlled (OHSA Regulations 1995:5). The HCS Regulations, therefore, provide the legal framework for the prevention and control of the *intake* of an HCS.

#### ***2.2.2.3 Compensation for Occupational Injuries and Diseases Act***

The Compensation for Occupational Injuries and Diseases Act (COID) 130 of 1993, as amended, provides for the right of an employee to claim compensation for an accident at work, which results in serious disablement or death (COID 1993:16). In addition, occupational diseases, such as occupational asthma or contact dermatitis are listed, which may arise from the handling or exposure to substances at work (COID 1993:32). The employer is obliged to report such disease to the Compensation Commissioner within fourteen days. Hence, exposures to hazardous chemical substances that cause occupational injury or disease should be reported accordingly.

#### *2.2.2.4 National stakeholders and initiatives*

An advisory council for occupational health and safety has been established under the amended OHSA, to advise the minister, conduct research and investigation and advise the Department of Labour in related matters (OHSA 1993:6).

The Department of Labour's (DOL) Directorate: Health and Hygiene signed a chemical sector health and safety accord on 7 November 2013 in line with the "Zero Harm" initiative to commit all stakeholders to report occupational incidents and promote compliance to legislation (DOL 2013:1).

The National Institute for Occupational Health (NIOH) provides diagnostic services to organisations and institutions on health hazard evaluation; toxicology; occupational medicine referrals; health risk assessments; and occupational hygiene surveys (NIOH 2014:1).

It appears that national regulation and agencies, established with the purpose to promote occupational health and safety as well as an acknowledged global classification system for HCS, form the foundation for the regulatory framework in the use and management of HCS in South Africa.

## 2.3 CLASSIFICATION OF HAZARDOUS CHEMICAL SUBSTANCES

### 2.3.1 Descriptions of phrases: *chemical, hazardous chemical*, *hazardous chemical substance* and *use of chemicals at work*

#### *2.3.1.1 Chemical*

The ILO Convention on safety in the use of chemicals at work, 1990 (No.170) defines the term *chemical* as "chemical elements and compounds, and their mixtures, whether natural or synthetic such as those obtained through production processes" (ILO 2013c:2).

#### *2.3.1.2 Hazardous chemical*

*Hazardous chemicals* are classified in relation to the type and scale of their intrinsic health and physical hazards. The hazards of mixtures consisting of two or more chemicals are dependent on assessments of the intrinsic hazards of their constituent chemicals (ILO 2013c:2).

#### *2.3.1.3 Hazardous chemical substance (HCS)*

The South African Hazardous Chemical Substances Regulations (OHSA Regulations 1995:2) define an HCS as "any toxic, harmful, corrosive, irritant or asphyxiant substance, or a mixture of such substances for which an occupational exposure limit is prescribed; or (for which) an occupational exposure limit is not prescribed; but which creates a hazard to health."

#### *2.3.1.4 Use of chemicals at work*

The phrase *use of chemicals at work* refers to any work that potentially exposes a worker to a chemical, including the production, handling, storage and transport of chemicals, the disposal and treatment of chemical waste, emission of chemicals and the maintenance, repair and cleaning of equipment and containers for chemicals (ILO 2013c:2).

### 2.3.2 The globally harmonised classification of chemicals

The UNECE, after a decade's collaboration with multiple international stakeholders and organisations published the *GHS* with the view of protecting human health and the environment but also to provide a globally accepted classification system to improve hazard communication. (UNECE 2013:iii). The hazard classification is based on the intrinsic hazard qualities of chemical substances and chemical mixtures. A *chemical substance* is regarded as a chemical in its natural, stable state, while a *chemical mixture* is a solution of two or more chemical substances in which they do not react (UNECE 2013:13). Dalvie, Rother and London (2013:51) report that the global target date for implementation of GHS was 2008. South Africa endorsed the GHS system and responded through the South African Bureau of Standards, which customised the GHS system by publishing it as a standard known as SANS 10234:2008 (SABS 2008 Edition 1.1). Draft legislation was prepared that incorporated GHS. South Africa created a committee on chemical safety in 2009 to provide oversight on monitoring and implementation of GHS: the expected dates were to be 2012 for substances and 2016 for mixtures. The UNECE confirms that South Africa is in the process of implementation.

GHS consequently has an important application for laboratory workers also in South Africa, because, according to Hill (2010:5), it "will become the standard in the future for classifying chemical hazards ...".

### 2.3.3 Hazard classes of chemicals (termed HCS under the HCS Regulations)

GHS (UNECE 2013:14) classifies hazards associated with chemicals into three hazard classes as described hereafter.

#### *2.3.3.1 Physical hazards of chemicals*

The *physical* hazard types of chemicals within this class consist of sixteen categories, namely explosives; flammable gases, liquids and solids; pyrophoric liquids and solids; gases under pressure; self-reactive and self-heating substances and mixtures; oxidizing gases, solids and liquids; aerosols; organic peroxides; substances and mixtures which, in contact with water, emit flammable gases and lastly corrosives to metals. Physical hazards of chemicals may present themselves as a gas, liquid or a solid (UNECE 2013:v).

#### *2.3.3.2 Health hazards of chemicals*

*Health* hazard types of chemicals, as classified by the GHS, are: acute toxicity, skin corrosion/irritation, serious eye irritation or damage, respiratory or skin sensitisation, germ cell mutagenicity, carcinogenicity, reproductive toxicology, target organ systemic toxicity and aspiration hazard (UNECE 2013:vii).

#### *2.3.3.3 Environmental hazards of chemicals*

The *environmental* hazards of chemicals are listed by the GHS as hazards that may adversely affect the aquatic environment in the short or long term (UNECE 2013:219) or present as halocarbon emissions that deplete ozone in the stratosphere (UNECE 2013: 245).

## 2.4 ACTUAL AND POTENTIAL EXPOSURE HAZARDS OF HAZARDOUS CHEMICAL SUBSTANCES AT ACADEMIC LABORATORIES

### 2.4.1 Actual HCS exposure hazards at academic laboratories

#### *2.4.1.1 Physical and health hazards of HCS present at academic laboratories*

“Hazardous chemicals present physical and/or health threats to workers in clinical, industrial and academic laboratories” (US-OSHA 2011:9). The United States Occupational Safety and Health Administration (US-OSHA) is clear on the prevailing types of hazards related to work with HCS at an academic laboratory: there are both *physical* and *health* hazards.

This view aligns well with the United States Chemical Safety and Hazard Investigation Board (CSB) study, undertaken into sentinel accidents at academic chemistry laboratories, where both hazard types were identified, although the *physical hazards had received far less attention and were the cause of many of the accidents* (CSB 2011b:2).

Leggett (2012b:22) further confirms that the US-OSHA laboratory standard focuses on *hazardous* chemicals and concentrates largely on *health* hazards of HCS. This is in contrast with the limited focus on the *physical* hazards of HCS such as “explosive”, “flammable” or “highly reactive”.

#### *2.4.1.2 Actual exposure hazards and incidents in academic laboratories within the HEI environment*

##### *2.4.1.2.1 The frequency of exposure hazard incidents and nature of exposure hazards*

- **Frequency of exposure hazard incidents**

In a video entitled “Experimenting with danger”, the CSB announced that it had collected data on 120 explosions, fires and chemical releases at HEI laboratories and other research facilities that had occurred in the USA since 2001. Incidents caused deaths, serious injuries and widespread property damage (CSB 2011c:1).

Basken (2012:1) confirms that there is an emerging prevalence of accidents because of exposure to hazardous chemical substances at academic research laboratories in American universities. The fatal explosion in 2008 and a growing body of reports on the higher prevalence of laboratory safety failures and accidents in American universities have shed light on a suggested low safety compliance level and poor culture of safety in academic laboratories.

Mulcahy, Young, Gibson, Hildreth, Ashbrook, Izzo and Backus (2013:13) revealed that the CSB recorded a further 65 HEI laboratory incidents, of which two fatalities, between January 2010 and October 2012.

Peplow and Morris *in* Meyer (2012:856) cite Kaufman, who found a 10 to 50 times higher accident rate in universities compared to the industry. Academic laboratories have a “more relaxed approach towards safety” (Meyer 2012:855).

The CSB is further “greatly concerned about the frequency of academic laboratory incidents in the United States” (CSB 2011a:19). Mulcahy et al (2013:9) report that unprecedented response related to safety culture in research laboratories has been sparked among universities.

- *Nature of exposure hazards*

In a focus on conventional safety management at an HEI laboratory, Fishwick (2014:9) explains that, apart from specific hazards in laboratories, certain general risks are present, such as spillages, tripping, electrical and ladder work hazards.

HEI laboratories often have biological, chemical, radiological, physical and explosive safety hazards and toxic agents (Guttierrez et al 2013:2).

In contrast with the manufacturing sector, where large volumes of a limited number of chemicals are used, in a chemistry research laboratory a comprehensive number of HCS is dealt with, including new substances being discovered with unknown hazards (Mulcahy et al 2013:9).

Husin, Mohamed, Abdullah and Anuar (2012:306) found significant risk of HCS at laboratories in an HEI in Malaysia, and that control measures could be improved towards a safe work environment for students and laboratory staff.

Marendaz, Suard and Meyer (2013:168) report that, despite the serious nature of accidents at academic laboratories, most reports appear only in newspapers and a few are reported in open literature.

The HEI laboratory is therefore a unique workplace where a large diversity of research is conducted in an autonomous fashion with very little regulatory oversight, a principle that is common in this domain (Gutierrez et al 2013:2).

#### ***2.4.1.3 Recent incidents at academic laboratories related to chemical exposures***

##### *2.4.1.3.1 Three prominent incidents at academic laboratories*

Three prominent incidents, all of which were associated with the *physical hazards of HCS* at academic laboratories in the USA in recent years, are discussed briefly:

- *University of California at Los Angeles case*

In the case at the University of California at Los Angeles, the 23-year old Sheri Sanji lost her life at a research laboratory in 2008. She died of burns after she spilled a chemical substance that ignites if exposed to air. It has led to possible criminal charges against the university. It has opened a debate on federally observed explosions, fires and chemical releases in the past decade in the USA at university laboratories. Safety advocates postulate that it may have been the results of a widespread culture of negligence. Until late 2011, the number of criminal cases resulting from laboratory safety at universities in the USA had been non-existent (Basken 2012:A20).

Kemsley and Torrice in the *Chemical and Engineering News* (CEN) add that a plastic syringe was used to transfer the tert-butyllithium to a reaction flask. The plunger came apart from the syringe and the substance was exposed to air, when it ignited. Sanji, wearing nitrile gloves as Personal Protective Equipment (PPE) (no protective laboratory coat), also bumped over an open container of hexane, which was in the extraction hood. The two substances reacted and her clothes were set alight (CEN 2012:2). The Royal Society of Chemistry (2009:1) described her injury: third degree burns were sustained on 40 per cent of her body and she passed away early in 2009.

- *Texas Tech University case*

An incident description by Johnson and Kemsley (2011) in the *Chemical and Engineering News* (CEN 2011:25) reveals that on 7 January 2010, Preston Brown, a fifth-year graduate at TTU, synthesised a 10 g batch of nickel hydrazine perchlorate. This production volume far exceeded the limit mentioned by the Principal Investigators of 100 mg for energetic materials (CSB 2011:1). The CSB continued by stating that the substance was lumpy, and Brown placed half if it in a pestle to break up the clumps, when it detonated in his hands. He was not wearing eye protection and sustained severe damage to his left hand, lost three fingers, perforated an eye and sustained cuts and burns. CSB found that two previous near-miss incidents had occurred at the laboratories from which key lessons were not heeded. In addition, the Board found that there was no formal system or communication about the limit for the synthesis of energetic material. According to Johnson and Kemsley (2011:26), safety gaps were found in the absence of written safety procedures for synthesis; the safety management oversight system was lacking; and no system was in place to track previous near-miss incidents. TTU responded during the two years after the incident by moving the Environmental Health and Safety office to the Vice-president of research, by including safety matters in their faculty annual reports and by creating a faculty chemical safety committee. TTU now includes safety into responsible conduct of research training.

- *Yale case*

The third case occurred on 13 April 2011 in the Yale university chemistry laboratory when an undergraduate student, Michele Dufault, died from accidental asphyxia when her hair was caught in a lathe (Van Noorden 2011:270).

### 2.4.2 Potential HCS exposure hazards at academic laboratories

The presence of HCS at academic laboratories implies potential exposure hazards such as chemical carcinogens and nanomaterials, as discussed hereafter.

#### *2.4.2.1 Occupational carcinogens*

In the WHO publication on occupational carcinogens, the IPCS (2004:20) specifies the three well-documented cancers resulting from occupational exposure to HCS: lung cancer, leukaemia and malignant mesothelioma. Lung carcinogens include asbestos, arsenic, chromium and nickel. Chemical leukaemogens (leukaemia-causing chemicals) are benzene and ethylene oxide, while asbestos is the main causative agent in the carcinogenesis of the lung.

The health outcomes of lung carcinogens, such as arsenic, asbestos, beryllium, cadmium, chromium, exhaust diesel, nickel and silica, are cancers of the trachea, bronchus or lung. Health outcomes for exposure to benzene, ionising radiation and ethylene oxide is leukaemia (WHO/Driscoll et al 2004c:52).

According to Polykronakis, Dounias, Makropoulos, Riza and Linos (2013:4), well-documented scientific knowledge existed to substantiate benzene as a risk factor in the etiology of leukaemia, confirming the above findings.

#### *2.4.2.2 Nanoparticle and nanomaterial risk*

Ramachandran, Ostraat, Evans, Methner, O'Shaughnessy, D'Arcy, Geraci, Stevenson, Maynard and Rickabaugh (2011:674) state that HEI research laboratories are expected to use lower volumes of nanomaterials with diverse compositions and features and that key mechanisms for exposure and toxicity are not well understood. "The absence of well-defined Occupational Exposure Limits as well as a lack of understanding of available instrumentation also hinders exposure monitoring".

The growing use of nanomaterials in chemistry laboratories brings new challenges. Particles measuring between 1 and 100 nanometers may display new characteristics and its exposure risks are as yet under-researched. The interim management of health hazards is recommended to be *as for other HCS with unknown toxicity.* It includes protection of laboratory employees and students from exposure while assessing hazards associated with nanomaterial research and work, and gaining understanding of the risk grading (Board on Chemical Sciences and Technology 2011:4).

US-OSHA concurs by stating that the risks and hazards associated with engineered nanomaterials are still being researched. It is imperative to consider the high reactivity of several nanomaterials, which implies the potential for fire or explosion. All routes of intake, such as ingestion, inhalation, injection and dermal exposure, should be taken into consideration, especially with airborne nanoparticles. Such substances should be kept in liquid or in tightly sealed containers. During synthesis of new nanomaterials, the hazards linked to every stage of synthesis as well as the end product must be attended to, because exposure may occur at every stage. Given the potential for exposure, current safe practice would consist of conducting work with nanoparticles in an enclosed space under negative pressure, independent of the breathing zone (US-OSHA 2011c:7).

Manufactured nanomaterials may pose new chemical risks to health. The Centers for Disease Control and Prevention (CDC) reports that there is a potential for single-walled and multi-walled carbon nanotubes and carbon nanofibers to be inhaled and reach the lungs. Animal studies have shown inflammation and fibrosis of the lungs. A recommended exposure limit was advised until more research is available (CDC 2013:2).

Furthermore, Groso, Petri-Fink, Magrez, Riediker and Meyer (2010:1) note that information required to develop a risk assessment on engineered nanoparticles or nanomaterials is “severely lacking”. Ramachandran et al (2011:674) concur that knowledge is presently insufficient to conduct an exact risk assessment and that little is known about the health risks of nanomaterials, including the exposure metrics which should be applied, the exposure mechanisms and toxicity. Neither the exposure nor the hazards are well understood. The key exposure mechanism appears to be inhalation, followed by the dermal route. This statement is further underscored by Groso et al (2010:6), who consider inhalation and skin contact as the main routes of exposure. Vagueness surrounding acute and chronic exposure risks has prompted the application of *control banding* in risk assessment (Ramachandran et al 2011:674) and the finding by Groso et al (2010:7) is that evidence is emerging to indicate detrimental effects on human health. Therefore, the “precautionary principle must be applied”.

## 2.5 EXPOSURE CONTROL MEASURES (HAZARD MANAGEMENT) IN LABORATORIES

### 2.5.1 Exposure control lessons learned from exposure incidents at HEI laboratories

The CSB findings, which were published after the Texas Tech University (TTU) investigation, included the fact that “comprehensive guidance on managing the hazards unique to laboratory chemical research in the academic environment is lacking” and that standards were pertinent to industrial settings; not always applicable to the academic research laboratory environment (CSB 2011a:18).

The investigation into the detonation accident in the TTU laboratory yielded recommendations to the institution. It was revealed, however, that the lacking laboratory safety matters were generalised among universities in the United States. The investigation identified *six key lessons* for noting by universities. HEIs were implored to:

1. expand laboratory safety management plans to assimilate both *physical* and *health* hazards of chemicals
2. conduct research-specific hazard evaluations and mitigation

3 take cognisance of the fact that current laboratory standards are designed for the industry and that standards directed to the unique hazards at academic chemistry laboratories are lacking
4 institute specified research-specific laboratory protocols and training on the management of research risks at laboratories
5 ensure that safety practitioners report to a person with the authority to enable the implementation of safety measures at research laboratories
6 document and communicate all near-miss incidents and actual accidents
7 improve safety (CSB 2011a:18)

### 2.5.2 The elements of control of exposure to HCS according to the South African HCS Regulations

The South African HCS Regulations list the following exposure control elements (OHSA Regulations 1995:3), which are discussed and further synthesised with related literature.

#### *2.5.2.1 Information and training*

The HCS Regulations (OHSA Regulations 1995:3) determine that an employer, before exposing an employee to an HCS hazard at work, shall ensure that the employee is informed and trained with respect to the source and potential risks of exposure and protective measures.

Messing (2013:593) declares that a programme to enhance their HEI laboratory safety culture involved all staff and students in annual training on chemical waste disposal, fire safety and the chemical inventory system. A change in their safety paradigm was achieved that surpasses pure policy implementation.

#### *2.5.2.2 Duties of persons exposed to HCS*

The HCS Regulations (OHSA Regulations 1995:4) state that a person exposed to an HCS shall obey any lawful instruction regarding the prevention of release of an HCS, wearing PPE and monitoring devices, reporting for health evaluations and biological monitoring, cleaning up and disposal of materials containing HCS, housekeeping, personal hygiene, health and environmental practices and information and training.

The aforementioned prescriptions are valid for persons exposed to HCS at an HEI chemistry department.

#### *2.5.2.3 Assessment of potential exposure*

The HCS Regulations (OHSA Regulations 1995:4) instruct that the health and safety committee need to be consulted and an assessment should be conducted to determine if an employee is exposed to HCS by any intake route, and repeat the assessment at least every two years. The health and safety committee should be allowed an opportunity for comment. The assessment should consist of the HCS, its effects, intake route to which an employee is exposed, nature of the work and the physical form and location of the HCS, and control measures. If found that the employee may be exposed, air monitoring and medical surveillance must be undertaken and the exposure must be controlled. At re-assessment, it might be found either that the exposure risk is no longer valid or that a new exposure risk has developed. In the latter case, the assessment and consequent processes must be repeated.

A renewed academic awareness in chemical risk assessment at university research facilities has initiated an urgency to develop a *theoretical* background for risk assessment and evaluation tools (Jensen & Jorgensen 2014:25).

#### *2.5.2.4 Hazard identification and risk assessment*

In the WHO Workers' health: global plan of action 2008-2017, workplace health risk assessment and management should include integrated management of chemicals (WHO 2007:6). Leggett (2012c:28) describes hazard analysis in the context of the chemical research laboratory as consisting of both hazard identification and hazard evaluation. Risk assessment is defined as the process of managing the risk identified during risk analysis (Leggett 2012c:26).

###### *2.5.2.4.1 Hazard identification and risk assessment in HEI laboratories*

- *Methodologies for hazard identification and risk assessment*

The WHO (2010c:12) regards hazard identification as an important first step in risk assessment, by which a specific chemical hazard is identified. Next it is determined if exposure to this substance has a potential harmful effect on human health.

One risk assessment system customised to the chemical research laboratory is known as Lab-HIRA (Laboratory Hazard Identification and Risk Analysis for the Chemical Research laboratory). This three-part process consists of a *chemical hazard review* (identifying hazards emerging from chemicals used in synthesis processes), a *risk analysis* based on the hazards identified during the chemical hazard review and lastly, *risk minimisation*, where risks are mitigated to an acceptable level (Leggett 2012a:393). Leggett (2012:393) maintains, "the use of hazard identification and risk analysis procedures in academia is an infrequent practice". He further offers explanations for this poor practice: "very few academic scientists have taken formal courses in safety, health and toxicology". There also seems to be a perception that risks are lower due to small quantities of HCS used. Consequently, when accidents occur, findings from the investigation often highlight the root cause as being the absence of hazard identification and risk analysis.

During the case study of the Texas Tech University explosion, it became clear that hazard evaluation methodologies, while directed at the industry, had not been created for the academic laboratory environment. *Significantly, the CSB's case study serves as a call to academia to ensure that practices and procedures for research laboratories are in place to safeguard hazard-specific assessment and mitigation* (CSB 2011a:18).

Following a further 65 HEI laboratory incidents, of which two fatalities, between January 2010 and October 2012, the CSB recommended strongly to the HEI sector that *leading indicators* should be designed to trigger the re-evaluation of hazards or prompt safer methods of research. *Lagging indicators* could provide secondary input as "failure data" into tracking the effectiveness of the HEI safety management system. The CSB, in addition, advised the implementation of a reporting system on actual and near-miss incidents (Mulcahy et al 2013:13).

- *Laboratory hazards and risks in the HEI environment*

Academia could not easily be compared to industry in terms of occupational health and safety. Grave safety concerns at HEIs lead to regular incidents. Langerman (2009) *in* Marendaz, Suard and Meyer (2013:169) states that "most academic laboratories are unsafe venues for work or study". Hazard identification is challenging due to the multiple laboratories, lack of common objectives, the wide scope of hazards and the rapid turnover rate of researchers and research themes. To add to the concerns, Mulcahy et al (2013:10) report that, after the fatal Sheri Sanji incident at the University of California Los Angeles, the director of Environmental Health and Safety conducted an extensive literature search and found very little empirical evidence to address the inherent risks and hazards at HEI laboratories.

Huising and Silbey (2013:159) give a portrayal on the ambivalence in the HEI research environment: the collegial, consensual side versus the top-down hierarchy. This fact leads to complex systems of decision-making, intractable regulation and opacity in governance, sometimes resulting in fatal outcomes at the academic laboratory. Furthermore, the principally academic objectives at research laboratories may add risk to worker health. Senior researchers are so intently focused on academic programmes: to teach, obtain funding, conduct thesis development and publish findings that laboratory safety principles and compliance management may become a secondary objective.

Amidst a swiftly changing research student population, the laboratory hazards and risks emanate from materials, animals, equipment and instrumentation. Accidents at HEI laboratories in the USA have emphasised the need to improve safety (Watson 2012:220).

- *New hazards and risks*

Meyer (2012:854) further supports the rapidly shifting nature of the research and teaching environment: it is occupied by a diverse group of researchers and lecturers, as well as technicians, administrative staff students and visitors, each with differing skills, knowledge and education. In addition, there is a new focus on reactive chemical hazards. Finally, teaching laboratories expose students with no experience to new risks (Meyer 2012:856).

Mulcahy et al (2013:9) underscore the fact that new materials with unknown hazards arise amidst a multitude of chemicals and complex research activities at research laboratories.

- *At-risk behaviour in academic laboratories*

Examples of at-risk behaviour appear in the publication by the American Chemical Society Joint Board – Council Committee on Chemical Safety: Safety in Academic Chemistry Laboratories (2003:5). Some of these examples are the absence of risk assessment of the work and the HCS at hand, wearing woven, loose hanging clothing, loose hair, high-heeled sandals, working alone or consuming food or beverages in the laboratory, pipetting by mouth, horseplay, unauthorised experiments.

- *Reduction in at-risk behaviour of students in academic laboratories*

Shariff and Norazahar (2011:29) implemented the Lab-ARAIS (Laboratory at-risk behaviour analysis and improvement system) at a chemical engineering laboratory at the Universiti Teknologi PETRONAS in Malaysia to observe students' frequent at-risk behaviours. Results were placed on the student portal to allow for acknowledgement of unsafe practices. A significant decrease was reported in frequent at-risk behaviours.

*2.5.2.4.2 Human health risk assessment*

The WHO (2010c:viii) publishes its Human Health Risk Assessment Toolkit (road map to information) required for the assessment and characterising of exposure to the health hazards of chemicals. The WHO/IPCS (2010c:4) explains that the toolkit offers methods or techniques used in the evaluation of hazards, exposure and untoward effects of HCS. The evaluation commences with a problem formulation and is followed by four steps, namely hazard identification, hazard characterisation, exposure assessment and risk characterisation.

The physical work environment at the HEI's chemistry department is included under the scope of the initiative. The South African HCS Regulations explicitly provide for an employer to conduct a health risk assessment on the route of intake of exposure to HCS (OHSA Regulations 1995:4). Meyer (2012:856) recommends that risk assessments be integrated into scientific work.

Thus, health risk assessment of potential exposure to HCS is relevant to the worker in the chemistry department.

*2.5.2.4.3 Chemical health risk assessment*

In a qualitative study reported on at the Universiti Kebangsaan Malaysia Teaching and Learning Congress in 2011, Husin, Mohamad, Abdullah and Anuar (2012:301) relay the methodology and findings of a chemical health risk assessment conducted at the chemical and biochemical engineering laboratory. The purpose of the study was to assess the use of HCS at a teaching and research laboratory. The chemical health risk assessment was assembled through the systemic identification of hazards and processes in the use and management of HCS, exploring the hazard risk, effectiveness of control measures in use, and eventually arriving at the level of risk at the workplace. Employees were observed while handling HCS. In addition, a review of work procedures and documents was undertaken and researchers were interviewed.

It was found that, despite periodic safety training, safety posters, briefings, good laboratory housekeeping practices and the use of personal protective equipment (PPE) by staff, the risk was significant in all departments and control measures were inadequate.

One recommendation comprised the recording of HCS in a *register* (a recommendation that is supported by the Malaysian act (Husin et al 2012:305) and by the US-OSHA laboratory standard, in which a periodic inventory for chemicals is prescribed (US-OSHA 2011c:5). In contrast, the South African HCS Regulations do not require a register or an inventory. This fact is, in the opinion of the researcher, a lacking practice in South Africa. The recommended chemical register by Husin et al is in line with the International Programme on Chemical Safety Harmonization project, which aims to enhance the assessment of chemical risk worldwide by aligning global approaches (WHO/IPCS 2009:1).

##### *2.5.2.4.4 Control banding*

Zalk and Heussen in an ICOH newsletter (2011:4), define control banding as a qualitative risk assessment undertaken to arrive at solutions and control measures. Should conclusive toxicological and exposure information not be available, worker exposure can be prevented by assessing health risks in terms of their severity and probability. A risk level is decided based on the two descriptors. This methodology is particularly useful where chemicals could reliably be clustered in groups based on knowledge about other chemical substances that display similar characteristics.

Backus, Fivizzani, Goodwin, Finster, Austin, Doub, Wiediger and Kinsley (2012:24), in a panel discussion on laboratory safety in university research and teaching laboratories, were strongly in favour of applying the “banding” of chemical hazard risk by type and quantities of chemicals used.

#### ***2.5.2.5 Air monitoring***

The HCS Regulations (OHSA Regulations 1995:5) determine that, where a risk of inhalation of HCS by an employee is possible, an approved inspection authority should do that air measurements and make results known to the health and safety committee. In case of an HCS with an Occupational Exposure Limit-control limit, it must be carried out every twelve months, in case of an HCS with a recommended limit, every 24 months. The report should be made available and the employer should keep the record for 30 years.

Ugranli, Toprak, Gursoy, Cimrim and Sofuoglu (2015:147) found that Turkish university laboratories are micro-environments where specific concentrations of air pollutants may be raised. Laboratory workers are therefore exposed to potential acute and chronic health risks. The gravity of this finding is reinforced because of limited air quality assessments at university laboratories. Their study at three research laboratories, including chemistry (biochemistry, analytical chemistry and organic chemistry), measured concentrations of particulate matter, volatile organic compounds (VOCs), carbon monoxide and carbon dioxide, as well as temperature and relative humidity (the latter two known as thermal comfort variables). The conclusion was that their results compared well with studies in Australia, Greece and Korea. Ventilation systems prevented the build-up of carbon dioxide, yet were inadequate for VOCs, where high concentrations were measured. The potential health effects of VOCs range from irritation of the eyes and upper respiratory tract, loss of memory and shortness of breath to being carcinogenic and mutagenic (Godish 2000 *in* Ugranli et al 2015:147).

#### ***2.5.2.6 Medical Surveillance***

##### *2.5.2.6.1 Duty of the employer of persons exposed to HCS*

The HCS Regulations (OHSA Regulations 1995:6) state that an employer shall ensure that an employee receives medical surveillance if exposed to a Table 3 substance in Annexure 1 (Biological Exposure Indices), if any adverse health effects are associated with the exposure, or when the Occupational Health Practitioner recommends medical surveillance, as ratified by the Occupational Medicine Practitioner (OMP). An initial baseline evaluation should be done within 14 days of commencement of employment. If the employee is found unfit by an OMP to work in an environment where he/she is exposed to HCS, the employer cannot permit the employee to continue work in that environment.

##### *2.5.2.6.2 Medical programmes and roles of Occupational Health Practitioners*

At the chemistry department of an HEI, the unique occupational risk exposure profile of each worker determines the nature and intervals of medical surveillance intervention, as advised by the occupational medicine practitioner (HCS Regulations 1995:14). An occupational health practitioner carries out the medical programmes. Biological monitoring (HCS Regulations 1995:14) registers the concentration of HCS and/or its metabolites in biological samples; while biological *affect* monitoring screens biochemical or physiological change due to exposure (HCS Regulations 1995:15). Medical screening (HCS Regulations 1995:16) of employees intends to detect subclinical and presymptomatic stages of disease, in order to reverse the health effects or slow down the progression thereof.

Duties directed at the occupational health practitioners in the service of an organisation, here meant the HEI, are described. Paragraph 5 notes the assessment of employee exposure by any intake route, which should be conducted every two years, followed by adjustment of measures to improve safety failures. Paragraph 7 prescribes the design and implementation of a medical surveillance programme, which is, according to annexure 1, rational, ethical and effective (OHSA Regulations 1995:17). Medical surveillance should cover the entire spectrum of potential HCS exposure effects on an employee in the chemistry department – from absorption to clinical disease. The baseline assessment is done within 14 days of commencing employment, and thereafter periodically as ratified by an occupational medicine practitioner. The assessment must consist of an occupational and medical history, physical assessment and other tests as deemed necessary by the OMP and must be repeated at least every two years. The annexure explains the elements of a medical surveillance programme: it includes a risk assessment to determine potential exposure and routes of intake; target-organ toxicity; action criteria; standardisation and ethical considerations; the assessment of an employee's fitness to continue performing his/her job; evaluation of control measures and related recordkeeping.

Lewis and Fishwick (2013:322) followed a semi-systematic review of literature published from 1990 to assess "health surveillance for occupational respiratory disease". They found lacking standardisation among methods used, which included respiratory questionnaires, lung function tests, chest X-rays and markers of immunology and inflammation.

A marked absence of literature on medical surveillance and biological monitoring types and design of such programmes for workers at HEI laboratories was found. Despite this gap, the occupational health practitioner in South Africa, in the opinion of the researcher, takes guidance from the HCS Regulations, from generic studies on bio-markers for exposure, from health risk assessments and indoor air quality assessments to design a medical surveillance programme for an HEI chemistry laboratory.

*2.5.2.6.3 Exposure assessment of the health hazards of HCS*

- *Exposome and exposure science*

Health professionals in collaboration with exposure scientists investigated the origins of occupational disease. It was established that toxic chemicals might enter the body from both exogenous sources (water, diet, drugs) and endogenous processes (inflammation, oxidative stress, infections and intestinal flora). The *exposome* therefore constitutes the totality of exposures a person receives during a lifetime. It is therefore possible that it may be difficult to distinguish the roles of the etiology of disease and other contributory risk factors. Exposure science, however, can reveal major exposures and their link with chronic disease (Rappaport 2011:5). Schutte, Pandalai, Wulsin and Chun (2012:434) concur that most diseases, injuries or illness reported by workers could be caused by a combination of work and non-work factors. Personal risk factors, such as age, obesity, gender, smoking, substance- and alcohol use, contribute to injuries and diseases observed at work. The link between occupational risk factors and personal risk factors needs to be studied concurrently to fully understand workers' health.

- *Monitoring of cytogenetic changes in chemical exposure*

Diler and Celik (2011:821) propose the monitoring of cytogenetic damage in humans by using a micronucleus assay collected from buccal epithelium. Genetic damage thus detected may display the exposure health effects by chemical carcinogens in the occupational health setting.

- *The role of molecular biology in bio-monitoring of human exposure to chemicals*

The biochemical methods that have been used to detect concentrations of toxic compounds in blood, urine or tissues to evaluate potential health risk *only mark the presence of a noxious chemical and its health effects. It does not prevent or reduce the risk.* A new molecular biomarker technique was introduced to monitor the effect of chemical exposure on human health. Bio-informatics offer large gene or protein databanks and data-integration of toxicodynamics and toxicokinetics of contaminants: it accelerates the search for potential biomarkers on occupational health (Munoz & Albores 2010:4511).

- *Exposure to multiple chemicals*

Both the Strategic Approach to International Chemicals Management (SAICM) and the WHO IPCS project on the *Harmonization of Approaches to the Assessment of Risk from Exposure to Chemicals* focused their efforts inter alia on risk assessments for exposures to multiple chemicals (WHO/IPCS 2009c:11). Upon the harmonisation of terminology, the following was decided: exposure to the same substance by multiple routes would be termed s*ingle chemical, all routes*. Other descriptions are m*ultiple chemicals by a single rout*e and *multiple chemicals by multiple routes.* The collective title would be *combined exposures to multiple chemicals.*

- *Exposure dose*

Some chemicals, which target the same human cell or tissue, are reported to act in a d*ose additive* manner. Effects of exposure by chemicals that act independently and by different modes of action may become compounded and are referred to as e*ffects additive*. Chemicals, by contrast, may also interact during exposure with the resulting effect: *depart from dose additivity*. The departures may be synergistic, where the effect is greater than the predicted additivity or could be antagonistic, where the effect is less than the predicted additivity (WHO/IPCS 2009a:12).

- *Modes of action in exposure to chemical mixtures*

Multiple chemicals, in combined exposure to humans, may act in s*ingle mode of action* or in *multiple modes of action*. A further very important distinction is that chemical mixtures may have a known composition or, in contrast, have an unknown or variable composition (WHO/IPCS 2009a:12).

- *Exposure to HCS through multiple routes of entry*

Humans may be exposed to HCS by means of more than one route of entry. In addition, guidance values for health effects will differ depending on whether the HCS is inhaled, dermally absorbed or ingested (WHO/IPCS 2010c:20).

- *The duration, concentration and rate of chemical exposure*

The duration of exposure is critical in the assessment of risks to health. Short-term exposure may last minutes, hours or a day and is relevant for chemicals that have a swift adverse effect, such as asphyxiation in carbon monoxide overexposure. Intermediate exposure duration ranges from weeks to months; a respiratory irritant such as hydrogen sulphide is included under this classification. Cumulative or long-term low-dose exposure is significant in carcinogenesis.

Exposures are expressed as either a concentration or a rate of exposure. The exposure rate can be calculated as the concentration of a chemical multiplied by the contact rate and exposure duration; divided by the body weight of the exposed person and averaging time. Averaging time differs for cancer and non-cancer risks: for non-carcinogenic chemicals, the contact time is equal to the duration of exposure; for carcinogens, the averaging time is set at a lifetime: assumed to be 70 years (WHO/IPCS 2010c:27).

It is concluded that scientific determinants in exposure science could refine the origin and accuracy of health impacts on workers exposed to HCS.

#### ***2.5.2.7 Respirator zone***

According to the HCS Regulations (OHSA Regulations 1995:7), an employer has to ensure that a respirator zone is demarcated if exposure to an HCS, without wearing PPE, exceeds the recommended limit. Signage must explain that PPE must be worn within the zone and the employer should ensure that no person enters the zone unless wearing PPE.

The regulations add prohibitions on the use of compressed air to remove particles or an HCS from any person and on smoking, eating, drinking or keeping food within a respirator zone (OHSA Regulations 1995:12).

#### *2.5.2.8 Records*

The HCS Regulations (OHSA Regulations 1995:7) require of the employer to keep records of all assessment reports, air monitoring and medical surveillance (medical records are confidential – only the occupational health practitioner should view medical records). All records, except medical records, should be made available to inspectors, upon written and approved requests by any person, to the health and safety representative or committee. All records must be kept for 30 years, including records of equipment maintenance and engineering control measures.

#### *2.5.2.9 Handling of HCS*

##### *2.5.2.9.1 Material Safety Data Sheets (MSDS)*

According to the HCS Regulations (OHSA Regulations 1995:8), any person who provides an HCS for use at work, must supply a written MSDS including prescribed elements such as product identification, first-aid measures and fire fighting measures. An employer must keep a copy of the MSDS for each HCS used and make it available to any interested or affected person.

Husin et al (2012:305) corroborate the need to have MSDS by stating that academic chemistry laboratories should keep MSDS on all HCS. It is advisable that a supplier of HCS should update their MSDS information every five years in accordance with latest research. Should a buyer find that their MSDS is older than five years, an update should be requested from the supplier.

##### *2.5.2.9.2 Chemical hazard communication*

London and Rother (2003) in Dalvie, Rother and London (2013:1) identify chemical hazard communication as a key strategy to prevent untoward health effects related to the unsafe use of and exposure to HCS. This viewpoint supports the GHS objectives to harmonise existing classification systems of chemicals, labels and safety data sheets into a global system (UNECE 2013:iii). Hill (2010:6) reiterates that GHS aims to "communicate information on chemical hazards through definitions, hazard classification and categorization, symbols (pictograms), signal words, warning or precautionary statements and Safety Data Sheets". GHS regards the aforementioned as the *hazard communication elements* of the GHS (UNECE 2013:10).

##### *2.5.2.9.3 Emergency plan*

Emergency planning for a laboratory might involve more than a strategy for an accidental spillage or minor exposures to HCS. *Prudent Practices in the Laboratory,* hereafter *Prudent Practices,* as commented on by the National Academy of Sciences (NAS) (2011:1), include planning for emergencies, which may range from power failures and flooding to malicious action. Four interconnected phases are cited. *Mitigation* refers to reducing the likelihood and impact of an accident by means of the creation of a Chemical Hygiene Plan to ensure safe storage and handling practices, or installation of a sprinkler system. The *preparedness* phase requires a communication plan, emergency equipment to be on hand and training for laboratory employees. In the *response* phase, attempts are made to respond to the incident with a chain of command and involvement of external stakeholders. During *recovery,* the restoration of facilities to a safe operational level is enabled. The effective execution of the mitigation phase might minimise the impact of an emergency and facilitate response and recovery phases; similarly, lessons learned from emergencies will inform more effective mitigation planning (NAS 2011:2).

Husin et al (2012:306) support emergency planning, stating that an emergency response plan should be ready and training should be given to staff on emergencies arising from a chemical spillage or fire.

#### ***2.5.2.10 Control of exposure to HCS***

The South African HCS Regulations set out the control principles to prevent exposures to HCS at workplaces.

The first method is to prevent exposure, which may occur by inhalation, ingestion or skin absorption; however, the most common route of entry is normally through inhalation. If not feasible, control should be instituted guided by the Recommended Limits, as in Table 2 of the regulations (OHSA Regulations 1995:50). Respirator zones could be demarcated to point out potential risk. The exposure should be kept as low as is reasonably practicable and PPE should be worn inside the respirator zone. A stronger form of control would be to heed the Control Limits for the HCS as in Table 1.

The second principle is to control exposure by limiting the amount of HCS in general, limiting the number of employees who may come into contact with an HCS and the period of exposure. Further measures include substitution for less hazardous chemicals, engineering controls such as wet methods, local extraction ventilation for airborne HCS and enclosure of a process to mitigate contact with HCS. Written safe work procedures are prescribed.

The last control method is for the user of HCS to prevent atmospheric emission of an airborne HCS by compliance to the Atmospheric Pollution Prevention Act (OHSA Regulations 1995:10).

*2.5.3.10.1 Occupational exposure limits*

Two tables in the HCS regulations provide for the classification of occupational exposure limits of HCS at the workplace.

Table 1 includes Occupational Exposure Limits-control limits (OEL-CL) and comprises the maximum concentration of an airborne substance as an average over the reference time, to which an employee may be exposed through inhalation (OHSA Regulations 1995:20).

The Occupational Exposure Limits-recommended limits (OEL-RL) are classified in Table 2. The OEL-RL entails the concentration of an airborne substance, as time-weighted average (TWA), at which, according to current knowledge, there would be no harm to employees inhaling the HCS daily (OHSA Regulations 1995:21).

A third table finally lists Biological Exposure Indices (BEIs). BEIs are described as the level of an HCS or metabolite expected to be collected from an exposed, healthy employee, if compared to a person exposed to the OEL-TWA for that substance (OHSA Regulations 1995:15).

A study conducted at an anatomy laboratory where students and workers were exposed to formaldehyde, certain clear short-term health effects and other longer-term effects were considered. The preference, above exposure control measures, is to use a less toxic substitute (Raja & Sultana 2012:36).

##### *2.5.3.10.2 Housekeeping*

*Safety in Academic Chemistry Laboratories*, a publication by the American Chemical Society (ACS), advises that a neat and clean environment normally lead to a safer environment, where cupboards and drawers are kept closed, chemicals are never stored on the floor and workspaces are kept clear. Aisles should be unobstructed by any items. Floors should not have ice, doorstoppers, glass beads, rods or any other small items on them. The laboratory waste disposal procedure for chemical waste must be heeded (ACS 2003:7).

The South African HCS Regulations state that the employer must provide written work procedures to ensure that machinery and work areas are kept clean. The US-OSHA Laboratory Standard advises that floors be cleaned regularly, formal housekeeping inspections be held every three months and informal inspections be on-going.

Mulcahy et al (2013:8) provide an update on progress in response to the TTU incident: a website now communicates laboratory safety issues, a process was instituted for laboratory safety improvement and laboratory clean-out processes were upgraded. Better academic representation on safety committees and peer reviews are considered for safety, and non-compliance is addressed.

#### ***2.5.2.11 Personal protective equipment (PPE) and facilities***

The South African HCS regulations allow for the use of PPE when it is not reasonably practicable to control an exposure adequately. The employer should provide PPE, including HCS-impermeable gloves and protective clothing.

Respiratory protection must provide appropriate control of the HCS below the Occupational Exposure Limit and must be used correctly (OHSA Regulations 1995:10). Zungu (2013:8) determined in a study that the PPE issued to women in mining was designed for men. Women attempted and failed to adjust PPE to fit. The poor fit resulted in a higher risk of exposure health effects of exposure.

According to the OHSA Regulations (1995:10), instruction on the use of PPE and supervision must be given; equipment should be used correctly and be kept in good working condition; dedicated storage must be provided for PPE; contaminated PPE must be treated as HCS waste; staff using PPE should have special washing areas equipped to prevent the spread of HCS; and separate lockers should be provided for PPE and personal clothing.

The American Chemical Society (ACS) Joint Board–Council Committee on Chemical Safety in their publication *Safety in Academic Chemistry Laboratories* (ACS 2003:3) discusses personal protection. Eye protection for everyone in the chemistry laboratory at all times must consist of chemical splash goggles. If the risk of explosion exists, further protection for ears and the neck should be added. Clothing should be non-flammable, non-porous and easy to remove in case of an emergency. An apron is the best option for protection against splashes and spillages. Shoes should cover the feet and should have leather or leather substitute uppers. Loose hair and clothing are unsafe and must be avoided.

Gloves are critical for handling of HCS in a laboratory; they should, however, be chosen and used correctly. Leather and woven gloves are not suitable for work with HCS, but rubber, latex, nitrile and other impervious materials are suitable. The length of the gloves should be appropriate to the nature of work and risk of exposure. Inspection of gloves prior to work with HCS must be carried out to ensure there are no imperfections or contamination. Care should be taken to avoid unintentional contamination by touching door handles and telephones. Should gloves become permeated by a HCS, they must be removed and discarded as hazardous waste. Phalen and Wong (2012:638), accordingly, found a significant permeability variability effect caused by movement (such as stretching or repetitive activity) during the use at laboratories. Different brands of disposable nitrile gloves offered varying levels of permeability upon contact with HCS. Laboratory workers are thus placed at risk of exposure to HCS and a call was made for certification of nitrile gloves for use with HCS.

Husin et al (2012:306) recommend that easy access be ensured to PPE and that each employee receives a bag for storage to prevent contamination.

#### *2.5.2.12 Maintenance of control measures*

According to the HCS Regulations (OHSA Regulations 1995:11), control equipment must be maintained in working order and inspections done every two years by an approved inspection authority.

#### *2.5.2.13 Prohibitions*

The HCS Regulations (OHSA Regulations 1995:11) state that no person should be allowed to eat, drink or smoke or allow others to do so in a respirator zone. Air pressure hoses may not be used to remove traces of HCS from a person or surface.

#### *2.5.2.14 Labelling, packaging, transportation and storage*

The HCS Regulations (OHSA Regulations 1995:12) determine that an HCS in storage should be identified and classified in accordance with national standards. The same ruling is valid for containers or vehicles in which HCS are transported. Upon decanting an HCS, the container must be clearly labelled with regard to its contents.

##### *2.5.2.14.1 Inventory of chemicals*

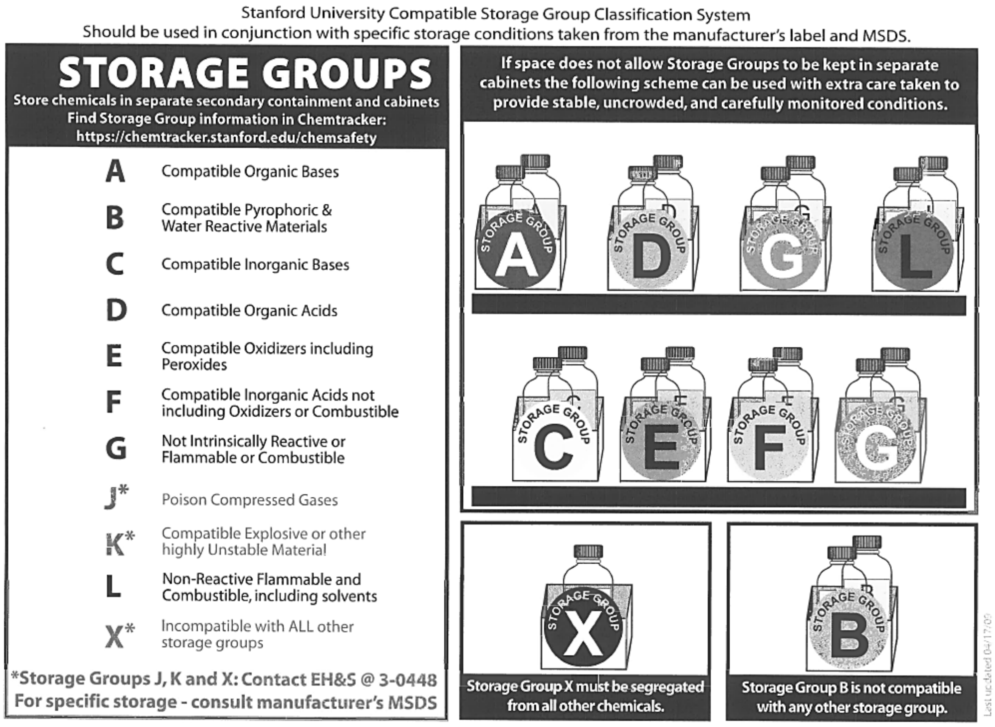
Husin et al (2012:305) advise that an academic laboratory should create and maintain a register of all HCS in the department, detailing the common name, trade names, chemical composition, quantities in stock and where HCS are used and stored.

##### *2.5.2.14.2 Compatible storage of HCS in an academic chemistry laboratory*

*Prudent Practices in the Laboratory (*hereafter *Prudent Practices)* as commented on by the National Academy of Sciences (NAS) (2011:1) suggests that requirements for HCS storage at laboratories and store rooms may vary widely depending on levels of expertise and security measures at the facility. In addition, radioactive substances or explosives may require regulated zones and specified waste containers. Considerations are given for the storage of volatile, toxic or odoriferous HCS, which should occur in a ventilated storage cabinet with a lip to prevent it from sliding off the shelf. The latest inclusion is to store incompatible HCS separately to mitigate the risk of chemicals – even fumes – to mix in case of fire or emergency response. The reactions may damage containers and shelves.

The *Stanford University Compatible Storage Group Classification System* is based on the *Prudent Practices'* classification and it details the storage groups and storage conditions. The system is intended to be used in conjunction with specific requirements derived from MSDS. The storage classification system, as depicted in Table 2.2 below, provides for eleven compatible storage groups, ranging from group A to group X. Groups should be separated by containment in a plastic tray or in separate cabinets NAS 2011:3).

**Table 2.1: Stanford University compatible storage group classification system**




Used with permission from Stanford University

The groups that could be stored in the same cabinet are Groups A and D (compatible organic bases and acids), Group G (not intrinsically reactive/ flammable/combustible substances) and Group L (non-reactive flammable, combustible HCS and solvents). A second cabinet may contain Group C (compatible inorganic bases), Group E (compatible oxidizers including peroxides), Group F (compatible inorganic acids not including oxidizers or combustible HCS) as well as Group G (not intrinsically reactive/flammable/combustible HCS). A third cabinet may only contain HCS from Group X (incompatible with all other storage groups). A separate cabinet should be reserved for Group B (compatible pyrophoric – ignite on contact with air and water reactive – react on contact with water) materials. It is most important to note that separate storage is critical for Groups B and X.

Husin et al (2012:306) also advise separate storage for different hazard types, for example, they advise against storing liquid HCS above eye level. In their research at chemistry and engineering laboratories at a Malaysian HEI, Husin et al (2012: 306) further recommend that liquid HCS not be kept beyond the expiry date, which should clearly appear on the label of the container. HCS with unclear labels must be disposed of.

#### *2.5.2.15 Disposal of HCS*

According to the HCS Regulations (OHSA Regulations 1995:12), the employer shall recycle all waste as far as is reasonably practicable; ensure all collectable waste is in containers that will prevent exposure during handling; and that vehicles in contact with HCS are decontaminated after use so as not to present a hazard on or outside the premises. Disposal of hazardous waste should proceed in accordance with Environmental Conservation Act, not causing a hazard on or outside the workplace premises. Employees who transport HCS waste should wear appropriate PPE. The employer has to ensure that waste disposal contractors comply with the HCS Regulations.

The South African Department of Water Affairs and Forestry's publication entitled *Minimum Requirements for the Handling, Classification and Disposal of Hazardous Waste* (2005:65) provides principles for hazardous waste substance classification under the SANS 10288 code. Nine classes of hazardous waste are listed: explosives, gases, flammable liquids, flammable solids or substances, oxidising substances and organic peroxides, toxic and infectious substances, radioactive substances, corrosive substances and other dangerous substances. The waste treatment for each class aims to reduce toxicity and the impact on the environment, and to achieve compliance with legislation. Waste treatment is followed by a hazard re-assessment and one of four hazard ratings is allocated: extreme, high, moderate or low. Only then is disposal indicated through landfill or incineration. The chemistry department at an HEI is operational within this context.

Karima (2013:142) conducted a study at the University of Tokyo to analyse circumstances and causes of accidents and incidents associated with the disposal of HCS. It was found that the majority of cases occurred during the treatment of HCS before discarding; at the placement of HCS in waste containers; when being discarded in sewage; and during the transport of HCS waste from laboratories to the waste collection site. In addition, accidents and incidents took place when unknown HCS were analysed for identification purposes; within storage spaces of laboratories; and finally when redundant HCS were being removed from laboratories**.**

## 2.6 CONCLUSION

In this chapter literature was reviewed to attain insight into the use and management of HCS at an HEI chemistry department. The next chapter contains the methodology followed to conduct this study.

# CHAPTER 3

# RESEARCH METHODOLOGY

## 3.1 INTRODUCTION

This chapter presents the research methodology used for this study and the justification thereof. The research purpose, objectives and study design are also described in this chapter. Furthermore, the target population and sampling rationale are explained, followed by the study setting. Data collection method, process and analysis are also discussed in this chapter. Finally, ethical considerations that guided the execution of the study as well as measures of reliability and validity are described in this chapter.

## 3.2 RESEARCH PURPOSE

Although a substantial range of HCS is used for academic purposes in the chemistry department of an HEI, limited information was obtainable on the types and forms of HCS available and used at such department and the nature and impact of associated hazards. The situation prompted a need to explore the use and management of HCS so that occupational injuries and disease can be assessed for risk, and prevented or mitigated appropriately. The purpose of this baseline survey was to investigate the use and management of hazardous chemical substances at a chemistry department in a selected higher education institution in Gauteng province.

## 3.3 RESEARCH PARADIGM

Creswell (2009:6) defines a paradigm as “a basic set of beliefs that guide action”. The quantitative approach is used in this research, as it is a valuable paradigm when research requires the development of statistical measures of observations, as explained in Creswell (2009:7).

The quantitative approach was selected to enable survey research and to enrich the survey inspections with additional numerical data and statistical analysis thereof to obtain information. The paradigm, therefore, allowed the researcher to collect data on years of experience, job categorisation in relation to sub-departments, and the age and gender of employees at the chemistry department. In this way, the data thus contextualised the survey.

## 3.4 RESEARCH DESIGN

According to Grove, Burns and Gray (2013:214), a research design is "a blueprint" to conduct research, which allows full control over aspects that could impede the legitimacy of the study.

The descriptive study design is useful either to validate current practice or to identify irregularities in practice and to make an assessment of what other persons in similar environments are doing (Grove et al 2013:215). The chosen study design presented itself as the design of choice in pursuit of the research objectives.

The cross-sectional nature of a design would inspect groups of subjects across different patterns or practices with the intent to describe changes in phenomena across stages (Grove et al 2013:220). This approach provided for a "snap-shot" of current practice among all designations of employees and in all laboratories at the chemistry department.

An observational measurement uses unstructured and designed inspection formats to test a study variable. Although there is an element of subjectivity, some practices could only be measured by structured observational measurement, provided that the researcher aims for consistency (Grove et al 2013:421). It was the researcher's objective to be consistent in the time spent, the number of survey elements investigated and in the general assessment of all sub-departments that were visited.

This study was therefore cross-sectional quantitative, descriptive and observational in nature as it included conducting an inspection of the chemical laboratory facilities at the study site to investigate the use and management of hazardous chemical substances by using a checklist and also by consulting with workers in the chemistry department to provide clarification regarding some of the observed aspects.

A retrospective study is described as a study where “the proposed cause and proposed effect have occurred” (Grove et al 2013:219). For this study, the researcher studied the demographic information of employees working at the chemistry department and reviewed a list of HCS, supplied by the chemistry department, in which the physical, health and environmental hazards are described. A collection of Material Safety Data Sheets (MSDS) of all HCS in use at the department were requested from a lecturer and studied. Finally, a pre-existing Occupational Hygiene report of a health risk assessment on environmental agents conducted at the faculty in 2010 was examined. This report ranked all identified occupational health risks at the department into “low”, “moderate” or “high” risk bands.

## 3.5 RESEARCH METHOD

### 3.5.1 Research setting

This study was undertaken at the chemistry department of a selected higher education institution in Gauteng province, South Africa. Research, teaching and learning are conducted at the chemistry department for a mix of undergraduate and postgraduate academic programmes. Facilities include offices, several first-year laboratories, post-basic laboratories and a technical workshop. Employee categories include administrative employees, technicians, lecturers, demonstrators and researchers.

### 3.5.2 Sampling procedure

#### *3.5.2.1 Study population*

The chemistry department at the HEI was included as target population. The following ten sub-departments were identified, namely, Offices, First-Year laboratories, Second- and Third-year laboratories, Honours laboratory, NMR (Nuclear Magnetic Resonance) laboratory, Inorganic Synthesis laboratory, High Pressure laboratory, Thermodynamic, Crystallography & Physical Chemistry laboratories, Analytical Chemistry laboratories, and Organic Chemistry laboratories. Three job categories were identified, namely *academic* employees were represented as lecturers, researchers or demonstrators, while *technical* employees and *administrative* employees were also working in the department. The total of 21 people employed at the department comprised eleven academics, eight technical and two administrative employees. The purposive sampling during the survey allowed for employees in the department to be consulted further for clarification to the checklist questions.

#### *3.5.2.2 Study setting*

For the purpose of this study, the actual inspection took place in a selection of different sub-departments of the chemistry department, namely Offices, First-Year laboratories, Inorganic Synthesis laboratory, Honours laboratory, Analytical Chemistry laboratories, and Organic Chemistry laboratories.

#### *3.5.2.3 Sample*

##### *3.5.2.3.1 Sampling method*

This study used a purposive sampling method to conduct the environmental inspection of facilities in the chemistry laboratory at the selected HEI whereby the researcher purposively selected elements and participants for inclusion in the study.

### 3.5.3 Data collection

#### *3.5.3.1 The data collection instrument*

For this study, a pre-designed, self-administered survey checklist was used to conduct an environmental inspection of facilities at the chemistry laboratory of the selected HEI.

##### *3.5.3.1.1 Design of the data collection instrument*

The workplace safety inspection checklist assimilated elements from the International Labour Organizations' occupational health management systems and the Occupational Health and Safety Act (Act No 85 of 1993) on the use and management of hazardous chemical substances. The checklist was designed for general use and it may not be exhaustive to address specific environmental issues associated with health and safety in a workplace. It comprised three sections, namely:

(a) the inspection items

(b) compliant response (Yes/No/N/A)

(c) corrective actions required which specify the location, good practices, problem observed and the possible cause of nonconformity and/or proposed corrective or preventative actions.

If any item on the checklist during inspection was identified as not compliant (for example, the researcher indicated a "No" in response to the item), a corrective action was specified and the action transferred to the Corrective Action section.

*3.5.3.1.2 Eight survey objectives*

Elements relative to standards for the use and management of HCS in a chemistry laboratory were clustered under eight survey objectives. The eight survey objectives reflected in the survey tool (checklist) are explained next.

An investigation was conducted into the availability and presence of laboratory health and safety policies, procedures and programmes. This investigation was followed by a section to determine employees' skills in their work with HCS: in this section the appropriate training for work with HCS and emergencies, safety signage and recordkeeping of training sessions were addressed. The third objective was to verify if the department was adequately prepared for an emergency: the display of emergency numbers, the availability of a first aider and first-aid bag, and the location of fire escape doors are examples of items included in this objective.

In the fourth objective, the general condition of the department was gauged, including housekeeping, machine guarding, safety inspections and equipment such as eyewash fountains and ventilation to prevent the build-up of HCS. It was also necessary to determine the safety behaviour of the department towards using hazardous materials, including access to MSDS, the labelling of containers and correct storage practices for HCS. The management of hazardous waste in the department included selection of the least toxic chemical, smallest scale reactions, waste separation and proper disposal. The objective on Personal Protective Equipment (PPE) intended to observe the assessment of potential exposure to hazards, and the utilisation and condition of PPE in the department. Finally, objective eight aimed to identify whether occupational health related matters had been addressed or not, and accessibility to emergency medical services on campus.

#### *3.5.3.2 Data collection plan*

The researcher obtained approval from the departmental head at the chemistry department to conduct the site visits on 11, 12 and 13 November 2013. With her consent, no formal appointments were made to visit specific sub-departments on given dates, allowing for the unannounced nature of visits to obtain insight into real-life practices. During the three days intended for survey data collection, a total of 4,5 hours were spent on site. The researcher used the survey checklist to guide observation of the environment and then recorded the presence, absence or non-applicability of checklist elements on the sheet by hand.

In the course of the site visits, employees at the chemistry department were approached for clarifying comment further to the observations made in the department. The researcher recorded all observations, descriptions and further clarifying notes on the checklist.

### 3.5.4 Ethical considerations

The Medical Research Council (MRC) of South Africa provides for four principles of biomedical research, namely autonomy, beneficence, non-maleficence and justice. Observation research is further described as “non-invasive, involving no risk and no interference with the mental or physical integrity of the human being” (MRC fourth edition:9). It was the intention of this study to conduct observational research, wherein the mental or physical aspects of persons remained untouched (MRC fourth edition: 11). The ethical intent of this study was to promote the health of workers and prevent occupational injuries and disease.

Below, consideration is given to standards of ethical conduct during research.

#### 3.5.4.1 Permission

The Ethics Committee of the University of South Africa granted permission to conduct the study. In addition, the Registrar at the HEI under study was approached for permission to conduct the study and responded with approval thereof. The head of the chemistry department – as the study site – finally provided permission.

#### 3.5.4.2 Beneficence

The principle of non-maleficence was applied in this study to protect freedom from harm to employees. The right to protection from exploitation, as described in Polit and Beck (2010:122), was upheld by expecting no information from employees for clarification purposes, unless given to the researcher freely and of their own will.

#### 3.5.4.3 Confidentiality

During the study, confidentiality was maintained for all data and information obtained Grove et al (2013:177) contend that all information obtained during a study should remain confidential.

#### 3.5.4.4 Privacy

Access to personal records should remain protected, as advised by the MRC (MRC 2004:5) and accordingly, the researcher, during this study, undertook to treat all personal demographic information with care to ensure its privacy.

#### 3.5.4.5 Anonymity

The University of British Columbia Behavioural Review on Ethics Guidance Notes defined anonymity as follows: “the research subject is only anonymous if the data does not include any identifiers, codes or unique information that can be used to identify the subject” (Andres 2012:130). Anonymity in this study will be assured by non-disclosure of the identities of employees and the institution’s name, also during the publication of findings. The survey checklist was devoid of any identification of respondents or their responses.

#### *3.5.4.6 Relevance*

The ethical responsibility of researchers in South Africa includes the rendering of research findings into instruments for health promotion of South Africans (MRC 2004:3). It is the intention of this study to provide findings that are valuable for application at HEIs nationally.

### 3.5.5 Data analysis method

Data were analysed by means of SPSS version 18.0. A coding system was developed for data to be entered into a computer for subsequent processing and analysis. Data were checked, cleaned and entered into MS Excel and then imported into SPSS version 18.0 for statistical analysis. Descriptive statistics including mean, median and standards deviation were used to calculate frequencies and percentages of various elements under study.

## 3.6 SCOPE AND LIMITATIONS OF THE STUDY

### 3.6.1 Methodological limitations

#### *3.6.1.1 Sample limitations*

According to Ornstein (2013:6), coverage refers to the "proportion of the target population that can actually be selected and surveyed". In this study, the sample consisted of the different sub-departments within the chemistry department at the chosen HEI in the Gauteng province, which were visited during data collection.

#### *3.6.1.2 Bias*

Objectivity could have been lessened during data collection, analysis and interpretation of data that might have resulted in conclusions being drawn that were not exact reflections of the reality. Although unintentional, bias is recognised as a study limitation. Therefore, the validity and reliability of the data collection instrument was of prime importance. Consistent interpretation of the survey results was important to ensure the highest degree of accuracy and reliability.

Bias could have been prevalent in the survey checklist questions, yet the questions were phrased in such a manner as to avoid leading questioning.

Sampling bias and response bias *were* probable occurrences, based on participants' availability or willingness to respond and the response types by participants.
Selection *bias* could be viewed as a study limitation due to the researcher's selection of sub-departments based on availability during data collection.

## 3.7 INTERNAL AND EXTERNAL VALIDITY OF THE STUDY

### 3.7.1 Validity

*Validity* refers to the degree of the truth or the correctness of a claim (Grove et al 2013:197). In this study, the principles on which the data collection instrument was formulated, originated from a global source, namely the ILO and the national regulatory universe in South Africa on the use and management of HCS. Survey questions were further explained to participants, when requested, in a consistent manner, for the purpose of clear understanding.

According to Edmonds and Kennedy (2013:4, 5), *External validity* is the "extent to which the results can be generalised to the relevant populations, settings, treatments or outcomes". The study findings have the potential for generalisation in view of the fact that comparable ranges of HCS might be used and managed at chemistry departments of numerous other HEIs.

### 3.7.2 Reliability

Andres (2012:122) holds the view that reliability refers to "the extent to which the findings of a study can be replicated" and Grove et al (2013:389) concur that a particular data collection instrument is reliable if it yields consistent results at different times. The instrument that was administered in this study was pre-designed, structured and consistently presented to respondents in the same manner, allowing no deviations and ensuring uniformity and replicability.

## 3.8 CONCLUSION

The research purpose and objectives preceded a review of research methodology and design in this chapter. The methodology examined the research environment, the population and sampling, while ethical and procedural aspects of data collection were followed by data analysis. Measures to ensure reliability and validity were discussed in conclusion. An interpretation of the analysed data follows in the next chapter.

# CHAPTER 4

# ANALYSIS, PRESENTATION AND DISCUSSION OF RESEARCH FINDINGS

## 4.1 INTRODUCTION

This chapter presents the findings of the data analysis. Data are presented in tables and in figure illustrations. Lastly, the chapter also includes the discussion of findings by referring to the relevant literature.

## 4.2 CONTEXT AND STATISTICAL ANALYSIS OF DEMOGRAPHIC DATA

This baseline study was observational in nature and was conducted at the chemistry department of an HEI in Gauteng province to investigate the use and management of hazardous chemical substances (HCSs). In the department, there were 10 sub-departments, namely, Offices, First-year laboratories, Second- and Third-year laboratories, Honours laboratory, NMR (Nuclear Magnetic Resonance) laboratory, Inorganic Synthesis laboratory, High Pressure laboratory, Thermodynamic, Crystallography and Physical Chemistry laboratories, Analytical Chemistry laboratories, and Organic Chemistry laboratories. Three job categories were identified: *academic* employees were represented as lecturers, researchers or demonstrators, while *technical* employees and *administrative* employees were also working in the department. The total of 21 people employed at the department comprised eleven academics, eight technical and two administrative employees. The purposive sampling during the survey allowed for employees in the department to be consulted further for clarification to the checklist questions. Employees from each of the three employee categories were randomly included during the survey to provide clarity where needed.

### 4.2.1 Findings of the statistical analysis of demographic data of the population

#### *4.2.1.1 Frequency distribution of age of employees in the chemistry department*

It was established that the average age of employees in the chemistry department was 44 years and that the majority (76.2%) were aged between 30 – 49 years.

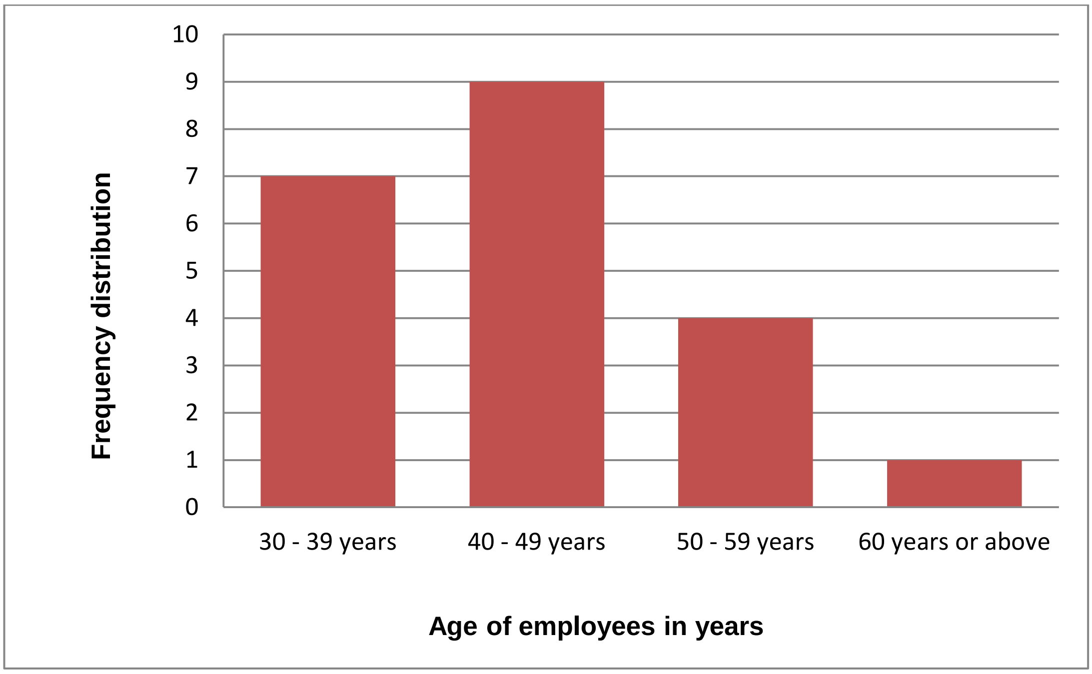



**Figure 4.1: Frequency distribution of age of employees in the chemistry department (n=21)**

#### *4.2.1.2 Frequency distribution of gender of employees in the chemistry department*

Two-thirds (66.6%) of employees in the targeted department were males compared to 33.3% who were females as shown in Figure 4.2.

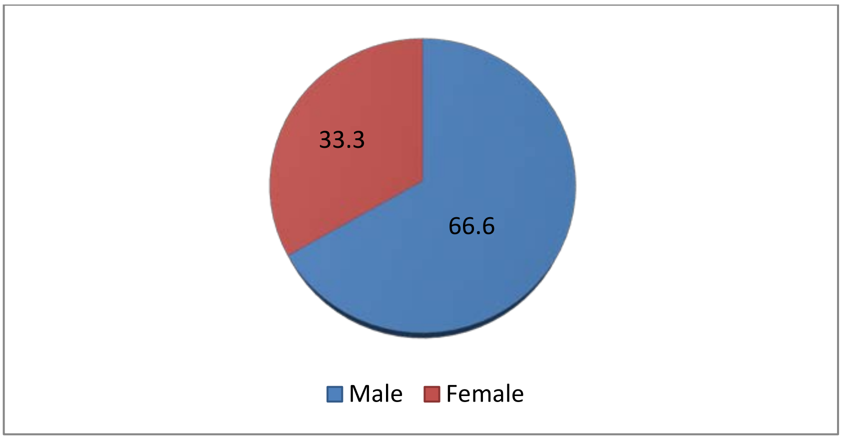



**Figure 4.2: Participants' frequency distribution of gender (n=21)**

#### *4.2.1.3 Frequency distribution of years of experience of employees in the chemistry department*

The research revealed that 71.4% of employees had been working at the chemistry department for more than five years as shown in Figure 4.3. Employees with between two and three years of experience comprised 19.0% of the total number of employees.

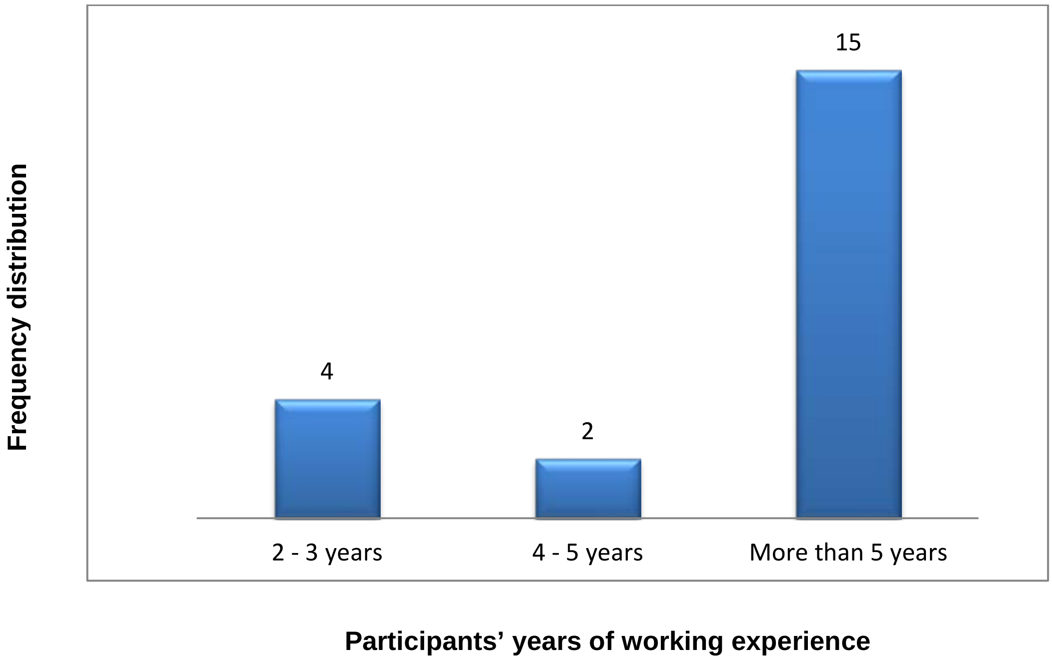



**Figure 4.3: Participants' frequency distribution of years of working experience (n=21)**

### *4.2.1.4 Frequency distribution of employees per job categorisation within sub-departments in the chemistry department*

The analysis showed that the majority of academic employees worked in the first-year laboratories, followed by the thermodynamic laboratory. By comparison, most of the technical employees were working in first-, second- and third-year laboratories, followed by the honours laboratory as shown in Figure 4.4. Further, it should be noted that selected employees from academic and technical job categories work in more than one laboratory. Therefore, Figure 4.4 represents the primary area to which employees are assigned.

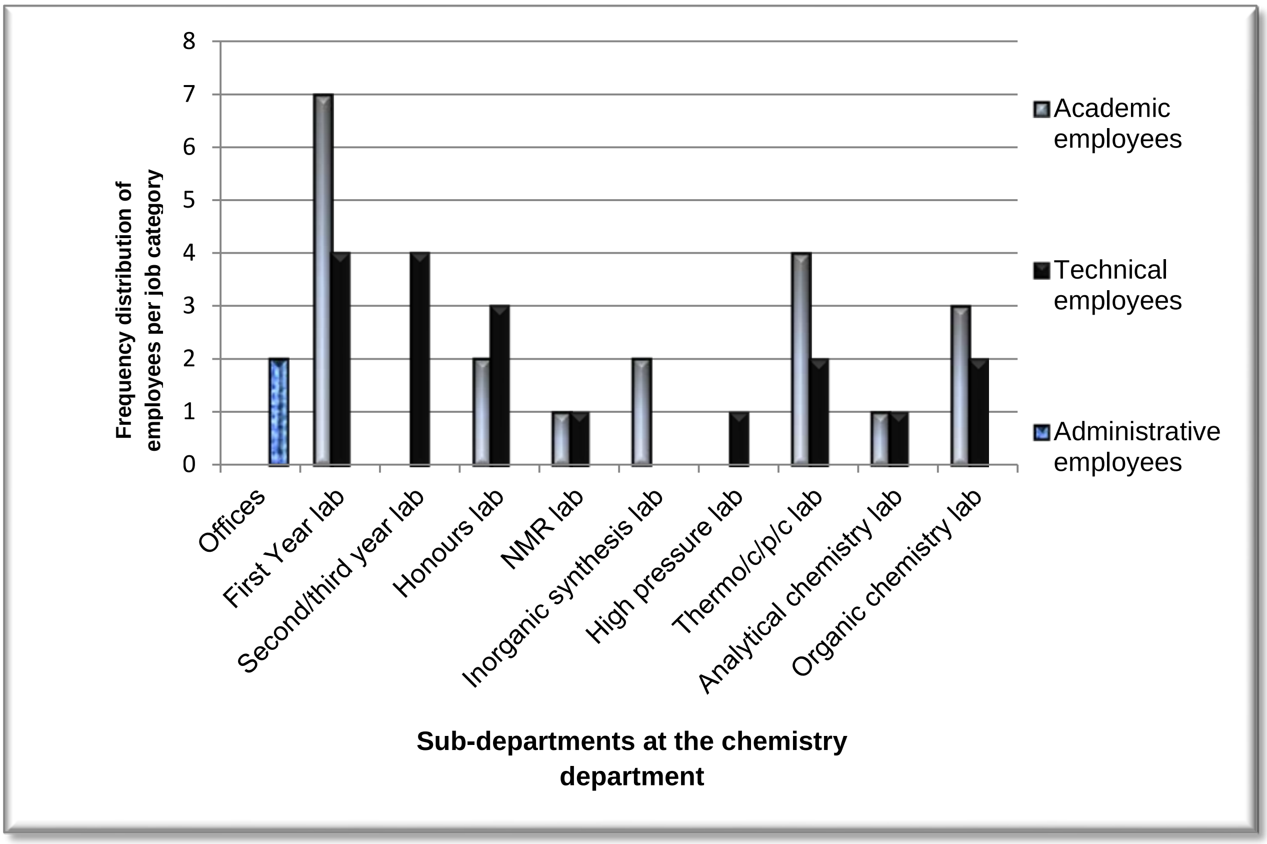



**Figure 4.4: Number of employees per job categorisation**

**(Note: Some academics and technical employees work in more than one laboratory)**

## 4.3 THEMATIC PRESENTATION OF FINDINGS

### 4.3.1 Introduction: the association between the research objectives, the survey objectives and supplementing sources

The three *research* objectives of this study were linked to the eight *survey* objectives and are described next. The particular survey objectives associated with each research objective yielded findings most closely answering the research objectives.

It should also be noted that supporting documents, such as the list of HCSs used at the chemistry department and an Occupational Hygiene Health Risk Assessment, served as additional sources of information to clarify survey questions. These sources will be integrated with discussions on each research objective.

### 4.3.2 Findings relative to research objective one: identification and description of the types and forms of hazardous chemicals used at the chemistry department of the selected Higher Education Institution (HEI) in Gauteng province

#### *4.3.2.1 Description of types and forms of HCS used in the chemistry department*

For the purpose of this study and in line with the Globally Harmonized System of Classification and Labelling of Chemicals (GHS), the study concept of *types* will be compared to the hazard class as it appears in the GHS. The concept of *forms* as in the research objective will be reflected as hazard types in the table.

##### *4.3.2.1.1 Table reflecting the hazard classes and hazard types of HCS used at the chemistry department*

The information required to complete the table was requested from the divisional heads of the chemistry department at the study site. After the researcher obtained the Material Safety Data Sheets (MSDSs) on each HCS present at the department, the HCSs were further classified into hazard class and hazard types in accordance with the GHS. The combined results are displayed in Table 4.1.

**Table 4.1: Hazard classes and hazard types of hazardous chemical substances at the chemistry department**

| Hazardous Chemical Substances at Chemistry Department | | |
|---|---|---|
| **Hazard class** | **Hazard type** | **Chemical substances used** |
| **Physical hazards** | Explosives | Hydrazine; perchloric acid |
| | Flammable gases | H2; CO |
| | Flammable aerosols | *None* |
| | Oxidizing gases | O2 |
| | Gases under pressure | N2, Ar, H2, H2/CO |
| | Flammable liquids | Hexane, diethylether, methanol, tetrahydrofuran, dichloromethane, acetonitrile |
| | Flammable solids | All organics |
| | Self-reactive substances | *None* |
| | Pyrophoric liquids | *None* |
| | Pyrophoric solids | Raney Nickel |
| | Self-heating substances | *None* |
| | Substances which, in contact with water, emit flammable gases | Na, K, Ca |
| | Oxidizing liquids | HClO4, H2O2 |
| | Oxidizing solids | KMnO4 |
| | Organic peroxides | tert-buthylhydroperoxide (TBHP) |
| | Corrosives to metals | *None* |
| **Health hazards** | Acute toxicity | CHCl3 (Chloroform), tert-buthylhydroperoxide, Hydrazine; hydrogen peroxide. |
| | Skin corrosion/irritation | Acetone, methanol, tetrahydrofuran, dichloromethane; perchloric acid |
| | Serious eye damage/eye irritation | Acetone, H2O2; perchloric acid |
| | Respiratory or skin sensitization | Cyclooctadiene |
| | Germ cell mutagenicity | tert-buthylhydroperoxide |
| | Carcinogenicity | Mercury (Hg); hydrazine; hydrogen peroxide; dichloromethane, arsenic, chloroform; formaldehyde; Raney nickel. |
| | Reproductive toxicology | Hg, As |
| | Target organ systemic toxicity – single exposure | All chemicals |
| | Target organ systemic toxicity – repeated exposure | All chemicals |
| | Aspiration toxicity | CO; tert-buthylhydroperoxide |
| **Environmental hazards** | Acute aquatic toxicity | All chemicals |
| | Chronic aquatic toxicity:<br>1 Bio-accumulation potential | 1 Hg; TBHP; Hydrazine; Raney Nickel; Arsenic |
| | 2 Rapid degradability | 2 *None* |

#### *4.3.2.1.2 Overview of hazard classes and hazard types of HCSs present at the chemistry department*

a) HCSs from each of the three hazard classes identified in Table 4.1 as physical-, health and environmental hazard classes were present at the chemistry department.

b) Under the physical hazard class, as depicted in Table 4.1, eleven hazard types were present at the chemistry department. The hazard types were Explosives, Flammable gases, Oxidizing gases, Gases under pressure, Flammable liquids, Flammable solids, Pyrophoric solids, Substances that, in contact with water, emit flammable gases, Oxidizing liquids, Oxidizing solids and Organic peroxides.

c) Health hazards found at the chemistry department consisted of HCSs from each of the ten health hazard types, as classified by the GHS in Table 4.3, namely Acute toxicity, Skin corrosion/irritation, Serious eye damage/eye irritation, Respiratory or skin sensitization, Germ cell mutagenicity, Carcinogenicity, Reproductive toxicology, Target organ systemic toxicity – single exposure, Target organ systemic toxicity – repeated exposure and Aspiration toxicity.

d) Acute aquatic toxicity is one of two hazard types within the environmental hazard class. It was found that all chemicals used at the chemistry department could be classified under this hazard type. Chronic aquatic toxicity in HCS which pose a bio-accumulation potential, originated from five HCSs, while no HCSs were present which carried a rapid degradability characteristic.

#### *4.3.2.1.3 Detailed discussion on the HCS hazard classes, hazard types and HCSs used at the chemistry department*

A detailed discussion follows next on the HCS hazard classes, hazard types and the identification of the corresponding HCSs found at the chemistry department.

*a) Physical hazard types*

Two explosives, namely hydrazine and perchloric acid, were present, while flammables were present in all three forms: gas (hydrogen and carbon monoxide), liquid (hexane, methanol, tetrahydrofuran dichloromethane, tert-buthylhydroperoxide and acetonitrile) and as solids (all organic substances). The only pyrophoric solid substance was Raney nickel. Gases under pressure found at the department were nitrogen, argon, hydrogen gas and a synthetic mixture of hydrogen gas and carbon monoxide (known as *syngas*).

Oxidising substances were present as a gas (oxygen), as a liquid (perchloric acid and hydrogen peroxide) and as a solid (potassium permanganate). Those HCSs that emit flammable gas upon contact with water were sodium, potassium and calcium. The only organic peroxide was tert-buthylhydrogenperoxide.

*b) Health hazard types*

Acute toxicity potential within the health hazard class was displayed by the presence of chloroform, tert-buthylhydroperoxide, hydrogen peroxide and hydrazine.

Health hazard types that may cause skin corrosion were acetone, methanol, tetrahydrofuran, dichloromethane and perchloric acid, while serious eye damage or irritation may be related with acetone, hydrogen peroxide and perchloric acid. Respiratory or skin sensitization risk is linked with cyclooctadiene.

Carcinogenicity was associated with eight of the HCSs present at the chemistry department, namely mercury, hydrazine, hydrogen peroxide, chloroform, dichloromethane, arsenic, formaldehyde and Raney nickel. In line with the International Agency for Research on Cancer (IARC) of the World Health Organization (WHO) classification tables on carcinogens (WHO 2004:ix), the group descriptors of carcinogenic risk and HCSs present at the department are represented in Table 4.2.

**Table 4.2: HCSs present at the chemistry department which are classified by the IARC Monographs on the Evaluation of Carcinogenic Risks to Humans (WHO)**

| GROUP | GROUP DESCRIPTORS | HCSs PRESENT AT THE CHEMISTRY DEPARTMENT |
|---|---|---|
| 1 | Carcinogenic to humans | Arsenic; formaldehyde |
| 2A | Probably carcinogenic to humans | Nil |
| 2B | Possibly carcinogenic to humans | Raney nickel, dichloromethane, chloroform; hydrazine |
| 3 | Not classifiable as to its carcinogenicity to humans | Hydrogen peroxide; mercury |

Health hazard types connected to reproductive toxicology were mercury and arsenic, while all HCSs posed the risk of target organ systemic toxicity upon single and repeated exposure. Aspiration toxicity was associated with carbon monoxide and tert-buthylhydroperoxide and germ cell mutagenicity was related to tert-buthylhydroperoxide.

*c) Environmental hazard types*

Acute aquatic toxicity was inherent to all HCS at the chemistry department, while chronic aquatic toxicity with a bio-accumulation potential was connected to mercury, tert-buthylhydroperoxide, hydrazine, arsenic and Raney nickel. No HCSs were found in the chronic aquatic toxicity hazard type, which was related to rapid degradability.

*4.3.2.1.4 Applicability of the regulated Occupational Exposure Limits to the use and management of HCSs at the chemistry department*

The HCS Regulations under the OHSA define two types of Occupational Exposure Limits for work with HCSs in the occupational setting. Biological Exposure Indices are also provided.

An Occupational Exposure Limits with a Control Limit (OEL-CL) in Table 1 is provided for an occupational exposure where a residual risk to health may exist at the exposure level (OHSA Regulations 1995:18).

When applying the Occupational Exposure Limits to the HCSs present at the chemistry department, it was found that four HCSs, namely dichloromethane, arsenic, formaldehyde and Raney nickel could be classified under Table 1, where Control Limits are provided.

Multiple HCSs at the department, however, resorted under Table 2, which prescribes a Recommended Limit. An Occupational Exposure Limits with a Recommended Limit (OEL-RL) in Table 2 is set at a level at which there is no indication of a risk to health at the exposure level, where deviations above the exposure limit is nor foreseen and where compliance is “reasonably practicable” (OHSA Regulations 1995:19). Table 2 applied to ten HCSs: chloroform, acetone, tetrahydrofuran, dichloromethane, hydrogen peroxide, hydrazine, mercury, carbon monoxide, hexane, diethylether and acetonitrile.

Biological Exposure Indices, which are defined as reference values, are intended as guidelines for the evaluation of potential health hazards as listed in Table 3 of Annexure 1 in the HCS Regulations. Biological Exposure Indices applied to methanol, arsenic, acetone, carbon monoxide, hexane and mercury in the study site.

#### *4.3.2.1.5 Tables reflecting HCSs present at the chemistry department*

In the next section, the first table reflects the HCS name, formula or symbol and MSDS, while the second table displays a synthesis of HCSs classified according to Occupational Exposure Limits, Biological Exposure Indices, carcinogenicity and hazard types.

a) *HCSs name, formula/symbol and MSDS at the chemistry department*

Table 4.3 below displays the HCSs present at the chemistry department. For each HCS, the relevant electronic link to the MSDS is provided.

**Table 4.3: Hazardous Chemical Substances (with MSDS) present at the chemistry department**

| HCS name | Hazardous Chemical Substance: | | MSDS |
|---|---|---|---|
| | Formula | Symbol | |
| Acetone | C3H6O | - | Acetone.pdf |
| Acetonitrile | C2H3N | - | PrintMSDSAction.do-2.pdf |
| Argon | - | Ar | Argon.pdf |
| Arsenic | - | As | Arsenic.pdf |
| Calcium | - | Ca | Calcium.pdf |

| HCS name | Hazardous Chemical Substance: | | MSDS |
|---|---|---|---|
| | Formula | Symbol | |
| Carbon Monoxide | CO | - | Carbon monoxide.pdf |
| Chloroform | CHCl3 | - | Chloroform.pdf |
| Cyclooctadiene | C8H12 | - | 1,5 Cyclooactadiene.pdf |
| Dichloromethane | CH2Cl2 | - | Dichloromethane.pdf |
| Diethylether | C4H10O | - | diethylether.pdf |
| Hexane | C6H14 | - | Hexane.pdf |
| Hydrazine | N2H4 | - | Hydrazine.pdf |
| Hydrogen | H2 | - | Hydrogen.pdf |
| Hydrogen peroxide | H2O2 | - | Hydrogen peroxide.pdf |
| Mercury | - | Hg | Mercury.pdf |

| HCS name | Hazardous Chemical Substance: | | MSDS |
|---|---|---|---|
| | Formula | Symbol | |
| Methanol | CH4O | - | Methanol.pdf |
| Nitrogen | N2 | N | Nitrogen.pdf |
| Oxygen | - | O | Oxygen.pdf |
| Perchloric acid | HClO4 | - | Perchloric acid.pdf |
| Potassium | - | K | Potassium.pdf |
| Potassium permanganate | KMnO4 | - | Potassium permanganate.pdf |
| Raney nickel | | | Raney Nickel.pdf |
| Sodium | - | Na | Sodium.pdf |
| Synthetic gas:<br>Carbon monoxide and hydrogen mixture | H2/CO | - | Hydrogen.pdf<br>Carbon monoxide.pdf |
| Tert-buthylhydroperoxide TBHP | C4H10O2 | - | tert-buthyl hydroperoxide.pdf |
| Tetrahydrofuran | C4H8O | - | Tetrahydrofuran.pdf |

*b)* *HCSs classified according to Occupational Exposure Limits, Biological Exposure Indices, carcinogenicity and hazard types*

Table 4.4 below displays the HCSs present at the chemistry department, classified in accordance with the Occupational Exposure Limits and Biological Exposure Indices as they appear in the HCS Regulations. Carcinogenicity is indicated according to the IARC classification groups of the relevant HCS. Each HCS used at the chemistry department is identified and physical, health and environmental hazard types related to the particular HCS are indicated.

**Table 4.4: Table depicting the Occupational Exposure Limits and Biological Exposure Indices, carcinogenicity and hazard types of HCS present at the chemistry department of the study site**

| OCCUPATIONAL EXPOSURE LIMITS, BIOLOGICAL EXPOSURE INDICES, CARCINOGENICITY AND HAZARD TYPES OF HAZARDOUS CHEMICAL SUBSTANCES AT THE CHEMISTRY DEPARTMENT | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Occupational Exposure Limits** and **Biological Exposure Indices** Tables as in HCS Regulations | HCS Identification | Physical, health and environmental hazard types | | | | | | | | | | | | | | | | | | |
| | | Carcinogenicity: IARC Groups* | Flammable aerosol, solid, liquid or gas | Acute toxicity | Explosive | Pyrophoric | Oxidising liquid, solid | Gases under pressure | HCS which emit flammable gas | Organic peroxide | Aspiration toxicity hazard | Respiratory- or skin Sensitization | Serious eye damage or irritation | Skin corrosion or irritation | Target organ Systemic toxicity (Single exposure.) | Target organ Systemic toxicity (repeated exposure) | Germ cell mutagenicity | Reproductive toxicity | Chronic aquatic toxicity | Acute aquatic toxicity |
| **Occupational Exposure Limits:** Control Limit Table 1 | Dichloromethane | 2B | Liquid | | | | | | | | | | | | | | | | | |
| | Raney nickel | 2B | | | | Liquid | | | | | | | | | | | | | | |
| | Arsenic | 1 | | Oral & inhalation | | | | | | | | | | | | | | | | |
| | Formaldehyde | 1 | | Oral dermal & inhalation | | | | | | | | | | | | | | | | |

| OCCUPATIONAL EXPOSURE LIMITS, BIOLOGICAL EXPOSURE INDICES, CARCINOGENICITY AND HAZARD TYPES OF HAZARDOUS CHEMICAL SUBSTANCES AT THE CHEMISTRY DEPARTMENT | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Occupational Exposure Limits** and **Biological Exposure Indices** Tables as in HCS Regulations | HCS Identification | Physical, health and environmental hazard types | | | | | | | | | | | | | | | | | | |
| | | Carcinogenicity: IARC Groups* | Flammable aerosol, solid, liquid or gas | Acute toxicity | Explosive | Pyrophoric | Oxidising liquid, solid | Gases under pressure | HCS which emit flammable gas | Organic peroxide | Aspiration toxicity hazard | Respiratory- or skin Sensitization | Serious eye damage or irritation | Skin corrosion or irritation | Target organ Systemic toxicity (Single exposure.) | Target organ Systemic toxicity (repeated exposure) | Germ cell mutagenicity | Reproductive toxicity | Chronic aquatic toxicity | Acute aquatic toxicity |
| **Occupational Exposure Limits:** Recommended Limit Table 2 | Chloroform | 2B | | Oral & inhalation | | | | | | | | | | | | | | | | |
| | Acetone | | Liquid | | | | | | | | | | | | | | | | | |
| | Tetrahydro-furan | | Liquid | | | | | | | | | | | | | | | | | |
| | Hydrogen peroxide | 3 | | Oral | | | Liquid | | | | | | | | | | | | | |
| | Hydrazine | 2B | Liquid | Oral dermal & inhalation | | | | | | | | | | | | | | | | |
| | Mercury | 3 | | | | | | | | | | | | | | | | | | |
| | Carbon monoxide | | Gas | | | | | | | | | | | | | | | | | |
| | Hexane | | Liquid | | | | | | | | | | | | | | | | | |
| | Diethylether | | Liquid | | | | | | | | | | | | | | | | | |
| | Acetonitrile | | Liquid | Oral dermal & inhalation | | | | | | | | | | | | | | | | |

**OCCUPATIONAL EXPOSURE LIMITS, BIOLOGICAL EXPOSURE INDICES, CARCINOGENICITY AND HAZARD TYPES OF HAZARDOUS CHEMICAL SUBSTANCES AT THE CHEMISTRY DEPARTMENT**

| **Occupational Exposure Limits** and **Biological Exposure Indices** Tables as in HCS Regulations | HCS Identification | Physical, health and environmental hazard types | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Carcinogenicity: IARC Groups* | Flammable aerosol, solid, liquid or gas | Acute toxicity | Explosive | Pyrophoric | Oxidising liquid, solid | Gases under pressure | HCS which emit flammable gas | Organic peroxide | Aspiration toxicity hazard | Respiratory- or skin Sensitization | Serious eye damage or irritation | Skin corrosion or irritation | Target organ Systemic toxicity (Single exposure.) | Target organ Systemic toxicity (repeated exposure) | Germ cell mutagenicity | Reproductive toxicity | Chronic aquatic toxicity | Acute aquatic toxicity |
| Biological Exposure Indices<br><br>Table 3 | Methanol | | Liquid | | | | | | | | | | | | | | | | | |
| | Arsenic | 1 | | | | | | | | | | | | | | | | | | |
| | Acetone | | Liquid | | | | | | | | | | | | | | | | | |
| | Carbon monoxide | | Gas | | | | | | | | | | | | | | | | | |
| | Hexane | | Liquid | | | | | | | | | | | | | | | | | |
| | Mercury | 3 | | | | | | | | | | | | | | | | | | |

| OCCUPATIONAL EXPOSURE LIMITS, BIOLOGICAL EXPOSURE INDICES, CARCINOGENICITY AND HAZARD TYPES OF HAZARDOUS CHEMICAL SUBSTANCES AT THE CHEMISTRY DEPARTMENT | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Occupational Exposure Limits** and **Biological Exposure Indices** Tables as in HCS Regulations | HCS Identification | Physical, health and environmental hazard types | | | | | | | | | | | | | | | | | |
| | | Carcinogenicity: IARC Groups* | Flammable aerosol, solid, liquid or gas | Acute toxicity | Explosive | Pyrophoric | Oxidising liquid, solid | Gases under pressure | HCS which emit flammable gas | Organic peroxide | Aspiration toxicity hazard | Respiratory- or skin Sensitization | Serious eye damage or irritation | Skin corrosion or irritation | Target organ Systemic toxicity (Single exposure.) | Target organ Systemic toxicity (repeated exposure) | Germ cell mutagenicity | Reproductive toxicity | Chronic aquatic toxicity | Acute aquatic toxicity |
| HCS not in HCS Regulations tables | Cyclo-octadiene | | | | | | | | | | | | | | | | | | | |
| | tert-buthyl hydroperoxide TBHP | | Liquid | Oral, dermal & ingestion | | | | | | | | Skin | | | | | | | | |
| | Potassium permanganate | | | | | | Solid | | | | | | | | | | | | | |
| | Perchloric acid | | | | | | Liquid | | | | | | | | | | | | | |
| | Na | | | | | | | | | | | | | | | | | | | |
| | K | | | | | | | | | | | | | | | | | | | |
| | Ca | | | | | | | | | | | | | | | | | | | |
| | Organic compounds | | Solid | | | | | | | | | | | | | | | | | |
| | Nitrogen | | | | | | | | | | | | | | | | | | | |
| | Argon | | | | | | | | | | | | | | | | | | | |
| | Synthetic gas H2/CO | | | | | | | | | | | | | | | | | | | |
| | Oxygen | | | | | | | | | | | | | | | | | | | |
| | Hydrogen H2 | | Gas | | | | | | | | | | | | | | | | | |

#### *4.3.2.2 Survey findings relating to the HCS types and forms and the health and safety measures of the department in using these hazardous materials*

The survey recorded observations on the presence of HCS types and forms as well as associated health and safety measures applied during the use of HCSs at the study site. Table 4.5 shows the findings upon observation of the studied department of chemistry regarding the chemical inventory, the storage of HCSs and the handling of particularly hazardous chemical substances.

##### *4.3.2.2.1 Chemical inventory*

It was found that a current inventory of HCSs was available and it included chemical amounts, container type, pressure and temperature. However, it was not on a campus Laboratory Safety System. Access to MSDSs was provided to all employees, both electronically and in hard copy format. While hard copies were accessible for most HCSs, not all employees knew how to access MSDS on the website. In addition, MSDSs were not available for all HCSs used in the study site. It was found that chemical containers were not all labelled, did not show chemical contents and did not display appropriate hazard warning labels

##### *4.3.2.2.2 Storage of HCS*

The hazardous chemical materials were stored in a mechanically ventilated storage area and chemically resistant containers. Chemical storage shelves were protected with a lip or barrier and were designed and installed to carry the current load. However, no placards were observed that clearly categorised the refrigerator as being ‘explosion proof’.

It was further observed that when highly flammable liquids were used, the flammable liquids were stored in a designated storage cabinet. Notably, flammable liquid storage areas were located away from open flames or sparks, and were clearly labelled with signs reading “Flammable”. In some cases, incompatible hazardous materials were not isolated from each other.

*4.3.2.2.3 Handling of particularly hazardous chemical substances*

With regard to the practice of the dating of peroxide-forming compounds, it could be neither observed nor verified verbally as it differs from one sub-department to another. In addition, no dates appeared on containers of ethers and peroxide-forming compounds to ensure they do not exceed allowable storage times prescribed for such containers.

It was found that not all employees were familiar with storage, handling and testing of peroxide-forming chemicals prior to performing procedures that could increase the potential for peroxide development (e.g. distillations), a factor that may lead to exposure of employees.

It was further observed that there were designated and marked areas for handling particularly hazardous chemical substances in the chemistry department at the study site. In addition, evidence of systems for replacement of reagents, procedures or equipment with less hazardous chemical materials (such as replacing mercury-containing thermometers) where possible, was observed.

**Table 4.5: Findings upon observation of the studied department of chemistry regarding the chemical inventory, the storage of HCSs and the handling of particularly hazardous chemical substances**

| Items | Yes | No | N/A |
|---|---|---|---|
| **NB: According to the hazardous chemical substances (HCS) regulation materials considered potentially hazardous include cleaners, solvents, laboratory chemicals, grease, disinfectants, dental products, etc.** | | | |
| **Is a current inventory of hazardous materials available for employees to make reference to it?** | x | | |
| a. If yes, does it include chemical amounts, container type, pressure and temperature? | x | | |
| b. If yes, is it on the campus Laboratory Safety System (LSS)? | | x | |
| **Do all laboratory personnel have access to Material Safety Data Sheets (MSDS) during all hours of operation?** | x | | |
| a. If the method is to download MSDS from the Web, can all employees prove they know how to get an MSDS? | | x | |
| b. If the method is to maintain a file of hard copy MSDS, can all employees prove they know where the file is located? | x | | |
| c. Are MSDS available for all hazardous chemicals used in the laboratory? | | x | |
| **Are all containers labelled, showing chemical contents and appropriate hazard warning labels?** | | x | |

| Items | Yes | No | N/A |
|---|---|---|---|
| **Are incompatible hazardous materials isolated from each other (i.e. stored according to chemical class)?** | | x | |
| **If hazardous materials are stored in this laboratory, are they stored in:**<br>a. A mechanically ventilated storage area?<br>b. Chemically-resistant containers?<br>c. Designated areas such as placarded cabinets, shelves, etc.? | <br>x<br>x<br> | <br><br><br>x | |
| **Are chemical storage shelves:**<br>a. Protected with a lip or barrier?<br>b. Designed and installed to carry the current load? | <br>x<br>x | | |
| **If present, are refrigerators containing hazardous materials placarded to identify contents and restrictions (e.g. "NO FOOD")?** | x | | |
| **If a refrigerator is used to store flammable materials, is it explosion-proof and labelled as explosion proof?** | | x | |
| **If highly flammable liquids are used and they are present in a room:**<br>a. Are the flammable liquids stored in a storage cabinet designed for storing flammables?<br>b. Are flammable liquids storage areas located away from open flames or sparks, and labelled (e.g. with signs reading "Flammable")? | <br>x<br>x | | |
| **Are ethers and peroxide-forming compounds (e.g. aldehydes, ethers, benzylic hydrogen compounds, allylic compounds, and vinyl compounds) dated when received by the department and when opened in the laboratory?** | | x | |
| **Are the dated containers of ethers and peroxide-forming compounds checked to ensure they do not exceed allowable storage times?** | | x | |
| **Are all employees familiar with storage, handling, and testing of peroxide-forming chemicals prior to performing procedures that can increase potential for peroxide development (e.g. distillations)?** | | x | |
| **Are piping (tubing), valves and fittings compatible with the hazardous materials for which they are used and checked periodically for integrity?** | | x | |
| **Are staff aware that state safety regulations protect worker's exposure for many specific hazardous materials (such as, but not limited to: benzene, formaldehyde, lead, vinyl chloride, and chemicals considered particularly hazardous; i.e. carcinogens, highly acute, and reproductive toxicants)?** | | x | |
| **Are there designated and labelled areas for handling particularly hazardous substances? (These particularly hazardous substances include but are not limited to: select carcinogens, reproductive toxicants, select agents, and materials with high acute toxicity.)** | x | | |
| **Has the laboratory replaced their reagents, procedures or equipment with less hazardous materials (such as replacing mercury-containing thermometers) when possible?** | x | | |
| **Are chemical spillage clean-up supplies (e.g. absorbents like spillage pads, or diatomaceous earth, and neutralizers like citric acid) readily available in the lab at all times and selected based on materials likely to spillage (e.g. if mercury is used, is a mercury spillage kit available)?** | | x | |

### 4.3.3 Findings relative to research objective two: examining the actual and potential exposure to HCSs among workers at the chemistry department of the selected HEI in Gauteng province

Upon examination of the actual and potential exposure to HCSs among workers in the chemistry department, the survey checklist contained four elements that correlated with the research objective. Employee training on HCSs and emergencies, laboratory conditions at the chemistry department, the chemical inventory, the storage of HCSs and the handling of particularly hazardous chemical substances were addressed. Finally, the survey identified whether occupational health related matters had been observed at the study site.

#### *4.3.3.1 Employee training on HCSs and emergencies*

Observations and responses regarding employee training on HCSs and emergencies at the study site are shown in Table 4.6. Results indicated that employees were trained on most of the hazardous materials except for bio-hazardous waste disposal, radioactive waste disposal, blood borne pathogen exposure control, and transporting hazardous materials. The inspection revealed that the head of the department, the supervisor or the department did keep records of training that was provided, detailing the instructor's name, date, who attended, and the scope of training. The external training service provider kept all training records for the department and also issued certificates of attendance.

All the employees were inducted or trained on the phone number to call for emergency assistance, the location of the fire alarm, the location of the nearest fire extinguisher, and how to evacuate upon hearing an alarm or other warning.

It was found that the awareness among academic employees and technical employees about all laboratory warning labels and signs used in the laboratory was adequate, but among cleaners and laboratory assistants awareness was low. It follows that the latter two groups may be potentially at risk of exposure to HCSs.

**Table 4.6: Employee training on HCSs and emergencies**

| Items | Yes | No | N/A |
|---|---|---|---|
| **Do laboratory personnel working with hazardous materials receive training in the following areas: (NB: *request for proof in writing or ask employees concerned*)** | | | |
| a. Chemical safety, addressing all hazardous chemicals, and including the proper selection, use and maintenance of personal protective equipment? | x | | |
| b. Chemical waste disposal? | x | | |
| c. Biohazard waste disposal, as applicable? | | | x |
| d. Radioactive waste disposal, as applicable | | | x |
| e. Laboratory fire safety? | x | | |
| f. Fire extinguisher training? | x | | |
| g. Location and use of safety/deluge showers? | x | | |
| h. Location and use of eye washes? | x | | |
| i. Chemical spillage clean-up? | x | | |
| j. Blood borne pathogen exposure control? | | | x |
| k. Transporting hazardous materials? | x | | |
| l. Safe work practices when using biological safety cabinets? | | x | |
| **Does the head of the department or supervisor or department keep records of what training was provided, detailing the instructor's name date, who attended, and scope of training?** | | x | |
| **Have employees been inducted and/or trained on the following:** | | | |
| a. What phone number to call for emergency assistance? | x | | |
| b. Where the fire alarm is located? | x | | |
| c. Where the nearest fire extinguisher is located? | x | | |
| d. How to evacuate upon hearing an alarm or other warning? | x | | |
| **Are all workers in the laboratory department aware of the meaning of all laboratory warning labels and signs used in the laboratory?** | | x | |

### *4.3.3.2 Laboratory conditions of the chemistry department*

Findings of the observations of the laboratory conditions at the study site are displayed in Table 4.7.

It was observed that the laboratory did not follow proper housekeeping practice. For example, residues were not removed from floor or bench tops, benches were cluttered and pathways to exits were not kept clear in all instances.

It was found that exposed moving equipment parts were guarded and that explosion shields were available.

General laboratory equipment in the department was serviced, yet equipment service and inspection records were not available.

Regarding safety equipment, it was found that a first-aid kit, appropriate for the size of the laboratory and located in an easily accessible place, was available. The first-aid kit was fully stocked with non-expired materials.

It was unfortunately found that when corrosive, irritating or substances toxic by eye and skin contact were being used, it was impossible to reach an eyewash fountain or a safety shower within 10 seconds.

There was enough ventilation in the department, as was evident in no detectable chemical odours or unduly elevated or lowered temperatures.

**Table 4.7: Laboratory conditions of the chemistry department at the study site**

| Items | Yes | No | N/A |
|---|---|---|---|
| **Does the chemistry laboratory use proper housekeeping practices which include:** | | | |
| a. Removal of residues on floor/bench tops? | | x | |
| b. Uncluttered bench tops and hoods? | | x | |
| c. Clear pathways to eyewashes and safety showers? | x | | |
| d. Clear pathways to exits, both inside and outside the laboratory? | | x | |
| **General Laboratory Equipment** | | | |
| a. Are belts, pulleys, and other exposed moving equipment parts guarded? | x | | |
| b. Are explosion shields available if they are needed? | x | | |
| c. Is equipment serviced to ensure that it functions safely? | x | | |
| d. Are equipment service and inspection records kept? | | x | |
| **Safety equipment** | | | |
| a. Is a first-aid kit available that is appropriate for the size of the laboratory and located in an easily accessible spot? | x | | |
| b. Is the laboratory first-aid kit fully stocked with non-expired materials? | x | | |
| c. If corrosive, irritating or substances toxic by eye contact are being used, can an eyewash be reached within 10 seconds? | | x | |
| d. If corrosive, irritating or substances toxic by skin contact are being used, can a safety shower be reached within 10 seconds? | | x | |
| **Is the general room ventilation adequate (temperature and odours controlled, etc.)** | x | | |

#### *4.3.3.3 Findings upon observation of the studied department of chemistry regarding the chemical inventory, the storage of HCSs and the handling of particularly hazardous chemical substances*

Table 4.5 shows the findings of observations of the chemistry department at the study site regarding the chemical inventory, the storage of HCSs and the handling of particularly hazardous chemical substances.

The fact that a current inventory of hazardous materials was available, yet was not on the campus Laboratory Safety System, could present employees with a risk of potential exposure to unknown HCSs.

The analysis showed that there were designated and marked areas for handling particularly hazardous substances in the department. In addition, the laboratory replaced their reagents, procedures or equipment with less hazardous materials (such as replacing mercury-containing thermometers) when possible.

All laboratory personnel had access to MSDSs, but not all employees knew how to access MSDSs, and MSDSs were not available for all HCSs used in the laboratory.

It was found that not all containers were labelled, were showing chemical contents and had appropriate hazard warning labels, and that incompatible hazardous materials were not isolated from each other. The hazardous materials were stored in a mechanically ventilated storage area and chemically resistant containers. The chemical storage shelves were protected with a lip or barrier and designed and installed to carry the current load. No placards were observed clearly identifying the refrigerator as ‘explosion proof’.

In addition, employees were not aware that the HCS Regulations protect workers from exposure to many specific hazardous materials.

Finally, no chemical spillage clean-up supplies were observed in the department.

#### *4.3.3.4 Observation of occupational health related matters in the chemistry department at the study site*

Findings of observations of occupational health-related matters within the chemistry department at the study site are shown in Table 4.8.

The analysis revealed that employees knew that they had to complete the appropriate report following an incident or accident and they knew where the closest medical facility was.

The study found that a copy of a Biohazard Safety Manual was not available in case of laboratory operations involved in potential bio-hazardous exposure. In view of the fact that no hazardous biological agents were in use within the chemistry department, employees had not received any training on blood borne pathogen exposure and the standard was not applicable. Employees, subsequently, had neither received the Hepatitis B immunization nor signed a declination.

**Table 4.8: Observation of occupational health related matters in the chemistry department at the study site**

| Items | Yes | No | N/A |
|---|---|---|---|
| **Do all personnel know that following an incident or accident they must complete the appropriate Incident / Accident / Report form?** | x | | |
| **In case of a medical emergency, staff should go to the nearest emergency room for care.** | x | | |
| **If laboratory operations involve potential biohazard exposure, is a copy of a Biohazard Safety Manual available?** | | | x |
| **If the Blood borne Pathogen Standard applies, have all of the staff:** | | | |
| a. Received the required training? | | | x |
| b. Received the Hepatitis B immunization or signed a declination? | | | x |

### 4.3.4 Findings relative to research objective three: the assessment of the exposure control measures (hazard management) implemented at the chemistry department of the targeted HEI

The assessment of written exposure control measures implemented at the chemistry department and employee training on HCS and emergencies were examined. Findings were further described about the observation of the studied department of chemistry regarding the chemical inventory, the storage of HCSs and the handling of particularly hazardous chemical substances. This was followed by a review of waste management and finally the utilisation and condition of Personal Protective Equipment (PPE) in the chemistry department were evaluated.

#### *4.3.4.1 Assessment of written exposure control measures implemented at the chemistry department*

Table 4.9 shows observations regarding the assessment of written exposure control measures implemented at the chemistry department.

It was found that a laboratory safety manual was not available and therefore no Standard Operating Procedures (SOPs) could be viewed. There were no written procedures available for any revised procedures necessary due to laboratory work outside usual work hours (such as first aid, emergency response, etc.), emergencies such as unplanned loss of power, gas, water or fire; and planned shut-down of gas, water, or electricity. Written SOPs existed for waste management and for chemical spillages. It was found that records were kept of previous safety inspections conducted and corrective actions recommended, and safety procedures/issues were discussed at staff, departmental, or other committee meetings and the discussions documented. Such records were also available.

**Table 4.9: Assessment of written exposure control measures implemented at the chemistry department**

| Items | Yes | No | N/A |
|---|---|---|---|
| **Is the laboratory chemical safety manual available?** | | x | |
| a. Has laboratory-specific information been added? | | x | |
| b. Have Standard Operating Procedures (SOPs) addressing all hazardous processes/chemicals been written and added to (or referenced in) the laboratory Safety Manual? | | x | |
| c. Are the SOPs up-to-date with current safety information? | | x | |
| **Does the laboratory or department have written procedures for the following?** | | | |
| a. Describing any revised procedures necessary due to laboratory work outside usual work hours (such as first aid/ emergency response, etc.)? | | x | |
| b. Waste minimization/management? | x | | |
| c. Chemical spillages? | x | | |
| i. Biohazard spillages, if applicable? | | | x |
| ii. Radioactive material spillages, if applicable? | | | x |
| d. Emergencies such as unplanned loss of power, gas or water; fire; etc.? | | x | |
| e. Planned shutdown of gas, water or electricity? | | x | |
| **Are records kept of previous safety inspections conducted and corrective actions recommended?** | x | | |
| **Are safety procedures/issues discussed at staff, department or other committee meetings and the discussions documented?** | x | | |
| a. Are such records available | x | | |

#### *4.3.4.2 Employee training on HCS and emergencies*

Table 4.6 depicts the findings of observations on employee training on HCSs and emergencies.

The analysis indicated that employees received training on most of the hazardous materials except for bio-hazardous waste disposal, radioactive waste disposal, blood borne pathogen exposure control, and transportation of hazardous materials.

The inspection revealed that the head of the department or supervisor or department did keep records of training that was provided, detailing the instructor's name, date, who attended, and scope of training. The external training service provider kept all training records for the department and also issued certificates of attendance.

All the employees were inducted or trained on the phone number to call for emergency assistance, the location of the fire alarm and the nearest fire extinguisher, and how to evacuate upon hearing an alarm or other warning. It was found that the awareness among academic employees and technical employees about all laboratory warning labels and signs used in the laboratory was adequate, but among cleaners and laboratory assistants, awareness was low.

#### ***4.3.4.3 General emergency preparedness of the chemistry department***

Table 4.10 shows findings of the analysis of the general emergency preparedness at the chemistry department under study.

It was observed that emergency phone numbers and emergency instructions addressing fire, medical and chemical emergencies, and bio-hazardous and radiation emergencies were clearly displayed in the department. Employees knew about the location of the nearest fire alarm pull box and of the fire extinguisher(s) in the room, and the location(s) of complete first-aid kit(s) and supplies. The contents of the emergency kits, however, had not been checked during the preceding six months. During the inspection, it was found that a health and safety representative was available in cases of an emergency.

The study showed that employees did not know about the number of escape "kick-out" panels in the room and that fire codes prohibited the use of any door wedges. The location of a chemical spillage kit was unknown. It was also observed that employees had not been provided with information about the importance of personal emergency preparedness.

**Table 4.10: General emergency preparedness of the chemistry department**

| Items | Yes | No | N/A |
|---|---|---|---|
| **Are the following available and clearly displayed in the chemistry laboratory department?** | | | |
| a. Emergency phone numbers? | x | | |
| b. Emergency instructions addressing fire, medical and chemical emergencies, and biohazard and radiation emergencies as needed? | x | | |
| **Do employees know:** | | | |
| a. The location of the nearest fire alarm pull box? | x | | |
| b. The number of exits (doors) in the room? **2 – 4 per room** | x | | |
| c. The number of escape "kick-out" panels in room? **None** | | x | |
| d. That fire codes prohibit the use of any door wedges? | | x | |
| e. The location of the fire extinguisher(s) in this room? | x | | |
| f. Location(s) of complete/up-to-date first-aid kit(s)/supply(ies)? | x | | |
| g. The location of a chemical spillage kit? | | x | |
| Have employees been provided information about the importance of personal emergency preparedness? | | x | |
| If the laboratory has an emergency preparedness kit or supplies, have it/they been checked in the last 6 months? | | x | |
| Is a First Aider and/or health safety representative available on all shifts that employees are working? | x | | |
| Are instructions for contacting first aiders and/or safety representatives in cases of an emergency readily available? | x | | |

#### *4.3.4.4 Findings upon observation of the studied department of chemistry regarding the chemical inventory, the storage of HCSs and the handling of particularly hazardous chemical substances*

Table 4.5 shows the observation of the department regarding the chemical inventory, storage of HCSs and handling of particularly hazardous chemical substances.

It was found that a current inventory of hazardous materials was available and it included chemical amounts, container type, pressure and temperature but it was not on campus Laboratory Safety System (LSS). All laboratory personnel had access to Material Safety Data Sheets (MSDS), but not all employees knew how to get an MSDS, and MSDS were not available for all hazardous chemicals used in the laboratory.

It was found that not all containers were labelled, were showing chemical contents or appropriate hazard warning labels, and that incompatible hazardous materials were not isolated from each other. The hazardous materials were stored in a mechanically ventilated storage area and chemically resistant containers as well as chemical storage shelves were protected with a lip or barrier, and designed and installed to carry the current load. No placards that clearly identified the refrigerator as "explosion proof" were observed.

It was further observed that if highly flammable liquids were used and they were present in a room, the flammable liquids were stored in a storage cabinet designed for storing flammables. Furthermore, flammable liquids storage areas were located away from open flames or sparks, and labelled (e.g. with signs reading "Flammable"). With regard to the practice of dating peroxide-forming compounds, it could be neither observed nor verified verbally, as it differs from one sub-department to another sub-department. In addition, no dates appeared on such containers.

It was further found that not all employees were familiar with storage, handling, and testing of peroxide-forming chemicals prior to performing procedures that could increase the potential for peroxide development (e.g. distillations). In addition, employees were not aware that the HCS Regulations protected workers from exposure to many specific hazardous materials.

The analysis further showed that there were designated and marked areas for handling particularly hazardous substances in the department. In addition, the department replaced their reagents, procedures or equipment with less hazardous materials (such as replacing mercury-containing thermometers) when possible.

With regard to chemical spillage clean-up, no chemical spillage clean-up supplies were observed in the department.

#### *4.3.4.5 Waste management at the chemistry department*

Findings on waste management at the chemistry department are summarised in Table 4.11.

It was observed that individual researchers consciously select less toxic materials, reactions were run on the smallest scale possible to reduce chemical waste, and employees generally seemed aware of the process and service provider for HCS waste management. It was found that glass and sharp plastic waste were segregated and disposed of separately from general waste, and glass waste was properly packaged and labelled.

Some discouraging observations were that empty containers originally containing acutely hazardous chemicals were not triple rinsed prior to being discarded; and the required sewer discharge log was not available or maintained. If a discharge log was kept, the signage was not posted, and hazardous chemicals were not neutralised, filtered or destroyed when possible in order to reduce hazardous waste quantity or hazard. In addition, no procedures were included as part of the protocol's SOP and a Treatment Log was not maintained to document quantities treated and filtration or destruction methods used for disposal.

**Table 4.11: Waste management at the chemistry department**

| Items | Yes | No | N/A |
|---|---|---|---|
| **Do people responsible for purchasing chemicals review reference materials (such as MSDS) to evaluate materials before purchase to select the least toxic materials possible and to identify possible waste streams?** | **x** | | |
| **Are reactions run on the smallest scale possible to reduce chemical waste?** | **x** | | |
| **Are process waste streams segregated (i.e. not mixing different chemicals), which makes disposal cheaper and easier?** | **x** | | |
| **Are employees familiar with the procedure for requesting chemical or waste pickup by the relevant person or waste management service provider?** | **x** | | |
| **Are glass and sharp plastic waste segregated and disposed of separately from general trash?** | **x** | | |
| **Is glass waste properly packaged and labelled?** | **x** | | |
| **Are empty containers originally containing acutely hazardous chemicals triple rinsed prior to being discarded?** | | **x** | |
| **A limited number of chemicals can be disposed of in the sink if any chemicals are disposed of in the sink:** | | | |
| a. Is the required sewer discharge log maintained? | | | **x** |
| b. If a discharge log is kept, is the following sign posted? | | | **x** |

| Items | Yes | No | N/A |
|---|---|---|---|
| **Are hazardous chemicals neutralised/filtered/destroyed when possible in order to reduce hazardous wastes quantity or hazard?** | | **x** | |
| a. Are procedures included as part of the protocol's SOP? | | **x** | |
| b. Is a Treatment Log maintained to document quantities treated and filtration or destruction methods used for disposal? | | **x** | |

#### *4.3.4.6 Utilisation and condition of Personal Protective Equipment (PPE) in the chemistry department*

Table 4.12 displays the summary of findings of the analysis of observations regarding the utilisation and condition of personal protective equipment (PPE).

It was established during the study that the department had been assessed for potential exposure hazards. It was also noted that the occupational health service conducted biennial health risk assessments and OHSA compliance surveys. The safety department conducted safety inspections. In the chemistry department, general guidelines were provided in the draft policy on HCS. Each individual researcher determined specialised requirements for PPE, but no formal, written SOP was observed. The study found that the required PPE for employees was available and it was in good condition.

All the laboratory personnel were instructed as to general departmental rules for PPE and they were trained on PPE matters. It was also observed that the staff used all glove selection resources available. During inspection of respirators, the study found that occupational hygienists had been contacted to assess the level of exposure; users had received medical evaluation, training and fit testing, in accordance with guidelines on medical surveillance. Respirators were properly inspected, cleaned, serviced and stored, and cartridges that were used were appropriate to each hazard exposure.

**Table 4.12: Utilisation and condition of Personal Protective Equipment (PPE) in the chemistry department**

| Items | Yes | No | N/A |
|---|---|---|---|
| **Have potential exposure hazards been assessed?** | x | | |
| **If PPE (e.g. gloves, goggles, face shields, lab coats, safety glasses with side-shields, etc.) is required, have the requirements been noted in SOPs, health and safety plans, or other guidance use by all laboratory workers?** | | x | |
| **Is required PPE for employees available and in good condition?** | x | | |
| **Are all laboratory personnel:** | | | |
| a. Instructed as to general departmental rules for PPE (such as rules to remove and store lab coats in the laboratory before leaving) and any process specific requirements for additional PPE? | x | | |
| b. Informed as to where these rules are posted or filed? | | x | |
| c. Trained in the correct procedures for selecting the appropriate PPE, inspecting for damaged PPE prior to wear, correctly donning and adjusting for proper fit (if required), donning without spreading contamination, and maintaining and disposing of the PPE? | x | | |
| **When selecting the type of protective gloves(s) required, do the staff use all glove selection resources available (e.g. MSDS, vendor catalogues) and do laboratory staff experience that the glove provides adequate dexterity?** | x | | |
| **If respirators (half face, full face, SCBA, Air Line) are being used:** | | | |
| a. Have occupational hygienists been contacted to assess the level of exposure? | x | | |
| b. Have users received medical evaluation, training and fit testing in accordance with guidelines on medical surveillance? | x | | |
| c. Are respirators properly inspected, cleaned, serviced and stored? | x | | |
| d. If cartridges are used, are they the correct ones for each hazard exposure? | x | | |

### 4.3.5 Pre-existing Occupational Hygiene report findings

In a document, supplementary to the checklist instrument, the Occupational Hygiene Report depicts a Health Risk Assessment on environmental stressors conducted at the chemistry department in 2010 (Potgieter 2010:82).

The environmental agents, found present at the site, were graded in three classes: ‘physical agents’, ‘chemical agents’ and ‘ergonomical agents’. Examples of *physical* agents listed in the report included poor illumination, thermal regulation, cryogenic skin burns, x-radiation, heat and explosion. *Chemical* agents indicated the presence of volatile organic compounds, organic compounds, inorganic acids and toxic chemical substances in liquid, vapour, solid or dust forms. *Ergonomical* agents cited were poor work posture and manual materials handling.

A total of 79 environmental stressors were identified at the chemistry department by the Approved Inspection Authority under the Department of Labour. A risk score was calculated for each occurring environmental stressor as a function of *consequence, frequency* and *probability* indices (Potgieter 2010:2). The risk score of ‘low’ was allocated to 72 (91%) of those risks, while six (7,5%) received a ‘moderate’ rating and one (1%) was shown as a ‘high’ risk.

The low risks comprised 22% physical stressors, 76% chemical stressors and 1% ergonomical stressors.

Moderate risks consisted of 20% physical, 40% chemical and 60% ergonomical stressors.

*The only high-risk score was significantly allocated to a physical hazard of HCS, namely explosion of solvent vapours in the organic chemistry laboratory.* At this laboratory, large quantities of hexane and ethyl acetate were handled during distillation and syntheses processes. Liquid nitrogen was being used daily and glassware was washed with a mixture of isopropanol and potassium hydroxide. The research was conducted in the presence of electrical lamps, which were not spark proof; Bunsen burners were used at times; and windows were not made of safety glass.

Routes of entry, named for each environmental stressor, ranged from inhalation, ingestion and eye and skin contact, to whole body entry route.

Potential health effects, associated with the environmental stressors, included eye strain, thermal discomfort, central nervous system effects, such a nausea, headaches and dizziness, skin irritation or dermatitis, cryogenic burns and simple or chemical asphyxiation leading to death.

The Occupational Hygiene report further listed all existing control measures, which had been implemented at the chemistry department, to mitigate exposure risk to employees.

To illustrate, control measures included gas monitors, the fact that gas cylinders were fastened to the wall with chains, access control, training of students and employees, provision of screens for hazardous processes and the use of personal protective equipment such as thermal gloves.

## 4.4 DISCUSSION OF THE RESULTS

### 4.4.1 Context and statistical analysis of demographic data

#### *4.4.1.1 Findings on the statistical analysis of demographic data of the population*

Demographic data of employees working at the chemistry department indicated that the majority of employees were aged between 30 – 49 years and two-thirds were males. A wealth of experience was evident from the 71.4% of employees who had worked at the department for more than five years. The majority of academic employees were assigned to the first-year laboratory, followed by the thermodynamic laboratory. Most of the technical employees were working in the first-, second- and third-year laboratories, followed by the honours laboratory.

### 4.4.2 Thematic presentation of findings

#### *4.4.2.1 Findings relative to research objective one: identification and description of the types and forms of hazardous chemicals used at the chemistry department of the selected Higher Education Institution (HEI) in Gauteng province*

An explanation follows on the identification and description of the types and forms of hazardous chemicals used at the study site.

##### *4.4.2.1.1 Description of types and forms of HCS used in the chemistry department*

This study revealed that HCSs used at the chemistry department were representative of all three *hazard classes* of HCSs. In accordance with the global GHS classification system, the hazard classes are known as physical, health and environmental hazard classes of HCSs. The hazard types under each hazard class of HCSs are discussed next.

- *Physical hazard types*

*Hazard types* under the physical hazard class present at the department comprised explosives; flammable gases, liquids and solids; oxidizing gases, liquids and solids; gases under pressure; pyrophoric solids; substances which, upon contact with water, emit flammable gases; and organic peroxides.

The largest number of physical hazard types of HCSs observed at the department was found to be flammable liquids, followed by explosives. Six flammable liquids were listed as being used at the chemistry department, namely hexane, diethylether, methanol, tetrahydrofuran, dichloromethane and acetonitrile. The two explosives present at the department were hydrazine and perchloric acid.

- *Health hazard types*

All of the ten hazard types, as classified by the GHS's health hazard class, were represented at the study site. They were acute toxicity, skin corrosion/irritation, serious eye damage/irritation, respiratory or skin sensitisation, carcinogenicity, germ cell mutagenicity, reproductive toxicology, target organ systemic toxicity for both single and repeated exposures and finally aspiration toxicity.

By comparison, the largest group of health hazard types was established to be "target organ systemic toxicity" for both single and repeated exposures that included *all* of the HCSs used in the department. This group is followed in numeric representation of HCSs at the department by carcinogens, thirdly by skin corrosives/irritants and fourthly by HCSs displaying acute toxicity.

Mercury and arsenic were found to be classified as displaying reproductive toxicity properties and germ cell mutagenicity was associated with tert-buthylhydroperoxide.

A finding related to the IARC classification of carcinogens as displayed in Table 4.2 unveiled that eight HCSs present at the chemistry department could be classified according to the IARC Monographs. Two substances, namely arsenic and formaldehyde were Group 1 substances and therefore their carcinogenicity to humans was confirmed. In terms of Group 2B ('possibly carcinogenic to humans'), four HCSs were identified, namely Raney nickel, dichloromethane, chloroform and hydrazine. Hydrogen peroxide and mercury, also in use at the chemistry department, were 'not classifiable as to its carcinogenicity to humans', yet resorted in Group 3. It was significant that, apart from "target organ systemic toxicity" – single or repeated exposures that included all the HCSs at the department, the next largest number of health hazard types of HCSs displayed carcinogenicity. The eight HCSs in the group of carcinogens were mercury. hydrazine, hydrogen peroxide, dichloromethane, arsenic, chloroform; formaldehyde and Raney nickel.

The health hazard type with the third highest number of HCSs was "skin corrosion/irritation". Five such hazard types were present, namely acetone, methanol, tetrahydrofuran, dichloromethane and perchloric acid.

- *Environmental hazard types*

The study found that environmental hazard types consisted of acute and chronic aquatic toxicity. All HCSs at the department, according to the list of HCSs provided to the researcher, posed a risk of acute aquatic toxicity. By contrast, five HCSs had a bio-accumulation potential within the hazard type of chronic aquatic toxicity, namely mercury, tert-buthylhydroperoxide, hydrazine, Raney nickel and arsenic.

- *Occupational Exposure Limits of HCSs at the chemistry department*

In accordance with the HCS Regulation tables, Occupational Exposure Limits with *Control Limits* (residual risk) could be attributed to four HCSs, namely dichloromethane, arsenic, formaldehyde and Raney nickel, while several HCSs were classified under *Occupational Exposure Limits* where a *Recommended Limit* (no indication of a risk to health) applied. Biological Exposure Indices (reference values intended as guidelines for the evaluation of potential health hazards) were relevant to six HCSs at the department, namely methanol, arsenic, acetone, carbon monoxide, hexane and mercury.

#### *4.4.2.1.2 Survey findings relating to the HCS types and forms and the health and safety measures of the department in using these hazardous materials*

*a) Chemical inventory*

The presence of a chemical inventory was a positive finding, although the inventory had not been captured on a laboratory safety system. Although MSDS were available electronically or in print, some employees did not know how to access MSDS on the website. It was further found that MSDSs were not available for all HCSs used in the study site. Chemical containers were not always labelled, did not show chemical contents and did not always display hazard warning signs.

*b) Storage of HCS*

Encouraging findings included the designated storage cabinets for duly labelled flammable liquids, away from open flames or sparks. Chemical storage shelves were protected with a lip or barrier and were designed to carry the load.

By contrast, the study found that incompatible HCSs were not isolated from one another in all instances and no placards were seen to clearly identify the refrigerator as being “explosion proof”.

*c) Handling of particularly hazardous chemical substances*

Dating of peroxide-forming compounds could not be verified and not all employees were familiar with the management of such HCSs. No chemical spillage clean-up supplies were observed in the department. The main findings cantered on the fact that not all HCS containers were labelled and they did not always display hazard warnings. Waste management was perceived to be effective owing to the designated and marked areas for handling particularly hazardous substances, and replacement of mercury-containing thermometers with less hazardous materials.

#### *4.4.2.2 Findings relative to research objective two: examining the actual and potential exposure to HCSs among workers at the chemistry department of the selected HEI in Gauteng province*

Results from the study in examining the actual and potential exposure to HCSs among workers at the chemistry department are further elucidated.

*a) Employee training on HCS and emergencies*

During the study, it was found that training had been provided to employees on the use of most of the HCSs, except for bio-hazardous and radioactive waste disposal, blood borne pathogen exposure control and the topic of the transportation of hazardous materials. However, it was found, as reported on in Section 4.4.2.2 (d), that no hazardous biological agents were used at the chemistry department, and therefore this fact made training in related topics irrelevant. Training and induction on emergency procedures were provided for employees.

A concerning finding consisted of the fact that, although an adequate awareness existed among academic and technical employees about all laboratory warning labels and signs used in the department, *among the cleaners and laboratory assistants the awareness was low.*

*b) Laboratory conditions of the chemistry department*

Although several positive aspects were found which relates to actual and potential human exposure at the department, some concerning factors were observed.

- A fully equipped and easily accessible first-aid kit was available at the department.
- There was apparently enough ventilation in the department based on the absence of chemical odours and the presence of thermal comfort in the department.
- It was commendable that exposed moving equipment parts were covered by machine guarding and that explosion shields were available.

- Although laboratory equipment was periodically serviced, the corresponding records could not be shown as evidence thereof.

The study found, however, that housekeeping of the department was not always optimal. For example, benches were cluttered and pathways towards exits were not kept clear in all cases. Residues were seen on floors and bench tops.

A further concerning observation was that in areas where HCSs that cause corrosion, irritation or toxicity to eyes or skin, it was impossible to reach the eyewash fountain or the emergency shower within ten seconds. In view of the finding that "target organ systemic toxicity" by single or repeated exposure and skin corrosives ranked high among the health hazard types described in Section 4.4.2.1.1, this risk is significant. The health hazard type "skin corrosion/irritation" was represented by five HCSs in the chemistry department, including acetone, methanol, tetrahydrofuran, dichloromethane and perchloric acid. Three HCSs (acetone, hydrogen peroxide and perchloric acid) that could cause serious eye damage or irritation were present at the study site, which would further underscore the risk of potential exposure and far proximity to an eyewash fountain.

c) *Findings upon observation of the studied department of chemistry regarding the chemical inventory, the storage of HCSs and the handling of particularly hazardous chemical substances*

The fact that a current inventory of hazardous materials was available, yet was not on the campus Laboratory Safety System, could present employees with a risk of potential exposure to unknown HCSs.

All laboratory personnel had access to Material Safety Data Sheets (MSDS) but not all employees knew how to access MSDS, and MSDS were not available for all HCSs used in the laboratory.

It was found that not all containers were labelled, were showing chemical contents, or appropriate hazard warning labels, and that incompatible hazardous materials were not isolated from one another. The hazardous materials were stored in a mechanically ventilated storage area and chemically-resistant container as well as chemical storage shelves were protected with a lip or barrier and designed and installed to carry the current load. No placards were observed clearly identifying the refrigerator as ‘explosion proof’.

In addition, employees were not aware that the HCS Regulations protect workers from exposure to many specific hazardous materials.

Finally, the analysis showed that there were designated and marked areas for handling particularly hazardous substances in the department. In addition, the laboratory replaced their reagents, procedures or equipment with less hazardous materials (such as replacing mercury-containing thermometers) when possible. No chemical spillage clean-up supplies were observed in the department.

Not all of the HCS containers was labelled and they did not always display hazard warnings, while incompatible HCSs were not isolated from one another in all instances. Dating of peroxide-forming compounds could not be verified and not all employees were familiar with the management of such HCSs. No chemical spillage clean-up supplies were observed in the department.

Some positive findings were designated storage for duly labelled flammable liquids away from open flames or sparks, and the presence of a chemical inventory, although this had not been captured on a laboratory safety system. Waste management was perceived to be effective, owing to the designated and marked areas for handling particularly hazardous substances, and the replacement of mercury-containing thermometers with less hazardous materials.

*d) Observation of occupational health related matters in the chemistry department at the study site*

It was encouraging to find that all employees knew that they should go to the nearest clinic for care in case of a medical emergency and complete the relevant incident documentation. No hazardous biological agents were in use at the department.

#### ***4.4.2.3 Findings relative to research objective three: the assessment of the exposure control measures (hazard management) implemented at the chemistry department of the targeted HEI***

Findings related to the assessment of the exposure control measures implemented at the chemistry department are discussed next.

*a) Assessment of written exposure control measures implemented at the chemistry department*

This study found that written Standard Operating Procedures (SOPs) existed for waste management and chemical spillages. Records were kept of previous safety inspections and related corrective action recommendations. Safety issues were regularly discussed at departmental meetings and decisions were documented. Documents were available for verification.

It is noteworthy that the laboratory safety manual was unavailable and therefore no SOPs could be viewed. In addition, no written procedures were observed for work outside of normal working hours, for planned shutdown of gas, power or water, for unplanned loss of power, gas and water or in case of fire.

*b) Employee training on HCSs and emergencies*

Training on the use of HCSs and emergency assistance was provided for employees at the department and training and attendance records were kept.

However, the lack of awareness about all laboratory warning labels and signs among cleaners and laboratory assistants is a control measure that should be improved.

*c) General emergency preparedness of the chemistry department*

It was observed that emergency phone numbers and emergency instructions addressing fire, medical and chemical emergencies, and bio-hazardous and radiation emergencies were clearly displayed in the department. Employees knew about the location of the nearest fire alarm pull box, the location of the fire extinguisher(s) in the room, and location(s) of complete first-aid kit(s) and supplies. The emergency kit, however, had not been checked within the past six months. During the inspection, it was found that a health and safety representative was available in cases of an emergency.

The employees did not know about the number of escape “kick-out” panels in the room and that fire codes prohibit the use of any door wedges. Of particular concern was the finding that employees did not know the location of a chemical spillage kit. It was also observed that employees had not been provided with information about the importance of personal emergency preparedness.

*d) Findings upon observation of the studied department of chemistry regarding the chemical inventory, the storage of HCSs and the handling of particularly hazardous chemical substances*

Not all HCS containers were labelled and they did not always display hazard warnings, while incompatible HCSs were not isolated from one another in all instances. Dating of peroxide-forming compounds could not be verified and not all employees were familiar with the management of such HCSs. No chemical spillage clean-up supplies were observed in the department. A discouraging observation, however, was that empty containers originally containing acutely hazardous chemicals were not triple rinsed prior to being discarded and the required sewer discharge log was not available or maintained. No signage was seen at the point of discharge and chemicals were not neutralised, filtered or destroyed where possible to reduce waste quantities or their hazard properties. A treatment log was not maintained to document quantities of treated, filtered or destruction methods before disposal.

Constructive findings were designated storage for duly labelled flammable liquids, away from open flames or sparks, and the presence of a chemical inventory, although this had not been captured on a laboratory safety system. Waste management was perceived to be effective owing to the designated and marked areas for handling particularly hazardous substances, and replacement of mercury-containing thermometers with less hazardous materials. Further positive findings were that researchers consciously selected less toxic materials; that reactions were run on the smallest scale possible to reduce waste; and employees generally seemed aware of the process and service provider for HCS waste management. Glass and sharp plastic waste were segregated and disposed of separately from general waste. Glass waste was properly packaged and labelled.

The department had been assessed for potential exposure hazards by the occupational health service through biennial health risk assessments and OHSA compliance surveys. The safety department at the HEI conducted safety inspections. A draft policy existed at the chemistry department and it provided for general guidelines, while specialised requirements were determined by each researcher, yet no formal SOP was observed

*e) Waste management at the chemistry department*

It was observed that individual researchers consciously selected less toxic materials; reactions were run on the smallest scale possible to reduce chemical waste; and employees generally seemed aware of the process and service provider for HCS waste management. It was found that glass and sharp plastic waste were segregated and disposed of separately from general waste, and glass waste was properly packaged and labelled.

Selected discouraging observations were that empty containers originally containing acutely hazardous chemicals were not triple rinsed prior to being discarded; and the required sewer discharge log was not available or maintained. If a discharge log was kept, the signage was not posted, and hazardous chemicals were not neutralised, filtered or destroyed when possible in order to reduce hazardous waste quantity or hazard. Furthermore, no procedures were included as part of the protocol’s SOP and a Treatment Log was not maintained to document quantities treated and filtration or destruction methods used for disposal***.***

*f) Utilisation and condition of Personal Protective Equipment (PPE) in the chemistry department*

Personal Protective Equipment (PPE) for employees exposed to HCSs was available and was in good condition. Laboratory personnel were instructed in departmental rules for the use of PPE. Glove selection resources were available. Respirators were properly inspected, cleaned, serviced and stored and cartridges were appropriate for each hazard exposure. Occupational hygienists had been contacted to assess the level of exposure, users had received medical evaluation, training and fit testing in accordance with guidelines on medical surveillance.

#### *4.4.2.4 Pre-existing Occupational Hygiene report findings*

A pre-existing Occupational Hygiene report on a health risk assessment in 2010 revealed that the one *single highest risk* detected was a physical hazard of HCSs, namely explosion of solvent vapours in the organic chemistry laboratory. The *moderate* risks reflected 40% chemical stressors, while the 91% *low* risk scores were mainly attributed to chemical stressors. Potential health effects ranged from eyestrain to asphyxiation. Control measures included gas monitors and shielding of hazardous processes (Potgieter 2010:82).

## 4.5 CONCLUSION

The presentation of findings derived from demographic data, the survey tool and supporting documents yielded a baseline indicator of the prevailing practices in the use and management of hazardous chemical substances at the chemistry department.

Research objectives were matched with survey objectives to provide results related to the types and forms of HCS, the actual and potential exposures and hazard management at the department. A discussion of results concluded this chapter. The next chapter will draw final conclusions on the study.

# CHAPTER 5

# SUMMARY, CONCLUSIONS, RECOMMENDATIONS AND LIMITATIONS OF THE STUDY

## 5.1 INTRODUCTION

This chapter presents the summary of the research findings, the limitations of the study, conclusions drawn from the research findings and a description of the contributions of this study. Recommendations are made towards improving occupational health and safety processes, standards and outcomes in the use and management of HCS at a chemistry department at an Higher Education Institution (HEI). In addition, associations between research objectives and study findings are assimilated into conclusions.

## 5.2 SUMMARY OF THE STUDY

The purpose of this study was to observe the use and management of HCS at a chemistry department in a selected HEI in Gauteng province. A baseline descriptive, observational study was conducted by means of a structured survey questionnaire. During data collection, the researcher recorded observations in accordance with the survey questions. Further, employees at the chemistry department were requested to clarify comments or substantiating documentation was for requested viewing.

Through the review of literature, it was found that employees at a chemistry department of an HEI might be exposed to both the physical and the health hazard classes of Hazardous Chemical Substances (HCS). Health hazard types associated with HCS included acute toxicity, carcinogenicity and new compounds such as manufactured nanomaterials with unknown toxicity, while the physical hazard types, including explosives and pyrophoric chemical substances, were prevailing. Between 2001 and 2011, data had been collected on 120 explosions, fires and chemical releases at HEI laboratories in the USA, which resulted in injuries and fatalities. If compared with industrial laboratories, the emerging prevalence of laboratory safety failures and poor safety culture at academic chemistry laboratories unveiled deficient practice in the identification and control of physical hazards of HCS. A system of recording incidents and near-miss incidents was advised.

Amidst generic global and national standards on the safe management of HCS and against the background of recorded serious incidents with HCS at peer institutions, the study set out to provide a baseline assessment on the use and management of HCS at a chemistry department of an HEI in South Africa.

By comparison, physical and health hazards, similar to those at HEIs where incidents were documented, existed in the study site, which yielded the same potential for chemical releases, explosions, fire and human exposure. It would be wise to heed the lessons learnt from peer institutions with comparable hazards.

The purpose of this study was thus to observe the use and management of HCS at a chemistry department in an HEI in Gauteng province. The research objectives were to:

- Identify and describe the types and forms of hazardous chemicals used at the chemistry department of the selected HEI in Gauteng province.
- Examine exposure to hazardous chemical substances (actual and potential) among workers at the chemistry department of the selected HEI in Gauteng province.
- Conduct an inspection of the physical working environment and conditions of the chemistry department at the targeted HEI.
- Assess the exposure control measures (hazard management) implemented at the chemistry department of the targeted HEI.

The study population consisted of the chemistry department of the selected HEI. The employee job categories at the study site were academic, technical and administrative in nature. The sampling method was effected through purposive observation and non-probability sampling of the study population by administering a survey questionnaire.

A structured, descriptive, observational research tool was enlisted to conduct this study. The data collection tool was a pre-designed, self-administered survey checklist that was used to conduct an environmental inspection of facilities, practices and control measures at the chemistry department of the selected HEI. The adopted checklist was modified to suit the context of the study site and work processes involved. If any item during inspection was identified as not compliant (for example, the researcher indicated a “No” in response to the item), a corrective action was specified and the action transferred to the *Corrective Action* section.

The data collection tool outlined eight survey objectives intended to elicit information. The titles of the survey objectives were:

- Written laboratory health and safety policies, procedures and programmes
- Employee training
- General emergency preparedness
- Laboratory conditions
- Hazardous material safety
- Hazardous chemical wastes
- Personal protective equipment
- Occupational Health

During the discussion of the research findings, the titles of the survey objectives were more broadly described for clarity.

Data analysis comprised a quantitative analysis by a statistician using SPSS version 18.0. Descriptive statistics included mean, median and standard deviations that were used to calculate frequencies and percentages of elements under study.

## 5.3 SUMMARY OF THE RESEARCH FINDINGS

Research findings were analysed and interpreted. Conclusions resulting from demographic findings will be followed by concluding remarks derived from the thematic presentation of findings.

### 5.3.1 Demographic findings

It was considered significant that 76.2% of the employees working at the chemistry department were aged between 30 – 49 years and that 71.4% of the total number of employees had had five years of experience at the chemistry department. Given their relatively mature age range and their expected understanding of the study site, the anticipation was to come across advanced practices in the use and management of HCS at the department. A potential skills gap may develop during institutional attrition of the fifteen employees who have had more than five years of experience, seeing that there are currently only four successors – who have two to three years of experience – who may not provide adequate cover to sustain current practice.

The majority of academics were working in the first-year laboratories: this fact aligned with the intensive induction and attention that should be afforded to first-year students coming into contact with an environment with unknown hazards.

It was found that the majority of technical employees were working in the first-, second- and third-year laboratories, which should be expected in facilities that accommodate large numbers of chemistry students conducting experimental work with HCS.

### 5.3.2 Identification and description of the types and forms of HCS used at the chemistry department

The GHS classification was utilised to identify and describe types (hazard class) and forms (hazard type) at the department. A total of 26 HCS from all three of the hazard classes, namely physical, health and environmental hazards, were present at the chemistry department. Several HCS appeared in the classification of more than one hazard type.

#### *5.3.2.1 Physical hazard types*

The physical hazard type most represented in numbers was *Flammable liquids* followed by *Gases under pressure*, and thirdly by *Substances, which in contact with water, emit flammable gases*. Six flammable liquids were present in all three forms: gas (hydrogen and carbon monoxide), liquid (hexane, methanol, tetrahydrofuran dichloromethane, tert-buthylhydroperoxide and acetonitrile) and as solids (all organic substances). The four gases under pressure were nitrogen, argon, oxygen and syngas (a mixture of hydrogen and carbon monoxide gases). The third group (Substances, which in contact with water, emit flammable gases) consisted of sodium, potassium and calcium.

Two explosives, namely hydrazine and perchloric acid, were also present and one pyrophoric (spontaneously igniting when exposed to air) solid substance was Raney nickel.

The proportionately high number of sixteen (61.5%) physical hazard types of HCS present at the chemistry department could therefore be associated with a risk of fire and explosion.

#### *5.3.2.2 Health hazard types*

Within the health hazard class, *all* of the HCS used at the department displayed the *Target organ systemic toxicity* health hazard type*. Carcinogenicity* – in line with the IARC classification tables on carcinogens – was associated with eight HCS: mercury, hydrazine, hydrogen peroxide, chloroform, dichloromethane, arsenic, formaldehyde and Raney nickel. The health hazard type, *Skin corrosion/irritation,* was further found in five HCS and *Acute toxicity* potential was verified by the presence of chloroform, tert-buthylhydroperoxide, hydrogen peroxide and hydrazine.

#### *5.3.2.3 Environmental hazard types*

*Acute aquatic toxicity* was inherent to all HCS at the chemistry department, while C*hronic aquatic toxicity with a bio-accumulation potential* related to mercury, tert-buthylhydroperoxide, hydrazine, arsenic and Raney nickel.

#### *5.3.2.4 Occupational Exposure Limits and Biological Exposure Indices*

It was found that four substances, namely dichloromethane, arsenic, formaldehyde and Raney nickel, could be classified under Table 1 in the HCS Regulations, where Occupational Exposure Control Limits are provided because of their residual risk to health. Multiple HCS, however, resorted under Table 2, which prescribes a Recommended Occupational Exposure Limit, where there is no indication of a risk to health.

Biological exposure indices (reference values to guide the evaluation of potential health hazards) applied to methanol, arsenic, acetone, carbon monoxide, hexane and mercury.

### 5.3.3 Actual and potential exposure to hazardous chemical substances among workers at the chemistry department

Pertinent findings associated with the actual and potential exposure of employees to HCS at the chemistry department are described next.

A low awareness existed among cleaners and laboratory assistants of laboratory warning labels and signs, in contrast with the academic and technical employees who were found to be fully aware of the significance of signage and labels. All laboratory employees had access to MSDS, yet not all employees knew how to access MSDS and MSDS were not available for HCS used in the department. Added to this fact was the nonappearance of the chemical inventory on a campus laboratory safety system.

In general, ventilation seemed to be sufficient throughout the department, and machine guarding had been installed on moving equipment parts. HCS, in general, were stored in ventilated storage facilities with chemically resistant containers and on shelves with barriers for protection against spillage. Designated storage for labelled flammable liquids, away from open flames or sparks, was observed. Incompatible HCS, however, were not always isolated from one another and no chemical spillage kits were observed within the department. Explosion shields were available. Not all HCS containers were labelled; and the practice of dating of peroxide-forming compounds could not be verified. In contrast, there were designated areas for the handling of particularly hazardous substances. Substitution of highly toxic HCS took place for less hazardous alternatives.

Given the risk of fire and explosion associated with the presence of physical hazard types, housekeeping findings, including disorderly benches and one partially obstructed emergency egress route, were a cause for concern. A further major concern, in view of the high health hazard risk of acute toxicity, skin corrosion and eye damage, presented itself. In areas where HCS were used that could cause corrosion, irritation or damage to eyes or skin, it was not possible to reach the eyewash fountain or the shower within ten seconds.

It was found that all personnel knew what do to if an incident or accident occurred and that they should go to the nearest emergency room for care in case of an emergency. No hazardous biological agents were in use within the chemistry department.

### 5.3.4 The assessment of exposure control measures implemented at the chemistry department

Although written Standard Operating Procedures (SOP) were reported to exist for waste management and for chemical spillages, it was found that a laboratory safety manual was not available and therefore no SOP could be viewed. There were no written procedures available for any revised procedures necessary due to laboratory work outside usual work hours (such as first aid, emergency response, etc.); emergencies such as unplanned loss of power, gas, water or fire; and planned shut-down of gas, water, or electricity. In the chemistry department, general guidelines were provided in the form of a comprehensive draft policy on HCS.

Results indicated that employees were trained on the safe use and management of the majority of the HCS present at the department. All the employees were inducted or trained on the emergency numbers and equipment and how to evacuate the department. It was observed that emergency phone numbers and instructions addressing fire, medical and chemical emergencies were clearly displayed in the department. During the inspection, it was found that a health and safety representative was available in cases of an emergency. Although employees knew where to find an emergency first-aid kit, the contents thereof had not been checked in the preceding six months.

It was commendable that individual researchers consciously select less toxic materials, reactions were run on the smallest scale possible to reduce chemical waste, and employees generally seemed aware of the process and service provider for HCS waste management. It was found that glass and sharp plastic waste were segregated and disposed of separately from general waste, and glass waste was properly packaged and labelled prior to disposal. However, observations revealed that empty containers originally containing acutely hazardous chemicals were not triple rinsed prior to being discarded; and the required sewer discharge log was not available or maintained. If a discharge log was kept, the signage was not posted, and hazardous chemicals were not neutralised, filtered or destroyed, when possible, in order to reduce hazardous waste quantity or hazard. In addition, no procedures were included as part of the protocol's SOP and a Treatment Log was not maintained to document quantities treated and filtration or destruction methods used for disposal.

Each individual researcher determined specialised requirements for Personal Protective Equipment (PPE), but no formal, written SOP was observed. The study found that the required PPE for employees was available and it was in good condition. All the laboratory personnel were instructed as to general departmental rules for PPE and they were trained in PPE matters. Respirators were properly inspected, cleaned, serviced and stored, and cartridges that were used were appropriate to each hazard exposure.

It was found that the department had been assessed formally for potential exposure hazards. The Occupational Health service conducted biennial health risk assessments, OHSA compliance surveys and medical surveillance of employees potentially exposed to HCS in accordance with the regulatory requirements. The most recent survey found that the *single highest risk in the report was a physical risk of explosion,* owing to solvent vapours in the organic chemistry laboratory.

The safety department conducted regular safety inspections. It was found that records were kept of previous safety inspections conducted and corrective actions recommended, and safety procedures/issues were discussed at staff, departmental, or other committee meetings and the discussions documented. Such records were also available.

## 5.4 RECOMMENDATIONS

Recommendations are presented next as a synopsis of the most critical priorities in accordance with the most critical findings of the study, followed by a detailed list of additional recommendations as incited by the survey tool.

### 5.4.1 Synopsis of priority recommendations in accordance with research findings

(a) Institute contingency human resource planning to bridge the potential future gap in coverage for experienced employees at the department

(b) In view of the high number of physical and health hazard types of HCS at the department, the risk of fire, explosion and acute and potential/repeated exposure to HCS should prompt careful and prioritised attention to:

- keeping emergency egress routes clear at all times
- providing access to emergency showers and eyewash fountains within ten seconds from any area where HCS that cause acute toxicity, skin corrosion/irritation or eye damage/irritation are used
- providing awareness training to all cleaners and laboratory assistants in the meaning of all laboratory warning labels and signs
- acquiring and placing chemical spillage kits
- acquiring MSDS for all HCS used at the department
- separating incompatible HCS throughout the department
- storing all HCS in ventilated, chemically resistant cabinets
- ensuring that all employees exposed to Table 1 HCS are under medical surveillance
- ensuring that the proper PPE is used to prevent actual and potential exposure of employees; writing an SOP on the safe use and management of PPE and including it in the safety manual
- designing and maintaining the patency of ventilation ducts to ensure optimal indoor air quality and prevent build-up of fumes
- conducting research work with HCS in fume cupboards with optimal extraction ventilation and the sash two-thirds closed
- placing the chemical inventory on the campus laboratory safety system
- dating peroxide-forming HCS
- labelling all HCS containers
- completing the laboratory safety manual to include written procedures for laboratory work outside of normal working hours and unplanned loss of

power, gas, water or electricity and planned shut-down of gas, water or electricity

- checking the content of the emergency first-aid kit every six months and signing the corresponding register
- triple rinsing empty containers originally containing acutely hazardous chemical substances before disposal
- instituting a sewer discharge log and related signage and ensuring neutralising, filtration or demolishing of HCS before discharging any HCs in a sewer

### 5.4.2 Additional recommendations

Further recommendations based on current findings include:

- Standardisation of procedures on the use and management of HCS recommended. This will ensure a uniform manner in managing HCS throughout the entire chemistry department.
- The advanced draft policy and several procedures on HCS management are to be commended.
- It is suggested that the following themes be added:
  - SOP on the unplanned loss of power, gas or water.
  - SOP on the planned shutdown of power, gas or water.
  - SOP/HCS treatment log for disposal.
  - Laboratory work outside normal work hours.
- MSDS and emergency protocols:
  - One system is recommended for the entire chemistry department – use the Merck comprehensive hard copy manual for quick reference (in case of human exposure, explosion, fire or spillage) in each room or laboratory.
  - Place the chemistry department’s inventory list with MSDS on every HCS on a CD and distribute to all employees.
  - Keep a dedicated laptop on charge at the emergency point in each passage with the CD ready downloaded for easy access.
  - Ensure the MSDS is short, relevant and easy to read.
- Record near-miss incidents on a laboratory safety management system.

- Implement chemical spillage kits urgently.
- Install enough additional eyewash stations to ensure that they could be reached within 10 seconds if required;
- Ensure that patent, functional extraction ventilation systems are connected to all fume cupboards. Ensure fresh air supply according to regulation to prevent heat and build-up of airborne substances.
- Institute a new system to ensure that labelling on all HCS containers correctly reflects the contents, the dilution and hazard warning.
- Conduct a comprehensive Chemical Risk Assessment at the chemistry department. A chemical risk assessment will provide comprehensive and accurate information for risk ranking and -control. The suggested strategy regarding MSDS will make these critical documents fully accessible to all employees in the department, and will be the source to consult in case of human exposure, an emergency, spillage and waste management and disposal. Spillage kits are essential sets of utensils to neutralise and safely handle and dispose of spilt HCS, limiting further human exposure. A new system to ensure correct and inclusive labelling should effectively reflect its contents, expiry date and hazard warning and prevent physical and health hazards. In order to prevent the inhalation of fumes and vapours and heat build-up associated with processes in the department, the maintenance of a patent, functional ventilation and extraction system should be a prime contributor.

## 5.5 FURTHER RESEARCH

A need exists for further research using a wider population of HEIs: all HEIs in Gauteng province could be considered. This will enable generalisation of results to the entire group of approximately 23 HEIs in South Africa.

The findings centred on one institution; however, the research could serve as a point of reference in related future studies of a local or national nature.

## 5.6 CONTRIBUTIONS OF THIS STUDY

Although it was generally found that the use and management of HCS at the chemistry department was under good governance, a number of gaps were identified which, if left unattended, may give rise to accidents, injuries or disease. The gaps were described and recommended action was included in this study. Recommended action, when implemented, should provide the chemistry department with underpinning for a sound policy and standardised procedure, a laboratory safety management system and a chemical inventory. In addition, the review on literature should resonate well with the employees at the study site in relaying interventions, programmes and practices by peer institutions and global agencies.

Results from this study could be used further by peers at South African HEIs to benefit from lessons learnt by academic chemistry laboratories elsewhere. It will enable them to implement evidence-based recommendations to prevent injuries and disease in their respective facilities.

## 5.7 LIMITATIONS OF THE STUDY

This study was limited to one chemistry department at a single HEI in Gauteng province and consequently generalisation of findings to other settings is limited.

## 5.8 CONCLUSION

Research into the use and management of HCS at a chemistry department in an HEI in Gauteng accomplished its objectives of identifying and describing the types and forms of HCS, of examining the actual and potential exposure of workers at the department and of assessing the exposure control measures implemented.

The literature review, actual findings during observation and recommended action flowing from the study, when implemented, should mitigate immediate risks to health and safety, provide sufficient information and benchmarking to instil a strong laboratory safety management system and prevent accidents, injuries and disease at the chemistry department.

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ANNEXURE 1

Request to conduct a research project

**ANNEXURE 1**

**MEMORANDUM**

To: Prof Marie Muller
REGISTRAR

From: Elana Venter
Head: Occupational Health Practice

Date: June 4th, 2013

Subject: Approval to conduct research at UJ

Dear Prof Muller

My current MA Nursing Science studies at Unisa, as approved, require that I conduct research at an environment within an institution of higher education.

The purpose of the study is to carry out a baseline survey on compliance to Occupational Health and Safety standards at an academic research laboratory in an institution of higher education. It is proposed that a retrospective review of occupational health and safety policies, Material Safety Data Sheets, as required by the checklist be included.

The research design is within a quantitative research paradigm. A descriptive, cross-sectional survey will be administered to the sample at the chemistry department, conducting participant observation and completion of an inspection tool. Questions will be posed to employees at the department only for the purpose of verification of items on the checklist.

The research objectives will yield value to UJ. They will be to:

1. Identify and describe occupational health and safety standards which apply in the chemistry department;
2. Identify the occupational hazards and main hazard types at the chemistry department;
3. Describe the control measures which are operational at the chemistry department to mitigate risk associated with hazards in accordance with health and safety standards;
4. Explore compliance to occupational health and safety standards by comparison of each identified hazard to the corresponding legal norm;
5. Explore non compliance to occupational health and safety standards by comparison of each identified hazard to the corresponding legal norm;
6. Associating non-compliance with occupational risk, to identify the hazards requiring high priority risk mitigating attention at the chemistry department.

Ethical considerations will be given due attention. No harm will befall participants and participation will be voluntary on an informed basis. Confidentiality and anonymity will be preserved. The reporting will be representative of the findings.

My request is that you kindly assess and grant permission to conduct the proposed study.

Best regards

Elana Venter

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Auckland Park Bunting Campus | Auckland Park Kingsway Campus
Doornfontein Campus | Soweto Campus

UNIVERSITY OF JOHANNESBURG

ANNEXURE 2

Permission from the study site to conduct the research

## ANNEXURE 2

**Division for Institutional Planning, Evaluation and Monitoring**
**Institutional Research and Planning Unit**

23 October 2013

Sr Elana Venter

**Permission to conduct research at the University of Johannesburg**

I have very thoroughly scrutinised your request (including all the required documentation). and am pleased to inform you that I have found all to be in order. Permission is therefore granted that you may conduct the research for your postgraduate studies at the University of Johannesburg.

Many pleasant hours of hard studying and good luck with your efforts.

Yours sincerely,

C. M. Fourie

**Prof CM Fourie**
Head: Institutional Research and Planning Unit

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ANNEXURE 3

Ethical Clearance Certificate from the University of South Africa

## ANNEXURE 3

UNISA university of south africa

**UNIVERSITY OF SOUTH AFRICA**
**Health Studies Higher Degrees Committee**
**College of Human Sciences**
**ETHICAL CLEARANCE CERTIFICATE**

**HSHDC/239/2013**

Date: 23 October 2013 Student No: 5088-724-6

Project Title: Baseline survey on the use and management of hazardous chemical substances at a chemistry department in a selected institution of higher education in Gauteng Province.

Researcher: Ms Elana Venter

**Degree:** MA in Nursing Science Code: MPCHS94

Supervisor: Prof L Zungu
Qualification: PhD
Joint Supervisor: -

**DECISION OF COMMITTEE**

**Approved** √ **Conditionally Approved**

**Prof L Roets**
**CHAIRPERSON: HEALTH STUDIES HIGHER DEGREES COMMITTEE**

UNIVERSITEIT VAN SUID-AFRIKA PRETORIA UNIVERSITY OF SOUTH AFRICA

**Prof MM Moleki**
**ACADEMIC CHAIRPERSON: DEPARTMENT OF HEALTH STUDIES**

PLEASE QUOTE THE PROJECT NUMBER IN ALL ENQUIRES

# ANNEXURE 4

Survey checklist

**ANNEXURE 4**

## CHEMISTRY LABORATORY HEALTH AND SAFETY SURVEY (INSPECTION) CHECKLIST

Building:______________________________Department:_____________________________

Date of inspection:______________________________ Time: _______________________

Laboratory Survey Conducted by:_______________________________________________

### INSTRUCTIONS REGARDING THE COMPLETION OF THE CHECKLIST

Please check "**YES**", "**NO**", or "**NOT APPLICABLE**" for each item. Comments will be written next to the question or at the end of the survey. Questions answered "NO" will require follow-up.

NB: Additional sheets will be attached if there is insufficient room in the Comments and Corrective Action Items.

### SECTION A: WRITTEN LABORATORY HEALTH AND SAFETY POLICIES / PROCEDURES / PROGRAMS

| Items | Yes | No | N/A |
|---|---|---|---|
| **1. Is the laboratory chemical safety manual available?**<br><br>a. Has laboratory-specific information been added<br>b. Have Standard Operating Procedures (SOPs) addressing all hazardous processes/chemicals been written and added to (or referenced in) the laboratory Safety Manual?<br>c. Are the SOPs up-to-date with current safety information? | | | |

| | | | |
|---|---|---|---|
| **2. Does the laboratory or department have written procedures for the following:**<br>a. Describing any revised procedures necessary due to laboratory work outside usual work hours (such as first aid / emergency response, etc.)?<br>b. Waste minimization / management?<br>c. Chemical spills?<br>i. Biohazard spills, if applicable?<br>ii. Radioactive material spills, if applicable?<br>d. Emergencies such as unplanned loss of power, gas, or water; fire; etc.?<br>e. Planned shut-down of gas, water, or electricity? | | | |
| **3. Are records kept of previous safety inspections conducted and corrective actions recommended?** | | | |
| **4. Are safety procedures/issues discussed at staff, department, or other committee meetings and the discussions documented?**<br>a. Are such records available | | | |

**Comments:**

**1 a**

**1 b**

**1 c**

**2 a**

**2 b**

**2 c**

**2 d**

**2 e**

**3**

**4** ____________________________________________

**Corrective Actions Required:**

1

2

3

4

**SECTION B: EMPLOYEE TRAINING**

| Items | Yes | No | N/A |
|---|---|---|---|
| **1. Do laboratory personnel working with hazardous materials received training in the following areas: (NB: *request for proof in writing or ask employees concerned*)**<br>a. Chemical safety, addressing all hazardous chemicals, and including the proper selection, use and maintenance of personal protective equipment?<br>b. Chemical waste disposal?<br>c. Biohazard waste disposal, as applicable?<br>d. Radioactive waste disposal, as applicable<br>e. Laboratory fire safety?<br>f. Fire extinguisher training?<br>g. Location and use of safety / deluge showers?<br>h. Location and use of eye washes<br>i. Chemical spill cleanup? | | | |

| | | | |
|---|---|---|---|
| j. Blood borne pathogen exposure control?<br>k. Transporting hazardous materials?<br>l. Safe work practices when using biological safety cabinets? | | | |
| **2. Does the head of the department or supervisor or department keep records of what training was provided, detailing the instructor's name date, who attended, and scope of training?**<br>Comments: | | | |
| **3. Have employees been inducted and/or trained on the following:**<br>a. What phone number to call for emergency assistance?<br>b. Where the fire alarm is located?<br>c. Where the nearest fire extinguisher is located?<br>d. How to evacuate upon hearing an alarm or other warning? | | | |
| **4. Are all workers in the laboratory department aware of the meaning of all laboratory warning labels and signs used in the laboratory?**<br>Comments: | | | |

**Comments:**

**1 a**

**1 b**

**1 c**

**1 d**

**1 e**

**1 f**

**1 g**

**1 h**

**1 i**

**1 j**

**1 k**

**1 l**

**3 a**

**3 b**

**3 c**

**3 d**

**Corrective Action Required:**

**1 a**

**1 b**

**1 c**

**1 c**

**1 d**

**1 e**

**1 f**

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**SECTION C: GENERAL EMERGENCY PREPAREDNESS**

| Items | Yes | No | N/A |
|---|---|---|---|
| **1. Are the following available and clearly displayed in the chemistry laboratory department?**<br>a. Emergency phone numbers?<br>b. Emergency instructions addressing fire, medical and chemical emergencies, and biohazard and radiation emergencies as needed? | | | |
| **2. Do employees know:**<br>a. The location of the nearest fire alarm pull box?<br>b. The number of exits (doors) in the room? _________<br>c. The number of escape "kick-out" panels in room? _________<br>d. That fire codes prohibit the use of any door wedges?<br>e. The location of the fire extinguisher(s) in this room?<br>f. Location(s) of complete / up-to-date first aid kit(s) / supply(ies)?<br>g. The location of a chemical spill kit? | | | |
| **3. Have employees been provided information about the importance of personal emergency preparedness?** | | | |
| **4. If the laboratory has an emergency preparedness kit or supplies, have it / they been checked in the last 6 months?** | | | |
| **5. Is a First Aider and / or health safety representative available on all shifts that employees are working?** | | | |
| **6. Are instructions for contacting first aiders and / or safety representatives in cases of an emergency readily available?** | | | |

**Comments:**

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**2 b**

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**Corrective Action Required:**

**1 b**

**2 a**

**2 b**

**2 c**

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**SECTION D: LABORATORY CONDITIONS**

| Items | Yes | No | N/A |
|---|---|---|---|
| **1. Does the chemistry laboratory use proper housekeeping practices which include:**<br>a. Removal of residues on floor / bench tops?<br>b. Uncluttered bench tops and hoods?<br>c. Clear pathways to eyewashes and safety showers?<br>d. Clear pathways to exits, both inside and outside the laboratory? | | | |
| **2. General Laboratory Equipment**<br>a. Are belts, pulleys, and other exposed moving equipment parts guarded?<br>b. Are explosion shields available if they are needed?<br>c. Is equipment serviced to ensure that if functions safely?<br>d. Are equipment service and inspection records kept? | | | |

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| **3. Safety equipment**<br>a. Is a first-aid kit available which is appropriate for the size of the laboratory and located in an easily accessible spot?<br>b. Is the laboratory first-aid kit fully stocked with non-expired materials?<br>c. If corrosive, irritating or substances toxic by eye contact are being used, can an eye wash be reached within 10 seconds?<br>d. If corrosive, irritating or substances toxic by skin contact are being used, can a safety shower be reached within 10 seconds? | | | |
| **4. Is the general room ventilation adequate (temperature and odors controlled, etc.)**<br>Comments: | | | |

**Comments:**

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**2 b**

**2 c**

**2 d**

**3 a**

**3 b**

**3 c**

**3 d**

**Corrective Action Required:**

**1 a**

**1 b**

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**2 b**

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**2 d**

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**3 b**

**3 c**

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**SECTION E: HAZARDOUS MATERIAL SAFETY**

| Items | Yes | No | N/A |
|---|---|---|---|
| **NB: According to the hazardous chemical substances (HCS) regulation materials considered potentially hazardous include cleaners, solvents, laboratory chemicals, grease, disinfectants, dental products, etc.** | | | |
| **1. Is a current inventory of hazardous materials available for employees to make reference to it?**<br>a. If yes, does it include chemical amounts, container type, pressure and temperature?<br>b. If yes, is it on campus Laboratory Safety System (LSS)? | | | |
| **2. Do all laboratory personnel have access to Material Safety Data Sheets (MSDS) during all hours of operation?**<br>a. If the method is to download MSDS from the Web can all employees prove they know how to get an MSDS?<br>b. If the method is to maintain a file of hard copy MSDS, can all employees prove they know where the file is located?<br>c. Are MSDS available for all hazardous chemicals used in the laboratory? | | | |
| **3. Are all containers labeled, showing chemical contents and appropriate hazard warning labels?**<br>Comments: | | | |
| **4. Are incompatible hazardous materials isolated from each other (i.e., stored according to chemical class)?**<br>Comments: | | | |
| **5. If hazardous materials are stored in this laboratory, are they stored in:**<br>a. A mechanically ventilated storage area?<br>b. Chemically-resistant containers?<br>c. Designated areas such as placarded cabinets, shelves, etc.? | | | |

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|---|---|---|---|
| **6. Are chemical storage shelves:**<br>a. Protected with a lip or barrier?<br>b. Designed and installed to carry the current load? | | | |
| **7. If present, are refrigerators containing hazardous materials placarded to identify contents and restrictions (e.g., "NO FOOD")?**<br>Comments: | | | |
| **8. If a refrigerator is used to store flammable materials, is it explosion-proof and labeled as explosion proof?**<br>Comments: | | | |
| **9. If highly flammable liquids are used and they are present in a room:**<br>a. Are the flammable liquids stored in a storage cabinet designed for storing flammables?<br>b. Are flammable liquids storage areas located away from open flames or sparks, and labeled (e.g., with signs reading "Flammable")? | | | |
| **10. Are ethers and peroxide-forming compounds (e.g., aldehydes, ethers, benzylic hydrogen compounds, allylic compounds, and vinyl compounds) dated when received by the department and when opened in the laboratory?**<br>Comments: | | | |
| **11. Are the dated containers of ethers and peroxide-forming compounds checked to ensure they do not exceed allowable storage times?**<br>Comments: | | | |

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| **12. Are all employees familiar with storage, handling, and testing of peroxide-forming chemicals prior to performing procedures that can increase potential for peroxide development (e.g., distillations)?**<br>Comments: | | | |
| **13. Are piping (tubing), valves, and fittings compatible with the hazardous materials for which they are used and checked periodically for integrity?**<br>Comments: | | | |
| **14. Are staff aware that state safety regulations protect worker's exposure for many specific hazardous materials (such as, but not limited to: benzene, formaldehyde, lead, vinyl chloride, and chemicals considered particularly hazardous; i.e. carcinogens, highly acute, and reproductive toxicants)?**<br>Comments: | | | |
| **15. Are there designated and labeled areas for handling particularly hazardous substances? (These particularly hazardous substances include but are not limited to: select carcinogens, reproductive toxicants, select agents, and materials with high acute toxicity.)**<br>Comments: | | | |
| **16. Has the laboratory replaced their reagents, procedures or equipment with less hazardous materials (such as replacing mercury-containing thermometers) when possible?**<br>Comments: | | | |

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| **17. Are chemical spill cleanup supplies (e.g., absorbents like spill pads, or diatomaceous earth, and neutralizers like citric acid) readily available in the lab at all times and selected based on materials likely to spill (e.g., if mercury is used, is a mercury spill kit available)?**<br>Comments: | | | |

**Comments:**

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**5 c**

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**6 a**

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**6 b**

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**9 a**

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**9 b**

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**Corrective Action Required:**

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**SECTION F: HAZARDOUS CHEMICAL WASTES**

| Items | Yes | No | N/A |
|---|---|---|---|
| 1. **Do people responsible for purchasing chemicals review reference materials (such as MSDS) to evaluate materials before purchase to select the least toxic materials possible and to identify possible waste streams?**<br>Comments: | | | |
| 2. **Are reactions run on the smallest scale possible to reduce chemical waste?**<br>Comments: | | | |
| 3. **Are process waste streams segregated (i.e., not mixing different chemicals), which makes disposal cheaper and easier?** | | | |
| 4. **Are employees familiar with the procedure for requesting chemical or waste pickup by the relevant person or waste management service provider?**<br>Comments: | | | |
| 5. **Are glass and sharp plastic waste segregated and disposed of separately from general trash?**<br>Comments: | | | |
| 6. **Is glass waste properly packaged and labeled?**<br>Comments: | | | |

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| **7. Are empty containers originally containing acutely-hazardous chemicals triple rinsed prior to being discarded?**<br>Comments: | | | |
| **8. A limited number of chemicals can be disposed of in the sink if any chemicals are disposed of in the sink:**<br>a. Is the required sewer discharge log maintained?<br>b. If a discharge log is kept, is the following sign posted? | | | |
| **9. Are hazardous chemicals neutralized / filtered / destroyed when possible in order to reduce hazardous wastes quantity or hazard?**<br>a. Are procedures included as part of the protocol's SOP?<br>b. Is a Treatment Log maintained to document quantities treated and filtration or destruction methods used for disposal? | | | |

**Comments:**

**3**

**8 a**

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**9 a**

**9 b**

**Corrective Action Required:**

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| **9 b** | |

## SECTION G: PERSONAL PROTECTIVE EQUIPMENT (PPE)

| Items | Yes | No | N/A |
|---|---|---|---|
| **1. Have potential exposure hazards been assessed?**<br>Comments: | | | |
| **2. If PPE (e.g., gloves, goggles, face shields, lab coats, safety glasses with side-shields, etc.) is required, have the requirements been noted in SOPs, health and safety plans, or other guidance use by all laboratory workers?**<br>Comments: | | | |
| **3. Is required PPE for employees available and in good condition?**<br>Comments: | | | |

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| **4. Are all laboratory personnel:**<br>a. Instructed as to general departmental rules for PPE (such as rules to remove and store lab coasts in the laboratory before leaving) and any process specific requirements for additional PPE?<br>b. Informed as to where these rules are posted or filed?<br>c. Trained in the correct procedures for selecting the appropriate PPE, inspecting for damaged PPE prior to wear, correctly donning and adjusting for proper fit (if required), doffing without spreading contamination, and maintaining and disposing of the PPE? | | | |
| **5. When selecting the type of protective gloves(s) required, does the staff use all glove selection resources available (e.g., MSDS, vendor catalogs and laboratory staff experience that the glove provides adequate dexterity)?**<br>Comments: | | | |
| **6. If respirators (half face, full face, SCBA, Air Line) are being used:**<br>a. Has occupational hygienists been contacted to assess the level of exposure?<br>b. Have users received medical evaluation, training and fit testing in accordance with guidelines on medical surveillance?<br>c. Are respirators properly inspected, cleaned, serviced and stored?<br>d. If cartridges are used, are they the correct ones for each hazard exposure? | | | |

**Comments:**

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| **6 d** |

**Corrective Action Required:**

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| **6 c** |
| **6 d** |
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## SECTION H: OCCUPATIONAL HEALTH

| Items | Yes | No | N/A |
|---|---|---|---|
| **1. Do all personnel know that following an incident or accident they must complete the appropriate Incident / Accident / Report form?**<br>Comments: | | | |
| **2. In case of a medical emergency, staff should go to the nearest emergency room for care.**<br>Comments: | | | |
| **3. If laboratory operations involve potential biohazard exposure, is a copy of a Biohazard Safety Manual available?**<br>Comments: | | | |
| **4. If the Blood borne Pathogen Standard applies, have all of the staff:**<br>a. Received the required training?<br>b. Received the Hepatitis B immunization or signed a declination? | | | |

**Comments:**

**4 a**

**4 b**

**Corrective Action Required:**

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4 a

4 b

**Other comments or information to note:**