

**Monitoring and control of hazardous chemical  
substances in research and testing laboratories  
in the Faculty of Health Sciences of the  
North-West University.**

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Hons. B.Sc

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of the requirements for the degree *Master of Science*  
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## Author's contribution

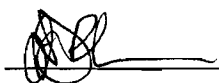
This study was planned and executed by a team of researchers. The contribution of each of the researchers is depicted in Table 1.

Table 1: Research team


NAME	CONTRIBUTION
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Prof. F.C. Eloff	<ul style="list-style-type: none"><li>• Assistant-supervisor</li><li>• Assisted with the approval of the protocol, interpretation of the results, reviewing of the documentation of the study.</li></ul>

The following is a statement from the supervisors that confirms each individual's role in the study:

*I declare that I have approved the article and that my role in the study as indicated above is representative of my actual contribution and that I hereby give my consent that it may be published as part of Anja Franken's M.Sc (Occupational Hygiene) dissertation.*



Mr. J.L. du Plessis  
(Supervisor)



Prof. F.C. Eloff  
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## List of abbreviations

ACGIH	American Conference of Governmental Industrial Hygienists
ASHRAE	American Society of Heating, Refrigerating and Air-conditioning engineers.
BEI	Biological Exposure Index
C	Ceiling limit
CL	Control Limits
FR	Fecundability ratio
HCS	Hazardous Chemical Substance
mg/m <sup>3</sup>	milligram per cubic meter
m/s	meters per second
MSDS	Material Safety Data Sheet
NIOSH	The National Institute for Occupational Safety and Health
OEL – CL	Occupational Exposure Limit – Control Limit
OEL – RL	Occupational Exposure Limit – Recommended Limit
OESSM	Occupational Exposure Sampling Strategies Manual
OSHA	Occupational Safety and Health Administration
ppm	Parts per million
PEL	Permissible exposure limit
RL	Recommended Limits
STEL	Short term exposure limit
TLV-TWA	Threshold limit value - Time Weighted Average
TWA OEL	Time Weighted Average Occupational Exposure limits
TWA - PEL	Time Weighted Average - Permissible Exposure Limit
TWA - REL	Time Weighted Average - Recommended Exposure Limit
VOC	Volatile organic compound

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## **Preface**

For the aim of this project it was decided to use article format. For uniformity the whole mini-dissertation is according to the guidelines of the chosen magazine for potential publications which is the Occupational Health Southern Africa. The magazine requires that the references should be inserted in the text as superscript numbers and the list of references should be set out in the Vancouver style.

For the purpose of this study all chemical exposures that were below the detectable level were taken as the lowest detectable value. Where break through of the chemicals occurred in the sorbent tube, the concentrations in both compartments were added together to give a minimum exposure level

## **ABSTRACT**

This study was launched because of alarming conditions in laboratories and lack of general occupational health and safety. Employees are exposed to a number of chemicals for extended periods of time, and these employees aren't 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. In this study personal and environmental sampling was conducted in three subject groups with the highest potential risk. With the sampling employee or environmental exposure to ten chemicals could be quantified. Questionnaires were used to assess employee as well as health and safety representative's general knowledge of occupational health and safety. In the course of this study it was found that employees are exposed to low concentrations of a wide variety of chemicals during the workday. The exposure to a combination of chemicals leads to an exceedingly high concentration of overall volatile organic substances. The exposure to these low concentrations takes place over a number of years for permanent employees. During the workday employees are also exposed to short periods of very high concentrations of hazardous chemical substances. These short term exposure levels are complicated to compare with international standards because of the lack of standards available. Therefore it is difficult to determine if an employee's exposure does exceed the international limits, and therefore it is difficult to control or prevent this short term exposure. The long term exposure to these hazardous chemical substances may lead to serious detrimental health effects, which often only develop years after exposure occurred. The biggest concern for employees working with hazardous chemical substances is depression of the nervous system and development of cancer. To prevent these negative health effects it is important to control or minimize employee exposure to hazardous chemical substances during the workday.

The institution should launch a thorough investigation to determine employee exposure of the various chemicals during the eight hour workday, but also during the short term exposure periods. Control measures such as ventilation systems or fume cupboards should be installed or repaired to provide adequate control to minimize employee exposure.

## OPSOMMING

Hierdie studie is geloods as gevolg van steurende kondisies in laboratoriums en 'n tekort aan algemene beroepsgesondheid en -veiligheid. Werkers is blootgestel aan 'n aantal chemikalieë vir verlengde periodes, en hierdie werkers is nie heeltemal ingelig oor die risiko's betrokke met die hantering van gevaarlike substansie nie. Daar is 'n algemene tekort aan bewustheid en bekommernis oor werkers se gesondheid en veiligheid in die werkplek, veral in laboratoriums. In hierdie studie is persoonlike en omgewings monsterneming uitgevoer in drie vakgroepe met die hoogste potensiële risiko. Deur die monsterneming is persoonlike en omgewings blootstelling aan tien chemikalieë gekwantifiseer. Vraelyste is gebruik om werkers asook gesondheid en veiligheids verteenwoordigers se kennis oor beroepsgesondheid en veiligheid te assessee. Tydens die studie is gevind dat werkers blootgestel word aan lae konsentrasies van 'n wye verskeidenheid van chemikalieë gedurende die werksdag. Die blootstelling aan 'n kombinasie van chemikalieë lei tot 'n uitermatige hoë konsentrasie van algemene vlugtige organiese substansie. Die blootstelling aan hierdie lae konsentrasies vind plaas oor 'n aantal jare vir permanente werkers. Gedurende die werksdag is werkers ook blootgestel aan kort periodes van baie hoë konsentrasies van gevaarlike chemiese substansie. Dit is moeilik om hierdie kort termyn blootstellings vlakke te vergelyk met internasionale standaarde, as gevolg van die tekort van standaarde beskikbaar. Daarom is dit moeilik om te bepaal of 'n werker se blootstelling die internasionale limiete oorskry, en dus is dit moeilik om hierdie kort termyn blootstelling te beheer of te beperk. Lang termyn blootstelling aan hierdie gevaarlike substansie kan lei tot ernstige negatiewe gesondheidseffekte, wat dikwels eers jare na blootstelling ontwikkel. Die grootste bekommernis vir werkers wat met gevaarlike chemiese substansie werk is onderdrukking van die senuwee sisteem en ontwikkeling van kanker. Dit belangrik om werkers se blootstelling aan gevaarlike chemiese substansie te beheer of te minimaliseer gedurende die werksdag om sodoende hierdie negatiewe gesondheidseffekte te voorkom.

Die institusie moet 'n deuglike ondersoek loods om die werkers se blootstelling aan 'n verskeidenheid gevaarlike chemikalieë gedurende die agt uur werksdag, asook die kort termyn blootstellings periodes te bepaal. Beheer maatreëls soos ventilasie sisteme of chemiese dampkaste moet geïnstalleer of herstel word om voldoende beheer te bied om sodoende die werkers se blootstelling te minimaliseer.

# *CHAPTER 1*

## **GENERAL INTRODUCTION**

### **1.1 Introduction**

In contrast to the manufacturing industry, research and testing laboratories are characterized by a wide variety of high risk hazards usually present in low volumes and a diverse workforce.<sup>1</sup> These hazards can be classified as either chemical, physical, radiological or biological.<sup>2</sup> A previous study identified 13 764 different chemical substances in a survey of eleven universities.<sup>3</sup> Hazardous chemicals could be characterized as carcinogens, haematopoietic system toxins, hepatotoxins, nephrotoxins, neurotoxins, toxic agents, and agents that damage the skin, eyes or mucus membranes. The routes of exposure are inhalation or absorption through skin or mucus membranes.<sup>1</sup> Employees at risk in university research and testing laboratories include full-time and part-time employees, postgraduate students and visitors. While full-time and part-time staff is highly qualified, trained and subjected to workplace monitoring and medical surveillance, students and visitors are inexperienced and not subjected to health and safety training, monitoring or surveillance.<sup>2</sup>

Because employees in academic and research institutions are potentially exposed to different types of chemical hazards simultaneously, it is necessary to maintain comprehensive health and safety services. If health and safety services are inadequate and employees are exposed to occupational hazards, it may result in increased risk of acute and chronic health effects. The absence of safety programs can cause financial burden through increased insurance premiums, regulatory fines, personal legal actions or even loss of working hours because of sickness.<sup>2</sup>

The Occupational Health and Safety Act (Act No. 85 of 1993) states that the employer must establish and maintain a workplace that is safe to the health and safety of the employees and any other person.<sup>4</sup> According to the Regulations for Hazardous Chemical Substances the employer must assess the potential exposure to HCS. If exposure occurs, air sampling must take place to measure the airborne concentrations of hazardous chemical substances. If any employee is exposed to certain hazardous chemical substances the employee must be placed under medical surveillance. If an assessment indicates exposure to hazardous chemical substances, the employer must take the necessary steps to control the exposure and assess the success of the control methods at regular intervals.<sup>5</sup>

Employees in research and testing laboratories in the Faculty of Health Sciences of the North-West University are exposed to hazardous chemical substances that can be detrimental to their health. There is also evidence of inadequacies in the assessment and monitoring of Hazardous Chemical Substances; medical surveillance of employees; and control measures in these laboratories. Because of the risk of developing serious illness after exposure to hazardous chemical substances, it is vital and required by the Occupational Health and Safety Act as well as the Regulations for Hazardous Chemical Substances that the exposure is quantified and controlled to protect the health and safety of employees in these laboratories.<sup>5</sup> Little has been written about the occupational health needs of research and testing laboratories of universities, despite the risk and complexity involved.

In order to protect the health and safety of all personnel in laboratories it is necessary to control the exposure by means of different control measures. The first control measure is engineering control such as separating processes or by utilizing adequate ventilation systems. An example of control through ventilation systems is the general purpose laboratory fume cupboard. The fume cupboard is a local exhaust system that reduces the levels of airborne contamination and thereby reduces the inhalation exposure of employees to hazardous substances.<sup>6</sup> The laboratory fume cupboard is designed for the protection of personnel by preventing contaminants like vapours, dusts, mists and fumes from being released into the laboratory and nearby environment.<sup>7</sup> If engineering controls are not satisfactory, control can be achieved by administrative control, which is control of exposure by measures such as controlling the number of employees that are exposed or by controlling the duration of exposure. When control measures are not sufficient to achieve control, the employer must ensure that appropriate personal protective equipment is provided in the form of masks, gloves or safety glasses.<sup>5</sup>

The intent of standards and regulations<sup>6</sup> are to ensure that laboratory employees are aware of the chemicals in their work area, and that appropriate work practices and procedures are in place to protect the employees from chemical hazards.<sup>8</sup>

An occupational hygiene plan should include hazard identification, training and information, chemical exposure assessment, chemical fume cupboard evaluation, work practices for handling laboratory chemicals, chemical storage and a waste disposal program. The plan should also include the training and distribution of personal protective

equipment when exposure to the hazardous chemical substances can not be adequately controlled.<sup>8</sup>

## **1.2 Aims and Objectives**

The aims of the study are:

- To assess the hazardous chemical substances used, stored and handled in research and testing laboratories in the Faculty of Health Sciences of the North-West University.
- To conduct personal air sampling of employees and postgraduate students potentially exposed to hazardous chemical substances.
- To conduct area sampling in laboratories with high potential risk to employees and postgraduate students working in the laboratories.
- To evaluate the effectiveness of fume cupboards as control measures.
- To develop an occupational health plan for managing hazardous chemical substances in research and testing laboratories of the North-West University.

## **1.3 Hypothesis**

Employees (full-time, part-time and postgraduate students) in research and testing laboratories in the Faculty of Health Sciences of the North-West University are exposed to hazardous chemical substances above the occupational exposure limits stated in the Hazardous Chemical Substances Regulations.

## 1.4 References

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# *CHAPTER 2*

## **LITERATURE STUDY**

The literature study will cover existing information important to this study. It will include information concerning laboratories and the hazards in these research and testing laboratories, as well as the employees that are potentially exposed. Legislation concerning laboratories and the use of hazardous chemicals will be discussed, as well as methods of control to minimize employee exposure. Special emphasis will be placed on the fume cupboard as an important method of inhalation exposure prevention. Finally the health effects of various hazardous chemicals found in the laboratories will be discussed to illustrate what effects can develop as a result of exposure to these chemicals.

### **2.1 Research and testing laboratories**

All laboratories share certain characteristic tasks regardless of the purpose or location. Commercially operated laboratories provide analytical testing services for products or are involved in research and development of new products. Medical or clinical laboratories are responsible for the processing of clinical specimens for medical diagnoses, while university laboratories are mostly used for research purposes. In some instances commercial laboratories are located in the university sector and employees, including students, are involved in the analytical procedures. Consequently a research laboratory is used to conduct experiments and tests for research purposes, which should lead to progress and the broadening of academic knowledge. A testing laboratory on the other hand is used for testing and analysis of samples on a commercial level in order to provide information on the sample. Although the laboratories are used for different purposes, the same hazards are still present and employees can be equally exposed. These laboratories represent one of the environments with the greatest diversity of risk combined with a diverse population that is at risk.<sup>1</sup>

Research and testing laboratories perform testing and diagnostic evaluations of samples and thus the potential exposure to large volumes of hazardous agents is low in comparison to industries that produce chemicals.<sup>1</sup>

## 2.2 Hazards in research and testing laboratories

The potential hazards present in laboratory environments can be classified into four categories: chemical, biological, physical or radiological. This study will focus on the chemical hazards present in laboratories at an academic and research institution.<sup>1</sup> A chemical substance is a compound or mixture of substances which may be present in the workplace in the form of a liquid, solid or a gas. These substances may present a hazard as a result of contact with the body or absorption into the body through the skin, by ingestion or inhalation.<sup>2</sup>

The hazardous properties of chemical substances can be divided into two categories: toxicity; and flammability and explosivity. Toxic describes anything that cause harm or damage to human health. The human toxicity data are known for a small number of substances, hence the term toxic should be used carefully to describe a chemical. Toxic refers to a harmful effect on a biological structure or its function and the condition under which the effect occurs. The relative toxicity of a chemical gives the degree of harmful effect that follows after the exposure. Toxicity relies on the conditions of exposure such as dose and concentration, route of entry, duration of exposure and the exposed person's attributes.<sup>3</sup>

There are a large number of chemical hazards that are used in laboratories. Analysis of laboratory samples involves processes that isolate a specific characteristic of a compound. In the processing and analysis a variety of hazardous chemicals can be used, which can be classified by their health and safety risks. These risk categories are carcinogens, haematopoietic system toxins, hepatotoxins, nephrotoxins, neurotoxins, toxic agents, and agents that damage the skin, eyes or mucus membranes.<sup>1</sup>

The use of hazardous chemicals in clinical, research and academic laboratories presents physical or health threats to personnel that come in contact with the hazardous chemicals. Laboratory use means performing chemical procedures using small quantities of hazardous chemicals as part of laboratory practices, and not as part of a production process in an environment where protective equipment is used.<sup>4</sup>

The university laboratories usually contain a wide variety of chemicals, and employees often use many different chemicals but in small amounts. This leads to low levels of

exposure, but to a wide variety of hazards. As a result of an employee's diverse exposure the combination of chemicals can cause greater adverse health effects than a single chemical. Therefore there are many challenges to health and safety programs of academic and research institutions because of the variety of potential hazards present and the possibility of simultaneous exposure to hazards. Health and safety programs must identify the types of hazards present, the programs in place to attend to hazards and the medical surveillance that is used to evaluate the health status of the employees that are at risk because of exposure to the hazards.<sup>5</sup>

Laboratory employees that work with carcinogenic, mutagenic and teratogenic agents or conduct experiments with biohazardous agents have a higher exposure risk than normal because their work occurs with direct or indirect contact with the substances. Special attention during work environment assessment is needed to ensure that all the potential health hazards are recognized. Employees should be trained in personal hygiene, dedication to laboratory protocol, accident and incident reporting and protocol, waste disposal procedures, and methods for ensuring protection of personnel.<sup>3</sup>

### **2.3 Workforce at risk**

The university sector in most countries is large and growing, and includes employees with varying cultures, and involves high risk exposures. There is little information about the occupational health needs of this sector. The needs refers to information about hazard and risk, and also information relevant to planning occupational health requirements in the university.<sup>6</sup> The workforce is continuously exposed to the different types of hazards often simultaneously because these laboratories continuously use, handle and store a variety of hazardous chemical substances.<sup>1,5</sup>

Universities are large organizations with diverse hazards and a lack of clarity about the responsibility for managing occupational health and safety issues. It isn't always clear who is responsible for the management of health and safety in laboratories, and it is difficult to appoint health and safety representatives because they do not want to take the responsibility that is associated with the job. This makes it difficult to maintain a healthy and safe work environment for all employees and postgraduate students in the laboratories.<sup>6</sup>

The workforce in University research and testing laboratories consists of permanent employees, postgraduate students and visitors.<sup>1,5</sup>

### 2.3.1 Permanent employees and contract workers

A large percentage of employees are permanently employed by the university and work on a fixed basis, and are thus exposed to the hazards over the long term. Contract workers usually have a minimum of a year contract with the institution, and therefore are exposed to hazards over the long term similar to permanent employees.<sup>6</sup>

### 2.3.2 Postgraduate students

The workforce in universities is unusual because of the large number of students, a high proportion of employees are young and inexperienced. The students have a short term commitment with the university, and this changes the hazard profile of the university sector. Postgraduate students work in the same workplaces as employees and are subjected to the same hazards. When compared to the industry, the work carried out in universities by postgraduate students is with little or no training and supervision.<sup>6</sup>

### 2.3.3 Visitors

Universities also have a large number of visitors such as academic visitors, contractors and members of the public. The university is responsible for guidance and giving information to these visitors to ensure their health and safety while they are in a laboratory of the university.<sup>6</sup>

## 2.4 Previous studies

### 2.4.1 Effectiveness of South Australian health and safety representatives.

In 1993 a research project was launched to determine the use and management of hazardous chemicals in South Australian workplaces. Health and safety representatives (410 in total) were asked to complete questionnaires in relation to the work performed by members of the work group that they represent. Through the questionnaires the following information was gained: 82% of employees have contact with hazardous chemicals, and of this contact 75% is through air contaminants and 68% through skin contact. Of the contact with hazardous chemicals 16% is accidental and 30% is rare contact at low levels, whereas 41% is frequent contact at low levels and 10% is frequent contact at high levels.<sup>7</sup>

The employees taking part in the survey got their information for hazardous chemicals from container labels (83%), material safety data sheet (72%) or from their health and safety representatives (70%). In 76% of the cases all the containers were labelled. In 23% of the cases only some of the containers were labelled and in 1% of the cases the containers were not labelled. 55% of employees have access to the MSDS for all the hazardous chemicals, 26% have access to only some of the MSDS and 19% do not have access to any MSDS. Of all the employees only 51% have received training in relation to the hazardous chemicals. In 71% of all the workplaces has there been assessments of the use of hazardous chemicals.<sup>7</sup>

In the survey it was clear that the most used control method was the use of personal protective equipment (86%), then the use of safe work practices (64%) and the use of respiratory protection (60%), and in 7% of the workplaces there were no control methods in place.<sup>7</sup>

This survey concluded that health and safety representatives were found to be an approachable and successful source of information about the use and management of hazardous chemicals in the workplace. The conclusion can be made that health and safety representatives would be a successful measure for the assessment and control of hazardous substances in any workplace if they are adequately trained and have the necessary resources.<sup>7</sup>

The data from similar surveys could be used as guideline for preventative measures because the data should indicate the priority areas for improvement in the management of hazardous chemicals in the workplace.<sup>7</sup>

#### 2.4.2 Swedish fecundability study.

In 1990 to 1994 a research project was launched in Sweden to clarify possible effects on fecundability from exposure to chemicals, biological and physical agents in laboratories. A questionnaire was circulated among female personnel who worked in Swedish biomedical research laboratories, and female personnel in non-laboratory departments were used as a reference group. Laboratory work and the use of organic solvents have been connected with several adverse pregnancy outcomes such as spontaneous abortions, malformations, decreased birth weight and reduced fertility. Five hundred and sixty women were included in the study and all these women had given birth at least once during the period of 1990 to

1994. The time elapsed from trying to get pregnant and the time until the women fell pregnant were used to estimate the fecundability. Fecundability is the probability of conception per cycle. In 58% of the exposed pregnancies, the mother had been working with solvents before the conception, and of these women 35,1% became pregnant during the first menstrual cycle, whereas with the women not exposed 49,1% became pregnant during the first menstrual cycle. Women in the non-laboratory department had a fecundability ratio (FR) of 1.06, and women working in the laboratories with organic solvents had a FR of 0.79. Therefore the use of solvents in general is associated with reduced fecundability of women working in laboratory environments.<sup>8</sup>

#### 2.4.3 Swedish congenital malformation study.

A study was launched in Sweden to investigate major congenital malformations in the offspring of laboratory employees. From the 1629 women included in the study, 959 were exposed to agents in laboratories and 670 were from other departments and not exposed. The prevalence of major malformations in offspring was 2.3% for exposed women and 1.9% for unexposed women. Neural crest malformations were 0.8% for exposed women and 0.7% for unexposed women. The study found no significant increase in risk of major congenital malformations in relation to laboratory work in general. Organic solvents, especially benzene, showed an increased risk for major congenital malformations and for neural crest malformations in offspring of women who had worked with benzene before the end of the second trimester of the pregnancy.<sup>9</sup>

#### 2.4.4 Study of the exposure of laboratory personnel to chemicals at MIT.

In 1999 a study was launched at the Massachusetts Institute of Technology in America to assess the exposure of laboratory personnel to selected OSHA-regulated chemicals during research activities. Eleven laboratories were selected out of the 2200 laboratories on the campus for monitoring, because of frequency of use of the chemicals. All of the research activities were required to be performed inside laboratory fume cupboards. In this study benzene, formaldehyde, chloroform, methylene chloride and arsenic were selected for monitoring. Both personal and area samples were taken, while information on waste disposal practices, use of personal protection equipment and physical conditions of the laboratory were noted. The results showed that exposure levels in 10 of the 11 laboratories were well below the OSHA time-weighted average. In these laboratories all the activities were conducted in a laboratory chemical fume cupboard, and where the

chemicals were used in large quantities the concentrations did not exceed the specified levels.<sup>10</sup>

In the remaining laboratory the short term exposure levels were exceeded. In this laboratory a procedure known as flash chromatography was performed. The laboratory fume cupboard was assessed and it failed a smoke visualization test, which indicated that the left-hand side at the front of the cupboard was not as effective as the rest of the cupboard. It was also observed that the employee did not conduct the procedure at least 15 cm inside the cupboard, but instead worked close to the front edge of the cupboard. This can result in vapours leaking out of the fume cupboard. Therefore the conclusion can be made that the high concentration was partly due to the employee's laboratory practices and the cupboard's performance. This employee was also sent for a medical consultation, and the laboratory fume cupboard was corrected.<sup>10</sup>

#### 2.4.5 Study of the effects on offspring as a result of paternal exposure to chemicals

Paternal exposure to solvents and chemicals have been associated with the occurrence of spontaneous abortion, low birth weight, birth defects, childhood leukemia and brain cancer of offspring. There have been reports of declining sperm counts over the past 50 years, and a possibility that exposure to chemicals in the environment and workplace may damage male reproductive health. Chemicals might interact with the male reproductive system in different ways depending on other toxicants present in the body. There is data to suggest that the incidence of certain urogenital abnormalities such as hypospadias and cryptorchidism have become more common, as well as increased incidence of testicular cancer in males exposed to solvents and chemicals.<sup>11</sup>

## 2.5 Legislation

The Occupational Health and Safety Act of 1993 states the duties of employer and employees as the following:

### 2.5.1 General duty of the employer

According to the Occupational Health and Safety Act of 1993 it is the employer's duty to provide and maintain as far as is reasonably practicable, a work environment that is safe and without risk to the health of the employees. The employer must provide and maintain

systems and machinery that are safe and without risk to health, as well as take steps to eliminate or reduce any hazard to the safety and health of employees before resorting to personal protective equipment. The employer must take precautions against hazards to health and safety that are present in the production, processing or use of substances and provide the necessary means to apply these precautionary measures. The employer must provide information and training that may be necessary to ensure the health and safety of each employee, and may not permit any employee to do any work unless the precautionary measures have been taken. The employer must take all necessary measures to ensure that the requirements of the Act are complied with, and must enforce the measures that may be necessary in the interest of health and safety. The employer must ensure that work is performed under supervision of a person trained to understand the hazards associated with the work, and who has the authority to ensure that precautionary measures taken by the employer are implemented.<sup>12</sup>

#### 2.5.2 General duties of employees

It is the employee's duty to take care of his and other's health and safety. The employee must perform any duty or requirement of this Act given by his employer, and carry out any lawful order given to him in the interest of health and safety. The employee must report any situation that is unsafe or unhealthy as soon as practicable to his employer or the health and safety representative. If any employee is involved in an incident which may affect his health, he must report the incident to the employer or to the health and safety representative as soon as practicable.<sup>12</sup>

The Regulations for Hazardous Chemical Substances of 1995 states the following:

#### 2.5.3 Information and training

The employer must inform and train all employees before they are exposed to HCS with regard to the contents of the regulations, the potential source of exposure, the potential risks caused by exposure and the measures to be taken by the employer to protect the employee against any risk of exposure. The employer must also inform the employee of the precautions that he/she must take to protect him/herself against the health risks associated with exposure, the necessity, correct use and maintenance of personal protective equipment. The employee must also be informed about the necessity of personal air sampling and medical surveillance, the importance of good housekeeping and personal hygiene, the safe working procedures regarding the use, handling and storage of

HCS, as well as the procedures to be followed in the event of spillages, leakages or any accident.<sup>13</sup>

#### 2.5.4 Assessment of potential exposure

The employer must ensure that assessment is conducted immediately if any employee may be exposed to HCS, and thereafter at intervals not exceeding two years, and the employer must inform the relevant health and safety representative. The employer must keep record of the assessment in terms of the HCS to which employees may be exposed, what effects the HCS can have on the employee, where the HCS may be present, the route of intake by which an employee may be exposed and the nature of the work or process where exposure may take place, and any deterioration in control measures. If the assessment indicates that any employee may be exposed, the employer must ensure that monitoring is carried out and ensure that the exposure be controlled. The employer must review the assessment if there is any reason to suspect that the previous assessment is no longer valid, or if there has been a change in the process, methods, equipment or procedures using HCS.<sup>13</sup>

#### 2.5.5 Air monitoring

Where the inhalation of HCS is concerned, the employer must ensure that the measurement program is carried out in accordance with the provisions of the Regulations after the health and safety representative has been informed, and that the measurement is carried out by an approved inspection authority. The measurement must be representative of the highest exposure of employees to airborne HCS. If the exposure group is homogenous, the sample size must be chosen to make provision to include the top 10% of the highest exposure in the group. For a chemical with a control limit the sample size must be chosen for the top 10% of the group at the 95% confidence level, and the top 10% of the group at the 90% confidence level for a chemical with a recommended limit. Measurements must be carried out at least every 12 months for HCS with a control limit, or at least every 24 months for HCS with a recommended limit. The employer must obtain the services of an approved inspection authority that shall verify the measurement program or carry out the measurements, and enter the results of the investigation in the record.<sup>13</sup>

#### 2.5.6 Medical surveillance

The employer must ensure that an employee is under medical surveillance if the employee is exposed to a substance listed in Table 3 of the Regulations, if the exposure to HCS has

adverse effects on his health or the exposure leads to the development of disease, or if the occupational health practitioner recommends that the employee must be under medical surveillance. The employer must ensure that any employee undergoes an initial health evaluation immediately before or within 14 days after a person commences employment, as well as subsequent examinations at intervals not exceeding two years. The employer must not permit any employee who has been certified as unfit for work by an occupational health practitioner to work in a workplace where he may be exposed.<sup>13</sup>

#### 2.5.7 Records

The employer must keep all records of the results of all assessments, air monitoring, and medical surveillance. The employer must make the records, excluding personal medical records, available for inspection by an inspector or health and safety representative or committee. The employer must keep all records of assessment, air monitoring and health surveillance for a minimum period of 30 years. The employer must keep all records of the investigation and tests of engineering controls and any repairs for at least three years.<sup>13</sup>

#### 2.5.8 Control of exposure to hazardous chemical substances

The employer must ensure that the exposure of any employee is prevented or where this is not reasonably practicable, adequately controlled. Where there is exposure to HCS with a recommended limit, the control shall be regarded as adequate if the level of exposure is below that limit. Where there is exposure to HCS with a control limit, the control shall be regarded as adequate if the exposure is at a level as low as is reasonably practicable below that control limit. In the case of a temporary excursion above the control limit, the employer must ensure that the excursion is without significant risk from exposure and that the excursion is not indicative of a failure to maintain adequate control. The employer shall control the exposure by limiting the amount of HCS used, limiting the number of employees exposed, limiting the period of exposure or by using a substitute for a HCS. By introducing appropriate work procedures that must be followed by employees where materials are used or processes are carried out which could lead to exposure the employer can ensure that employee exposure is kept to a minimum. The employer must introduce engineering controls if none of the above can control exposure adequately. Engineering control includes separation of processes, enclosing processes, installation of local exhaust ventilation systems or by separating workplaces for different processes. These control methods will be discussed in detail in section 2.6 of this chapter.<sup>13</sup>

The employer must ensure that emission of HCS into the atmosphere complies with the provisions of the Atmospheric Pollution Prevention Act No. 45 of 1965.<sup>13</sup>

#### 2.5.9 Personal protective equipment

If it is not reasonably practicable to ensure that the exposure of an employee is adequately controlled the employer must provide suitable respiratory equipment and protective clothing to employees. The employer must ensure that protective equipment is capable of controlling the exposure below the limits, that the equipment is correctly selected and properly used, that information, instructions and training is given to the employee with regard to the use of the equipment, and that the equipment is kept in good condition. The employer shall as far as is reasonably practicable issue no used personal protective equipment unless it has been decontaminated and sterilized, and provide storage facilities for personal protective equipment. The employer must ensure that no person removes contaminated personal protective equipment from the premises, and where contaminated personal protective equipment has to be disposed of; it shall be treated as HCS waste.<sup>13</sup>

#### 2.5.10 Maintenance of control measures

The employer must ensure that all control equipment and personal protective equipment and facilities are maintained in good working order, and that thorough examinations and tests of engineering control measures are carried out at intervals not exceeding 24 months by an approved inspection authority.<sup>13</sup>

#### 2.5.11 Disposal of hazardous chemical substances

The employer shall as far as is reasonably practicable recycle all HCS waste, ensure that all collected HCS waste is placed into containers that will prevent the likelihood of exposure during handling, ensure that all re-usable containers which have been in contact with HCS waste are cleaned and decontaminated. The employer must ensure that all HCS waste is only disposed of on sites specifically designated for this purpose in terms of the Environmental Conservation Act No. 73 of 1989, in such a manner that it does not cause a hazard. All employees occupied in the collection and disposal of HCS waste must be provided with suitable personal protective equipment.<sup>13</sup>

These Regulations must be followed to ensure that the work environment is in compliance and to prevent offences.<sup>13</sup>

## 2.6 Control

### Management of occupational health and safety

Employees in a laboratory must be protected by a combination of management commitment, facility design, engineering controls, employee training, personal protective equipment, routine surveillance, periodic audits and inspections, and effective and successful communication. An effective health and safety program depends on upper management support and commitment.<sup>1</sup>

#### 2.6.1 Facility design and engineering controls

Planning and design of the laboratory environment is vital for the protection of employees. When the facility is designed, special attention should be given to areas for storage of chemicals, general and local exhaust ventilation, workstation design and lighting, appropriate fume cupboards, wash basins and emergency showers and disposal of laboratory waste. Because laboratories are usually housed in larger structures it is essential to implement structural safety hazard control such as fire detection and suppression.<sup>1</sup>

Laboratories widely use local exhaust ventilation systems to remove vapours from the employee's breathing zone or to prevent the release of aerosols, and these devices should be closely monitored. Laboratory exhaust hoods draw air from the room into the hood to prevent that contaminants are released into the breathing zone of the employee. Improper placement, malfunction or misuse of the enclosures can result in the release of contaminants. Fume cupboards as engineering control will be discussed in more detail in section 2.7.<sup>1</sup>

#### 2.6.2 Employee training

According to the potential hazards present, special attention should be given to the training and orientation of all personnel in laboratories as well as visitors and students. Employees should be trained on the facility's features, operation procedures and how to proceed in an emergency. Safety training should include the proper use and maintenance of fume cupboards, as well as proper selection and use of personal protective equipment. When using personal protective equipment it is essential that employees receive information about the compatibility of the equipment with the employee.<sup>1</sup>

In the United States of America it is required that every laboratory that handles hazardous chemicals have a chemical hygiene plan in place. This program is developed and implemented by the employer and it addresses procedures, equipment, work practices, employee training, and exposure control for protection of employees against health hazards presented by hazardous chemicals. Laboratory employees should receive training in the identification and safe handling of chemicals because of the variety of chemicals and their potential toxicities. The MSDS can provide information regarding specific risks and should be readily available in the workplace.<sup>1</sup>

### 2.6.3 Surveillance

In the laboratory environment there is constant change, and therefore it is necessary to do routine assessments and inspections of the workplace. These health and safety audits are conducted to determine if any changes have resulted in new potential hazards. Periodic inspections should be conducted by health and safety personnel with involvement of the laboratory staff. Routine inspections and assessments can determine procedures that work, and those that need attention.<sup>1</sup>

### Strategies for exposure control

#### 2.6.4 Assessment of risks of working with hazardous chemical substances

Risk assessment is a process that determines probability of risk of injury or illness that can be associated with each identified hazard, to control the hazard to decrease risk. If the hazard is not identified the risk assessment fails.<sup>2,13</sup>

It is important to identify the hazardous properties of any substance to be used before work begins. There are many sources of information to assist you to identify the hazardous properties of substances, these include: labels on substances give information on hazards and precautions or safety data sheets which list information like hazards, handling, storage and disposal. The information gathered is not an assessment of risk as the risk will vary according to the way in which the substance is used, the quantity and the people involved.<sup>13,14</sup>

When the hazardous properties of substances have been identified the employer must ensure that a suitable and sufficient assessment of the risks to health and safety is conducted. The assessment should include the assessment of the risks to health and safety from exposure to substances by any route; identification of people who could be

exposed; the practicality of preventing exposure or where this is not possible the necessary steps to control exposure to the risks; storage arrangements; emergency procedures and disposal of waste substances. The purpose of the risk assessment is to enable the employer to select the most suitable controls or combination of controls that are in proportion to the risk.<sup>13,14</sup>

### 2.6.5 Control measures

Control measures should be applied in the following order of priority according to the magnitude of risk as identified by the risk assessment. When it is not reasonably practicable to prevent exposure to substances, employers must ensure that exposure is adequately controlled. If preventing exposure is not possible then exposure must be controlled in such a way that the health of employees and students are not affected by the substances in use, through methods like:

- Engineering controls

Engineering control can be achieved by separating processes or automating; by installing ventilation systems and equipment to control airborne chemical substances; by replacing substances with less harmful substances; by using a substance in a different form; or by using different work places for different processes.<sup>14</sup>

- Administrative controls

According to the Regulations for Hazardous Chemical Substances of 1995 the employer must control the exposure of employees by controlling the amount of chemical substances that are used, controlling the amount of employees that are exposed, controlling the time period in which an employee is exposed or by using a substitute for the chemicals used. The employer must also ensure that employees maintain good personal hygiene and housekeeping to ensure a clean work environment. This is called administrative control measures.<sup>13</sup>

By implementing work procedures the employer can control the employee's exposure as part of administrative control. Work procedures for control include procedures for safe handling, use and disposal of chemical substances; procedures for installing and maintenance of equipment and ventilation systems; and procedures for keeping the workplace and machines clean.<sup>13</sup>

Where measures to control exposure are not adequate to achieve control, the employer must ensure that appropriate personal protective equipment is also provided.

- Personal protective equipment

Using personal protective equipment protects the employee against health hazards that arise from exposure to hazardous chemical substances. Personal protective equipment may be used as additional protection in combination with other control measures.<sup>9</sup> Masks or respirators can be provided to protect against airborne chemical substances; gloves and lab coats can protect against absorption through the skin if the chemical comes in contact with the person. Other personal protective equipment is available for working with highly toxic substances.<sup>14</sup>

#### 2.6.6 Use of control measures

Employers must ensure that the control measures provided to reduce the risk of exposure to substances are used correctly. The employer must ensure that employees and students are given sufficient instruction and information to enable them to use control measures correctly. This includes supervision, periodic inspection and ensuring a system for fault reporting is in place. The employer should also develop a system for the repair or replacement of faulty items.<sup>14</sup>

Employees and students must use the control measures that are provided to reduce the risk of exposure to substances as instructed and according to the information which they have been given.<sup>14</sup>

#### 2.6.7 Maintenance and test of control measures

In order to ensure that control measures perform as they were intended they should be maintained as follows.

Engineering controls should be:

- Visually inspected at least once a week
- Maintained according to the manufacturers instruction
- Examined and tested by a competent person every 12-24 months
- Cleaned regularly
- Decontaminated when contamination occurs.<sup>14</sup>

Personal protective equipment should be:

- Cleaned and maintained according to manufacturer's instructions
- Visually inspected for damage or contamination
- Decontaminated or disposed of when contaminated or as recommended by manufacturer
- Disposed of in accordance with waste procedures
- Stored in a separate place<sup>14</sup>

A system should be developed to enable individuals to report faults and problems and procedures should be established for removal from use, repair and replacement of faulty equipment. Records of maintenance and inspection of personal protective equipment and engineering controls must be kept. Records of annual testing and examination of engineering controls must be kept for 3 years.<sup>14</sup>

#### 2.6.8 Information and training

The findings in the assessment should be given to every person who will be affected by the work including visitors who may not be directly participating in the work. Employees and students must be provided with information about the substances they are working with, including the name of the substances and the hazards, the risks to health and safety, symptoms of health problems, precautions they must take to prevent or control exposure, how to use control measures and emergency procedures.

The purpose of instruction and training is to ensure that employees and students that work with substances do not put themselves or others at risk. Instruction and training should include how and when to use control measures, the standard operating procedures, how to use, clean and store personal protective equipment and what to do in an emergency. A record of all the information, instruction and training should be kept.<sup>13,14</sup>

#### 2.6.9 Monitoring

Employers should monitor the implementation of the control measures where exposure cannot be prevented. Inspections of working practices and procedures should be carried out periodically. By observing employees and students carrying out their normal work routines this can be achieved to ensure that procedures are followed.<sup>13,14</sup>

As most engineering controls do not provide absolute protection it is reasonable to periodically monitor exposure. Air monitoring can be used to confirm that the control measures are working as intended; this is important where a substance has been assigned an exposure limit. These substances have the most serious health effects and therefore exposure must be adequately controlled. Where these substances are used routinely periodic monitoring of exposure would be appropriate.<sup>13,14</sup>

#### 2.6.10 Health surveillance

If employees are exposed to certain substances the employer must provide suitable health surveillance. Health surveillance is only required where employees are exposed to a substance that is linked to a particular disease and it is possible to detect that disease or health effect.<sup>13,14</sup>

#### 2.6.11 Review of risk assessment

Risk assessment must be reviewed every 12 months or sooner if there is reason to suspect that the assessment is no longer valid or if there has been a significant change in the work.<sup>14</sup>

### **2.7 Fume cupboards in laboratories**

One of the most important safety devices in a laboratory is the fume cupboard.<sup>15</sup> The fume cupboard was patented in 1970 by David J Ellis and Malcolm J Sanders with the US patent number 3,496,857. The patent certificate states: 'A fume cupboard of the back extraction type comprising means for introducing auxiliary air into the top and bottom of the cupboard, in a direction such as to induce a flow of air and vapours towards a back extraction point constituted by the lower end portion of a baffle plate which is spaced from the floor of the cupboard and curved in the direction of extraction.'<sup>16</sup>

The fume cupboard is the first defense to minimize chemical exposure to employees in research and testing laboratories. It is the primary means of protection from inhalation of hazardous gasses, fumes, vapours, and particulate material that are generated inside the enclosure, if it is used correctly and is functioning optimally.<sup>17</sup>

The fume cupboard relates to the removal of toxic vapours from a confined space. A well designed fume cupboard must replace the contaminated air with clean air that flow into the

space in a direction away from the operator. The conditions in the fume cupboards should not be subject to any turbulence which might lead to escape of toxic vapours towards the operator, and ideally extraction should be efficient from all levels in the fume cupboard to avoid dead spaces and re-circulation of toxic vapours.<sup>16</sup>

By measuring face velocity of the air moving into the fume cupboard opening the effectiveness and performance of the fume cupboard can be determined. Various factors can cause leakage of contaminants from the fume cupboard like the sash height, location of the exhaust outlet, and obstructions in the way of air flow.<sup>15</sup> The opening of the fume cupboard provides access for the operator, but also provides an escape route for the pollutant; therefore it is necessary to maintain an air velocity that is sufficient to prevent the pollutants from escaping. Some fume cupboards have a sliding front that can be raised or lowered to adjust the opening area. It is advisable to enclose as much of the process as possible and minimize the area of access to ensure that pollutants don't escape. The opening can also be covered by a flexible curtain to further reduce the face area. This curtain could be made of plastic hung in narrow overlapping strips to allow passage into the fume cupboard with minimum disturbance. The front of the fume cupboard can also be washed by a vertical air curtain.<sup>18</sup>

The fume cupboard can be categorized as conventional box types or modern aerodynamic types. The air flow visualization and face velocity measurements lead to the development of aerodynamic cupboards where attention was paid to the smoothness of air flow into and inside the work space to reduce turbulence.<sup>19</sup>

To improve pollutant control it is possible to supply the fume cupboard with air in addition to extracting from it. If additional air is supplied it is necessary to extract 15% more air to prevent the excess air from escaping through the opening.<sup>18</sup>

The face velocity that is required to prevent the pollutant from escaping depends on the toxicity of the substances and the momentum it has as a result of the way it has been released. As a general rule the face velocity should never fall below 0.5 m/s, and for toxic pollutants a face velocity of 1.5 m/s may be required. Many institutes and organizations have standards for the face velocity of the fume cupboard according to the substances that are used.<sup>18</sup>

Table 1: Recommended face velocities for fume cupboards

Situation	Recommended face velocity (m/s)	Reference
Low toxicity substances	0.4	Ashton & Gill <sup>20</sup>
General use	0.5	
Radiotoxic and highly toxic substances	0.75	
Spraying chromatographs	0.9	
Work with non-toxic substances	0.3 – 0.5	University College London <sup>21</sup>
Work with toxic, carcinogenic or radioactive substances	0.5 – 0.75	
Storage only	0.2	University of Nottingham <sup>22</sup>
Standard work with hazardous substances	0.5	
Radioactive work	0.7	
Low toxicity substances	0.3	ASHRAE <sup>23</sup>
Toxic substances	0.5	

Older types of fume cupboards have a variable face velocity that depends on the position of the sliding front, but modern fume cupboards have a bypass arrangement or a variable performance fan to ensure that the face velocity remains reasonably constant whatever the position of the front.<sup>18</sup>

In a study where fume cupboard performance was assessed the importance of the baffle and lipfoil in an aerodynamic fume cupboard was discovered. The baffle and lipfoil prevent the forming of recirculation zones near the opening. These design features are important when an employee is standing in front of the fume cupboard, or if there is a cross flow of air in front of the opening.<sup>19</sup>

Another study found that flow patterns can be dramatically changed due to sash movements or by people walking by, and this change in flow patterns could cause turbulent vortices. These turbulent vortices near the face of the cupboard could induce turbulence and therefore cause dispersion of the recirculated contaminant and this contributes to the mechanism that causes leakage of contaminants. The contaminant leakage from the fume cupboard influences the ability of the fume cupboard to provide protection for the employee.<sup>17</sup>

The University College London has general recommendations concerning fume cupboards to ensure that they function optimally and provide the necessary protection to the employee using the fume cupboard. Fume cupboards should be located as far away as possible from doors and opening windows. The normal sash opening should be 500 mm or 600 mm maximum in exceptional circumstances. Face velocity should be determined with the sash at 500 mm, and it should average 0.5 m/s. There must be 1000 mm undisturbed space in front of the fume cupboard.<sup>21</sup> The fume cupboard must be made out of suitable material that is easy to clean and should have a 5ℓ minimum capacity for spillage. The sash should be transparent and resistant to corrosion, and should close off the opening substantially. The sash must move easily and stay at a certain point. If a baffle is fitted, it must be easily removed for cleaning. There must be a minimum of 400 Lux illuminance at the work surface, either outside the cupboard, or behind a sealed panel. If additional air is passed into the laboratory passively or by fan, it must not disturb the flow into the fume cupboard. The ducts used to remove the contaminants from the fume cupboard must be smooth, non-absorbent and non-reactive with any fumes. Fume cupboards must not be used for storage of chemicals.<sup>24</sup>

## **2.8 Chemical hazards in laboratories and their health effects**

The use of many toxic chemical substances in workplaces can result in harmful effects if exposure is not properly controlled. The most common health effects resulting from chemical exposure are those classified as carcinogenic, mutagenic and teratogenic.<sup>3</sup>

A carcinogen is any substance known to cause cancer in humans and animals. Carcinogens represent a broad range of organic and inorganic chemicals, hormones, immunosuppressants and solid-state materials. Carcinogenesis has been divided into two stages: The initiation stage occurs after exposure of cells or tissue to a dose of a carcinogenic substance. The promotion stage is the process whereby the altered cells proliferate.<sup>3</sup>

A mutagen is a chemical substance that has the ability to produce a mutation in the genetic composition of the DNA in a cell. The change is capable of being passed on to next generations. The changes can be caused by exposure to ionizing radiation or chemicals.<sup>3</sup>

A teratogen is any substance that is capable of producing physical defects in an unborn fetus. These changes can result in fetal death, a high rate of embryonic mortality, or in the birth of physical abnormal offspring.<sup>3</sup>

Hazardous chemicals could also be haematopoietic system toxins, hepatotoxins, nephrotoxins, neurotoxins, toxic agents or agents that damage the skin, eyes or mucus membranes.<sup>1</sup>

A haematopoietic system toxin is a substance that disrupts the formation of blood cells and a hepatotoxin is a substance that is toxic to the liver. A nephrotoxin is a cytotoxin that is destructive to kidney cells, and a neurotoxin is a poisonous protein complex that acts on the nervous system.<sup>25</sup>

Most people are not exposed to only a single chemical compound but often to mixtures. Although various substances may have independent actions, in many cases two substances may act at the same site in additive or non-additive ways. In some cases there may be synergistic effects, where the effects of two substances together are greater than the sum of either effect alone. In reality most people are exposed to many chemicals and therefore the effects of a chemical mixture are extremely complex and may vary for each mixture depending on the chemical composition.<sup>26</sup>

Although the health effects of single substances may be obvious in high exposure, the majority of people are exposed to chemical mixtures at low concentrations, and therefore the health effects are not always identified. The complexity of the chemical mixtures is a major reason why mixtures have not been well studied.<sup>26</sup>

In some instances a chemical's toxicity has not been determined yet, so it is unknown what the risk of exposure is and to what health effects it can lead. When such a chemical is combined with any other toxic chemical the risk associated with exposure is unknown and therefore it must be assumed to be highly toxic and handled with the utmost care.<sup>26</sup>

Because of the diverse range of hazardous chemical substances only a few important chemicals that are found in the research and testing laboratories will be discussed. A table with the occupational exposure limits will follow the discussion of all the chemicals.

### **2.8.1 Acetone**

Exposure to acetone can occur through inhalation, ingestion or contact. If acetone is inhaled it can cause irritation of the eyes, nose and throat. Symptoms of inhalation exposure include headaches, light headedness, tiredness, dizziness, nausea and vomiting. If exposure is extremely high it can lead to central nervous system depression, unconsciousness, coma and death. Acetone may cause irritation to the skin. Skin contact causes mild redness, swelling, pain, drying and cracking of the skin after an extended period of time. The risk of developing health effects following the absorption of acetone through unbroken skin is very slight. Acetone vapour causes mild irritation of the eyes however liquid acetone is severely irritating. If acetone comes in contact with the eye directly it causes corneal injury and can lead to permanent damage of the eye.<sup>27</sup> Ingestion is not a typical route of occupational exposure, nonetheless if ingested it causes headache, dizziness and drowsiness. Ingestion of large amounts can result in vomiting, unconsciousness and coma. If acetone is aspirated it can cause severe lung injury.<sup>27,28,29</sup> If exposure occurs over an extended period of time it can cause dermatitis of the skin, but acetone would not produce significant health effects after long term inhalation exposure. Acetone acts in a synergistic manner; it increases liver toxicity of chloroform, carbon tetrachloride and other chemicals. Acetone inhibits the metabolism and elimination of ethyl alcohol and thereby it potentially increases the toxicity.<sup>27</sup>

### **2.8.2 Chloroform**

The inhalation toxicity of chloroform is low, and it is moderately toxic by ingestion. Acute inhalation exposure to chloroform causes central nervous system depression. At very high levels chloroform exposure may result in death. Intermediate concentrations can cause anaesthesia and lower concentrations result in dizziness, headache and tiredness. A fatal oral dose of chloroform may be as low as 10 ml because it causes respiratory or cardiac arrest.<sup>29</sup>

Chronic exposure to chloroform by inhalation is associated with effects on the liver, which include hepatitis and jaundice; and central nervous system effects, such as depression and irritability; and effects on the heart.<sup>29</sup> When a person is chronically exposed orally to chloroform it results in effects on the liver, where zonal hepatocellular alterations take place such as necrosis or steatosis. Steatosis is the formation of a fatty liver where triglycerides are deposited in the liver.<sup>30,31</sup> Chloroform is a suspected human carcinogen.<sup>29</sup>

### 2.8.3 Cyclohexane

Exposure to cyclohexane can occur through inhalation, ingestion, and contact through the skin or eyes. In acute exposure to low concentrations it is an irritant of the eyes, mucous membranes and skin; and exposure to high concentrations cause dizziness, nausea and narcosis.<sup>29,32</sup> If exposure is severe; nausea, vomiting, incoordination and coma may occur.<sup>32</sup> Repeated exposure to large amounts of cyclohexane in the air causes nervous system effects, eye damage, and effects range from headaches to anaesthesia, tremors and convulsions.<sup>33</sup> Ingestion of cyclohexane may produce abdominal pain and nausea and can produce severe lung damage.<sup>34</sup> When a person is chronically exposed to cyclohexane dermal contact may cause dry, scaly dermatitis.<sup>32</sup> Cyclohexane is not likely to remain in the body due to its breakdown and removal in exhaled air and in urine.<sup>33</sup>

### 2.8.4 Diethyl ether

People are exposed to diethyl ether through inhalation, ingestion or contact to the skin or eyes. Symptoms of exposure include dizziness, drowsiness, anaesthesia, vomiting, decreased body temperatures, respiratory arrest and it can lead to death. Diethyl ether is an irritant when exposure occurs through inhalation, ingestion, skin or eye contact.<sup>29,35</sup> Brief exposures of the eyes to high concentrations produce a burning sensation, but no injury. When prolonged exposure occurs it may cause temporary corneal epithelial injury and eye damage, or skin contact cause burns or dermatitis.<sup>35</sup> Repeated exposure can cause drying and cracking of the skin, due to the extraction of oils.<sup>29</sup> Chronic and prolonged exposure may result in headache, drowsiness, excitation and psychic disturbances. Diethyl ether can have teratogenic effects.<sup>36</sup>

### 2.8.5 Dichloromethane

Dichloromethane is also known as methylene chloride. The toxic routes of exposure are inhalation of vapours, ingestion and absorption through the skin. Inhalation of dichloromethane can cause slight irritation and mild central nervous system depression. Symptoms include headache, dizziness, nausea and reduced coordination. In more severe cases it can lead to unconsciousness, respiratory failure, pulmonary edema and death. Dichloromethane is metabolized to carbon monoxide which binds to red blood cells and forms carboxyhemoglobin and this may cause heart problems.<sup>29,37,38</sup> Liquid dichloromethane is a moderate to severe irritant when it comes in contact with skin, and causes redness and pain. Prolonged contact can cause skin burns. Absorption through the skin can occur, but it is not significant.<sup>37,38</sup> A vapour of dichloromethane causes mild

irritation and liquid and concentrated vapours may cause moderate to severe irritation. If liquid dichloromethane comes in contact with the eyes it may cause temporary corneal damage. If dichloromethane is accidentally swallowed it has a low toxicity and ingestion of large amounts can cause severe burns and swelling in the throat as well as irritation with vomiting.<sup>37</sup> Long term exposure may result in dermatitis and neurological effects such as memory loss, speech and balance problems. Dichloromethane is a suspected human carcinogen. Impaired liver function has been associated with occupational exposure to dichloromethane.<sup>37,38</sup>

### **2.8.6 Ethanol**

Human exposure to ethanol is through ingestion of alcoholic beverages and inhalation of ethanol vapours from industrial or laboratory processes and consumer products. Ethanol is a central nervous system depressant that can induce all stages of anaesthesia. It is easily absorbed by the gastrointestinal tract and lungs, and is distributed throughout the body water. People exposed to 5000-10000 ppm of ethanol vapour suffered eye irritation and coughing.<sup>30</sup> Exposure may result in stupor, fatigue and sleepiness.<sup>29</sup> Individuals with tolerance to alcohol experienced headaches, drowsiness, and coma when exposed to large concentrations. Individuals with blood alcohol levels of approximately 0.05-0.15 percent may show decreased inhibitions, poor coordination, blurred vision and slowed reaction time. When blood levels are increased to 0.15-0.30 percent it can result in slurred speech, visual impairment, hypoglycaemia and staggering. At 0.3-0.5 percent blood alcohol content symptoms can include muscular incoordination, hypothermia, vomiting and nausea, and convulsions. In an adult an exposure level exceeding 0.5 percent can lead to coma and death.<sup>30</sup> Long-term intake of ethanol in the form of alcohol can lead to liver disease like alcoholic fatty liver, acute alcoholic hepatitis or alcoholic cirrhosis. The alcoholic cirrhosis is the most severe form of alcoholic liver injury and it is irreversible.<sup>39</sup>

### **2.8.7 Ethyl acetate**

When exposed to ethyl acetate through inhalation, ingestion, eye and skin contact it causes irritation of the eyes, nose and throat; redness and tearing of the eyes; followed by headache, nausea, vomiting and unconsciousness.<sup>40,41,42,29</sup> Ethyl acetate is a severe irritant when ingested, inhaled or if it comes in contact with the skin. Chronic exposure to ethyl acetate to the skin may cause dermatitis and anemia. Prolonged exposure may cause clouding of the eye, damage to the lungs, heart and kidney and liver damage.<sup>40,41,42</sup>

Ethyl acetate occasionally causes sensitization with inflammation of the mucous membranes and eczema of the skin.<sup>40</sup>

### **2.8.8 Hexane**

Hexane is a respiratory tract irritant and at high concentrations a narcotic.<sup>29</sup> Mild exposure causes irritation of the eyes, nose, throat and skin, or disturbances in the nervous system like polyneuropathy or narcosis.<sup>26,43</sup> Hexane is an irritant when inhaled, ingested or when it comes in contact with the skin or eyes. When exposed to hexane in the air, symptoms include nausea, numbness, tingling of extremities, muscle weakness, dizziness, and blurred vision.<sup>43,44,29</sup> If it is ingested it causes abdominal pain.<sup>43,44</sup> Hexane is biotransformed to 2-hexanol, then 2,5 hexanediol and then to 2,5 hexadione. These three metabolites all produce polyneuropathy on exposure.<sup>25</sup> Repeated or prolonged skin contact can produce dermatitis, and chronic inhalation may cause peripheral nerve disorders and central nervous system effects.<sup>43</sup>

### **2.8.9 Tetrahydrofuran**

The target organs of tetrahydrofuran are primarily the respiratory system and central nervous system.<sup>29</sup> Tetrahydrofuran is a central nervous system depressant when exposure occurs through inhalation, ingestion, or contact with the skin or eyes. Acute exposure to tetrahydrofuran causes headache and a marked decrease in white blood cell count, as well as redness and inflammation of the eyes and eyelids, coughing and sneezing, and difficulty in breathing.<sup>45</sup> Tetrahydrofuran cause irritation of the mucous membranes and upper respiratory tract when inhaled and cause irritation to the gastrointestinal tract when ingested or skin irritation if it comes in contact with the skin.<sup>46,29</sup> Repeated or high exposures may cause liver and kidney damage, or may affect the lungs. Repeated skin exposure can cause dryness and cracking of the skin, and development of a rash.<sup>46</sup>

Persons with pre-existing skin disorders or eye problems, or impaired liver, kidney or respiratory function may be more susceptible to the effects of these substances.

### **2.8.10 Acetonitrile**

When mildly exposed to acetonitrile it causes irritation of the eyes, nose and throat. Acute toxicity leads to cyanosis, cardiac- or respiratory arrest. Symptoms of acetonitrile exposure are nausea, vomiting, headache, chest pain, convulsions or tachycardia. Acetonitrile is metabolized by the liver to cyanide.<sup>47</sup>

### 2.8.11 Benzene

Benzene is a volatile solvent with a distinctive odour and narcotic action. Poisoning by benzene or a homologue of benzene through handling, fumes or vapours is a prescribed occupational disease. Poisoning may be acute or chronic.<sup>48</sup>

Neurological symptoms of inhalation exposure include drowsiness, dizziness, headaches, and unconsciousness. Ingestion of large amounts of benzene may result in vomiting, dizziness and convulsions. If a person is exposed to liquid and vapour it may irritate the skin, eyes, and upper respiratory tract whereas dermal exposure may result in redness and blisters.<sup>25,29,49</sup>

When a person is exposed to benzene and ethanol simultaneously it can increase the benzene toxicity. People that are occupationally exposed to benzene have shown an increased incidence of leukemia.<sup>49</sup>

Target organs to acute and chronic poisoning are the blood, bone marrow, central nervous system, respiratory system, eyes and skin.<sup>29</sup> Chronic benzene poisoning leads to progressive depression of bone marrow function and this causes anaemia.<sup>30,48</sup> Symptoms include muscular weakness, mild digestive disturbances and paleness. The symptoms can increase to severe anaemia, haemorrhages from the mucous membranes and skin hemorrhages.<sup>29,48</sup> Death as a result of exposure to extremely high concentrations of benzene may occur because of respiratory failure or cardiac arrhythmias or from aplastic anaemia.<sup>30,48</sup>

Benzene has been classified as a human carcinogen.<sup>29,50</sup> Human exposure to benzene has been shown to result in hematotoxicity such as pancytopenia and leukemia, as well as myeloma and lung cancer.<sup>29,51</sup> The oxidative activation of the benzene metabolite in the bone marrow to benzoquinone has been suggested to play an important role in benzene's ability to cause hematotoxicity.<sup>51</sup>

Employees that are exposed to benzene must take part in biological monitoring to determine the concentration of benzene in the blood, urine or expired air.<sup>14</sup>

### **2.8.12 Methanol**

The main routes of exposure to methanol are through inhalation and dermal contact. Symptoms from inhalation include headache, blurred vision in people who ingested methanol. Methanol is readily absorbed when oral, inhalation or dermal exposure occurs and is distributed throughout the body according to the water content of the tissues. Ingestion of as little as 2 teaspoonfuls may cause toxicity. When medical treatment is absent, a dose of between 4 and 10 ml can lead to blindness, and depending on the amount of methanol ingested, it can cause mild to severe central nervous system depression.<sup>30</sup>

When exposure to methanol occurs abdominal pain, difficult breathing, blurred vision and pain in the eyes along with other symptoms can occur after a latent period of 12 to 24 hours. Visual impairment or total blindness can occur within days depending on individual susceptibility and the time when treatment began. The delayed symptoms and ocular toxicity are caused by metabolic acidosis due to formic acid production.<sup>30</sup>

Methanol metabolism in the liver accounts for a high percentage of absorbed methanol, and the lesser amounts are excreted in the urine and breath. Methanol is oxidized by alcohol dehydrogenase system to formaldehyde, then to formic acid (formate) and finally to carbon dioxide and water. The metabolic process is slower in humans than in primates and this causes the build-up of formate in tissues like the eye and this results in the toxicity.<sup>30</sup>

Ethanol has been used in the treatment of methanol poisoning because ethanol inhibits the oxidation of methanol by competing for the same metabolic pathway.<sup>30</sup>

### **2.8.13 Toluene**

Exposure to toluene can occur via inhalation, ingestion, and eye or skin contact. Toluene is a central nervous system depressant and an irritant of the eyes, mucous membranes, and skin. If it comes in contact with the eyes, toluene causes reversible corneal injury while extended skin contact causes dermatitis.<sup>30,52</sup>

Symptoms of acute exposure include redness and inflammation of the eyes and eyelids, fatigue, weakness, incoordination, confusion, headache, dizziness and drowsiness. Chronic exposure has symptoms like tremors; impaired speech, vision, hearing or

memory; nausea and lack of appetite.<sup>25,52</sup> Chronic abusers of toluene often show signs of irreversible neurological toxicity and reversible renal damage. Exposure to high concentrations of toluene may cause death by sensitizing the myocardium, or because it causes arrhythmias, especially ventricular fibrillation.<sup>25,30</sup>

#### **2.8.14 Xylene**

Exposure to xylene can occur via inhalation, ingestion, and eye or skin contact. When xylene vapour is inhaled it depresses the central nervous system with symptoms such as headaches, dizziness, nausea and vomiting. Extremely high concentrations could cause incoordination, loss of consciousness, respiratory failure and death. In some cases, an accumulation of fluid in the lungs may develop, which can be fatal.<sup>53</sup>

When xylene comes into contact with skin it causes irritation, redness and a burning sensation. These effects are reversible usually within one hour after the contact stops. Repeated or prolonged exposure to xylene can result in dermatitis. Xylene liquid or vapour can be absorbed through the skin, but not as readily as when it is inhaled or ingested.<sup>53</sup>

When xylene liquid comes in contact with the eyes it causes eye irritation or even forming of corneal vacuoles; which is pockets of fluid or air in the cornea.

Xylene is only slightly toxic by ingestion; ingestion of large amounts can also cause central nervous system effects such as dizziness, nausea and vomiting.<sup>53</sup>

Table 2: Exposure limits for hazardous chemical substances.

HCS	Regulations for HCS		ACGIH		NIOSH		OSHA	
	TWA OEL (ppm)	TWA OEL (mg/m <sup>3</sup> )	TLV-TWA (ppm)	TLV-TWA (mg/m <sup>3</sup> )	TWA REL (ppm)	TWA REL (mg/m <sup>3</sup> )	TWA PEL (ppm)	TWA PEL (mg/m <sup>3</sup> )
	Recommended limit							
Acetone	750	1780	500	1190	250	590	1000	2400
Acetonitrile	40	70	20	34	20	34	40	70
Benzene*	5 (CL)	16	0.5	1.6	0.1	0.32	1	3.19
Chloroform	2	9.8	10	49	2	9.78	50	240
Cyclohexane	100	340	100	334	300	1050	300	1050
Dichloromethane (Methylene chloride)	100	350	50	174	-	-	25	87
Diethyl ether	400	1200	400	1210	-	-	400	1200
Ethanol	1000	1900	1000	1880	1000	1900	1000	1900
Ethyl acetate	400	1400	400	1440	400	1400	400	1400
Hexane*	20	70	50	176	50	180	500	1800
Methanol*	200	260	200	262	200	260	200	260
Tetrahydrofuran	200	590	200	590	200	590	200	590
Toluene*	50	188	50	188	100	375	200	754
Xylene*	100	435	100	434	100	435	100	435

13,54,55

\* Biological exposure monitoring required by law.

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## **GUIDELINES FOR AUTHORS**

### **Occupational Health Southern Africa**

#### Guidelines for articles

The article should follow the format of: Introduction, Methodology, Results, Discussion and References. The length should be between 2000 and 2500 words. The article must include a short abstract of less than 150 words.

The manuscript should be typed in 1.5 spacing, using only one side of the paper.

Pages should be numbered consecutively and leave wide margins.

Illustrations, tables and graphs should be clearly identified and should be submitted separate to text in electronic format.

A separate title page should contain the title, the author(s)' full names and contact details for correspondence. A word count should be included on this page.

References should be inserted in the text as superscript numbers and listed at the end of the article in numerical order. References should be set out in the Vancouver style.

#### Guidelines for case studies

A case study should be no longer than 1000 words and should be structured as introduction, case description, discussion, conclusions and recommendations, references and summary box. It should comply with the general style requirements for all articles for publication in the journal.

# *CHAPTER 3*

## ARTICLE

### EMPLOYEE EXPOSURE TO HAZARDOUS CHEMICAL SUBSTANCES IN RESEARCH AND TESTING LABORATORIES AT AN UNIVERSITY IN SOUTH AFRICA.

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## **ABSTRACT**

Employees in laboratories are at risk of developing serious health effects from their exposure to various hazardous chemicals. Personal and environmental exposure to HCS were measured by using sorbent tubes and a direct reading instrument. The laboratory fume cupboard as control measure was evaluated to determine effectiveness. Employees are continuously exposed to a wide variety of chemicals at low concentrations, with short periods of exposure above the short term exposure limits. The simultaneous exposure to various chemicals adds to the total concentration which employees are exposed to on a daily basis. Long term exposure to HCS can endanger employee health and safety in the laboratory.

## **INTRODUCTION**

Research and testing laboratories are characterized by a wide variety of high risk hazards usually present in low volumes and a diverse workforce. These hazards are chemical, physical, radiological or biological in nature.<sup>1,2</sup> Hazardous chemicals could be characterized as carcinogens, haematopoietic system toxins, hepatotoxins, nephrotoxins, neurotoxins, toxic agents, and agents that damage the skin, eyes or mucus membranes. The routes of exposure are inhalation or absorption through skin or mucus membranes.<sup>1</sup> The diverse employees at universities' research and testing laboratories include full-time and part-time employees, postgraduate students and visitors.

Because employees in laboratories of academic and research institutions are potentially exposed to different types of chemical hazards simultaneously, it is necessary to ensure comprehensive health and safety management. If health and safety management is inadequate and employees are exposed to occupational hazards, it may result in increased risk of acute and chronic health effects.<sup>2</sup>

World wide little has been written about the occupational health needs of research and testing laboratories of universities, despite the risks involved. Employees in research and testing laboratories are exposed to hazardous chemical substances that can be detrimental to their health. Because of the risk of developing serious illness due to exposure to hazardous chemical substances, it is vital and required by the Occupational Health and Safety Act as well as the Regulations for Hazardous Chemical Substances that the exposure is quantified and if exposure occurs controlled; to protect the health and safety of employees in these laboratories.<sup>3,4</sup>

One important engineering control measure in research and testing laboratories is laboratory fume cupboards. The fume cupboard is a local exhaust system that reduces the levels of airborne contamination and thereby reduces the inhalation exposure of employees to hazardous substances if chemicals are handled in them.<sup>5</sup> The laboratory fume cupboard is designed for the protection of personnel by preventing contaminants like vapours, dusts, mists and fumes from being released into the laboratory and nearby environment.<sup>6</sup> Also of importance is administrative control, which is control of exposure by measures such as controlling the amount of employees that are exposed or by controlling the duration of exposure. When engineering and administrative control measures are not sufficient to achieve control, the employer must ensure that appropriate personal protective equipment is provided.<sup>4</sup>

The aims of the study are to conduct personal air sampling and environmental sampling in laboratories with high potential risk of HCS exposure, and also to evaluate the effectiveness of fume cupboards as control measures. Questionnaires are used to determine employee and health and safety representative's knowledge of occupational health and safety.

## **METHODOLOGY**

### Study design

Walk through surveys were conducted in all the research and testing laboratories of one faculty. In the survey the number of laboratories, laboratory layout, number of fume cupboards and the number of full-time and part-time employees and postgraduate students in the laboratories were noted.

Risk assessments were conducted in all the research and testing laboratories to determine which chemicals potentially held the highest risk. The frequency of use, amount of chemicals used and toxicity of the chemical were taken into consideration to determine the risk involved. In the risk assessment ten chemicals were identified as potential hazards. Three subject groups with the highest potential risk were identified and HCS monitoring was conducted in these laboratories.

Environmental sampling was conducted in subject group A, because the majority of employees in these laboratories were students, and did not work a full eight hour shift. In subject group B, personal sampling and environmental sampling were conducted.

subject group C, personal sampling was conducted on the two full-time employees of the laboratory. In subject group B, three laboratories were included in the monitoring and 12 of the 18 employees working in these laboratories participated. According to OESSM the sample size ensures that at least one individual from the highest 10% exposure group was contained in the sample with a confidence level of 90%.

### Questionnaires

Employees, postgraduate students and health and safety representatives completed a questionnaire in order to evaluate their knowledge of health and safety in the laboratory, knowledge of health and safety procedures and the training they received.

### Fume cupboards

The effectiveness of fume cupboards were determined by using the University College London method for determining the average face velocity of the fume cupboard.<sup>7</sup> The fume cupboard was turned on for five minutes before measurements were taken. The opening of the fume cupboard was measured, and divided into rectangles of 200 mm x 300 mm. The person measuring the fume cupboard stood away from the opening to avoid influencing airflow. A calibrated vane anemometer (Pacer Industries Serial No. 4200-07-07246) was used to record the airflow in the middle of each rectangle, and the measurements were repeated three times and the average face velocity of the fume cupboard was calculated. If the average was lower than the international recommended values, the opening was reduced by moving the sash down in order to establish an acceptable face velocity. Loose objects in the fume cupboard were removed where possible and if the objects could not be removed, their position was noted. Air current tubes (Dräger Air current tubes CH 216) were also used to determine airflow and turbulent flow in the fume cupboard.

### Air monitoring

Personal sampling was conducted in accordance with NIOSH 1500 and 1501 methods. The Gilair personal air sampler pumps were calibrated at a constant airflow of 200 mL/min. The sample pump was attached to the waist of the employee and the sorbent tubes (SKC No. 226-01) were placed in the breathing zone of the employee at the beginning of the workday. Two sorbent tubes were used to sample 4 hours each. After sampling the sorbent tubes were transported on ice and stored at - 4 °C until analysis. Analysis was performed by an accredited laboratory.

Environmental sampling was conducted by means of a sorbent tube that was placed at a height of 1.6 m above floor level. The sorbent tube was attached to a sampler pump which was placed on the working surface. Two sorbent tubes were used to sample 4 hours each. Transport and analysis were performed as mentioned before. Environmental sampling was also conducted by means of an EntryRAE (RAE systems) direct reading apparatus which was placed at a height of 1.6 m above floor level. The EntryRAE sampled every 60 seconds for eight hours. The EntryRAE was calibrated for fresh air, and then by using isobutylene as prescribed by the manufacturer.

### Statistics

Statistical analysis included basic statistics (mean, standard deviation, variation) and t-tests. Independent t-tests were performed on the various chemicals to determine if there was a difference between personal and environmental exposure. Independent t-tests were performed to determine if there was a difference between exposure in the first 4 hours and the second 4 hours. A correlation was performed between personal and environmental exposure for the various chemicals. All differences were evaluated at a significance level of 0.05. The statistical analysis was completed by using Statistica 7.1 (Statsoft Inc.).

### RESULTS

Personal and environmental sampling of 10 chemicals were conducted in a number of laboratories in three subject groups. From personal and environmental samples a total of 26 samples were obtained.

Table 1: The overall time weighted average exposure to hazardous chemical substances and the South African occupational exposure limits. Only dichloromethane has a control limit (\*), and all the other chemicals have recommended limits. Exposure to acetone and hexane require biological exposure monitoring (#) as these chemicals have biological exposure indices.

HCS	TWA Mean (mg/m <sup>3</sup> )	Minimum (mg/m <sup>3</sup> )	Maximum (mg/m <sup>3</sup> )	Standard Deviation	TWA Occupational exposure threshold Regulations for HCS
Acetone #	2.85	0.23	25.81	5.18	1780
Chloroform	1.25	0.001	8.61	1.96	9.8
Cyclohexane	0.01	0.0003	0.10	0.02	340
Diethyl ether	0.43	0.001	8.26	1.62	1200
Dichloromethane	1.67	0.001	24.20	4.88	350 *
Ethanol	13.02	0.001	45.66	12.71	1900
Ethyl acetate	1.08	0.002	12.77	2.76	1400
Hexane #	0.33	0.01	5.52	1.11	70
Tetrahydrofuran	0.08	0.001	1.15	0.27	590
Total VOC's	24.71	1.19	64.32	16.96	-

Table 1 indicates the average chemical exposure does not exceed local and international limits, but the exposure has a wide range of variance. The maximum exposure level of chloroform for one sample exceeds the action level, therefore chloroform exposure must be actively controlled. Ethanol demonstrates the highest average of 13.03 mg/m<sup>3</sup> and Cyclohexane demonstrates the lowest average of 0.01 mg/m<sup>3</sup>. The total VOC average is extremely high, and this indicates the vast risk of multiple exposures to a combination of chemicals which can have additive or synergistic effects.

Table 2: Correlation between personal and environmental exposure. The values in bold indicate a significant positive correlation between personal and environmental exposure.

HCS	Correlation	
	r value	p value
Acetone	0.1193	0.712
Chloroform	- 0.1169	0.717
Cyclohexane	- 0.1507	0.640
Diethyl ether	-	-
Dichloromethane	<b>0.6781</b>	<b>0.015</b>
Ethanol	- 0.5455	0.067
Ethyl acetate	<b>0.6854</b>	<b>0.014</b>
Hexane	- 0.3630	0.246
Tetrahydrofuran	-	-
Total VOC's	0.1593	0.621

There is significant correlation between the personal and environmental exposure of dichloromethane and ethyl acetate. Both of these chemicals indicated a positive correlation between the personal and environmental exposure, therefore as environmental exposure increases the personal exposure increases as well.

An independent t-test was performed to determine if there is any difference in personal or environmental exposure, or if all employees in one laboratory are exposed to the same concentrations of HCS. An Independent t-test was performed to determine if there is any significant difference between the separate sampling periods, to determine if exposure differs from the morning to the afternoon.

Table 3: Comparison between the sampling strategies and sampling periods. In the first column the personal exposure was compared with the environmental exposure. The second column shows the comparison between the separate 4 hour sampling periods. The values in bold indicate the significant differences.

HCS	Personal and environmental exposure (p)	Separate 4 hour sampling periods (p)
Acetone	0.057	0.225
Chloroform	0.884	<b>0.009</b>
Cyclohexane	0.063	0.665
Diethyl ether	0.146	0.133
Dichloromethane	0.101	-
Ethanol	0.424	0.105
Ethyl acetate	<b>0.034</b>	<b>0.009</b>
Hexane	0.126	0.647
Tetrahydrofuran	0.116	-
Total VOC's	<b>0.016</b>	0.076

The independent t-tests of the various chemicals showed that only ethyl acetate and the total VOC's showed a significant difference between personal and environmental exposure. Chloroform and ethyl acetate demonstrated significant differences between the morning and afternoon exposure.

Environmental exposure was determined by both a direct reading instrument and a sorbent tube; this indicated that the direct reading instruments detected a large number of chemicals that possibly could not be determined by the specific sorbent tube. The direct reading apparatus provides the variance of exposure concentrations over time. The results of the environmental exposure are graphically depicted in Figure 1.

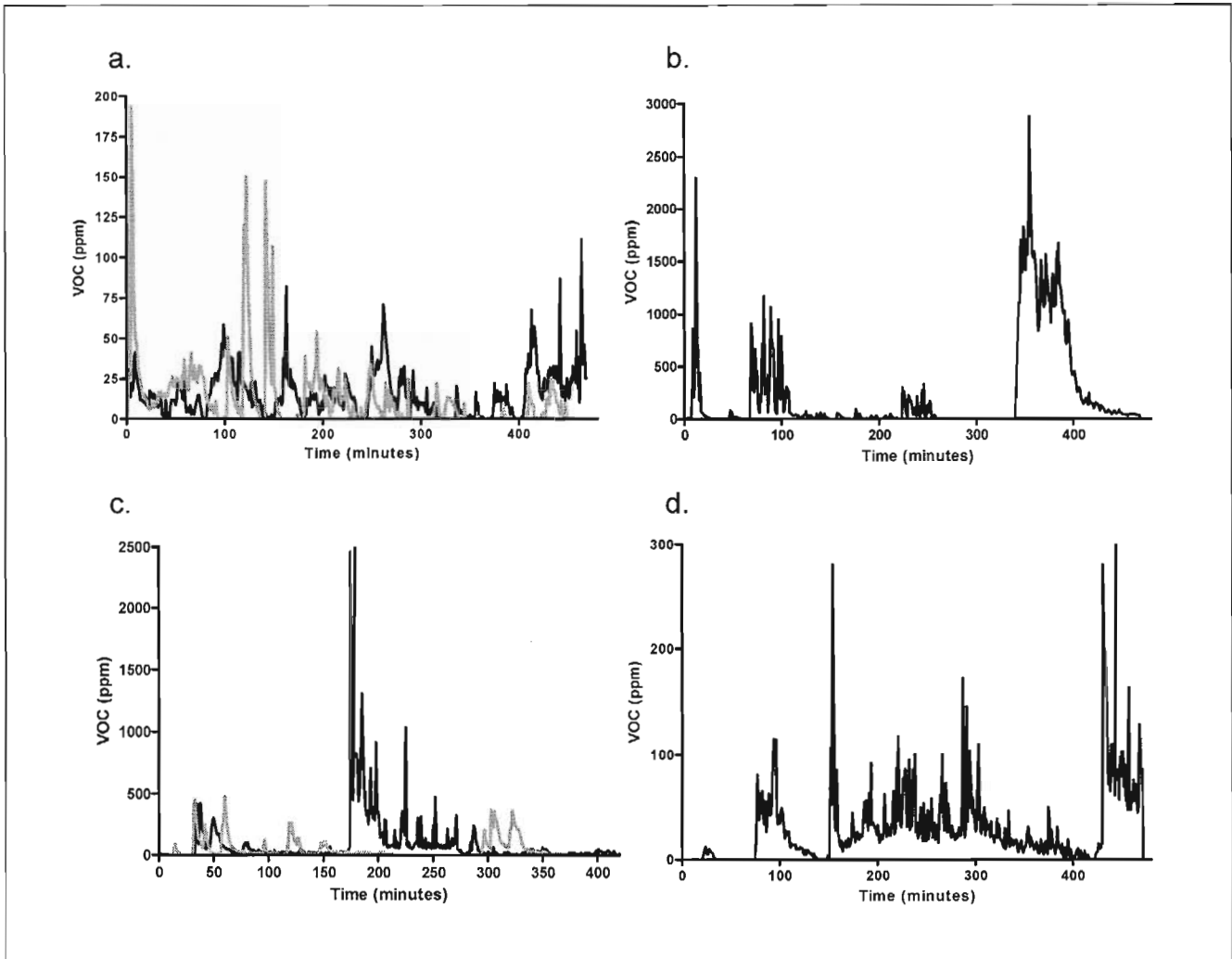


Figure 1: Environmental exposure to volatile organic compounds in different laboratories of two subject groups obtained from the direct reading instrument.

Graph a and c indicates sampling on different days, day one is depicted in black, and day 2 is depicted in grey. These graphs indicate the environmental exposure to volatile organic compounds over an eight hour working day in parts per million. It gives an indication of the high concentrations employees are exposed to in the laboratories. In graph a the highest concentration measured was 194 ppm, in graph b 2875 ppm, graph c 2530 ppm and graph 281 ppm. These concentrations are potentially a combination of various HCS present in the laboratory at a specific time.

Of the 36 fume cupboards measured, 50% were effective with a face velocity above 0.5 m/s. 31% of the fume cupboards were effective if the sash was moved down, and 19 % of the fume cupboards were ineffective or not working. The average of all the fume cupboards was  $0.50 \pm 0.2$  m/s.

Table 4: Information obtained from employee's questionnaires on the working conditions and duration of work.

Duration of work in the laboratory	46 % Longer than 2 years 21 % Between 1 and 2 years 33 % Less than 6 months
Number of days working in the laboratory per week	88 % Every day 12 % More than twice a week
Number of hours working per week	76 % More than 30 hours 15 % Between 20 and 30 hours 6 % Between 10 and 20 hours 3 % Less than 10 hours

In the questionnaires, 61% of employees stated that they received training before working in the laboratories, and 33% stated that they received limited training. Sixty four percent of employees were aware of who their health and safety representative was. Twenty four percent of employees were aware of previous risk assessment conducted in the laboratory, and 18% were aware of previous air monitoring conducted. Thirty six percent of the employees took part in medical surveillance the previous year. Seventy three percent of employees knew what a MSDS is, and only 64% of employees admitted that they always follow the correct work procedures, while 79% of employees acknowledge that they follow the correct waste disposal procedures. Only 48% of employees had knowledge of the Regulations for Hazardous Chemical Substances of 1995, but 76% of the employees knew of their right to a healthy and safe work environment.

## DISCUSSION

The time weighted average exposure to the various chemicals are below South African OEL's, but exposure varies to a great extent between subject groups, laboratories and processes. Although the average exposure over eight hours is of no immediate concern, the short term exposure is still unknown and it can't be assumed that the short term exposure limits (15 minutes) will not be exceeded. The short term exposure carries a

greater risk because employees can be exposed to dangerously high concentrations of various hazardous chemicals above STEL limits for short periods of time. It is difficult to compare short term exposure because only a limited number of chemicals have STEL limits available, despite the risks associated with short term exposure to high concentrations. Although exposure may be short in terms of time, repeated exposures over a long period of time can lead to serious health effects. In example of the possible health effects dichloromethane is a potential carcinogen. A number of chemicals also have synergistic or additive effects when their exposure occurs simultaneously over a long period of time. Therefore long term continuous exposure to low concentrations can have more detrimental effects to laboratory employees than a once off high exposure. Employees are also exposed to a wide range of concentration seen with ethanol with the lowest exposure concentration being  $0.001 \text{ mg/m}^3$  and the highest exposure concentration being  $45.66 \text{ mg/m}^3$ . Calculations were completed to determine the additive effect of exposure to multiple chemicals simultaneously, the results are not shown but there was no additive effect between the chemical exposures for these concentrations.

There was a positive correlation in some cases between personal and environmental exposure. Dichloromethane and ethyl acetate indicated a positive association between the personal and environmental exposure to these chemicals. The correlation between two chemicals can be a result of less use of other chemicals, or of good working practices when handling the other chemicals. This association between these two chemicals signifies the fact that all employees present in a laboratory will be exposed to the HCS used in the laboratory, and also depicts the inadequacies of control measures or lack of using the control measures correctly.

The insignificant differences between personal and environmental exposure in a number of samples indicates a high risk to all employees working in laboratories. This is as a result of various highly volatile chemicals used in the laboratory without adequate ventilation systems to extract the vapours or mists. The current control measures in place are fume cupboards that are not all functioning optimally, and employees are unwilling to handle chemicals in the functioning fume cupboards. Therefore any employee present in a laboratory is exposed to HCS even if the employee is not working with any HCS. This indicates that activity with HCS in one part of the laboratory will lead to exposure to all employees in the particular laboratory if the control measures are not adequate. In some laboratories there are more than one process active, and this leads to employees being

exposed to chemicals that they normally do not work with. Therefore control of exposure should be sufficient to ensure that the vapours and mist does not extend beyond the point of activity. This information indicates the importance of ensuring only necessary employees in laboratories, and the importance that no desks or offices are located in laboratories, which in this study did occur. The correlation of a number of chemicals between personal and environmental exposure and the insignificant difference between the two exposures emphasizes the overall exposure of employees in a laboratory and the need for adequate control measures.

There was statistically no difference between exposure in the first four hours of work and the second four hours of work for eight of the chemicals. Only chloroform and ethyl acetate indicated a difference. This is due to the activity in the particular laboratory on the specific day. The highest exposure to the hazardous chemicals differs between the morning and afternoon sampling, in some cases the exposure is the highest in the morning and in other cases in the afternoon. In most laboratories the activity, processes and the chemicals differ from time to time, and therefore the HCS exposure will differ among days, but during one day the actions in a laboratory mostly stay the same. Therefore exposure to HCS will vary according to the chemicals used and the activities in the laboratory on the particular day, which makes it difficult to perform representative monitoring.

The results show exceedingly high exposures to volatile organic compounds for short periods of time. The average of the ten chemicals detected by the sorbent tube is very low in comparison with the total VOC's. This indicates that employees are exposed to a wide variety of HCS simultaneously which adds to the total concentration of VOC the employees are exposed to. It is apparent that there are short periods of time where employee exposure exceeds the local and international STEL limits and employees are exposed to numerous HCS in the 8 hour work shift in the laboratory.

The long term exposure to HCS may lead to detrimental health effects on the liver, nervous system, kidneys, mucus membranes and even cancer. The most common health effect is depression of the nervous system and irritation of the mucus membranes and skin. Women working in laboratories that are in the reproductive phase of their lives are continuously exposed to HCS, this can reduce their fertility and ability to bear children. Exposure during pregnancy can also lead to serious malformations of the fetus and even miscarriages. This is a major concern because the majority of laboratory workers are

female and many are young and still planning on having children. These women should be monitored carefully and should avoid contact with toxic chemicals during pregnancy.

The measurements of the fume cupboard effectiveness indicated that only half of the fume cupboards in research and testing laboratories are effective in protecting employees from exposure to HCS. The ineffectiveness and lack of enough fume cupboards contributes to employee's exposure to HCS. Another factor that contributes to employee exposure is their reluctance to work in the fume cupboard. The fume cupboard is an effective method of control of employee exposure if used correctly.

From the questionnaires it was apparent that the majority of employees have been working in laboratories for longer than 2 years, and these employees all work more than 30 hours per week in a laboratory. These employees are therefore exposed to HCS continuously over a long period of time. The long term exposure can lead to health effects, therefore it is necessary to monitor and control employee exposure. It is obvious that employee health and safety is not a priority, because of the lack of training and information available to employees, and the absence of monitoring of employee exposure.

A more thorough follow up investigation should be launched to determine the exposure of employees in laboratories to various HCS, and consequently the exposure to these chemicals should be controlled or prevented by adequate control measures such as ventilation systems. Fume cupboards should be repaired immediately to ensure optimal functioning to protect employees from unnecessary exposure. Employees must be thoroughly trained and instructed to work in the laboratory fume cupboard in order to minimize occupational exposure to HCS and to ensure a healthy and safe work environment.

## **CONCLUSION**

This study indicated that laboratory employees are continuously exposed to low concentrations HCS with short term exposure to very high concentrations of a combination of chemicals. The long term exposure may lead to detrimental health effects on the liver, nervous system, kidneys, mucus membranes and even cancer. Although the time weighted average exposure is below the limits, there is an indication of short periods of time where exposure to extremely high concentrations of a combination of various chemicals occur which may exceed the STEL limits. This shows the false sense of security that a TWA concentration can provide, while the STEL limits can be exceeded. In research and testing laboratories it is necessary to determine the 8 hour exposure as well as short term exposure to the hazardous chemicals. This places an emphasis on the importance of sufficient monitoring and control of employee exposure to HCS to ensure a healthy and safe work environment for all employees in the laboratories.

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# *CHAPTER 4*

## **CASE STUDY**

### **SHORT-TERM PERSONAL EXPOSURE OF AN EMPLOYEE TO ACETONE, DICHLOROMETHANE AND CHLOROFORM.**

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## **INTRODUCTION**

The subject has been an employee of the North-West University for the past 12 years. The employee is responsible for the collection and distribution of various hazardous chemical substances (HCS) from a chemical store room to various laboratories on campus. This task is performed on average twice a week. A Health and Safety audit conducted noted inadequate use of personal protective equipment when performing this task.

The purpose of this survey was to quantify the short term exposure of the subject to hazardous chemical substances.

A chemical substance is a compound or mixture of substances which may be present in the workplace in the form of a liquid, solid or a gas. These substances may present a hazard as a result of contact with the body or absorption into the body through the skin, by ingestion or inhalation.<sup>1</sup> Hazardous chemicals could be characterized as carcinogens, haematopoietic system toxins, hepatotoxins, nephrotoxins, neurotoxins, toxic agents, and agents that damage the skin, eyes or mucus membranes.<sup>2</sup>

## **CASE DESCRIPTION**

The employee is active in the chemical store room for an average of 40 minutes. The store room has a floor surface area of approximately 6 m<sup>2</sup> and a height of approximately 3 m. It has a metal mesh floor with a containment pit approximately 1 m below floor level to contain any spillages. Three of the interior walls have shelving from floor to ceiling. Large containers of chemicals are stored on the floor surface.

During the employee's activity in the store room he opens large containers (20 - 25ℓ) with chemicals and uses a small funnel to transfer the chemical substance to 2.5ℓ bottles. During the transfer large volumes of chemical is spilled. This releases a large number of vapours into the small store room where the employee is standing, and it is unavoidable that he inhales the vapours. The employee is only issued and equipped with a laboratory overcoat, household cleaning gloves and a standard FFP1 dust mask.

Personal sampling in the breathing zone of the employee was conducted for 42 minutes with a sorbent tube (SKC ST 226-01) which was connected to a sampling pump (200mℓ/min) as well as an EntryRAE direct reading apparatus. Environmental sampling was conducted by means of an EntryRAE that was placed on a shelf inside the store

room. Data was recorded at 5 second intervals. No detectable background levels of volatile organic compounds were recorded outside the chemical store room. Once the employee entered the store room readings started to increase. The door of the store room was kept open for the duration of the task. On this particular day 25 bottles of 2.5l were filled. Of the chemicals transferred were dichloromethane (13 bottles), ethanol (2), acetone (2), ethyl acetate (7) and chloroform (1).

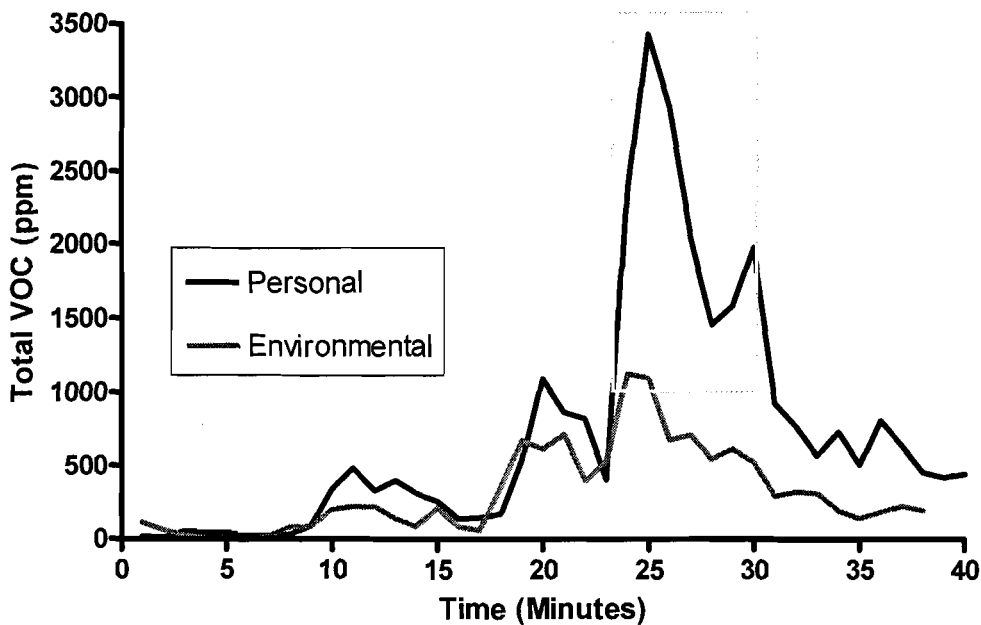


Figure 1: Short term exposure to hazardous chemical substances.

This figure illustrates the employee’s exposure to the total amount of volatile organic compounds in the short period of time that he is active in the store room. The personal exposure has a short period of very high exposure. For these 6 minutes (shown in the block) the employee is exposed to volatile organic compounds high above the local and international STEL limits.

Table 1: Personal exposure to HCS from the sorbent tube analysis.

HCS	Exposure in 42 minutes (ppm)	TWA exposure (ppm)
Acetone	14.04	1.23
Dichloromethane	387.79	33.93
Chloroform	50.13	4.39

Table 2: Occupational exposure limits according to the various institutions.

HCS	Regulations for HCS		ACGIH		OSHA	
	TWA OEL (ppm)	STEL (ppm)	TLV-TWA (ppm)	STEL (ppm)	TWA PEL (ppm)	STEL (ppm)
Acetone	750	1500	500	750	1000	-
Chloroform	2	-	10	-	50	-
Dichloromethane (Methylene chloride)	100	250	50	-	25	125

3,5,6

## DISCUSSION

In this survey only acetone, dichloromethane and chloroform was detected, but this depends on the bottles the employee has to fill on the particular day and the number of bottles to be filled. Therefore the employee's exposure will vary every day according to his activities. The TWA values were calculated with the assumption that the subject was not exposed to any HCS for the remainder of the workday, but in reality he is active in laboratories delivering the bottles where he is also exposed to HCS for short periods of time. When comparing the exposure concentrations in Table 1 it is clear that dichloromethane exceeds the STEL values of both South African Regulations and OSHA. Although there is no know STEL value for chloroform, the general rule is to multiply the TWA value with 3. In this case the employee's exposure to chloroform exceeds the STEL values of both South African Regulations and ACGIH.

If the TWA for 8 hours is calculated this gives a much lower exposure level however, chloroform exceeded the TWA limit of the South African Regulations. The results show that a TWA value can give a false sense of security, because over 8 hours the exposure may be below the exposure limits, but the employee can be exposed to a HCS for a short period at dangerously high levels which exceed the STEL limits. Therefore monitoring must be planned carefully to ensure that 8 hour exposure as well as short term exposures are monitored.

In the Regulations for Hazardous Chemical Substances of 1995 dichloromethane has a control limit with no STEL value, but methylene chloride has a recommended value with a STEL value. These are synonyms for the same chemical and this causes confusion about the control to be followed for this chemical.

## **CONCLUSION AND RECOMMENDATIONS**

### Conclusion

In this survey it was found that the employee's short term exposure to dichloromethane and chloroform were very high, although it didn't exceed the known limits in all the cases, but long term exposure to these concentrations without adequate control and protection can lead to serious detrimental health effects. Dichloromethane is a potential carcinogen and long term exposure can lead to cancer.

### Recommendations

Chemical store room:

The empty containers must be removed from the store room and the store room must be reorganized to create more space. The containment area below the floor must be decontaminated by a company specializing in clean up and removal of hazardous chemical substances. The extraction fan must be switched on at all times.

Employee exposure:

Due to the absence of any assessments, monitoring and the presence of possible symptoms related to long term long exposure to solvents, it is recommended that the employee be withdrawn immediately and referred to an occupational health practitioner for a physical evaluation and other tests necessary to determine his health status. The employer must make an immediate assessment of exposure because there is no record of any previous assessments. Thereafter assessments of exposure must be made at intervals not exceeding two years. The employer must keep record of such assessments. Monitoring must be carried out by an approved inspection authority. Monitoring must be carried out at least every 12 months for HCS with a control limit such as dichloromethane and every 24 months for a HCS with a recommended limit, such as acetone and ethanol. There is no record of any previous personal air monitoring of this employee. If the employee is also exposed to HCS listed in Table 3, the employee must be placed under medical surveillance. This employee is exposed to methanol on occasion, therefore medical surveillance is required. The employee must be informed and trained in

accordance with the HCS Regulations. Adequate control measures must be employed such as ventilation systems which will reduce exposure to vapours. Spillages can be prevented by using appropriate siphoning equipment.<sup>3,4</sup>

The employee should be provided with a protective coverall, gloves and respiratory protection suitable for vapours and mists instead of the dust mask previously provided.

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## SUMMARY BOX

STEL exposure to dichloromethane was 387.79 ppm.

TWA exposure to dichloromethane was 33.93 ppm.

TWA exposure to chloroform was 4.39 ppm.

The employee was issued with a FFP1 dust mask for respiratory protection against HCS vapours.

# *CHAPTER 5*

## **CONCLUDING CHAPTER**

### **CONCLUSION**

From this study laboratory employees' exposure to a limited number of hazardous chemical substances has been quantified, and awareness of health and safety in the workplace has been immensely increased.

The majority of employee exposures to hazardous chemical substances in laboratories are long term exposure to low concentrations. In a small number of cases employees are exposed to high concentrations of hazardous chemical substances for short periods of time. The most important reasons for exposure is the unwillingness to work in fume cupboards, lack of fume cupboards or ineffectiveness of fume cupboards. Employees are exposed to a variety of dangerous chemicals which increases the total exposure to hazardous chemical substances. The hypothesis can therefore not be accepted as employees are not exposed to hazardous chemical substances above the occupational exposure limits stated in the Hazardous Chemical Substances Regulations. However employees are continuously exposed to low concentrations of various hazardous chemical substances over long periods of time.

The majority of chemicals have detrimental health effects when an employee is exposed to it, either short term or long term. Continuous exposure to low concentrations can have various health effects, and a number of chemicals such as benzene, chloroform and dichloromethane are carcinogenic. In informal conversations with employees a number of employees complained about dizziness and headaches after a working day in the laboratory. Some chemicals have an immediate effect such as a skin irritation or burning of the skin, and other chemicals only show effects years after exposure occurred, for example cancer. The most common health effect of chemicals is depression of the nervous system and irritation of the mucus membranes and skin. The depression of the nervous system can be permanent and can lead to serious detrimental effects which can influence an employee's ability to perform his daily tasks. Various chemicals have additive or synergistic effects when exposure occurs in combination with other chemicals. Acetone is an example of these additive and synergistic effects, it increases the liver toxicity of chloroform and carbon tetrachloride. Acetone also inhibits the metabolism and elimination of ethyl alcohol and thereby potentially increases the toxicity of it.<sup>1</sup>

There has been inadequate monitoring of employee exposure to the hazardous chemical substances, which increases the risk of exposure and therefore there can't be sufficient control measures in place to control or prevent employee exposure. There is no indication of current control measures being effective, or investigations to determine if control measures are effective. All chemicals with a control limit, such as benzene and dichloromethane, must be controlled to concentrations as low as possible below the limits. This can't take place if there is no indication of exposure to these chemicals. If employees are exposed to chemicals listed in Table 3 of the Regulations for Hazardous Chemical Substances, such as benzene, hexane or methanol, these employees must take part in medical surveillance. If the exposure to these chemicals are not known it is impossible to ensure that these exposed employees are taking part in medical surveillance, and to ensure that their health is not endangered.

It is apparent that occupational health and safety, especially in laboratories, was not very important to the Institution. From the questionnaires it was obvious that employee training and information were very limited, health and safety representatives were not trained to fulfill their duties, and a number of employees didn't even know who their health and safety representatives are. In the questionnaires and informal conversations with employees, numerous employees admitted to not always follow the correct working procedures such as using a fume cupboard or the correct waste disposal procedures because they were not informed of the waste disposal methods. In the majority of the laboratories the chemicals were stored in the laboratory on the working surfaces or in the fume cupboards. In a small number of laboratories there were old chemicals that were stored in the laboratories, and in one laboratory chemicals were used past the expiry date.

One of the shortcomings of this study was the limited finances. This led to a limited number of chemicals that could be sampled, and also a limited number of laboratories and employees that could be sampled. Biological monitoring could not be carried out to determine the long term exposure by means of testing blood or urine. Another limitation to the study was compliance and willingness of management and employees, which led to a delay in sampling. Under ideal circumstances more chemicals could be sampled in all research and testing laboratories that work with hazardous chemical substances. Biological monitoring should be conducted to determine the concentrations of hazardous chemical substances present in the blood or urine.

Employees are continuously exposed to numerous hazardous chemical substances without the necessary control or prevention of exposure from the employer. The Institution should launch an intensive investigation into occupational health and safety in laboratories, and take the necessary steps to comply with the legislation, and therefore ensure a healthy and safe work environment for all employees.

## **RECOMMENDATIONS**

The recommendations for this study are all included in the health and safety plan for laboratories using hazardous chemical substances. The health and safety plan includes a wordlist, emergency numbers, the current situation in laboratories, and the recommendations for the use of hazardous chemicals in laboratories.

## **HEALTH AND SAFETY PLAN FOR LABORATORIES USING HCS**

**Anja Franken, Johan du Plessis, Fritz Eloff**

### **INTRODUCTION**

#### **Purpose**

The purpose of this Health and Safety Plan for laboratories is to supply policies, procedures and work practices to protect University personnel and students from the hazards inherent to laboratories where HCS are used, handled and stored.

The aim of this plan is to:

- to ensure a safe and healthy work environment.
- to comply with the Occupational Health and Safety Act No. 85 of 1993 and the Regulations for Hazardous Chemical Substances of 1995.
- to ensure that the necessary instructions are in place to ensure the safe and healthy work environment.
- to align with OSHAS 18001.

#### **Scope**

This Health and Safety Plan for Laboratories will apply to all laboratories of the University. The laboratories include academic, research and testing laboratories where hazardous chemical substances are used. This Health and Safety Plan for Laboratories has been developed primarily from the Occupational Health and Safety Act No. 85 of 1993 and the Regulations for Hazardous Chemical Substances of 1995 as well as other general guidance documents.

#### **OSHAS 18001**

OSHAS 18001 is an internationally recognized Occupational Health and Safety management system which would, if implemented and managed or adhered to, ensure that legal compliance is achieved and that there is an effective structure for the management of Occupational Health and Safety in place.

By implementing or aligning to the requirements of OSHAS 18001 it will ensure that there is a structured management approach to Occupational Health and Safety which will ensure that it can easily be maintained at all times. If OSHAS 18001 is implemented it will ensure that within any organization, the responsibilities are met and legal liabilities are kept to a minimum. Legal compliance will also ensure that incidents or accidents are kept to a minimum.

The benefits of implementing the OSHAS 18001 system are having an international Occupational Health and Safety management system, complying with legislation, and ensuring a safe and healthy work environment.

### **Campus plan**

The University intend to:

- Protect laboratory employees and students from health hazards associated with the use of hazardous chemicals in the laboratories.
- Ensure that the laboratory employees and students are not exposed to substances above the recommended or control limits that are defined by the Regulations for Hazardous Chemical Substances of 1995.

This plan will be available to all employees and students for review, and a copy will be located in each appropriate laboratory.

This plan will be reviewed annually and updated as necessary by the Institution's Health and Safety Officer.

### **Emergency numbers**

<b>Emergency</b>	<b>Contact person</b>	<b>Number</b>
General emergency	Protection Services	(018) 299 1110 / 2211
Fire	Fire brigade	(018) 293 1111 / 1112
Injury at work	Mr. Penrose Diphoko	(018) 299 2700

## Wordlist

Definitions were taken from the Occupational Health and Safety Act No. 85 of 1993 and the Regulations for Hazardous Chemical Substances of 1995.

**Air monitoring** - the monitoring of the concentrations of airborne hazardous chemical substances.<sup>2</sup>

**Approved inspection authority** - an inspection authority approved by the chief inspector: Provided that an inspection authority approved by the chief inspector with respect to any particular service shall be an approved inspection authority with respect to that service only.<sup>3</sup>

**Assessment** - a program to determine any risk from exposure to a hazardous chemical substance associated with any hazard thereof at the workplace in order to identify the steps needed to be taken to remove, reduce or control such hazard.<sup>2</sup>

**Danger** - anything which may cause injury or damage to persons or property.<sup>3</sup>

**Employee** - any person who is employed by or works for an employer and who receives or is entitled to receive any remuneration or who works under the direction or supervision of an employer or any other person.<sup>3</sup>

**Employer** - any person who employs or provides work for any person and remunerates that person or expressly or tacitly undertakes to remunerate him, but excludes a labour broker as defined in section I (1) of the Labour Relations Act, 1956 (Act No. 28 of 1956).<sup>3</sup>

**Engineering control measures** - control measures that remove or reduce the exposure of persons at the workplace by means of engineering methods.<sup>2</sup>

**Exposed** - exposed to a hazardous chemical substance whilst at the workplace and "exposure" has a corresponding meaning.<sup>2</sup>

**Hazard** - a source of or exposure to danger.<sup>3</sup>

**HCS or Hazardous chemical substance** - 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.<sup>2</sup>

**Healthy** - free from illness or injury attributable to occupational causes.<sup>3</sup>

**Incident** - an occurrence at work or arising out of or in connection with the activities of persons at work, or in connection with the use of plant or machinery, where any person dies, becomes unconscious, suffers the loss of a limb; a major incident occurred or the health or safety of any person was endangered.<sup>3</sup>

**Medical surveillance** - a planned program 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.<sup>3</sup>

**Monitoring** - the planning, carrying out and recording of the results of a measurement program.<sup>2</sup>

**MSDS or Material safety data sheet** - Document containing the physical properties, hazard warning and storing instructions of a chemical.

**Occupational health practitioner** - an occupational medicine practitioner or a person who holds a qualification in occupational health recognized as such by the South African Medical and Dental Council as referred to in the Medical, Dental and Supplementary Health Service Professions Act, 1974 (Act No. 56 of 1974), or the South African Nursing Council as referred to in the Nursing Act, 1978 (Act No. 50 of 1978).<sup>3</sup>

**OESSM** - the Occupational Exposure Sampling Strategy Manual, published by the National Institute for Occupational Safety and Health (NIOSH), Publication No. 77-173 of 1977, United States of America: Department of Health, Education and Welfare.<sup>2</sup>

**Postgraduate student** - Any student that have completed a first degree and is currently busy with his Honours, Masters or Doctoral degree who performs research in a laboratory as part of his research project.

**Reasonably practicable** - practicable having regard to-

- (a) the severity and scope of the hazard or risk concerned;
- (b) the state of knowledge reasonably available concerning that hazard or risk and of any means of removing or mitigating that hazard or risk;
- (c) the availability and suitability of means to remove or mitigate that hazard; and
- (d) the cost of removing or mitigating that hazard or risk in relation to the benefits deriving therefrom.<sup>3</sup>

**Respiratory protective equipment** - a devise which is worn over at least the mouth and nose to prevent the inhalation of airborne hazardous chemical substances and which is of a type, or conforms to a standard approved by the Minister.<sup>2</sup>

**Risk** - the probability that injury or damage will occur.<sup>3</sup>

**Substance** - includes any solid, liquid, vapour, gas or aerosol, or combination thereof.<sup>3</sup>

## **HEALTH AND SAFETY PLAN FOR CHEMICAL USE IN LABORATORIES**

In the plan the situation currently in the laboratories will be discussed and this will be followed by the recommendations to ensure a safe and healthy work environment for all employees and postgraduate students. In this plan where there is reference to a gender this will include both genders.

### **1. Health and Safety Representatives**

#### **Current situation**

There are 20 health and safety representatives appointed in the 15 subject groups, except one subject group where the position is vacant at this time. The health and safety representatives are not informed of their rights and duties and did not receive the necessary training to complete their duties prior to appointment. The health and safety representatives only received training recently. There is no evidence of monthly inspections of the workplace. A number of health and safety representatives were not chosen but forced into the position. A number of employees do not know who their health and safety representative is.

#### **Recommendations**

- The primary function of health and safety representatives (H&SR) is to act as a representative of employees at specific work areas in the interest of health and safety.
- The University and representatives of employees must consult regarding the arrangements and procedures for the nominations or election of health and safety representatives.
- Health and safety representative's must be elected democratically by the people that they represent, and then be appointed for 2 years.
- All activities of health and safety representatives must be performed during working hours.
- All health and safety representatives must receive extensive training to equip them with the necessary knowledge before they accept responsibility.
- Duties of health and safety representatives:
  - Review the effectiveness of health and safety measures.
  - Identify potential hazards (including HCS) and potential major incidents at the workplace.

- Examine the causes of incidents in the workplace, in collaboration with the University and Campus Health and Safety Officer.
- Investigate complaints by employees relating to health and safety at work.
- Inspect the workplace at regular intervals,
- Attend meetings of the health and safety committee.
- Monthly inspections must be conducted in all laboratories and workplaces, and every 3 months inspections must be conducted in all offices and administrative areas.
- A health and safety representative does not sustain any civil liability because he failed to do anything which he may do or is required to do in terms of the Occupational Health and Safety Act No. 85 of 1993.<sup>3,4</sup>

## **2. Health and Safety Committee**

### **Current situation**

There is a health and safety committee for the faculty which holds meetings every 3 months. The members of the health and safety committee are not entirely informed on the legislation concerning occupational health and safety, or the duties of the health and safety representatives.

### **Recommendations**

A health and safety committee must be established in the workplaces where there are more than 2 health and safety representatives. This health and safety committee must hold meetings as often as necessary, but at least once every 3 months where issues on workplace health and safety can be discussed. In these meetings the health and safety representatives must make recommendations to the University regarding any matter affecting the health or safety of employees at the workplace and discuss any incident where an employee or postgraduate student was injured, became ill or died. The committee must also discuss the results of hazard monitoring and biological monitoring, and inform employees of the results.<sup>3,4</sup>

## **3. Information and Training**

### **Current situation**

Of the 33 employees who completed a questionnaire 20 of them received the necessary training before they started working in the laboratory, but 11 employees only received training in some aspects. Two employees stated that they did not receive any

training before they started working in a laboratory. Employees receive training courses at irregular intervals which not all employees attend. Not all of the employees are familiar with the legislation concerning occupational health and safety or their right to a healthy and safe working environment. A small number of employees know what a MSDS is, and what it is used for.

A large percentage of employees are not aware of the Regulations for Hazardous Chemical Substances of 1995, and a number of employees are not aware of their right to a healthy and safe work environment.

### **Recommendations**

- Any employees exposed, or potentially exposed, to hazardous chemicals while performing their laboratory duties must receive information and training regarding the following:
  - the contents of the Regulations for Hazardous Chemical Substances of 1995.
  - the potential source of exposure
  - the potential risks to health caused by exposure
  - the potential detrimental effects of exposure
  - the precautions that he/she must take to protect himself against the health risks associated with the exposure, including the wearing and use of personal protective equipment
  - the necessity, correct use and maintenance of safety equipment, facilities and engineering control measures provided
  - the necessity of personal air sampling and medical surveillance
  - the importance of good housekeeping at the workplace and personal hygiene
  - the safe working procedures regarding the use, handling, storage and labelling of HCS at the workplace
  - procedures to be followed in the event of spillages, leakages or accidents in the workplace
  - location and availability of reference materials on the hazardous chemicals such as the MSDS.
  - the recommended or control limits for hazardous chemical substances stated in the Regulations for Hazardous Chemical Substances of 1995
  - signs and symptoms associated with exposure to hazardous chemicals in the laboratory

- Training should be conducted prior to employment, just after employment, or when an employee is assigned to another working area where exposure situations can vary. The University must ensure that annual refresher training sessions are held.
- All records of training must be kept for the duration of the employee's employment with the University.
- All training must be conducted by competent trainers or instructors.
- Refresher courses must be held at least once per year.
- Employees must receive additional training from competent instructors in first aid and cardiopulmonary resuscitation (CPR), fire extinguisher hands-on training, electrical safety and radiation protection training where applicable as a measure of safety in the laboratory.<sup>2,5,6</sup>

#### **4. Assessment of Potential Exposure**

##### **Current situation**

According to the majority of employees (25), there has been no assessment of the potential for exposure to the hazards present in the laboratories. Only 8 employees are aware of assessment that was conducted in the laboratories. According to the current occupational health and safety plan for the campus there will be annual risk assessment conducted by the Campus Health and Safety Officer.

##### **Recommendations**

- Employee exposure must be assessed at regular intervals to determine if personal monitoring is necessary. The assessment should be based on the frequency of chemical use, the type of chemical used, the toxicity of the chemicals and symptoms of exposure to toxic chemicals.
- The assessment conducted by the Campus Health and Safety Officer or Occupational Hygiene Officer will initially be qualitative, and may be followed by specific quantitative monitoring.
- A report documenting the assessment must be sent to the health and safety representatives and subsequently to all employees.
- Assessment must be repeated if any process or control measure changes.
- All records of assessments conducted must be kept for a period of 30 years.<sup>5</sup> (Refer to section 19)

## **5. Hazard Identification**

### **Current situation**

In all the laboratories there is no hard copies of the MSDS. Various chemical bottles are not labelled appropriately.

### **Recommendations**

- Consult MSDS of chemical substance or label on chemical bottle for hazard information. (Refer to section 15)
- Any new chemical substances that are developed for laboratory use only must be labelled with the known hazardous properties and chemical name. If the chemical produced is of unknown composition, it must be assumed to be hazardous and appropriate precautions must be taken.
- If a chemical substance is produced for another user outside the facility, the laboratory that is producing the substance is required to provide as much information as possible regarding the identity and known hazardous properties of the substance to the receiver of the substance.<sup>5</sup>

## **6. Air Monitoring**

### **Current situation**

According to the majority of employees (27), there has been no exposure monitoring in the laboratories. Only 6 employees are aware of exposure monitoring that was conducted in the laboratories.

### **Recommendations**

- When the assessment indicates that any employee may be exposed to hazardous chemical substances, the University must ensure that monitoring is carried out in accordance with the provisions of the Regulations for Hazardous Chemical Substances of 1995.
- The monitoring must only be carried out after the relevant health and safety representative or committee has been informed.
- The monitoring must be carried out by an approved inspection authority or by a person whose ability to do the measurements is verified by an approved inspection authority.
- The measurement must be representative of the highest exposure of employees to airborne HCS. The sample size must be chosen to comply with OESSM. If the

exposure group is homogenous and the highest exposed employee cannot be identified, the sample size must be chosen to make provision to include the top 10% of the highest exposure in the group. For a chemical with a control limit (OEL-CL) the sample size must be chosen for the top 10% of the group at the 95% confidence level, and the top 10% of the group at the 90% confidence level for a chemical with a recommended limit (OEL-RL).

- Representative measurements must be conducted at least every 12 months for a HCS with a control limit, and at least 24 months for a HCS with a recommended limit.
- The University must notify the employees of monitoring results, and provide interpretation of monitoring results to these employees.
- All records of monitoring conducted must be kept for a period of 30 years.<sup>2,6</sup> (Refer to section 19)

## **7. Medical Surveillance**

### **Current situation**

According to the current occupational health and safety plan for the campus medical surveillance must be carried out in accordance with the law and regulations. This includes procedures such as risk assessment, selection of test schedules, identification of target organ or toxicity, development of action criteria, standardizing test processes, ethical consideration, determining of employees capacity, evaluation of control and record keeping.

There is no evidence of baseline medical surveillance prior to commencement of employment or within 14 days of commencing work of any employee potentially exposed to HCS in Table 3 of the Regulations of Hazardous Chemical Substances of 1995.

There has been a trial run of medical surveillance the previous year to establish a baseline of exposure, but this was not completed. Of the 33 employees who completed a questionnaire only 12 took part in the medical surveillance. The surveillance would not have been a true indication of baseline, because some employees have been working in laboratories for an extended period of time before the surveillance. Not all exposed employees took part in the surveillance, and the employees that did take part were not allowed to receive their results. The validity of medical surveillance can also be questioned, because samples were not all taken on the same time of day or day of the week.

## **Recommendations**

- The University must ensure that an employee is under medical surveillance if:
  - the employee may be exposed to a substance listed in Table 3 of the Regulations for Hazardous Chemical Substances of 1995.
  - the exposure of the employee to any hazardous substance can have adverse health effects or causes an identifiable disease.
  - the occupational health practitioner recommends that the employee should be under medical surveillance.
- The University must ensure that an initial health evaluation is carried out by an occupational health practitioner immediately before or within 14 days after a person commences employment; where any exposure exists. This includes an evaluation of medical history and a physical examination.
- The University must ensure that the employee undergoes examinations at intervals not exceeding 2 years, or at intervals specified by an occupational health practitioner.
- The University must not permit an employee who has been certified unfit for work by an occupational health practitioner to work in a workplace in which he/she can be exposed.
- The University must consider gender, pregnancy and fecundity.
- The University must keep all records of medical surveillance.
- All records of medical surveillance must be kept for a period of 30 years.<sup>2,5</sup> (Refer to section 19)

## **8. Control of Exposure to Hazardous Chemical Substances**

### **Current situation**

There are some control measures present in the laboratories. The engineering control present consists of fume cupboards and in some laboratories ventilation. The ventilation in some laboratories is not adequate to prevent exposure to HCS. In one subject group's laboratories there is air supplied to the laboratory, but there is no method of extracting the contaminated air out of the laboratory, and therefore the fumes and vapours are blown into the hallway and offices. In some instances different processes are located in the same laboratory.

There is no indication of any administrative control. There are excessive bottles of chemicals stored in the laboratories, and there is no housekeeping in laboratories.

Employees are provided with some personal protective equipment for example gloves, lab coats and in some instances respiratory protection (masks). (Refer to section 9)

## Recommendations

- The University must ensure that the exposure of an employee to HCS is prevented or adequately controlled.
- Exposure to substances with a recommended limit must be reduced below the recommended limit or as low as is practicable, and exposure to substances with a control limit must be reduced to a level as low as practicable below that limit.
- In any case where exposure is above the control limit, the University must ensure that the exposure is without significant risk, and that the exposure is not indicative of a failure to maintain adequate control.
- Exposure may be controlled by the following methods:<sup>2</sup>

### - Engineering control

Separate processes, automate processes or enclose potential exposure areas.

Install local extraction ventilation systems to control airborne HCS.

Separate workplaces for different processes.

Use a substitute for a HCS.<sup>2</sup>

### - Administrative control

Limit the amount of HCS used in the working environment.

Limit the number of employees exposed to HCS.

Limit the period of exposure.

Establish appropriate work procedures to be carried out to ensure that exposure is limited.

Establish procedures to ensure personal hygiene and good housekeeping.<sup>2</sup>

### - Personal protective equipment

Personal protective equipment should only be used where other measures to control the exposure are not adequate to achieve control. These devices are viewed as less protective than other controls because they rely on the employee's work practices and training to be effective.<sup>2</sup>

## 9. Personal Protective Equipment

### Current situation

The employees are provided with general personal protective equipment such as gloves and lab coats, but only a few employees receive masks and safety glasses.

Only one of the subject groups provide visitors with lab coats and protective glasses before they may enter their laboratories.

### **Recommendations**

- The University must provide suitable respiratory protective equipment, protective clothing and safety glasses where personnel may be exposed to airborne HCS or HCS that can be absorbed through the skin.
- The University must provide this protective equipment at no cost to the employee.
- The University must enforce employees to wear the personal protective equipment provided.
- The University must ensure that the relevant equipment is correctly selected.
- The University must provide information, instructions, training and supervision with regard to the use of the equipment to all personnel.
- The University must provide storage facilities for personal protective equipment when not in use.
- The University must provide personal protective equipment to all visitors that enter any laboratory.<sup>2,5,6</sup>

## **10. Maintenance of Control Measures**

### **Current situation**

There is little evidence of maintenance or examinations of control measures such as fume cupboards or other ventilation systems. Many of the fume cupboards that were tested were not functioning effectively. There are no log books of maintenance or repairs of control measures. There are no records of testing or repairs conducted on control measures.

### **Recommendations**

- All laboratory equipment should be maintained as per manufacturer's instructions. Routine maintenance should be performed and noted in a laboratory logbook.
- Thorough examinations of engineering control measures must be carried out at intervals not exceeding 24 months by an approved inspection authority or a person whose ability to do the measurements is verified by an approved inspection authority.

- Fume cupboard should always be checked for adequate flow before commencing operations. Non operational or ineffective fume cupboards must be reported to the appropriate department for repair.
- Records of all tests carried out and any repairs conducted on control measures must be kept for 30 years.<sup>2,5,6</sup> (Refer to section 19)

## **11. Laboratory Safety Equipment**

### **Current situation**

There are laboratory safety equipment in most of the laboratories. The number of fume cupboards provided in the laboratories are not enough for the number of employees that have to work in the laboratories.

Not all fume cupboards that were tested were functioning effectively. Some fume cupboards were only in use for approximately 3 years, and are not functioning effectively. There is no indication that the fume cupboards are tested regularly. Some fume cupboards are full of equipment and bottles which influences their effectiveness, and some fume cupboards are contaminated by previous spills or accidents. A small number of fume cupboards had markings of the height where the sash should be to ensure effective functioning which is indicative of previous assessment of effectiveness but no records thereof exists.

There are safety showers and eye washes in some of the laboratories or in the hallways, but these are not well marked or indicated. There is no evidence that safety showers and eye washes are tested regularly.

There are fire safety equipment in the majority of the laboratories and in the hallways.

### **Recommendations**

- Chemical Fume Cupboard Evaluation

Every laboratory fume cupboard used for the control of air contaminants must be tested once per year to assure adequate airflow is maintained to provide protection against employee exposure. The Campus Health and Safety Officer is responsible for performing this testing, or should appoint an accredited Occupational Hygiene Officer. Laboratory fume cupboard airflow is considered adequate when the average face velocity is 0.5 m/s.

Principles for safe operation:

- Keep all chemicals and apparatus at least 15 cm inside the fume cupboard.

- Fume cupboards are not intended for storage of chemicals. Materials stored in them should be kept to a minimum, and these materials should not block vents or alter air flow patterns.
- Keep the sash opening at a minimum when you are not manipulating chemicals, or adjusting apparatus inside the fume cupboard.
- When working in the fume cupboard, make sure that the sash is placed at the right height to ensure effective air flow into the fume cupboard. The working height should be appointed by arrows on the side of the sash.
- Do not allow objects such as paper to enter the exhaust ducts, this can block the ducts and affect the operation of the fume cupboard.<sup>5</sup>

- **Eyewash and Safety Showers**

Where employees work with chemicals that can damage the skin or eyes, there must be an emergency supply of water available. Keep all passageways to the eyewash and shower clear of any obstacle. Eyewashes should be checked monthly to be certain that water flows through it. Showers should be checked monthly to assure that access is not restricted, to ensure sufficient flow of water and that the start chain is within reach.

The Campus Health and Safety Officer must check eyewashes and showers twice yearly to supplement the above work which is to be conducted by laboratory personnel.<sup>5</sup>

- **Fire Safety Equipment**

Fire safety equipment must be easily accessible to the laboratory, and must include a fire extinguisher, fire hoses, fire blankets and automatic extinguishing systems.

This equipment must be checked annually to ensure that they function properly.<sup>5</sup>

## **12. Spills and accidents**

### **Current situation**

According to the current occupational health and safety plan for the campus any accident must be reported to the employer and the employee must provide the stipulated documentation to the employer when reporting the accident or when asked. Any incident that concerns health and safety in the workplace must be reported to the health and safety representative, direct head or at the designated notice point on campus.

There is no personal protective equipment or spill kits available to employees in case of a minor spill. There are no MSDS available in the laboratories to consult on clean-up information.

### **Recommendations**

- The necessary equipment such as spill kits and personal protective equipment must be accessible to all employees to respond to a minor spill.
- Consult a MSDS on spill clean-up information.
- Chemical spills should only be cleaned up by knowledgeable and experienced personnel.
- If the spill is too large to handle, is a threat to health and safety of the environment, involves a highly toxic chemical, call for assistance immediately and evacuate the laboratory.
- Call protection services on campus at x2211 or x2215, they will contact the appropriate authorities.
- When a spill has occurred the employees must inform the health and safety representative, who must inform the Campus Health and Safety Officer.<sup>5,6</sup>
  
- In case of a minor spill:
  - Alert people in the immediate area of spill.
  - Increase ventilation in area of spill by opening windows or turning on fume cupboards.
  - Wear protective equipment including safety goggles, gloves and long-sleeve lab coat.
  - Avoid breathing vapours from the spill.
  - Use appropriate kit to neutralize and absorb spill, collect residue and dispose as chemical waste.
  - Clean spill area with water.<sup>5</sup>
- In case of a major spill:
  - Attend to injured or contaminated persons and remove them from exposure.
  - Alert people in the laboratory to evacuate.
  - If spill material is flammable, turn off ignition and heat sources.
  - Close doors to the area.<sup>5</sup>
  
- In case of any accident, it must be reported to the health and safety representative, which in turn must inform the Campus Health and Safety Officer.

- The University must ensure that any employee who develops signs or symptoms associated with excessive exposure to HCS used in the laboratory, or may have been exposed to HCS during a chemical incident receive medical attention, including follow-up examinations which may be necessary.<sup>5,6</sup>

### **13. Inspections**

#### **Current situation**

There have been inspections of some subject groups recently, but there is no record of previous inspections conducted.

#### **Recommendations**

- The Campus Health and Safety Officer must complete inspections of the University facilities, equipment, instruments, material and processes, employee activities and dangerous situations to identify risks and problems to ensure that they are corrected.
- The inspections must be completed at regular intervals, minimum once a year.<sup>4</sup>

### **14. Incident Investigation**

#### **Current situation**

There has been incident investigations by the Campus Health and Safety Officer.

According to the current occupational health and safety plan for the campus all incidents will be investigated by an investigation authority appointed by the University.

#### **Recommendations**

- Any incident where people are injured must be investigated by the Campus Health and Safety Officer, and records of these investigations must be kept.
- According to the Occupational Health and Safety Act No. 85 of 1993 any major incident where the health and safety of any person was endangered, or where a dangerous substance was spilled must be reported to an inspector of the Department of Labour.
- All records of investigations must be kept for a period of 30 years.<sup>3,4</sup> (Refer to section 19)

### **15. Labelling and Storage of Hazardous Chemical Substances**

#### **Current situation**

Secondary bottles (refilled and used after original chemical is finished) in the laboratories are not all properly marked with the chemical name, properties and hazard

warnings. Some of the subject groups does not have clearly indicated storage areas or rooms and chemicals are stored in the laboratories on the shelves. None of the laboratories had hard copies of the MSDS for the chemicals used in the laboratories.

### **Recommendations**

- The University must ensure that HCS in storage are properly identified and classified.
- All containers of hazardous chemicals must have a label containing the common name and the appropriate hazard warning.
- Hard copies of the MSDS for each chemical in a laboratory must be available in the laboratory to help employees understand the potential health and physical hazards of the chemical.<sup>2,5</sup>

## **16. Disposal of Hazardous Chemical Substances**

### **Current situation**

Some of the laboratories does not have clearly marked containers or areas for HCS waste. In some laboratories there were many chemicals that had expired and have not been disposed of. Not all employees are familiar with the appropriate disposal methods for HCS, and 7 of the employees who completed a questionnaire do not always follow the correct waste disposal procedures.

### **Recommendations**

- Hazardous chemical substance waste must be removed at regular intervals to prevent a build-up of waste in laboratories.
- All HCS waste must be placed into containers that will prevent the likelihood of exposure during handling, and these containers must be closed at all times during storage.
- All re-usable containers and covers which have been in contact with HCS must be cleaned and decontaminated after use.
- All HCS waste must be labelled at the time the first waste is placed in the container.
- HCS waste must be kept in designated storage areas.
- Sinks or rubbish bins must not be used for waste disposal.
- The University must ensure that all HCS waste is disposed of only on sites specifically designated for this purpose, and that disposal takes place in accordance with the Environmental Conservation Act No. 73 of 1989.

- The University must ensure that all employees that are responsible for disposal of HCS waste are provided with suitable personal protective equipment.
- The University must ensure that the waste disposal contractor is accredited and will comply with the provisions for the Regulations on Hazardous Chemical Substances of 1995.<sup>2,5,6</sup>

## **17. Standard Operating Procedures for working with chemicals**

### **Current situation**

There is no evidence of any written standard operating procedures for any laboratory. Some laboratories are not kept clean, and working surfaces were crowded with equipment and bottles.

In some laboratories there is evidence of employees eating or drinking in the laboratory, and prevention of this is not enforced. A number of postgraduate students' and employees' work stations are located in laboratories which is not acceptable.

A number of employees are aware of the procedures to be followed, but admitted to not always following these procedures.

### **Recommendations**

- General
  - Carefully read the label before using a chemical.
  - Be aware of the potential hazards existing in the laboratory and the appropriate safety precautions.
  - Know the location and proper use of emergency equipment and the appropriate procedures for responding to emergencies.
  - Know the proper methods for storage, transport, and disposal of chemicals.
  - Do not work alone in the laboratory, or let someone know and have them check on you.
  - Label all secondary chemical containers with appropriate identification and hazard information.
  - Use exposure control methods such as fume cupboards when working with volatile substances and use these apparatus correctly.
  - Use hazardous chemicals and all laboratory equipment only as directed or for the intended purpose.
  - Inspect equipment or apparatus for damage before adding a hazardous chemical, and do not use damaged equipment.

- Inspect personal protective equipment for integrity or proper functioning before use.
  - Malfunctioning laboratory equipment, like fume cupboards, must be labelled 'out of service' to ensure that other employees don't use it.
  - Handle and store laboratory glassware with care.
  - Do not dispense more of a hazardous chemical than is needed for immediate use.
  - Ensure that signs are visible that prohibits eating or drinking in a laboratory. <sup>5,6</sup>
- Housekeeping
    - Maintain general cleanliness and housekeeping.
    - Do not use aisles and hallways as storage.
    - Work surfaces must be kept reasonably clear and should allow work to be conducted in an efficient and safe manner.
    - Work surfaces should be clear of chemical spills and contamination.
    - Fume cupboards:
      - Only equipment which is absolutely necessary should be kept in a fume cupboard.
      - Fume cupboard sashes must be used by the operating height that has been indicated on the side of the fume cupboard.
      - Equipment in fume cupboards should not be operated if the airflow is below the minimum acceptable levels.
      - Chemicals may only be stored in a designated chemical storage fume cupboard.
      - Fume cupboards which are used for processing or manipulations may not be used to store chemicals or hazardous waste.
    - Storage in laboratories
      - Chemicals must be stored according to compatibility, properly labelled and stored below eye level, but off the floor.
      - Chemical storage shelves must be equipped with lips to prevent containers from falling.
      - Compressed gas bottles must be secured with a strap or chain that is fastened to a permanent object.
      - Storage must not block access to emergency eyewashes, fire extinguishers or drench showers.
    - Broken glassware must be kept in a solid container with a lid that is marked appropriately. <sup>5,6</sup>

- Personal Hygiene
    - Remove contaminated clothing and gloves before leaving the laboratory by following the correct procedures to prevent contamination.
    - Avoid direct contact with any chemical. Keep chemicals off your hands, face and clothing. Never smell, inhale or taste a hazardous chemical. Wash hands thoroughly with soap and water after handling any chemical.
    - Smoking, drinking, eating and application of cosmetics is forbidden in laboratories where hazardous chemicals are used.
    - Never pipette by mouth, always use a pipette bulb or mechanical pipette filling device.
- 5,6

## **18. Record Keeping**

### **Current situation**

The Campus Health and Safety Officer has records from the previous year's medical surveillance trial and investigations of incidents.

There is no evidence of any other record keeping in the laboratories.

### **Recommendations**

- The University must keep all records of the following:
  - results of assessments.
  - results of air monitoring.
  - medical surveillance reports.
  - reports on incident investigations.
  - tests and repairs performed on control measures.
- The University must make the records of assessments and air monitoring available to the relevant health and safety representatives and the health and safety committee as well as to the employee or postgraduate student.
- All records must be kept for a minimum of 30 years.<sup>2,5,6</sup>

## **19. General duty of employer**

### **Current situation**

In a recent meeting a statement was issued regarding the occupational health and safety of the campus. In this statement the following was given:

- Safety representatives and building representatives can register for a practical internal training course at the Campus Health and Safety Officer.

- Lecturers who give practical in laboratories devote the first lecture to making students aware of dangers in laboratories and the occupational health and safety guidelines for laboratories and substances used.
- Academic personnel must accept responsibility for internal housekeeping that holds risk for occupational health and safety.
- The faculty health and safety committee must see that the above mentioned be managed.

This statement shifts all the responsibility for occupational health and safety to academic personnel and management personnel without giving them the necessary training and information.

### **Recommendations**

- The University shall provide and maintain as far as is reasonably practicable a working environment that is safe and without risk to the health of the employees.<sup>3</sup>
- The University shall provide and maintain systems and machinery that are safe and without risk to health, as well as take steps to eliminate or reduce any hazard to the safety and health of employees before resorting to personal protective equipment.
- The University shall take precautions against hazards to health and safety that are present in the production, processing or use of substances and provide the necessary means to apply these precautionary measures.
- The University shall provide information and training that may be necessary to ensure the health and safety of each employee, and may not permit any employee to do any work unless the precautionary measures have been taken.
- The University shall take all necessary measures to ensure that the requirements of the Act are complied, and must enforce the measures that may be necessary in the interest of health and safety.
- The University shall ensure that work is performed under supervision of a person trained to understand the hazards associated with the work, and who has the authority to ensure that precautionary measures taken by the University are implemented.
- By delegating duties it does not eliminate responsibilities from the University or management personnel. The University must ensure that management personnel complete their duties regarding occupational health and safety, and management personnel must ensure that employees comply with instructions and obligations.

## **20. General duties of employees and postgraduate students at work**

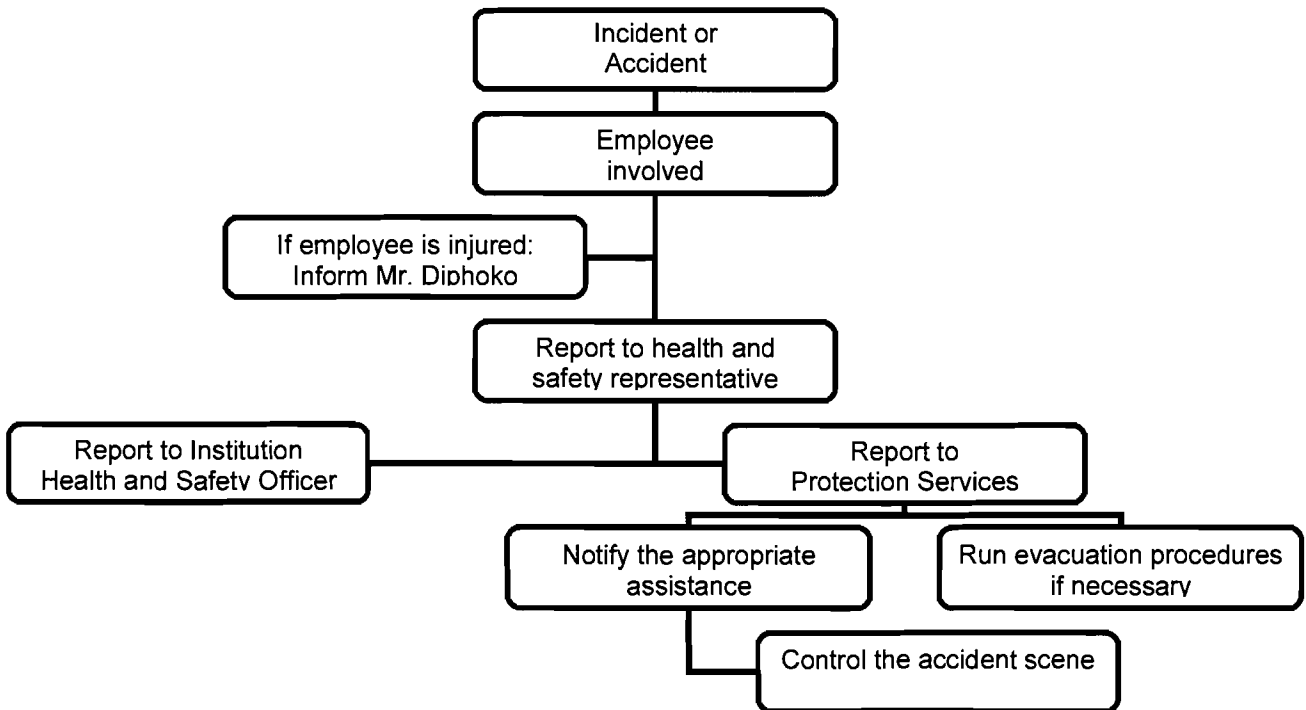
### **Current situation**

A number of employees are not informed on occupational health and safety or legislation regarding this and therefore cannot take care of their own health and safety or of others. The majority of employees wear the personal protective equipment they are provided, but a small number of employees did not cooperate with personal exposure measurement.

### **Recommendations**

- All employees/postgraduate students shall:
  - take reasonable care for the safety and health of himself and others who may be affected by his acts or lack thereof.
  - carry out any lawful order give to him, and obey the health and safety rules laid down by the University.
  - obey lawful instruction given by the University regarding the prevention of HCS from being released, wearing personal protective equipment and wearing monitoring equipment to measure personal exposure.
  - report for health evaluations and biological tests required by law.
  - obey instructions regarding clean up and disposal of materials containing HCS, housekeeping and personal hygiene.
  - report any situation which is unsafe or unhealthy as soon as practicable to the health and safety representative.
  - report any incident which may affect his health or which has caused injury to the University or health and safety representative as soon as possible.<sup>3</sup>

## 21. Emergency plan



## 22. References

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# CHAPTER 6

*Appendix*

## QUESTIONNAIRE – EMPLOYEE / POSTGRADUATE STUDENT.

All the information that is obtained through this questionnaire is confidential  
Please answer the questions honestly.

Name and Surname .....

Department .....

Laboratory .....

Are you: Academic personnel  Support personnel   
Job description .....

1. How long have you worked in this laboratory?

Longer than 2 years  Between 1 and 2 years  Less than 6 months .

2. Have you worked in a laboratory previously?

Yes  No .

3. How often do you work in the laboratory?

Every day  More than twice a week  Less than twice a week .

4. How many hours per week do you work in the laboratory?

More than 30 hours  Between 20 and 30 hours .

Between 10 and 20 hours  Less than 10 hours .

5. Before you started work in the laboratory, did you receive any training in terms of:

Potential health risks caused by exposure to the hazardous chemical substances?

Yes  No .

Actions of management to protect you against the risks?

Yes  No .

Precautionary actions that you must take to protect yourself against health risks linked to exposure to hazardous substances?

Yes  No .

The necessity and correct use of protective equipment and facilities available?

Yes  No .

Safe work procedures for handling and storage of chemical substances?

Yes  No .

Procedures that you must follow in case of a spill or emergency?

Yes  No .

6. Who did the training?  
 Safety representative  Other .....
7. Do you know who your safety representative is?  
 Yes  No .
8. Was there any assessment to determine if you are exposed to hazardous chemical substances?  
 Yes  No .
9. Was there any air monitoring to determine the concentrations of hazardous chemical substances that are present in the laboratory?  
 Yes  No .
10. Did you participate in a medical surveillance program? (Biological monitoring where blood or urine was taken to monitor exposure)  
 Yes  No .
11. Do you know what MSDS of a chemical substance is and how to get it?  
 Yes  No .
12. Is there works procedures that you must follow to limit your exposure to hazardous chemical substances?  
 Yes  No .
- Name examples:  
 .....  
 .....
13. Do you always follow the procedures in 12?  
 Yes  No .
14. Do you get personal protective equipment if you work with hazardous chemical substances? (ex. Masks or gloves)  
 Yes  No .
15. Are you trained to use the protective equipment correctly?  
 Yes  No .
16. Are you trained in the correct methods of waste disposal?  
 Yes  No .
17. Do you always follow the correct methods of waste disposal?  
 Yes  No .
18. Are you aware of the Regulations for Hazardous Chemical Substances that is part of the law on occupational health and safety and what it contains?  
 Yes  No .

19. Are you aware of your right to a safe and healthy work environment?

Yes

No .

20. Do you know to which chemical substances you are exposed?

Yes

No .

21. Name the liquid chemical substances that you work with.

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# QUESTIONNAIRE –HEALTH AND SAFETY REPRESENTATIVE

All the information that is obtained through this questionnaire is confidential  
Please answer the questions honestly.

Name and Surname .....

Department / Subject group .....

Laboratory .....

Are you: Academic personnel  Support personnel   
Job description .....

Contact information.....

1. How long have you been the safety representative of the department or subject group?

.....

2. Where you chosen or nominated as safety representative?

Nominated  Chosen .

3. Does your job description allow you to perform your task as safety representative?

Yes  No .

4. Are you satisfied with the way you perform your duties as safety representative?

Yes  No .

5. Has there previously been assessment of the laboratories that you are responsible for  
to determine if any people are exposed to hazardous chemical substances?

Yes  No .

6. Is an assessment conducted every 2 years?

Yes  No .

7. Did you receive any results from an assessment?

Yes  No .

8. Are you aware of any hazardous chemical substances that are used in the labs?

Yes  No .

9. Is there any records of hazardous chemical substances that are present and the effects  
that it can have on people?

Yes  No .

10. Is there an existing measuring program to determine the concentrations that people are  
exposed to?

Yes  No .

11. Is air monitoring carried out by an approved person or authority?

Yes  No .

12. Is the air monitoring conducted on a regular basis?

Yes  No .

Yearly  Every 2 years .

13. Is there any medical surveillance for employees that are exposed to chemical substances where the exposure threatens their health? (Medical surveillance is a periodic program where people's blood or urine is taken and tested to determine their exposure to chemical substances.)

Yes  No .

14. Are all employees subjected to an initial health evaluation within 14 days after the person commences employment?

Yes  No .

15. Are records of all assessments, air monitoring and medical surveillance reports kept?

Yes  No .

16. Are the MSDS of all chemical substances available for people working with it?

Yes  No .

17. Are there standard work procedures that employees must follow to limit their exposure to chemical substances?

Yes  No .

18. Are there control measures like ventilation to limit exposure in the labs?

Yes  No .

19. Does the ventilation system work efficiently?

Yes  No .

20. Is the ventilation evaluated regularly?

Yes  No .

21. Is personal protective equipment provided for employees that work with toxic chemical substances?

Yes  No .

22. Are employees trained in the use and maintenance of the personal protective equipment?

Yes  No .

23. Are there procedures for the correct waste disposal?

Yes  No .

24. How is waste disposed of?

.....  
.....

25. Are the waste disposal procedures always followed accurately?

Yes  No .

26. Are you aware of the Regulations for Hazardous Chemical Substances that is part of the law on occupational health and safety and what it contains?

Yes  No .

27. Are you aware of the employee's right to a safe and healthy work environment?

Yes  No .